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IODEF Usage Guidance
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Abstract

The Incident Object Description Exchange Format v2 [I-D.ietf-mile-rfc5070-bis] defines a data representation that provides a framework for sharing information commonly exchanged by Computer Security Incident Response Teams (CSIRTs) about computer security incidents. Since the IODEF model includes a wealth of available options that can be used to describe a security incident or issue, it can be challenging for security practicioners to develop tools that can leverage IODEF for incident sharing. This document provides guidelines for IODEF practicioners. It also addresses how common security indicators can be represented in IODEF and use-cases of how IODEF is being used so far. The goal of this document is to make IODEF's adoption by vendors easier and encourage faster and wider adoption of the model by Computer Security Incident Response Teams (CSIRTs) around the world.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

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This Internet-Draft will expire on January 9, 2017.

Table of Contents

1. Introduction

The Incident Object Description Exchange Format v2 in [I-D.ietf-mile-rfc5070-bis] defines a data representation that provides a framework for sharing information commonly exchanged by Computer Security Incident Response Teams (CSIRTs) about computer security incidents. The IODEF data model consists of multiple classes and data types that are defined in the IODEF XML schema.

The IODEF schema was designed to be able to describe all the possible fields that would be needed in a security incident exchange. Thus, IODEF contains plenty data constructs that could potentially make it harder for IODEF implementers to decide which are the most important ones to use. Additionally, in the IODEF schema, there exist multiple fields and classes which do not necessarily need to be used in every possible data exchange. Moreover, there are fields that are useful only in data exchanges of non-traditional security events. This document tries to address these issues. It also addresses how common security indicators can be represented in IODEF. It points out the most important IODEF classes for an implementer and describe other ones that are not as important. Also, it presents some common challenges for IODEF implementers and how to address them. The end goal of this document is to make IODEF's adoption by vendors easier and encourage faster and wider adoption of the model by Computer Security Incident Response Teams (CSIRTs) around the world.

Section 3 discusses the recommended classes and how an IODEF implementer should chose the classes to implement. Section 4 presents common considerations a practicioner will come across and how to address them. Section 5 goes over some common uses of IODEF.

2. Terminology

The terminology used in this document follows the one defined in [RFC5070] and [RFC7203].

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

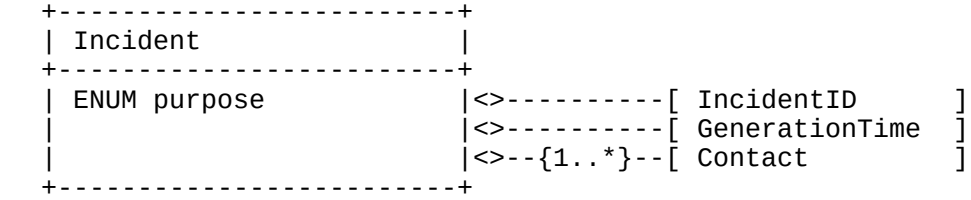
3. Implementation Strategy

It is important for IODEF practicioners to be able to distinguish how the IODEF classes will be used in incident information exchanges. It is critical to follow a strategy according to which of the various IODEF classes will be implemented. It is also important to know the most common classes that will be used to describe common security incidents or indicators. Thus, this section will describe the most

important classes and factors an IODEF implementer should take into consideration before designing the implementation or tool.

3.1. Minimal IODEF document

An IODEF document MUST include at least an Incident class and a version attribute. An Incident MUST contain three minimal mandatory-to-implement classes. An Incident class needs to have a Generation time and at least one Contact and IncidentID class. The structure of the minimal-style Incident class follows below.



Minimal-style Incident class

This minimal Incident class needs to include a purpose attribute and the IncidentID, GenerationTime, and Contact elements.

The Contact class requires the type and role attributes, but no elements are required by the IODEF v2 specification. Nevertheless, at least one of the elements in the Contact class, such as Email class, need to be implemented so that the IODEF document can be practical.

Implementers can refer to Appendix A and Section 7 of [I-D.ietf-mile-rfc5070-bis] for example IODEF and IODEF v2 documents respectively.

3.2. Decide what IODEF will be used for

There is no need for an practicioner to implement IODEF classes and fields other than the minimal ones (Section 3.1) and the ones that are necessary for his use-cases. The implementer SHOULD carefuly look into the schema and decide classes to implement (or not).

For example, if we have has DDoS as a potential use-case, then the Flow class and its included information are the most important classes to use. The Flow class describes information related to the attacker hosts and victim hosts, which information may help automated filtering or sink-hole operations.

Another potential use-case is malware command and control. After modern malware infects a device, it usually proceeds to connect to one or more command and control (c2) servers to receive instructions from its master and potentially exfiltrate information. To protect against such activity, it is important to interrupt the c2 communication by filtering the activity. IODEF can describe such activities using the Flow and the ServiceName classes.

For use-cases where indicators need to be described more than events themselves, the IndicatorData class and the necessary included in it classes will be implemented instead of the EventData class and its classes.

In summary, an implementer SHOULD identify the use-cases and find the classes that are necessary to support in IODEF v2. Implementing and parsing all IODEF classes can be cumbersome in some occasions and is not always necessary. Other external schemata can also be used in IODEF to describe incidents or indicators which should be treated accordingly only if the implementer’s IODEF use-cases require external schema support.

3.3. Indicators vs Events

[I-D.ietf-mile-rfc5070-bis] contains classes that can describe attack Methods, Events, Indicents, how they were discovered and the Assessment of the reprecussions of the incident to the victim. It is important for implementers to know the distinction between these classes in order to decide which ones fullfulls their use-cases.

An IndicatorData class depicts a threat indicator or observable that could be used to describe a threat that does not necessarily mean that an exploit happened. For example, we could see an attack happening but it might have been prevented and not have resulted in an incident or security event. On the other hand an EventData class usually describes a security event and can be considered as a incident report of something that took place.

Classes like Discovery, Assessment, Method, RecoveryTime are used in conjuction with EventData as they related to the incident report described in the EventData. The RelatedActivity class can reference an incident, an indicator or other related threat activity.

While deciding what classes are important for the needed use-cases, IODEF users SHOULD carefuly evaluate the necessary classes and how these are used in order to avoid unecessary work. For example, if we want to only describe indicators in IODEF, the implementation of Method or Assessment might not be important.

4. IODEF considerations and how to address them

4.1. External References

The IODEF format includes the Reference class that refers to externaly defined information such as a vulnerability, Intrusion Detection System (IDS) alert, malware sample, advisory, or attack technique. To facilitate the exchange of information, the Reference class was extended to the Enumeration Reference Format [RFC7495]. The Enumeration Reference Format specifies a format to include enumeration values from external data representations into IODEF like CVE, and manages references to external representations using IANA registry. Practicioners SHOULD only support external enumerations that are expected to be used in IODEF documents for their use-cases.

4.2. Extensions

The IODEF data model ([RFC5070]) is extensible. Many class attributes and their values can be extended using using the "ext-*" prefix. Additional classed can also be defined by using the AdditionalData and RecordItem classes. An extension to the AdditionalData class for reporting Phishing emails is defined in [RFC5901].

Additionally, IODEF can import existing schemata by using an extension framework defined in [RFC7203]. The framework enables IODEF users to embed XML data inside an IODEF document using external schemata or structures defined by external specifications. Examples include CVE, CVRF and OVAL. Thus, [RFC7203] enhances the IODEF capabilities without further extending the data model.

IODEF practicioners can consider using their own IODEF extensions only for data that cannot be described using existing standards or importing them in and IODEF document using [RFC7203] is not a suitable option.

Information about extending IODEF classes attributes and enumarated values can be found in Section 5 of [I-D.ietf-mile-rfc5070-bis].

4.3. Indicator predicate logic

An IODEF [I-D.ietf-mile-rfc5070-bis] document can describe incident reports and indicators. The Indicator class can include references to other indicators, observables and more classes the contain details about the indicator. When describing security indicators, it is often common to need to group them together in order to form a group of indicator that constitute a security threat. For example, a botnet might have multiple command and control servers. For that

reason, IODEF v2 introduced the IndicatorExpression class that is used to add the indicator predicate logic when grouping more than one indicators or observables.

It is important for implementers to be able to parse and apply the boolean logic offered by an IndicatorExpression in order to evaluate the existance of an indicator. As explained in Section 3.29.5 of [I-D.ietf-mile-rfc5070-bis] the IndicatorExpression element operator defines the operator applied to all the child element of the IndicatorExpression. If no operator is defined "and" SHOULD be assumed. IndicatorExpressions can also be nested together. Child IndicatorExpressions should be treated as child elements of their parent and they SHOULD be evaluated first before evaluated with the operator of their parent.

In the following example the EventData class evaluates as a Flow of one System with source address being (10.10.10.104 OR 10.10.10.106) AND target address 10.1.1.1

```
<!-- ...XML code omitted... -->
 <IndicatorData>
   <Indicator>
     <IndicatorID name="csirt.example.com" version="1">
     G90823490
     </IndicatorID>
     <Description>C2 domains</Description>
     <IndicatorExpression operator="and">
       <IndicatorExpression operator="or">
         <Observable>
           <System category="source" spoofed="no">
             <Node>
               <Address category="ipv4-addr">
                 10.10.10.104
               </Address>
             </Node>
           </System>
         </Observable>
         <Observable>
           <System category="source" spoofed="no">
             <Node>
               <Address category="ipv4-addr">
                 10.10.10.106
               </Address>
             </Node>
           </System>
         </Observable>
       </IndicatorExpression>
       <Observable>
         <System category="target" spoofed="no">
           <Node>
             <Address category="ipv4-addr">
               10.1.1.1
             </Address>
           </Node>
         </System>
       </Observable>
     </IndicatorExpression>
   </Indicator>
 </IndicatorData>
<!-- ...XML code omitted... -->
```

Similarly, the FileData Class can be an observable in an IndicatorExpression. The hash values of two files can be used to match against an indicator using boolean "or" logic. In the following example the indicator consists of either of the two files with two different hashes.

```
<!-- ...XML code omitted... -->
 <IndicatorData>
   <Indicator>
     <IndicatorID name="csirt.example.com" version="1">
     A4399IWQ
     </IndicatorID>
     <Description>File hash watchlist</Description>
     <IndicatorExpression operator="or">
         <Observable>
           <FileData>
             <File>
               <FileName>dummy.txt</FileName>
               <HashData>
                 <Hash>
                  <ds:DigestMethod Algorithm=
                  "http://www.w3.org/2001/04/xmlenc#sha256"/>
                  <ds:DigestValue>
                   141accec23e7e5157de60853cb1e01bc38042d
                   08f9086040815300b7fe75c184
                  </ds:DigestValue>
                 </Hash>
               </HashData>
             </File>
           </FileData>
         </Observable>
         <Observable>
           <FileData>
             <File>
               <FileName>dummy2.txt</FileName>
               <HashData>
                 <Hash>
                  <ds:DigestMethod Algorithm=
                  "http://www.w3.org/2001/04/xmlenc#sha256"/>
                  <ds:DigestValue>
                   141accec23e7e5157de60853cb1e01bc38042d
                   08f9086040815300b7fe75c184
                  </ds:DigestValue>
                 </Hash>
               </HashData>
             </File>
           </FileData>
         </Observable>
     </IndicatorExpression>
   </Indicator>
 </IndicatorData>
<!-- ...XML code omitted... -->
```

4.4. Disclosure level of IODEF

The information conveyed in IODEF documents SHOULD be treated carefully since the content may be confidential. IODEF provides a disclosure level indicator, but its enforcement depends on operations at the practicioner's side.

IODEF has a common attribute, called "restriction", which indicates the disclosure guideline to which the sender expects the recipient to adhere to for the information represented in the class and its children. That way, the sender can express the level of disclosure for each component of an IODEF document. Appropriate external measures could be implemented based on the restriction level. One example is when RID is used to transfer the IODEF documents, it can provide policy guidelines for handling IODEF documents by using the RIDPolicy class.

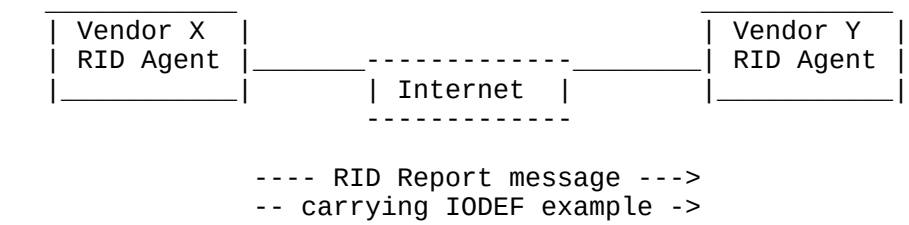
The enforcement of the disclosure guidelines goes beyond IODEF. The recipient of the IODEF document needs to follow the guidelines, but these guidelines themselves do not provide any enforcement measures. For that purpose, practicioners SHOULD consider appropriate measures, technical or operational.

5. Current uses of IODEF

IODEF is currently used by various organizations in order to represent security incidents and share incident and threat information between security operations organizations.

5.1. Inter-vendor and Service Provider Exercise

Various vendors organized and executed an exercise where multiple threat indicators were exchanged using IODEF. The transport protocol used was RID. The threat information shared included incidents like DDoS attacks. Malware and Spear-Phishing. As this was a proof-of-concept (PoC) exercise only example information (no real threats) were shared as part of the exchanges.



PoC peering topology

The figure above shows how RID interactions took place during the PoC. Participating organizations were running RID Agent software on-premises. The RID Agents formed peering relationships with other participating organizations. When Entity X had a new incident to exchange it would package it in IODEF and send it to Entity Y over TLS in a RID Report message. In case there was an issue with the message, Entity Y would send an RID Acknowledgement message back to Entity X which included an application level message to describe the issue. Interoperability between RID agents and the standards, [RFC6545] and [RFC6546], was also proven in this exercise. Appendix A includes some of the incident IODEF example information that was exchanged by the organizations' RID Agents as part of this proof-of-concept.

The first use-case included sharing of Malware Data Related to an Incident between CSIRTs. After Entity X detected an incident, she would put data about malware found during the incident in a backend system. Entity X then decided to share the incident information with Entity Y about the malware discovered. This could be a human decision or part of an automated process.

Below are the steps followed for the malware information exchange that was taking place:

(1) Entity X has a sharing agreement with Entity Y, and has already been configured with the IP address of Entity Y's RID Agent

(2) Entity X's RID Agent connects to Entity Y's RID Agent, and mutual authentication occurs using PKI certificates.

(3) Entity X pushes out a RID Report message which contains information about N pieces of discovered malware. IODEF is used in RID to discribe the

(a) Hash of malware files

(b) Registry settings changed by the malware

(c) C&C Information for the malware

(4) Entity Y receives RID Report message, sends RID Acknowledgement message

(5) Entity Y stores the data in a format that makes it possible for the back end to know which source the data came from.

Another use-case was sharing Distributed Denial of Service (DDoS) as presented below information: Entity X, a Critical Infrastructure and Key Resource (CIKR) company detects that their internet connection is saturated with an abnormal amount of traffic. Further investigation determines that this is an actual DDoS attack. Entity X's computer incident response team (CIRT) contacts their ISP and shares information with them about the attack traffic characteristics. In addition, Entity X has an information sharing relationship with Entity Y. It shares information with Entity Y on characteristics of the attack to watch for. Entitty X's ISP is being overwhelmed by the amount of traffic, so it shares attack signatures and IP addresses of the most prolific hosts with its adjacent ISPs.

Below are the steps followed for a DDoS information exchange:

(1) Entity X has a sharing agreement with Entity Y, and has already been configured with the IP address of Entity Y's RID Agent

(2) Entity X's RID Agent connects to Entity Y's RID Agent, and mutual authentication occurs using PKI certificates.

(3) Entity X pushes out a RID Report message which contains information about the DDoS attack. IODEF is used in RID to discribe the

(a) Start and Detect dates and times

(b) IP Addresses of nodes sending DDoS Traffic

(c) Sharing and Use Restrictions

(d) Traffic characteristics (protocols and ports)

(e) HTTP User-Agents used

(f) IP Addresses of C&C for a botnet

(4) Entity Y receives RID Report message, sends RID Acknowledgement message

(5) Entity Y stores the data in a format that makes it possible for the back end to know which source the data came from.

One more use-case was sharing spear-phishing email information as explained in the following scenario: The board members of several defense contractors receive an email inviting them to attend a conference in San Francisco. The board members are asked to provide their personally identifiable information such as their home address, phone number, corporate email, etc in an attached document which came with the email. The board members were also asked to click on a URL which would allow them to reach the sign up page for the conference. One of the recipients believes the email to be a phishing attempt and forwards the email to their corporate CSIRT for analysis. The CSIRT identifies the email as an attempted spear phishing incident and distributes the indicators to their sharing partners.

Below are the steps followed for a spear-phishing information exchange between CSIRTs that was part of this PoC.

(1) Entity X has a sharing agreement with Entity Y, and has already been configured with the IP address of Entity Y’s RID Agent

(2) Entity X’s RID Agent connects to Entity Y’s RID Agent, and mutual authentication occurs using PKI certificates.

(3) Entity X pushes out a RID Report message which contains information about the spear-phishing email. IODEF is used in RID to discribe the

   (a) Attachment details (file Name, hash, size, malware family

   (b) Target description (IP, domain, NSLookup)

   (c) Email information (From, Subject, header information, date/ time, digital signature)

   (d) Confidence Score

(4) Entity Y receives RID Report message, sends RID Acknowledgement message

(5) Entity Y stores the data in a format that makes it possible for the back end to know which source the data came from.

5.2. Implementations

In order to use IODEF, some tools that cope with IODEF documents, such as the IODEF parser, are needed. Though arbitrary implementations can be done, some guidelines are provided in [I-D.ietf-mile-implementreport]. IODEF , but [I-D.ietf-mile-implementreport] provides guidelines for implementers. The document does not specify any specific MTI but provides a list of implementations the authors have surveyed at the time of its publication as well as some tips on the implementations. Implementers are encourage to read the draft.

5.3. Other

IODEF is also used in various projects and products to consume and share security information. Various vendor incident reporting products have the ability to consume and export in IODEF format [implementations]. Perl and Python modules (XML::IODEF, Iodef::Pb, iodeflib) exist in order to parse IODEF documents and their extensions. Additionally, some worldwide CERT organizations are already able to use receive incident information in IODEF.

Future use-cases of IODEF could be:

(1) ISP notifying a national CERT or organization when it identifies and acts upon an incident and CERTs notifying ISPs when they are aware of incidents.

(2) Suspected phishing emails could be shared amongst organizations and national agencies. Automation could validate web content that the suspicious emails are pointing to. Identified malicious content linked in a phishing email could then be shared using IODEF. Phishing campaigns could thus be subverted much faster by automating information sharing using IODEF.

(3) When finding a certificate that should be revoked, a thrid-party would forward an automated IODEF message to the CA with the full context of the certificate and the CA could act accordingly after checking its validity. Alternatively, in the event of a compromise of the private key of a certificate, a third-party could alert the certificate owner about the compromise using IODEF.

6. Updates

version -06 updates:

(1) Updated wording in various sections to make content clearer.

(2) Updated Predicate Logic section to reflect the latest IndicatorExpression logic in iodef-bis.

(3) Updated section to describe the difference between events and indicators and their use in IODEF v2.

version -05 updates:

(1) Changed section title from "Restrictions in IODEF" to "Disclosure level of IODEF" and added some description

(2) Mixed "Recommended classes to implement" section with "Unnecessary Fields" section into "Minimal IODEF document" section

(3) Added description to "Decide what IODEF will be used for" section, "Implementations" section, and "Security Considerations" section

version -04 updates:

(1) Expanded on the Extensions section using Take’s suggestion.

(2) Moved Future use-cases under the Other section.

(3) CIF and APWG were consolidated in one "Implementation" section

(4) Added abstract of RFC7495 to the "External References" section

(5) Added Kathleen’s example of malware delivery URL to "Appendix"

(6) Added a little description to "Recommended classes to implement" section

version -03 updates:

(1) Added "Updates" section.

(2) Added details about the flow of information exchanges in "Inter-vendor and Service Provider Exercise" section. Also updated the usecases with more background information.

(3) Added future use-cases in the "Collective Intelligence Framework" section

(4) Updated Perl and Python references with the actual module names. Added IODEF implementation reference "implementations".

(5) Added Predicate logic section

(6) Updated Logic of watchlist of indicators section to simplify the logic and include examples.

(7) Renamed Externally defined indicators section to Indicator reference and elaborated on the use of indicator-uid and indicator-set-uid attribute use.

version -02 updates:

(1) Updated the "Logic for watchlist of indications" section to clarify the logic based on community feedback.

(2) Added "Inter-vendor and Service Provider Exercise" section.

(3) Added Appendix to include actual use-case IODEF examples.

7. Acknowledgements

8. Security Considerations

This document does not incur any new security issues, since it only talks about the usage of IODEF, which is defined in RFC 5070 [RFC5070]. Nevertheless, readers of this document SHOULD refer to the security consideration section of RFC5070 and [I-D.ietf-mile-rfc5070-bis].

9. References

9.1. Normative References

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[RFC5901] Cain, P. and D. Jevans, "Extensions to the IODEF-Document Class for Reporting Phishing", RFC 5901, DOI 10.17487/RFC5901, July 2010, <http://www.rfc-editor.org/info/rfc5901>.

[RFC6545] Moriarty, K., "Real-time Inter-network Defense (RID)", RFC 6545, DOI 10.17487/RFC6545, April 2012, <http://www.rfc-editor.org/info/rfc6545>.

[RFC6546] Trammell, B., "Transport of Real-time Inter-network Defense (RID) Messages over HTTP/TLS", RFC 6546, DOI 10.17487/RFC6546, April 2012, <http://www.rfc-editor.org/info/rfc6546>.

[RFC7203] Takahashi, T., Landfield, K., and Y. Kadobayashi, "An Incident Object Description Exchange Format (IODEF) Extension for Structured Cybersecurity Information", RFC 7203, DOI 10.17487/RFC7203, April 2014, <http://www.rfc-editor.org/info/rfc7203>.

[RFC7495] Montville, A. and D. Black, "Enumeration Reference Format for the Incident Object Description Exchange Format (IODEF)", RFC 7495, DOI 10.17487/RFC7495, March 2015, <http://www.rfc-editor.org/info/rfc7495>.

9.2. Informative References

[APWG] "APWG", <http://apwg.org/>.

[CIF] "CIF", <http://csirtgadgets.org/collective-intelligence-framework/>.

[I-D.ietf-mile-implementreport] Inacio, C. and d. daisu-mi@nc.u-tokyo.ac.jp, "MILE Implementation Report", draft-ietf-mile-implementreport-06 (work in progress), October 2015.

[I-D.ietf-mile-rfc5070-bis] Danyliw, R., "The Incident Object Description Exchange Format v2", draft-ietf-mile-rfc5070-bis-18 (work in progress), March 2016.

[implementations] "Implementations on IODEF", <http://siis.realmv6.org/implementations/>.

Appendix A. Inter-vendor and Service Provider Exercise Examples

Below some of the incident IODEF example information that was exchanged by the vendors as part of this proof-of-concept Inter-vendor and Service Provider Exercise.

A.1. Malware

In this test, malware information was exchanged using RID and IODEF. The information included file hashes, registry setting changes and the C&C servers the malware uses.

```
<?xml version="1.0" encoding="UTF-8"?>
            <iodef:IODEF-Document xmlns:ds="
                http://www.w3.org/2000/09/xmldsig#"
                xmlns:iodef="urn:ietf:params:xml:ns:iodef-1.41">
      <iodef:Incident purpose="reporting">
        <iodef:ReportID name="EXAMPLE CSIRT">
           189234
        </iodef:ReportID>
        <iodef:ReportTime>
           2013-03-07T16:14:56.757+05:30
        </iodef:ReportTime>
        <iodef:Description>
           Malware and related indicators identified
        </iodef:Description>
        <iodef:Assessment occurrence="potential">
          <iodef:Impact severity="medium" type="info-leak">
             Malware with Command and Control Server
             and System Changes
          </iodef:Impact>
        </iodef:Assessment>
        <iodef:Contact role="creator" type="organization">
          <iodef:ContactName>EXAMPLE CSIRT</iodef:ContactName>
          <iodef:Email>emccirt@emc.com</iodef:Email>
        </iodef:Contact>
        <iodef:EventData>
          <iodef:Method>
            <iodef:Reference>
              <iodef:ReferenceName>Zeus</iodef:ReferenceName>
              <iodef:URL>
                  http://www.threatexpert.com/report.aspx?
                  md5=e2710ceb088dacdcb03678db250742b7
              </iodef:URL>
            </iodef:Reference>
          </iodef:Method>
          <iodef:Flow>
            <iodef:System category="watchlist-source">
              <iodef:Node>
                <iodef:Address category="ipv4-addr">
                   192.168.2.200
                </iodef:Address>
                <iodef:Address category="site-uri">
                   http://zeus.556677889900.com/log-bin/
```

```
                        lunch_install.php?aff_id=1&amp;amp;
                        lunch_id=1&amp;amp;maddr=&amp;amp;
                        action=install
                    </iodef:Address>
                    <iodef:NodeRole attacktype="c2-server"/>
                  </iodef:Node>
                </iodef:System>
              </iodef:Flow>
              <iodef:Record>
                <iodef:RecordData>
                  <iodef:HashData>
                    <ds:Reference>
                      <ds:DigestMethod Algorithm="
                         http://www.w3.org/2001/04/xmlenc#sha1"/>
                      <ds:DigestValue>
                           MHg2NzUxQTI1MzQ4M0E2N0Q4NkUwRjg0NzYwRj
                           YxRjEwQkJDQzJFREZG</ds:DigestValue>
                    </ds:Reference>
                  </iodef:HashData>
                  <iodef:HashData>
                    <ds:Reference>
                      <ds:DigestMethod Algorithm="
                          http://www.w3.org/2001/04/xmlenc#md5"/>
                      <ds:DigestValue>
                          MHgyRTg4ODA5ODBENjI0NDdFOTc5MEFGQTg5NTE
                          zRjBBNA==
                      </ds:DigestValue>
                    </ds:Reference>
                  </iodef:HashData>
                  <iodef:WindowsRegistryKeysModified>
                    <iodef:Key registryaction="add_value">
                      <iodef:KeyName>
                          HKLM\Software\Microsoft\Windows\
                          CurrentVersion\Run\tamg
                      </iodef:KeyName>
                      <iodef:Value>
                         ?\?\?%System%\wins\mc.exe\?\??
                      </iodef:Value>
                    </iodef:Key>
                    <iodef:Key registryaction="modify_value">
                      <iodef:KeyName>HKLM\Software\Microsoft\
                         Windows\CurrentVersion\Run\dqo
                      </iodef:KeyName>
                      <iodef:Value>"\"\"%Windir%\Resources\
                          Themes\Luna\km.exe\?\?"
                      </iodef:Value>
                    </iodef:Key>
                  </iodef:WindowsRegistryKeysModified>
```

```
          </iodef:RecordData>
        </iodef:Record>
      </iodef:EventData>
      <iodef:EventData>
        <iodef:Method>
          <iodef:Reference>
            <iodef:ReferenceName>Cridex</iodef:ReferenceName>
            <iodef:URL>
                http://www.threatexpert.com/report.aspx?
                md5=c3c528c939f9b176c883ae0ce5df0001
            </iodef:URL>
          </iodef:Reference>
        </iodef:Method>
        <iodef:Flow>
          <iodef:System category="watchlist-source">
            <iodef:Node>
              <iodef:Address category="ipv4-addr">
                 10.10.199.100
              </iodef:Address>
              <iodef:NodeRole attacktype="c2-server"/>
            </iodef:Node>
            <iodef:Service ip_protocol="6">
              <iodef:Port>8080</iodef:Port>
            </iodef:Service>
          </iodef:System>
        </iodef:Flow>
        <iodef:Record>
          <iodef:RecordData>
            <iodef:HashData>
              <ds:Reference>
                <ds:DigestMethod Algorithm="
                   http://www.w3.org/2001/04/xmlenc#sha1"/>
                <ds:DigestValue>
                   MHg3MjYzRkUwRDNBMDk1RDU5QzhFMEM4OTVBOUM
                   1ODVFMzQzRTcxNDFD
                </ds:DigestValue>
              </ds:Reference>
              <ds:Reference>
                <ds:DigestMethod Algorithm="
                   http://www.w3.org/2001/04/xmlenc#md5"/>
                <ds:DigestValue>MHg0M0NEODUwRkNEQURFNDMzMEE1
                   QkVBNkYxNkVFOTcxQw==</ds:DigestValue>
              </ds:Reference>
            </iodef:HashData>
            <iodef:HashData>
              <ds:Reference>
                <ds:DigestMethod Algorithm="
                    http://www.w3.org/2001/04/xmlenc#md5"/>
```

```
                    <ds:DigestValue>MHg0M0NEODUwRkNEQURFNDMzMEE
                        1QkVBNkYxNkVFOTcxQw==</ds:DigestValue>
                  </ds:Reference>
                  <ds:Reference>
                    <ds:DigestMethod Algorithm="http://www.w3.org/
                        2001/04/xmlenc#sha1"/>
                    <ds:DigestValue>MHg3MjYzRkUwRDNBMDk1RDU5QzhFME
                        M4OTVBOUM1ODVFMzQzRTcxNDFD</ds:DigestValue>
                  </ds:Reference>
                </iodef:HashData>
                <iodef:WindowsRegistryKeysModified>
                  <iodef:Key registryaction="add_value">
                    <iodef:KeyName>
                       HKLM\Software\Microsoft\Windows\
                       CurrentVersion\Run\KB00121600.exe
                    </iodef:KeyName>
                    <iodef:Value>
                       \?\?%AppData%\KB00121600.exe\?\?
                    </iodef:Value>
                  </iodef:Key>
                </iodef:WindowsRegistryKeysModified>
              </iodef:RecordData>
            </iodef:Record>
          </iodef:EventData>
          <iodef:EventData>
            <iodef:Expectation action="other"/>
              <iodef:Flow>
                <iodef:System category="source"
                      indicator-set-id="91011">
                  <iodef:Node>
                      <iodef:Address category="url"
                         indicator-uid="qrst">
                            http://foo.com:12345/evil/cc.php
                      </iodef:Address>
                  <iodef:NodeName indicator-uid="rstu">
                      evil.com
                  </iodef:NodeName>
                      <iodef:Address category="ipv4-addr"
                         indicator-uid="stuv">
                            1.2.3.4</iodef:Address>
                      <iodef:Address category="ipv4-addr"
                         indicator-uid="tuvw">
                            5.6.7.8 </iodef:Address>
                      <iodef:Address category="ipv6-addr"
                         indicator-uid="uvwx">
                             2001:dead:beef::</iodef:Address>
                   <iodef:NodeRole category="c2-server"/>
                   </iodef:Node>
```

```
      </iodef:System>
    </iodef:Flow>
    <iodef:Record>
      <iodef:RecordData indicator-set-id="91011">
        <iodef:HashData>
           <ds:Reference>
              <ds:DigestMethod Algorithm=
                  "http://www.w3.org/2001/04/xmlenc
                   #sha256"/>
               <ds:DigestValue>
                141accec23e7e5157de60853cb1e01bc3804
                2d08f9086040815300b7fe75c184
               </ds:DigestValue>
           </ds:Reference>
        </iodef:HashData>
        <iodef:WindowsRegistryKeysModified
          indicator-set-id="91011">
          <iodef:Key registryaction="add_key"
          indicator-uid="vwxy">
            <iodef:KeyName>
                HKLM\SYSTEM\CurrentControlSet\
                Services\.Net CLR
            </iodef:KeyName>
          </iodef:Key>
          <iodef:Key registryaction="add_key"
            indicator-uid="wxyz">
            <iodef:KeyName>
                HKLM\SYSTEM\CurrentControlSet\
                Services\.Net CLR\Parameters
            </iodef:KeyName>
            <iodef:Value>
                \"\"%AppData%\KB00121600.exe\"\"
            </iodef:Value>
          </iodef:Key>
          <iodef:Key registryaction="add_value"
            indicator-uid="xyza">
            <iodef:KeyName>
               HKLM\SYSTEM\CurrentControlSet\Services\
               .Net CLR\Parameters\ServiceDll
            </iodef:KeyName>
            <iodef:Value>C:\bad.exe</iodef:Value>
          </iodef:Key>
          <iodef:Key registryaction="modify_value"
            indicator-uid="zabc">
            <iodef:KeyName>
                HKLM\SYSTEM\CurrentControlSet\
                Services\.Net CLR\Parameters\Bar
            </iodef:KeyName>
```

```
                        <iodef:Value>Baz</iodef:Value>
                      </iodef:Key>
                    </iodef:WindowsRegistryKeysModified>
                  </iodef:RecordData>
                </iodef:Record>
              </iodef:EventData>
            </iodef:Incident>
          </iodef:IODEF-Document>
```

A.2. Malware Delivery URL

This example indicates malware and related URL for file delivery.

```
<?xml version="1.0" encoding="UTF-8"?>
<IODEF-Document version="2.00"
        xmlns="urn:ietf:params:xml:ns:iodef-2.0"
        xmlns:iodef="urn:ietf:params:xml:ns:iodef-2.0"
        xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
<iodef:Incident purpose="reporting">
      <iodef:IncidentID name="csirt.example.com">
          189801
      </iodef:IncidentID>
      <iodef:RelatedActivity>
          <iodef:URL>http://zeus.556677889900.example.com/log-bin/lunch_install.
php?aff_id=1&amp;lunch_id=1&amp;maddr=&amp;action=install
          </iodef:URL>
      </iodef:RelatedActivity>
      <iodef:ReportTime>2012-12-05T12:20:00+00:00</iodef:ReportTime>
      <iodef:GenerationTime>2012-12-05T12:20:00+00:00</iodef:GenerationTime>
      <iodef:Description>Malware and related indicators</iodef:Description>
          <iodef:Assessment occurrence="potential">
              <iodef:SystemImpact severity="medium" type="breach-privacy">Malwar
e with C&amp;C </iodef:SystemImpact>
           </iodef:Assessment>
                   <iodef:Contact role="creator" type="organization">
                <iodef:ContactName>example.com CSIRT
                </iodef:ContactName>
                <iodef:Email>contact@csirt.example.com</iodef:Email>
            </iodef:Contact>
            <iodef:EventData>
            <iodef:Flow>
<iodef:System category="source">
                  <iodef:Node>
                    <iodef:Address category="ipv4-addr">192.0.2.200</iodef:Addre
ss>
                    <iodef:NodeRole category="www"/>
                 </iodef:Node>
              </iodef:System>
            </iodef:Flow>
        </iodef:EventData>
    </iodef:Incident>
</IODEF-Document>
```

A.3. DDoS

The DDoS test exchanged information that described a DDoS including protocols and ports, bad IP addresses and HTTP User-Agent fields. The IODEF version used for the data representation was based on [I-D.ietf-mile-rfc5070-bis]

```
 <?xml version="1.0" encoding="UTF-8"?>
 <IODEF-Document version="1.00" lang="en"
     xmlns="urn:ietf:params:xml:ns:iodef-1.41"
     xmlns:iodef="urn:ietf:params:xml:ns:iodef-1.41"
```

```
     xmlns:iodef-sci="urn:ietf:params:xml:ns:iodef-sci-1.0"
     xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
     xmlns:ds="http://www.w3.org/2000/09/xmldsig#">
      <iodef:Incident purpose="reporting" restriction="default">
          <iodef:IncidentID name="csirt.example.com">
              189701
          </iodef:IncidentID>
          <iodef:StartTime>2013-02-05T00:34:45+00:00</iodef:StartTime>
          <iodef:DetectTime>2013-02-05T01:15:45+00:00</iodef:DetectTime>
          <iodef:ReportTime>2013-02-05T01:34:45+00:00</iodef:ReportTime>
          <iodef:description>DDoS Traffic Seen</iodef:description>
             <iodef:Assessment occurrence="actual">
                 <iodef:Impact severity="medium" type="dos">
                 DDoS Traffic</iodef:Impact>
                 <iodef:Confidence rating="numeric">90
                 </iodef:Confidence>
             </iodef:Assessment>
             <iodef:Contact role="creator" type="organization">
                 <iodef:ContactName>Dummy Test</iodef:ContactName>
                 <iodef:Email>contact@dummytest.com</iodef:Email>
             </iodef:Contact>
             <iodef:EventData>
                <iodef:Description>
                    Dummy Test sharing with ISP1
                </iodef:Description>
             <iodef:Expectation action="other"/>
             <iodef:Method>
                <iodef:Reference>
                   <iodef:ReferenceName>
                       Low Orbit Ion Cannon User Agent
                   </iodef:ReferenceName>
                   <iodef:URL>
                      http://blog.spiderlabs.com/2011/01/loic-ddos-
                      analysis-and-detection.html
                   </iodef:URL>
                   <iodef:URL>
                      http://en.wikipedia.org/wiki/Low_Orbit_Ion_Cannon
                   </iodef:URL>
                </iodef:Reference>
             </iodef:Method>
             <iodef:Flow>
                <iodef:System category="watchlist-source" spoofed="no">
                   <iodef:Node>
                     <iodef:Address category="ipv4-addr">
                        10.10.10.104</iodef:Address>
                   </iodef:Node>
                   <iodef:Node>
                     <iodef:Address category="ipv4-addr">
```

```
                        10.10.10.106</iodef:Address>
                                    </iodef:Node>
                    <iodef:Node>
                      <iodef:Address category="ipv4-net">
                       172.16.66.0/24</iodef:Address>
                       </iodef:Node>
                    <iodef:Node>
                      <iodef:Address category="ipv6-addr">
                       2001:db8:dead:beef::</iodef:Address>
                                   </iodef:Node>
    <iodef:Service ip_protocol="6">
       <iodef:Port>1337</iodef:Port>
       <iodef:Application user-agent="Mozilla/5.0 (Macintosh; U;
              Intel Mac OS X 10.5; en-US; rv:1.9.2.12) Gecko/
              20101026 Firefox/3.6.12">
       </iodef:Application>
    </iodef:Service>
               </iodef:System>
                <iodef:System category="target">
                   <iodef:Node>
                     <iodef:Address category="ipv4-addr">
    10.1.1.1</iodef:Address>
                  </iodef:Node>
                  <iodef:Service ip_protocol="6">
                    <iodef:Port>80</iodef:Port>
                  </iodef:Service>
                </iodef:System>
                <iodef:System category="sensor"><iodef:Description>
                    Information provided in FLow class instance is from
                    Inspection of traffic from network tap
                </iodef:Description></iodef:System>
              </iodef:Flow>
          </iodef:EventData>
      </iodef:Incident>
 </IODEF-Document>
```

A.4. Spear-Phishing

The Spear-Phishing test exchanged information that described a Spear-Phishing email including DNS records and addresses about the sender, malicious attached file information and email data. The IODEF version used for the data representation was based on [I-D.ietf-mile-rfc5070-bis].

```
 <?xml version="1.0" encoding="UTF-8"?>
 <IODEF-Document version="1.00" lang="en"
     xmlns="urn:ietf:params:xml:ns:iodef-1.41"
     xmlns:iodef="urn:ietf:params:xml:ns:iodef-1.41"
```

```
     xmlns:iodef-sci="urn:ietf:params:xml:ns:iodef-sci-1.0"
     xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
     xmlns:ds="http://www.w3.org/2000/09/xmldsig#">
      <iodef:Incident purpose="reporting">
          <iodef:IncidentID name="csirt.example.com">
             189601
          </iodef:IncidentID>
          <iodef:StartTime>2013-01-04T08:01:34+00:00</iodef:StartTime>
          <iodef:StopTime>2013-01-04T08:31:27+00:00</iodef:StopTime>
          <iodef:DetectTime>2013-01-04T08:06:12+00:00</iodef:DetectTime>
          <iodef:ReportTime>2013-01-04T09:15:45+00:00</iodef:ReportTime>
          <iodef:description>
             Zeus Spear Phishing E-mail with Malware Attachment
          </iodef:description>
             <iodef:Assessment occurrence="potential">
                 <iodef:Impact severity="medium" type="info-leak">
                 Malware with Command and Control Server and System
                 Changes</iodef:Impact>
             </iodef:Assessment>
             <iodef:Contact role="creator" type="organization">
                 <iodef:ContactName>example.com CSIRT
                 </iodef:ContactName>
                 <iodef:Email>contact@csirt.example.com</iodef:Email>
             </iodef:Contact>
             <iodef:EventData>
               <iodef:Description>Targeting Defense Contractors,
                  specifically board members attending Dummy Con
               </iodef:Description>
             <iodef:Expectation action="other"/>
             <iodef:Method>
                <iodef:Reference indicator_uid="1234">
                   <iodef:ReferenceName>Zeus</iodef:ReferenceName>
                   </iodef:Reference>
             </iodef:Method>
             <iodef:Flow>
                <iodef:System category="source">
                   <iodef:Node>
                     <iodef:Address category="url">
                           http://www.zeusevil.com</iodef:Address>
                     <iodef:Address category="ipv4-addr">
                           10.10.10.166</iodef:Address>
                    <iodef:Address category="as">
                           225</iodef:Address>
                     <iodef:Address category="ext-value"
                       ext-category="as-name">
                       EXAMPLE-AS - University of Example"
                       </iodef:Address>
                     <iodef:Address category="ext-value"
```

```
                      ext-category="as-prefix">
                      172.16..0.0/16
                      </iodef:Address>
                    <iodef:NodeRole category="www"
                      attacktype="malware-distribution"/>
                  </iodef:Node>
              </iodef:System>
            </iodef:Flow>
            <iodef:Flow>
               <iodef:System category="source">
                  <iodef:Node>
                   <iodef:NodeName>mail1.evildave.com</iodef:NodeName>
                    <iodef:Address category="ipv4-addr">
                          172.16.55.6</iodef:Address>
                   <iodef:Address category="asn">
                          225</iodef:Address>
                    <iodef:Address category="ext-value"
                      ext-category="as-name">
                      EXAMPLE-AS - University of Example
                    </iodef:Address>
    <iodef:DomainData>
       <iodef:Name>evildaveexample.com</iodef:Name>
       <iodef:DateDomainWasChecked>2013-01-04T09:10:24+00:00
       </iodef:DateDomainWasChecked>
       <iodef:RelatedDNS RecordType="MX">
           evildaveexample.com MX prefernce = 10, mail exchanger
           = mail1.evildave.com</iodef:RelatedDNS>
       <iodef:RelatedDNS RecordType="A">
           mail1.evildaveexample.com
           internet address = 172.16.55.6</iodef:RelatedDNS>
       <iodef:RelatedDNS RecordType="SPF">
            zuesevil.com. IN TXT \"v=spf1 a mx -all\"
       </iodef:RelatedDNS>
    </iodef:DomainData>
                  <iodef:NodeRole category="mail"
                        attacktype="spear-phishing"/>
                  </iodef:Node>
                  <iodef:Service>
                     <iodef:EmailInfo>
                        <iodef:Email>emaildave@evildaveexample.com
                        </iodef:Email>
                        <iodef:EmailSubject>Join us at Dummy Con
                        </iodef:EmailSubject>
                        <iodef:X-Mailer>StormRider 4.0
                        </iodef:X-Mailer>
                     </iodef:EmailInfo>
                  </iodef:Service>
              </iodef:System>
```

```
            <iodef:System category="target">
               <iodef:Node>
                  <iodef:Address category="ipv4">
                    192.168.54.2</iodef:Address>
               </iodef:Node>
             </iodef:System>
          </iodef:Flow>

          <iodef:Record>
            <iodef:RecordData>
              <iodef:HashData type="file_hash"
                 indicator_uid="1234">
                 <iodef:FileName>Dummy Con Sign Up Sheet.txt
                 </iodef:FileName>
                 <iodef:FileSize>152</iodef:FileSize>
              <ds:Reference>
                 <ds:DigestMethod Algorithm=
                    "http://www.w3.org/2001/04/xmlenc#sha256"/>
                    <ds:DigestValue>
                      141accec23e7e5157de60853cb1e01bc38042d
                      08f9086040815300b7fe75c184
                    </ds:DigestValue>
              </ds:Reference>
            </iodef:HashData>
           </iodef:RecordData>
           <iodef:RecordData>
            <iodef:HashData type="PKI_email_ds" valid="0">
              <ds:Signature>
               <ds:KeyInfo>
                  <ds:X509Data>
                     <ds:X509IssuerSerial>
                        <ds:X509IssuerName>FakeCA
                     </ds:X509IssuerName>
                     </ds:X509IssuerSerial>
                     <ds:X509SubjectName>EvilDaveExample
                     </ds:X509SubjectName>
                  </ds:X509Data>
               </ds:KeyInfo>
                  <ds:SignedInfo>
                   <ds:Reference>
                      <ds:DigestMethod Algorithm=
                        "http://www.w3.org/2001/04/xmlenc#sha256"/>
                      <ds:DigestValue>
                       352bddec13e4e5257ee63854cb1f05de48043d09f9
                       076070845307b7ce76c185
                      </ds:DigestValue>
                  </ds:Reference>
                </ds:SignedInfo>
```

```
                </ds:Signature>
             </iodef:HashData>
          </iodef:RecordData>
         </iodef:Record>
        </iodef:EventData>
     </iodef:Incident>
 </IODEF-Document>
```

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Incident Object Description Exchange Format Usage Guidance
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Abstract

The Incident Object Description Exchange Format (IODEF) v2 (RFC7970) defines a data representation that provides a framework for sharing information about computer security incidents commonly exchanged by Computer Security Incident Response Teams (CSIRTs) . Since the IODEF model includes a wealth of available options that can be used to describe a security incident or issue, it can be challenging for security practitioners to develop tools that leverage IODEF for incident sharing. This document provides guidelines for IODEF implementers. It addresses how common security indicators can be represented in IODEF and use-cases of how IODEF is being used. This document aims to make IODEF's adoption by vendors easier and encourage faster and wider adoption of the model by CSIRTs around the world.

Status of This Memo

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This Internet-Draft will expire on March 11, 2018.

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Table of Contents

1. Introduction

The Incident Object Description Exchange Format (IODEF) v2 [RFC7970] defines a data representation that provides a framework for sharing computer security incident information commonly exchanged by Computer Security Incident Response Teams (CSIRTs). The IODEF data model

consists of multiple classes and data types that are defined in the IODEF XML schema.

The IODEF schema was designed to describe all the possible fields needed in a security incident exchange. Thus, IODEF contains a plethora of data constructs which could make it hard for IODEF implementers to decide which are important. Additionally, in the IODEF schema, there exist multiple fields and classes which do not necessarily need to be used in every possible data exchange. Moreover, some IODEF classes are useful only in rare circumstances. This document tries to address these concerns. It also presents how common security indicators can be represented in IODEF. It points out the most important IODEF classes for an implementer and describes other ones that are not as important. Also, it presents some common pitfalls for IODEF implementers and how to address them. The end goal of this document is to make IODEF's use by vendors easier and encourage wider adoption of the model by CSIRTs around the world.

Section 3 discusses the recommended classes and how an IODEF implementer should choose the classes to implement. Section 4 presents common considerations a practitioner will come across and how to address them. Section 5 goes over some common uses of IODEF.

2. Terminology

The terminology used in this document follows the one defined in [RFC7970] and [RFC7203].

3. Implementation and Use Strategy

It is important for IODEF implementers to distinguish how the IODEF classes will be used in incident information exchanges. It is also important to understand the most common IODEF classes that describe common security incidents or indicators. This section describes the most important classes and factors an IODEF practitioner should take into consideration before using IODEF or designing an implementation.

3.1. Minimal IODEF document

An IODEF document must include at least an Incident class, an xml:lang attribute that defines the supported language and the IODEF version attribute. An Incident must contain a purpose attribute and three mandatory-to-implement elements. These elements are Generation time class that describes the time of the incident, an IncidentID class and at least one Contact class. The structure of the minimal IODEF-Document is shown in Figure 1.

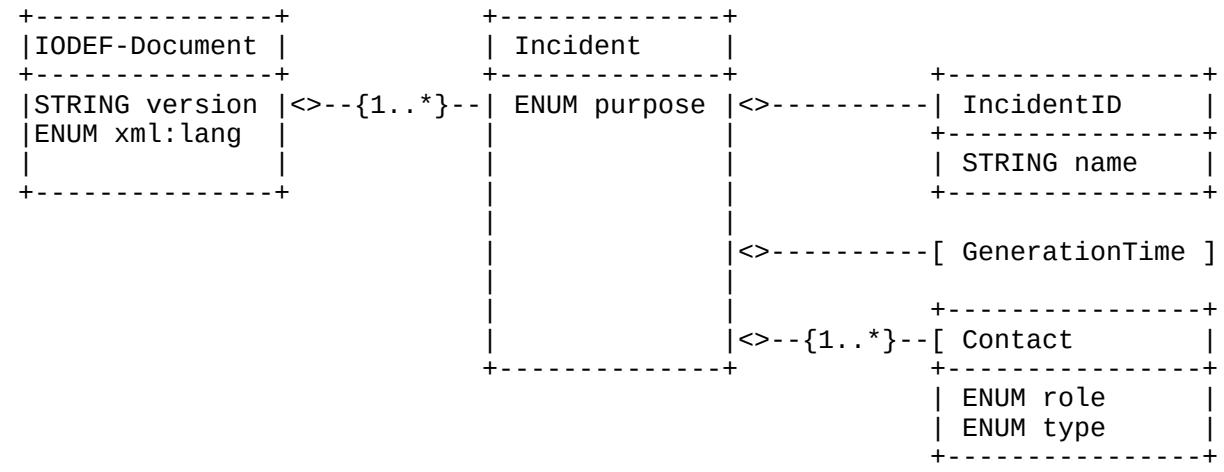

Figure 1: Minimal IODEF-Document class

The IncidentID class must contain at least a name attribute.

In turn, the Contact class requires the type and role attributes, but no elements are required by the IODEF v2 specification. Nevertheless, at least one of the elements in the Contact class, such as an Email class, should be implemented so that the IODEF document is useful.

Section 7.1 of [RFC7970] presents a minimal IODEF document with only the mandatory classes and attributes. Implementers can also refer to Section 7 of [RFC7970] and Appendix B for example IODEF v2 documents.

3.2. Information represented

There is no need for a practitioner to use or implement IODEF classes and fields other than the minimal ones (Section 3.1) and the ones necessary for her use-cases. The implementer should carefully look into the schema and decide which classes to implement (or not).

For example, if we have Distributed Denial of Service (DDoS) as a potential use-case, then the Flow class and its included information are the most important classes to use. The Flow class describes information related to the attacker and victim hosts, which information could help automated filtering or sink-hole operations.

Another potential use-case is malware command and control (c2). After modern malware infects a device, it usually proceeds to connect to one or more c2 servers to receive instructions from its master and potentially exfiltrate information. To protect against such

activity, it is important to interrupt the c2 communication by filtering the activity. IODEF can describe c2 activities using the Flow and the ServiceName classes.

For use-cases where indicators need to be described, the IndicatorData class will be implemented instead of the EventData class.

In summary, an implementer should identify her use-cases and find the classes that are necessary to support in IODEF v2. Implementing and parsing all IODEF classes can be cumbersome in some occasions and unnecessary. Other external schemata can also be used in IODEF to describe incidents or indicators. External schemata should be parsed accordingly only if the implementer's IODEF use-cases require external schema information. But even when an IODEF implementation cannot parse an external schema, the IODEF report can still be valuable to an incident response team. The information can also be useful when shared further with content consumers able to parse this information.

IODEF supports multiple language translations of free-form, ML_STRING text in all classes [RFC7970]. That way, text in Description elements can be translated to different languages by using a translation identifier in the class. Implementers should be able to parse iodef:MLStringType classes and extract only the information relevant to languages of interest.

3.3. IODEF Classes

[RFC7970] contains classes that can describe attack Methods, Events, Incidents, Indicators, how they were discovered and the Assessment of the repercussions for the victim. It is important for IODEF users to know the distinction between these classes in order to decide which ones fulfill their use-cases.

An IndicatorData class depicts a threat indicator or observable that could be used to describe a threat that resulted in an attempted attack. For example, we could see an attack happening but it might have been prevented and not have resulted in an incident or security event. On the other hand, an EventData class usually describes a security event and can be considered as a report of something that took place.

Classes like Discovery, Assessment, Method, and RecoveryTime are used in conjunction with EventData as they related to the incident report described in the EventData. The RelatedActivity class can reference an incident, an indicator or other related threat activity.

While deciding what classes are important for the needed use-cases, IODEF users should carefully evaluate the necessary classes and how these are used in order to avoid unnecessary work. For example, if we want to only describe indicators in IODEF, the implementation of Method or Assessment might not be important.

4. IODEF usage considerations

Implementers need to consider some common, standardized options for their IODEF use strategy.

4.1. External References

The IODEF format includes the Reference class used for externally defined information such as a vulnerability, Intrusion Detection System (IDS) alert, malware sample, advisory, or attack technique. To facilitate the exchange of information, the Reference class was extended to the Enumeration Reference Format [RFC7495]. The Enumeration Reference Format specifies a means to use external enumeration specifications (e.g. CVE) that could define an enumeration format, specific enumeration values, or both. As external enumerations can vary greatly, implementers should only support the ones expected to describe their specific use-cases.

4.2. Extensions

The IODEF data model ([RFC7970]) is extensible. Many attributes with enumerated values can be extended using the "ext-*" prefix. Additional classes can also be defined by using the AdditionalData and RecordItem classes. An extension to the AdditionalData class for reporting Phishing emails is defined in [RFC5901]. Information about extending IODEF class attributes and enumerated values can be found in Section 5 of [RFC7970].

Additionally, IODEF can import existing schemata by using an extension framework defined in [RFC7203]. The framework enables IODEF users to embed XML data inside an IODEF document using external schemata or structures defined by external specifications. Examples include CVE, CVRF and OVAL. [RFC7203] enhances the IODEF capabilities without further extending the data model.

IODEF implementers should not use their own IODEF extensions unless data cannot be represented using existing standards or importing them in an IODEF document using [RFC7203] is not a suitable option.

4.3. Indicator predicate logic

An IODEF [RFC7970] document can describe incident reports and indicators. The Indicator class can include references to other indicators, observables and more classes that contain details about the indicator. When describing security indicators, it is often common to need to group them together in order to form a group of indicators that constitute a security threat. For example, a botnet might have multiple command and control servers. For that reason, IODEF v2 introduced the IndicatorExpression class that is used to add the indicator predicate logic when grouping more than one indicators or observables.

Implementations must be able to parse and apply the Boolean logic offered by an IndicatorExpression in order to evaluate the existence of an indicator. As explained in Section 3.29.5 of [RFC7970] the IndicatorExpression element operator defines the operator applied to all the child element of the IndicatorExpression. If no operator is defined "and" should be assumed. IndicatorExpressions can also be nested together. Child IndicatorExpressions should be treated as child elements of their parent and they should be evaluated first before evaluated with the operator of their parent.

Users can refer to Appendix A for example uses of the IndicatorExpressions in an IODEF v2.

4.4. Disclosure level

Access to information in IODEF documents should be tightly locked since the content may be confidential. IODEF has a common attribute, called "restriction", which indicates the disclosure guideline to which the sender expects the recipient to adhere to for the information represented in the class and its children. That way, the sender can express the level of disclosure for each component of an IODEF document. Appropriate external measures could be implemented based on the restriction level. One example is when Real-time Inter-network Defense (RID) [RFC6545] is used to transfer the IODEF documents, it can provide policy guidelines for handling IODEF documents by using the RIDPolicy class.

The enforcement of the disclosure guidelines is out of scope for IODEF. The recipient of the IODEF document needs to follow the guidelines, but these guidelines themselves do not provide any enforcement measures. For that purpose, implementers should consider appropriate privacy control measures, technical or operational for their implementation.

5. IODEF Uses

IODEF is currently used by various organizations in order to represent security incidents and share incident and threat information between security operations organizations.

5.1. Implementations

In order to use IODEF, tools like IODEF parsers are necessary. [RFC8134] describes a set of IODEF implementations and uses by various vendors and Computer Emergency Readiness Team (CERT) organizations. The document does not specify any specific mandatory to implement (MTI) IODEF classes but provides a list of real world uses. Perl and Python modules (XML::IODEF, Iodef::Pb, iodeflib) are some examples. Moreover, implementers are encouraged to refer to Section 7 of [RFC8134] practical IODEF usage guidelines. [implementations], on the other hand, includes various vendor incident reporting products that can consume and export in IODEF format.

5.2. Inter-vendor and Service Provider Exercise

As an interoperability exercise, in 2013 a limited number of vendors organized and executed threat indicators exchanges in IODEF. The transport protocol used was RID. The threat information shared included indicators from DDoS attacks; and Malware incidents and Spear-Phishing that targets specific individuals after harvesting information about them. The results served as proof-of-concept (PoC) about how seemingly competing entities could use IODEF to exchange sanitized security information. As this was a PoC exercise only example information (no real threats) were shared as part of the exchanges.

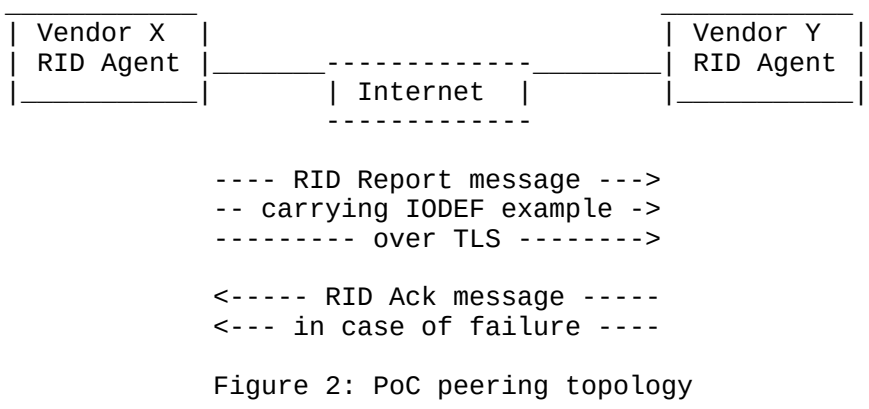

Figure 2: PoC peering topology

Figure 2 shows how RID interactions took place during the PoC. Participating organizations were running RID Agent software on-premises. The RID Agents formed peering relationships with other participating organizations. When Entity X had a new incident to exchange it would package it in IODEF and send it to Entity Y over TLS in a RID Report message. In case there was an issue with the message, Entity Y would send an RID Acknowledgement message back to Entity X which included an application level message to describe the issue. Interoperability between RID agents implementing [RFC6545] and [RFC6546] was also confirmed.

The first use-case included sharing of Malware Data Related to an Incident between CSIRTs. After Entity X detected an incident, she would put data about malware found during the incident in a backend system. Entity X then decided to share the incident information with Entity Y about the malware discovered. This could be a human decision or part of an automated process.

Below are the steps followed for the malware information exchange that was taking place:

(1) Entity X has a sharing agreement with Entity Y, and has already been configured with the IP address of Entity Y’s RID Agent.

(2) Entity X’s RID Agent connects to Entity Y’s RID Agent, and mutual authentication occurs using PKI digital certificates.

(3) Entity X pushes out a RID Report message which contains information about N pieces of discovered malware. IODEF is used in RID to describe the

    (a) Hash of malware files

    (b) Registry settings changed by the malware

    (c) C&C Information for the malware

(4) Entity Y receives RID Report message, sends RID Acknowledgement message

(5) Entity Y stores the data in a format that makes it possible for the back end to know which source the data came from.

Another use-case was sharing a DDoS attack as explained in the following scenario: Entity X, a Critical Infrastructure and Key Resource (CIKR) company detects that their internet connection is saturated with an abnormal amount of traffic. Further investigation determines that this is an actual DDoS attack. Entity X’s CSIT

contacts their ISP, Entity Y, and shares information with them about the attack traffic characteristics. Entity X's ISP is being overwhelmed by the amount of traffic, so it shares attack signatures and IP addresses of the most prolific hosts with its adjacent ISPs.

Below are the steps followed for a DDoS information exchange:

(1) Entity X has a sharing agreement with Entity Y, and has already been configured with the IP address of Entity Y's RID Agent.

(2) Entity X's RID Agent connects to Entity Y's RID Agent, and mutual authentication occurs using PKI digital certificates.

(3) Entity X pushes out a RID Report message which contains information about the DDoS attack. IODEF is used in RID to describe the

    (a) Start and Detect dates and times

    (b) IP Addresses of nodes sending DDoS Traffic

    (c) Sharing and Use Restrictions

    (d) Traffic characteristics (protocols and ports)

    (e) HTTP User-Agents used

    (f) IP Addresses of C&C for a botnet

(4) Entity Y receives RID Report message, sends RID Acknowledgement message

(5) Entity Y stores the data in a format that makes it possible for the back end to know which source the data came from.

(6) Entity Y shares information with other ISP Entities it has an established relationship with.

One more use-case was sharing spear-phishing email information as explained in the following scenario: The board members of several defense contractors receive a targeted email inviting them to attend a conference in San Francisco. The board members are asked to provide their personally identifiable information such as their home address, phone number, corporate email, etc in an attached document which came with the email. The board members are also asked to click on a URL which would allow them to reach the sign up page for the conference. One of the recipients believes the email to be a phishing attempt and forwards the email to their corporate CSIRT for

analysis. The CSIRT identifies the email as an attempted spear phishing incident and distributes the indicators to their sharing partners.

Below are the steps followed for a spear-phishing information exchange between CSIRTs that was part of this PoC.

(1) Entity X has a sharing agreement with Entity Y, and has already been configured with the IP address of Entity Y's RID Agent.

(2) Entity X's RID Agent connects to Entity Y's RID Agent, and mutual authentication occurs using PKI digital certificates.

(3) Entity X pushes out a RID Report message which contains information about the spear-phishing email. IODEF is used in RID to describe the

   (a) Attachment details (file Name, hash, size, malware family

   (b) Target description (IP, domain, NSLookup)

   (c) Email information (From, Subject, header information, date/ time, digital signature)

   (d) Confidence Score

(4) Entity Y receives RID Report message, sends RID Acknowledgement message

(5) Entity Y stores the data in a format that makes it possible for the back end to know which source the data came from.

Appendix B includes some of the incident IODEF example information that was exchanged by the organizations' RID Agents as part of this proof-of-concept.

5.3. Use-cases

Other use-cases of IODEF, other than the ones described above, could be:

(1) ISP notifying a national CERT or organization when it identifies and acts upon an incident and CERTs notifying ISPs when they are aware of incidents.

(2) Suspected phishing emails could be shared amongst organizations and national agencies. Automation could validate web content that the suspicious emails are pointing to. Identified

malicious content linked in a phishing email could then be shared using IODEF. Phishing campaigns could thus be subverted much faster by automating information sharing using IODEF.

(3) When finding a certificate that should be revoked, a third-party would forward an automated IODEF message to the CA with the full context of the certificate and the CA could act accordingly after checking its validity. Alternatively, in the event of a compromise of the private key of a certificate, a third-party could alert the certificate owner about the compromise using IODEF.

6. IANA Considerations

This memo does not require any IANA actions.

7. Security Considerations

This document does not incur any new security issues, since it only talks about the usage of IODEFv2 defined RFC7970. Nevertheless, readers of this document should refer to the Security Considerations section of [RFC7970].

8. References

8.1. Normative References

[RFC5901] Cain, P. and D. Jevans, "Extensions to the IODEF-Document Class for Reporting Phishing", RFC 5901, DOI 10.17487/RFC5901, July 2010, <https://www.rfc-editor.org/info/rfc5901>.

[RFC6545] Moriarty, K., "Real-time Inter-network Defense (RID)", RFC 6545, DOI 10.17487/RFC6545, April 2012, <https://www.rfc-editor.org/info/rfc6545>.

[RFC7203] Takahashi, T., Landfield, K., and Y. Kadobayashi, "An Incident Object Description Exchange Format (IODEF) Extension for Structured Cybersecurity Information", RFC 7203, DOI 10.17487/RFC7203, April 2014, <https://www.rfc-editor.org/info/rfc7203>.

[RFC7495] Montville, A. and D. Black, "Enumeration Reference Format for the Incident Object Description Exchange Format (IODEF)", RFC 7495, DOI 10.17487/RFC7495, March 2015, <https://www.rfc-editor.org/info/rfc7495>.

[RFC7970] Danyliw, R., "The Incident Object Description Exchange Format Version 2", RFC 7970, DOI 10.17487/RFC7970, November 2016, <https://www.rfc-editor.org/info/rfc7970>.

8.2. Informative References

[implementations] "Implementations on IODEF", <http://siis.realmv6.org/implementations/>.

[RFC6546] Trammell, B., "Transport of Real-time Inter-network Defense (RID) Messages over HTTP/TLS", RFC 6546, DOI 10.17487/RFC6546, April 2012, <https://www.rfc-editor.org/info/rfc6546>.

[RFC8134] Inacio, C. and D. Miyamoto, "Management Incident Lightweight Exchange (MILE) Implementation Report", RFC 8134, DOI 10.17487/RFC8134, May 2017, <https://www.rfc-editor.org/info/rfc8134>.

Appendix A. Indicator predicate logic examples

In the following example the EventData class evaluates as a Flow of one System with source address being (192.0.2.104 OR 192.0.2.106) AND target address 198.51.100.1.

```
<!-- ...XML code omitted... -->
 <IndicatorData>
   <Indicator>
     <IndicatorID name="csirt.example.com" version="1">
     G90823490
     </IndicatorID>
     <Description>C2 domains</Description>
     <IndicatorExpression operator="and">
       <IndicatorExpression operator="or">
         <Observable>
           <System category="source" spoofed="no">
             <Node>
               <Address category="ipv4-addr">
                 192.0.2.104
               </Address>
             </Node>
           </System>
         </Observable>
         <Observable>
           <System category="source" spoofed="no">
             <Node>
               <Address category="ipv4-addr">
                 192.0.2.106
               </Address>
             </Node>
           </System>
         </Observable>
       </IndicatorExpression>
       <Observable>
         <System category="target" spoofed="no">
           <Node>
             <Address category="ipv4-addr">
               198.51.100.1
             </Address>
           </Node>
         </System>
       </Observable>
     </IndicatorExpression>
   </Indicator>
 </IndicatorData>
<!-- ...XML code omitted... -->
```

Similarly, the FileData Class can be an observable in an IndicatorExpression. The hash values of two files can be used to match against an indicator using Boolean "or" logic. In the following example the indicator consists of either of the two files with two different hashes.

```
   <!-- ...XML code omitted... -->
    <IndicatorData>
      <Indicator>
        <IndicatorID name="csirt.example.com" version="1">
        A4399IWQ
        </IndicatorID>
        <Description>File hash watchlist</Description>
        <IndicatorExpression operator="or">
            <Observable>
              <FileData>
                <File>
                  <FileName>dummy.txt</FileName>
                  <HashData scope="file-contents">
                    <Hash>
                     <ds:DigestMethod Algorithm=
                     "http://www.w3.org/2001/04/xmlenc#sha256"/>
                     <ds:DigestValue>
                      141accec23e7e5157de60853cb1e01bc38042d
                      08f9086040815300b7fe75c184
                     </ds:DigestValue>
                    </Hash>
                  </HashData>
                </File>
              </FileData>
            </Observable>
            <Observable>
              <FileData>
                <File>
                  <FileName>dummy2.txt</FileName>
                  <HashData scope="file-contents">
                    <Hash>
                     <ds:DigestMethod Algorithm=
                     "http://www.w3.org/2001/04/xmlenc#sha256"/>
                     <ds:DigestValue>
                      141accec23e7e5157de60853cb1e01bc38042d
                      08f9086040815300b7fe75c184
                     </ds:DigestValue>
                    </Hash>
                  </HashData>
                </File>
              </FileData>
            </Observable>
        </IndicatorExpression>
      </Indicator>
    </IndicatorData>
   <!-- ...XML code omitted... -->
```

Appendix B. Inter-vendor and Service Provider Exercise Examples

Below some of the incident IODEF example information that was exchanged by the vendors as part of this proof-of-concept Inter-vendor and Service Provider Exercise.

B.1. Malware Delivery URL

This example indicates malware and related URL for file delivery.

```
<?xml version="1.0" encoding="UTF-8"?>
<IODEF-Document version="2.00"
                xmlns="urn:ietf:params:xml:ns:iodef-2.0"
                xmlns:iodef="urn:ietf:params:xml:ns:iodef-2.0"
                xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
  <iodef:Incident purpose="reporting">
    <iodef:IncidentID name="csirt.example.com">
      189801
    </iodef:IncidentID>
    <iodef:ReportTime>2012-12-05T12:20:00+00:00</iodef:ReportTime>
    <iodef:GenerationTime>2012-12-05T12:20:00+00:00</iodef:GenerationTime>
    <iodef:Description>Malware and related indicators</iodef:Description>
    <iodef:Assessment occurrence="potential">
      <iodef:SystemImpact severity="medium" type="breach-privacy">
        <iodef:Description>Malware with C&amp;amp;C
        </iodef:Description>
      </iodef:SystemImpact>
    </iodef:Assessment>
    <iodef:Contact role="creator" type="organization">
      <iodef:ContactName>example.com CSIRT
      </iodef:ContactName>
      <iodef:Email>
        <iodef:EmailTo>contact@csirt.example.com
        </iodef:EmailTo>
      </iodef:Email>
    </iodef:Contact>
    <iodef:EventData>
      <iodef:Flow>
        <iodef:System category="source">
          <iodef:Node>
            <iodef:Address category="ipv4-addr">192.0.2.200
            </iodef:Address>
                        <iodef:Address category="site-uri">
              /log-bin/lunch_install.php?aff_id=1&amp;lunch_id=1&amp;maddr=&amp;
action=install
            </iodef:Address>
          </iodef:Node>
          <iodef:NodeRole category="www"/>
        </iodef:System>
      </iodef:Flow>
    </iodef:EventData>
  </iodef:Incident>
</IODEF-Document>
```

B.2. DDoS

The DDoS test exchanged information that described a DDoS including protocols and ports, bad IP addresses and HTTP User-Agent fields.

The IODEF version used for the data representation was based on [RFC7970].

```
<?xml version="1.0" encoding="UTF-8"?>
<IODEF-Document version="2.00"
                xmlns="urn:ietf:params:xml:ns:iodef-2.0"
                xmlns:iodef="urn:ietf:params:xml:ns:iodef-2.0"
                xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
  <iodef:Incident purpose="reporting" restriction="default">
    <iodef:IncidentID name="csirt.example.com">
      189701
    </iodef:IncidentID>
    <iodef:DetectTime>2013-02-05T01:15:45+00:00</iodef:DetectTime>
    <iodef:StartTime>2013-02-05T00:34:45+00:00</iodef:StartTime>
    <iodef:ReportTime>2013-02-05T01:34:45+00:00</iodef:ReportTime>
    <iodef:GenerationTime>2013-02-05T01:15:45+00:00</iodef:GenerationTime>
    <iodef:Description>DDoS Traffic Seen</iodef:Description>
    <iodef:Assessment occurrence="actual">
      <iodef:SystemImpact severity="medium" type="availability-system">
        <iodef:Description>DDoS Traffic
        </iodef:Description>
      </iodef:SystemImpact>
      <iodef:Confidence rating="high"/>
    </iodef:Assessment>
    <iodef:Contact role="creator" type="organization">
      <iodef:ContactName>Dummy Test</iodef:ContactName>
      <iodef:Email>
        <iodef:EmailTo>contact@dummytest.com
        </iodef:EmailTo>
      </iodef:Email>
    </iodef:Contact>
    <iodef:EventData>
      <iodef:Description>
        Dummy Test sharing with ISP1
      </iodef:Description>
      <iodef:Method>
        <iodef:Reference>
          <iodef:URL>
            http://blog.spiderlabs.com/2011/01/loic-ddos-
            analysis-and-detection.html
          </iodef:URL>
          <iodef:URL>
            http://en.wikipedia.org/wiki/Low_Orbit_Ion_Cannon
          </iodef:URL>
          <iodef:Description>
            Low Orbit Ion Cannon User Agent
          </iodef:Description>
        </iodef:Reference>
```

```
      </iodef:Method>
      <iodef:Flow>
        <iodef:System category="source" spoofed="no">
          <iodef:Node>
            <iodef:Address category="ipv4-addr">
              192.0.2.104
            </iodef:Address>
          </iodef:Node>
          <iodef:Service ip-protocol="6">
            <iodef:Port>1337</iodef:Port>
          </iodef:Service>
        </iodef:System>
        <iodef:System category="source" spoofed="no">
          <iodef:Node>
            <iodef:Address category="ipv4-addr">
              192.0.2.106
            </iodef:Address>
          </iodef:Node>
          <iodef:Service ip-protocol="6">
            <iodef:Port>1337</iodef:Port>
          </iodef:Service>
        </iodef:System>
        <iodef:System category="source" spoofed="yes">
          <iodef:Node>
            <iodef:Address category="ipv4-net">
              198.51.100.0/24
            </iodef:Address>
          </iodef:Node>
          <iodef:Service ip-protocol="6">
            <iodef:Port>1337</iodef:Port>
          </iodef:Service>
        </iodef:System>
        <iodef:System category="source" spoofed="yes">
          <iodef:Node>
            <iodef:Address category="ipv6-addr">
              2001:db8:dead:beef::1
            </iodef:Address>
          </iodef:Node>
          <iodef:Service ip-protocol="6">
            <iodef:Port>1337</iodef:Port>
          </iodef:Service>
        </iodef:System>
        <iodef:System category="target">
          <iodef:Node>
            <iodef:Address category="ipv4-addr">
              203.0.113.1
            </iodef:Address>
          </iodef:Node>
```

```
          <iodef:Service ip-protocol="6">
            <iodef:Port>80</iodef:Port>
          </iodef:Service>
        </iodef:System>
        <iodef:System category="sensor">
          <iodef:Node>
          </iodef:Node>
          <iodef:Description>
            Information provided in Flow class instance is from
            Inspection of traffic from network tap
          </iodef:Description>
        </iodef:System>
      </iodef:Flow>
      <iodef:Expectation action="other"/>
    </iodef:EventData>
    <iodef:IndicatorData>
      <iodef:Indicator>
        <iodef:IndicatorID name="csirt.example.com" version="1">
          G83345941
        </iodef:IndicatorID>
        <iodef:Description>
          User-Agent string
        </iodef:Description>
        <iodef:Observable>
          <iodef:BulkObservable type="http-user-agent">
            <iodef:BulkObservableList>
              user-agent="Mozilla/5.0 (Macintosh; U; Intel Mac OS X 10.5; en-US;
 rv:1.9.2.12) Gecko/20101026 Firefox/3.6.12">
            </iodef:BulkObservableList>
          </iodef:BulkObservable>
        </iodef:Observable>
      </iodef:Indicator>
    </iodef:IndicatorData>
  </iodef:Incident>
</IODEF-Document>
```

B.3. Spear-Phishing

The Spear-Phishing test exchanged information that described a Spear-Phishing email including DNS records and addresses about the sender, malicious attached file information and email data. The IODEF version used for the data representation was based on [RFC7970].

```
<?xml version="1.0" encoding="UTF-8"?>
<IODEF-Document version="2.00"
               xmlns="urn:ietf:params:xml:ns:iodef-2.0"
               xmlns:iodef="urn:ietf:params:xml:ns:iodef-2.0"
               xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
               xmlns:ds="http://www.w3.org/2000/09/xmldsig#">
```

```
  <iodef:Incident purpose="reporting">
    <iodef:IncidentID name="csirt.example.com">
      189601
    </iodef:IncidentID>
    <iodef:DetectTime>2013-01-04T08:06:12+00:00</iodef:DetectTime>
    <iodef:StartTime>2013-01-04T08:01:34+00:00</iodef:StartTime>
    <iodef:EndTime>2013-01-04T08:31:27+00:00</iodef:EndTime>
    <iodef:ReportTime>2013-01-04T09:15:45+00:00</iodef:ReportTime>
    <iodef:GenerationTime>2013-01-04T09:15:45+00:00</iodef:GenerationTime>
    <iodef:Description>
      Zeus Spear Phishing E-mail with Malware Attachment
    </iodef:Description>
    <iodef:Assessment occurrence="potential">
      <iodef:SystemImpact severity="medium" type="takeover-system">
        <iodef:Description>
          Malware with Command and Control Server and System Changes
        </iodef:Description>
      </iodef:SystemImpact>
    </iodef:Assessment>
    <iodef:Contact role="creator" type="organization">
      <iodef:ContactName>example.com CSIRT</iodef:ContactName>
      <iodef:Email>
        <iodef:EmailTo>contact@csirt.example.com</iodef:EmailTo>
        </iodef:Email>
    </iodef:Contact>
    <iodef:EventData>
      <iodef:Description>
        Targeting Defense Contractors,
        specifically board members attending Dummy Con
      </iodef:Description>
      <iodef:Method>
        <iodef:Reference observable-id="ref-1234">
          <iodef:Description>Zeus</iodef:Description>
        </iodef:Reference>
      </iodef:Method>
      <iodef:Flow>
        <iodef:System category="source">
          <iodef:Node>
            <iodef:Address category="site-uri">
              http://www.zeusevil.example.com
            </iodef:Address>
            <iodef:Address category="ipv4-addr">
              192.0.2.166
            </iodef:Address>
            <iodef:Address category="asn">
              65535
            </iodef:Address>
            <iodef:Address category="ext-value"
```

```
                        ext-category="as-name">
              EXAMPLE-AS - University of Example"
            </iodef:Address>
            <iodef:Address category="ext-value"
                        ext-category="as-prefix">
              192.0.2.0/24
            </iodef:Address>
          </iodef:Node>
          <iodef:NodeRole category="malware-distribution"/>
        </iodef:System>
      </iodef:Flow>
      <iodef:Flow>
        <iodef:System category="source">
          <iodef:Node>
            <iodef:DomainData>
              <Name>mail1.evildave.example.com</Name>
            </iodef:DomainData>
            <iodef:Address category="ipv4-addr">
              198.51.100.6
            </iodef:Address>
            <iodef:Address category="asn">
              65534
            </iodef:Address>
            <iodef:Address category="ext-value"
                        ext-category="as-name">
              EXAMPLE-AS - University of Example
            </iodef:Address>
            <iodef:DomainData>
              <iodef:Name>evildave.example.com</iodef:Name>
              <iodef:DateDomainWasChecked>2013-01-04T09:10:24+00:00
              </iodef:DateDomainWasChecked>
              <!-- <iodef:RelatedDNS RecordType="MX"> -->
              <iodef:RelatedDNS dtype="string">
                evildave.example.com MX prefernce = 10, mail exchanger
                = mail1.evildave.example.com
              </iodef:RelatedDNS>
              <iodef:RelatedDNS dtype="string">
                mail1.evildave.example.com
                internet address = 198.51.100.6
              </iodef:RelatedDNS>
              <iodef:RelatedDNS dtype="string">
                zuesevil.example.com. IN TXT \"v=spf1 a mx -all\"
              </iodef:RelatedDNS>
            </iodef:DomainData>
          </iodef:Node>
          <iodef:NodeRole category="mail">
            <iodef:Description>
              Sending phishing mails
```

```
            </iodef:Description>
          </iodef:NodeRole>
          <iodef:Service>
            <iodef:EmailData>
              <iodef:EmailFrom>
                emaildave@evildave.example.com
              </iodef:EmailFrom>
              <iodef:EmailSubject>
                Join us at Dummy Con
              </iodef:EmailSubject>
              <iodef:EmailX-Mailer>
                StormRider 4.0
              </iodef:EmailX-Mailer>
            </iodef:EmailData>
          </iodef:Service>
        </iodef:System>
        <iodef:System category="target">
          <iodef:Node>
            <iodef:Address category="ipv4-addr">
              203.0.113.2
            </iodef:Address>
          </iodef:Node>
        </iodef:System>
      </iodef:Flow>
      <iodef:Expectation action="other"/>
      <iodef:Record>
        <iodef:RecordData>
          <iodef:FileData observable-id="fd-1234">
            <iodef:File>
              <iodef:FileName>
                Dummy Con Sign Up Sheet.txt
              </iodef:FileName>
              <iodef:FileSize>
                152
              </iodef:FileSize>
              <iodef:HashData scope="file-contents">
                <iodef:Hash>
                  <ds:DigestMethod
                          Algorithm="http://www.w3.org/2001/04/xmlenc#sha256"/>
                  <ds:DigestValue>
                    141accec23e7e5157de60853cb1e01bc38042d
                    08f9086040815300b7fe75c184
                  </ds:DigestValue>
                </iodef:Hash>
              </iodef:HashData>
            </iodef:File>
          </iodef:FileData>
        </iodef:RecordData>
```

```
        <iodef:RecordData>
          <iodef:CertificateData>
            <iodef:Certificate>
              <ds:X509Data>
                <ds:X509IssuerSerial>
                  <ds:X509IssuerName>FakeCA
                  </ds:X509IssuerName>
                  <ds:X509SerialNumber>
                    57482937101
                  </ds:X509SerialNumber>
                </ds:X509IssuerSerial>
                <ds:X509SubjectName>EvilDaveExample
                </ds:X509SubjectName>
              </ds:X509Data>
            </iodef:Certificate>
          </iodef:CertificateData>
        </iodef:RecordData>
      </iodef:Record>
    </iodef:EventData>
  </iodef:Incident>
</IODEF-Document>
```

B.4. Malware

In this test, malware information was exchanged using RID and IODEF. The information included file hashes, registry setting changes and the C&C servers the malware uses.

```
<?xml version="1.0" encoding="UTF-8"?>
<IODEF-Document version="2.00"
                xmlns="urn:ietf:params:xml:ns:iodef-2.0"
                xmlns:iodef="urn:ietf:params:xml:ns:iodef-2.0"
                xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
                xmlns:ds="http://www.w3.org/2000/09/xmldsig#">
  <iodef:Incident purpose="reporting">
    <iodef:IncidentID name="csirt.example.com">
      189234
    </iodef:IncidentID>
    <iodef:ReportTime>2013-03-07T16:14:56.757+05:30</iodef:ReportTime>
    <iodef:GenerationTime>2013-03-07T16:14:56.757+05:30</iodef:GenerationTime>
    <iodef:Description>
      Malware and related indicators identified
    </iodef:Description>
    <iodef:Assessment occurrence="potential">
      <iodef:SystemImpact severity="medium" type="breach-proprietary">
        <iodef:Description>
          Malware with Command and Control Server and System Changes
        </iodef:Description>
```

```
      </iodef:SystemImpact>
    </iodef:Assessment>
    <iodef:Contact role="creator" type="organization">
      <iodef:ContactName>example.com CSIRT</iodef:ContactName>
      <iodef:Email>
        <iodef:EmailTo>contact@csirt.example.com</iodef:EmailTo>
      </iodef:Email>
    </iodef:Contact>
    <iodef:EventData>
      <iodef:Method>
        <iodef:Reference>
          <iodef:URL>
            http://www.threatexpert.example.com/report.aspx?
            md5=e2710ceb088dacdcb03678db250742b7
          </iodef:URL>
          <iodef:Description>Zeus</iodef:Description>
        </iodef:Reference>
      </iodef:Method>
      <iodef:Flow>
        <iodef:System category="source">
          <iodef:Node>
            <iodef:Address category="ipv4-addr" observable-id="addr-c2-91011-001
">
              203.0.113.200
            </iodef:Address>
            <iodef:Address category="site-uri" observable-id="addr-c2-91011-002"
>
              http://zeus.556677889900.example.com/log-bin/
              lunch_install.php?aff_id=1&amp;amp;
              lunch_id=1&amp;amp;maddr=&amp;amp;
              action=install
            </iodef:Address>
          </iodef:Node>
          <iodef:NodeRole category="c2-server"/>
        </iodef:System>
      </iodef:Flow>
      <iodef:Record>
        <iodef:RecordData>
          <iodef:FileData observable-id="file-91011-001">
            <iodef:File>
              <iodef:HashData scope="file-contents">
                <iodef:Hash>
                  <ds:DigestMethod Algorithm="http://www.w3.org/2001/04/xmlenc#s
ha1"/>
                  <ds:DigestValue>
                    MHg2NzUxQTI1MzQ4M0E2N0Q4NkUwRjg0NzYwRjYxRjEwQkJDQzJFREZG
                  </ds:DigestValue>
                </iodef:Hash>
              </iodef:HashData>
            </iodef:File>
            <iodef:File>
```

```
              <iodef:HashData scope="file-contents">
                <iodef:Hash>
                  <ds:DigestMethod Algorithm="http://www.w3.org/2001/04/xmlenc#m
d5"/>
                  <ds:DigestValue>
                    MHgyRTg4ODA5ODBENjI0NDdFOTc5MEFGQTg5NTEzRjBBNA==
                  </ds:DigestValue>
                </iodef:Hash>
              </iodef:HashData>
            </iodef:File>
          </iodef:FileData>
          <iodef:WindowsRegistryKeysModified observable-id="regkey-91011-001">
            <iodef:Key registryaction="add-value">
              <iodef:KeyName>
                HKLM\Software\Microsoft\Windows\
                CurrentVersion\Run\tamg
              </iodef:KeyName>
              <iodef:Value>
                ?\?\?%System%\wins\mc.exe\?\??
              </iodef:Value>
            </iodef:Key>
            <iodef:Key registryaction="modify-value">
              <iodef:KeyName>HKLM\Software\Microsoft\
                Windows\CurrentVersion\Run\dqo
              </iodef:KeyName>
              <iodef:Value>"\"\"%Windir%\Resources\
                Themes\Luna\km.exe\?\?"
              </iodef:Value>
            </iodef:Key>
          </iodef:WindowsRegistryKeysModified>
        </iodef:RecordData>
      </iodef:Record>
    </iodef:EventData>
    <iodef:EventData>
      <iodef:Method>
        <iodef:Reference>
          <iodef:URL>
            http://www.threatexpert.example.com/report.aspx?
            md5=c3c528c939f9b176c883ae0ce5df0001
          </iodef:URL>
          <iodef:Description>Cridex</iodef:Description>
        </iodef:Reference>
      </iodef:Method>
      <iodef:Flow>
        <iodef:System category="source">
          <iodef:Node>
            <iodef:Address category="ipv4-addr" observable-id="addr-c2-91011-003
">
              203.0.113.100
            </iodef:Address>
```

```
          </iodef:Node>
          <iodef:NodeRole category="c2-server"/>
          <iodef:Service ip-protocol="6">
            <iodef:Port>8080</iodef:Port>
          </iodef:Service>
        </iodef:System>
      </iodef:Flow>
      <iodef:Record>
        <iodef:RecordData>
          <iodef:FileData observable-id="file-91011-002">
            <iodef:File>
              <iodef:HashData scope="file-contents">
                <iodef:Hash>
                  <ds:DigestMethod Algorithm="http://www.w3.org/2001/04/xmlenc#s
ha1"/>
                  <ds:DigestValue>
                    MHg3MjYzRkUwRDNBMDk1RDU5QzhFMEM4OTVBOUM1ODVFMzQzRTcxNDFD
                  </ds:DigestValue>
                </iodef:Hash>
              </iodef:HashData>
            </iodef:File>
          </iodef:FileData>
          <iodef:FileData observable-id="file-91011-003">
            <iodef:File>
              <iodef:HashData scope="file-contents">
                <iodef:Hash>
                  <ds:DigestMethod Algorithm="http://www.w3.org/2001/04/xmlenc#m
d5"/>
                  <ds:DigestValue>
                    MHg0M0NEODUwRkNEQURFNDMzMEE1QkVBNkYxNkVFOTcxQw==
                  </ds:DigestValue>
                </iodef:Hash>
              </iodef:HashData>
            </iodef:File>
          </iodef:FileData>
          <iodef:WindowsRegistryKeysModified observable-id="regkey-91011-002">
            <iodef:Key registryaction="add-value">
              <iodef:KeyName>
                HKLM\Software\Microsoft\Windows\
                CurrentVersion\Run\KB00121600.exe
              </iodef:KeyName>
              <iodef:Value>
                \?\?%AppData%\KB00121600.exe\?\?
              </iodef:Value>
            </iodef:Key>
          </iodef:WindowsRegistryKeysModified>
        </iodef:RecordData>
      </iodef:Record>
    </iodef:EventData>
    <iodef:IndicatorData>
```

```
      <iodef:Indicator>
        <iodef:IndicatorID name="csirt.example.com" version="1">
          ind-91011
        </iodef:IndicatorID>
        <iodef:Description>
          evil c2 server, file hash, and registry key
        </iodef:Description>
        <iodef:IndicatorExpression operator="or">
          <iodef:IndicatorExpression operator="or">
            <iodef:Observable>
              <iodef:Address category="site-uri" observable-id="addr-qrst">
                http://foo.example.com:12345/evil/cc.php
              </iodef:Address>
            </iodef:Observable>
            <iodef:Observable>
              <iodef:Address category="ipv4-addr" observable-id="addr-stuv">
                192.0.2.1
              </iodef:Address>
            </iodef:Observable>
            <iodef:Observable>
              <iodef:Address category="ipv4-addr" observable-id="addr-tuvw">
                198.51.100.1
              </iodef:Address>
            </iodef:Observable>
            <iodef:Observable>
              <iodef:Address category="ipv6-addr" observable-id="addr-uvwx">
                2001:db8:dead:beef::1
              </iodef:Address>
            </iodef:Observable>
            <iodef:ObservableReference uid-ref="addr-c2-91011-001"/>
            <iodef:ObservableReference uid-ref="addr-c2-91011-002"/>
            <iodef:ObservableReference uid-ref="addr-c2-91011-003"/>
          </iodef:IndicatorExpression>
          <iodef:IndicatorExpression operator="and">
            <iodef:Observable>
              <iodef:FileData observable-id="file-91011-000">
                <iodef:File>
                  <iodef:HashData scope="file-contents">
                    <iodef:Hash>
                      <ds:DigestMethod Algorithm="http://www.w3.org/2001/04/xmle
nc#sha256"/>
                      <ds:DigestValue>
                        141accec23e7e5157de60853cb1e01bc38042d08f9086040815300b7
fe75c184
                      </ds:DigestValue>
                    </iodef:Hash>
                  </iodef:HashData>
                </iodef:File>
              </iodef:FileData>
            </iodef:Observable>
```

```
            <iodef:Observable>
              <iodef:WindowsRegistryKeysModified observable-id="regkey-91011-000
">
                <iodef:Key registryaction="add-key"
                           observable-id="regkey-vwxy">
                  <iodef:KeyName>
                    HKLM\SYSTEM\CurrentControlSet\
                    Services\.Net CLR
                  </iodef:KeyName>
                </iodef:Key>
                <iodef:Key registryaction="add-key"
                           observable-id="regkey-wxyz">
                  <iodef:KeyName>
                    HKLM\SYSTEM\CurrentControlSet\
                    Services\.Net CLR\Parameters
                  </iodef:KeyName>
                  <iodef:Value>
                    \"\"%AppData%\KB00121600.exe\"\"
                  </iodef:Value>
                </iodef:Key>
                <iodef:Key registryaction="add-value"
                           observable-id="regkey-xyza">
                  <iodef:KeyName>
                    HKLM\SYSTEM\CurrentControlSet\Services\
                    .Net CLR\Parameters\ServiceDll
                  </iodef:KeyName>
                  <iodef:Value>C:\bad.exe</iodef:Value>
                </iodef:Key>
                <iodef:Key registryaction="modify-value"
                           observable-id="regkey-zabc">
                  <iodef:KeyName>
                    HKLM\SYSTEM\CurrentControlSet\
                    Services\.Net CLR\Parameters\Bar
                  </iodef:KeyName>
                  <iodef:Value>Baz</iodef:Value>
                </iodef:Key>
              </iodef:WindowsRegistryKeysModified>
            </iodef:Observable>
          </iodef:IndicatorExpression>
          <iodef:IndicatorExpression operator="or">
            <iodef:IndicatorExpression operator="and">
              <iodef:ObservableReference uid-ref="file-91011-001"/>
              <iodef:ObservableReference uid-ref="regkey-91011-001"/>
            </iodef:IndicatorExpression>
            <iodef:IndicatorExpression operator="and">
              <iodef:IndicatorExpression operator="or">
                <iodef:ObservableReference uid-ref="file-91011-002"/>
                <iodef:ObservableReference uid-ref="file-91011-003"/>
              </iodef:IndicatorExpression>
```

```
              <iodef:ObservableReference uid-ref="regkey-91011-002"/>
            </iodef:IndicatorExpression>
          </iodef:IndicatorExpression>
        </iodef:IndicatorExpression>
      </iodef:Indicator>
    </iodef:IndicatorData>
  </iodef:Incident>
</IODEF-Document>
```

B.5. IoT Malware

The IoT Malware test exchanged information that described a bad IP address of IoT malware and its scanned ports. This example information is extracted from alert messages of a Darknet monitoring system referred in [RFC8134]. The IODEF version used for the data representation was based on [RFC7970].

```
<?xml version="1.0" encoding="UTF-8"?>
<IODEF-Document version="2.00"
                xmlns="urn:ietf:params:xml:ns:iodef-2.0"
                xmlns:iodef="urn:ietf:params:xml:ns:iodef-2.0"
                xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
  <iodef:Incident purpose="reporting">
    <iodef:IncidentID name="csirt.example.com">
      189802
    </iodef:IncidentID>
    <iodef:ReportTime>2017-03-01T01:15:00+09:00</iodef:ReportTime>
    <iodef:GenerationTime>2017-03-01T01:15:00+09:00</iodef:GenerationTime>
    <iodef:Description>IoT Malware and related indicators</iodef:Description>
    <iodef:Assessment occurrence="potential">
      <iodef:SystemImpact severity="medium" type="takeover-system">
        <iodef:Description>IoT Malware is scanning other hosts
        </iodef:Description>
      </iodef:SystemImpact>
    </iodef:Assessment>
    <iodef:Contact role="creator" type="organization">
      <iodef:ContactName>example.com CSIRT
      </iodef:ContactName>
      <iodef:Email>
        <iodef:EmailTo>contact@csirt.example.com
        </iodef:EmailTo>
      </iodef:Email>
    </iodef:Contact>
    <iodef:EventData>
      <iodef:Discovery source="nidps">
        <iodef:Description>
          Detected by darknet monitoring
        </iodef:Description>
```

```
      </iodef:Discovery>
      <iodef:Flow>
        <iodef:System category="source">
          <iodef:Node>
            <iodef:Address category="ipv4-addr">
              192.0.2.210
            </iodef:Address>
          </iodef:Node>
          <iodef:NodeRole category="camera"/>
          <iodef:Service ip-protocol="6">
            <iodef:Port>23</iodef:Port>
          </iodef:Service>
          <iodef:OperatingSystem>
            <iodef:Description>
              Example Surveillance Camera OS 2.1.1
            </iodef:Description>
          </iodef:OperatingSystem>
        </iodef:System>
      </iodef:Flow>
      <iodef:EventData>
        <iodef:Flow>
          <iodef:System category="target">
            <iodef:Node>
              <iodef:Address category="ipv4-addr">
                198.51.100.1
              </iodef:Address>
            </iodef:Node>
            <iodef:NodeRole category="honeypot"/>
            <iodef:Service ip-protocol="6">
              <iodef:Port>23</iodef:Port>
            </iodef:Service>
          </iodef:System>
        </iodef:Flow>
      </iodef:EventData>
      <iodef:EventData>
        <iodef:Flow>
          <iodef:System category="target">
            <iodef:Node>
              <iodef:Address category="ipv4-addr">
                198.51.100.94
              </iodef:Address>
            </iodef:Node>
            <iodef:NodeRole category="honeypot"/>
            <iodef:Service ip-protocol="6">
              <iodef:Port>23</iodef:Port>
            </iodef:Service>
          </iodef:System>
        </iodef:Flow>
```

```
      </iodef:EventData>
      <iodef:EventData>
        <iodef:Flow>
          <iodef:System category="target">
            <iodef:Node>
              <iodef:Address category="ipv4-addr">
                198.51.100.237
              </iodef:Address>
            </iodef:Node>
            <iodef:NodeRole category="honeypot"/>
            <iodef:Service ip-protocol="6">
              <iodef:Port>2323</iodef:Port>
            </iodef:Service>
          </iodef:System>
        </iodef:Flow>
      </iodef:EventData>
    </iodef:EventData>
  </iodef:Incident>
</IODEF-Document>
```

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MILE Working Group
Internet-Draft
Obsoletes: 5070, 6685 (if approved)
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June 24, 2016

The Incident Object Description Exchange Format v2
draft-ietf-mile-rfc5070-bis-25

Abstract

The Incident Object Description Exchange Format (IODEF) defines a data representation for security incident reports and indicators commonly exchanged by operational security teams for mitigation and watch and warning. This document describes an updated information model for the IODEF and provides an associated data model specified with XML Schema. This new information and data model obsoletes Request for Comment (RFC) 5070 and 6685.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

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This Internet-Draft will expire on December 26, 2016.

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Table of Contents

1. Introduction

Organizations require help from other parties to mitigate malicious activity targeting their network and to gain insight into potential threats. This coordination might entail working with an ISP to filter attack traffic, contacting a remote site to take down a botnet, or sharing watch-lists of known malicious indicators in a consortium.

The Incident Object Description Exchange Format (IODEF) is a format for representing computer security information commonly exchanged between Computer Security Incident Response Teams (CSIRTs) or other operational security teams. It provides an XML representation for conveying:

- indicators to characterize a threat;
- security incident reports to document attacks against an organization;
- response activity taken or that could be taken in response to an incident; and
- meta-data so that these various classes of information can be exchanged among parties.

The purpose of the IODEF is to enhance the operational capabilities of CSIRTs. Adoption of the IODEF will improve the ability of a CSIRT to resolve security incidents; understand threats; and coordinate response activities and proactive mitigations by simplifying collaboration and data sharing with its partners. This structured format provided by the IODEF allows for:

- machine-to-machine exchange of incident and indicator data;
- automated processing of this data whereby allowing more rapid execution of appropriate courses of action; and
- the development of an ecosystem of interoperable tools enabling security operations.

Sharing and coordinating with other organizations is not strictly a technical problem. There are numerous procedural, cultural, legal and trust-related barriers to overcome. The IODEF does not attempt to address them directly. However, operational implementations of the IODEF will need to consider these challenges.

Section 1 provides the background for the IODEF. Sections 3 and 8 specify the IODEF information and data model respectively. The data types used in this document are described in Section 2. Processing considerations, extending the specification, internationalization and security issues are covered in Sections 4, 5, 6 and 9 respectively. Examples are listed in Section 7.

1.1. Terminology

The key words "MUST," "MUST NOT," "REQUIRED," "SHALL," "SHALL NOT," "SHOULD," "SHOULD NOT," "RECOMMENDED," "MAY," and "OPTIONAL" in this document are to be interpreted as described in [RFC2119].

1.2. Notations

The IODEF is specified as an Extensible Markup Language (XML) [W3C.XML] Schema [W3C.SCHEMA]. The normative IODEF data model is found in the XML schema in Section 8. To aid in the understanding of the data elements, Section 3 also depicts the underlying information model using Unified Modeling Language (UML). This abstract presentation of the IODEF is not normative.

For clarity in this document, the term "XML document" will be used when referring generically to any instance of an XML document. The term "IODEF document" will be used to refer to an XML document conforming to the IODEF specification. The terms "schema" will be used to refer to Section 8 of this document. The terms "data model" and "schema" will be used interchangeably. The terms "class" and "element" will be used to reference either the corresponding data element in the UML-based information or XML Schema-based data models, respectively.

1.3. About the IODEF Data Model

A number of considerations were made in the design of the IODEF data model.

- The data model found in this document is an evolution of the one previously specified in [RFC5070]. New fields were added to represent additional information. [RFC5070] was developed primarily to represent incident reports. This document builds upon it by adding support for indicators and revising it to reflect the current challenges faced by CSIRTs. An attempt was made to preserve backward compatibility but this was not possible in all cases. See Section 4.4. This document obsoletes [RFC5070].

- The IODEF is a transport format. Therefore, the data model may not be the optimal archival or in-memory processing format.

- The IODEF is intended to be a framework to convey only commonly exchanged information. It ensures that there are mechanisms for extensibility to support organization-specific information and techniques to reference information kept outside of the data model.

- Not all commonly exchanged information has a well-defined format or taxonomy. The IODEF attempts to strike a balance between enforcing sufficient structure to allow automated processing and supporting free-form content that enables maximum flexibility.

- The IODEF fits into a broader ecosystem of standards and conventions. An attempt was made to harmonize the data model with this context.

1.4. Changelog

A detailed list of additions made to the [RFC5070] data model are enumerated in this section. See Section 4.4 for a list of incompatible changes.

- Updated the data types (Section 2) to improve internationalization, clarify ambiguity, and ensure consistency in extensions.

- Added the observable-id attribute (Section 3.3.2) and IndicatorData (Section 3.28) class (Section 3.28) to represent indicators.

- Added the private-enum-name and -id attributes to the IODEF-Document class (Section 3.1) to disambiguate private extensions.

- Updated the Incident class (Section 3.2) to represent additional timing and workflow information.

- Added the ThreatActor (Section 3.7) and Campaign (Section 3.8) classes to represent attack attribution information.

- Updated the Contact class (Section 3.9) and its children to improve internationalization and represent additional information about an entity.

- Updated the Method class (Section 3.11) to improve extensibility through externally referenced resources.

- Added the Discovery class (Section 3.10) to describe how an incident was discovered.
- Updated the Assessment class (Section 3.12) to enable more descriptive characterizations of the impact of an incident.
- Updated the HistoryItem (Section 3.13.1) and Expectation (Section 3.15) classes to support a reference to a course of action.
- Updated the EventData class (Section 3.14) with additional meta-data added to the Incident class.
- Updated the System (Section 3.17) class with additional meta-data.
- Updated the Counter class (Section 3.18.3) to support additional rate metrics.
- Added the DomainData (Section 3.19), EmailData (Section 3.21), WindowsRegistryKeysModified (Section 3.23), CertificateData (Section 3.24) and FileData (Section 3.25) to improve the description of an incident and support this data as indicators.
- Added the SignatureData (Section 3.27) and HashData classes (Section 3.26) to represent digital signatures and hashes.
- Added support for public enumerated attribute extensions using IANA registries (Section 5.1.2).
- Updated numerous enumerated attributes for completeness.

2. IODEF Data Types

The IODEF uses a number of simple and complex types. This section describes these data types.

2.1. Integers

An integer is represented in the information model by the INTEGER data type. Integer data MUST be encoded in Base 10.

The INTEGER data type is implemented in the data model as a "xs:integer" type per Section 3.3.13 of [W3C.SCHEMA.DTYPES].

2.2. Real Numbers

A real (floating-point) number is represented in the information model by the REAL data type. Real data MUST be encoded in Base 10.

The REAL data type is implemented in the data model as a "xs:float" type per Section 3.2.4 of [W3C.SCHEMA.DTYPES].

2.3. Characters and Strings

A single character is represented in the information model by the CHARACTER data type. A string is represented by the STRING data type. Special characters MUST be encoded using entity references. See Section 4.1.

The CHARACTER and STRING data types are implemented in the data model as a "xs:string" type per Section 3.2.1 of [W3C.SCHEMA.DTYPES].

2.4. Multilingual Strings

A string that needs to be represented in a human-readable language different than the default encoding of the document is represented in the information model by the ML_STRING data type.

The ML_STRING data type is implemented in the data model as the "iodef:MLStringType" type. This type extends the "xs:string" to include two attributes.

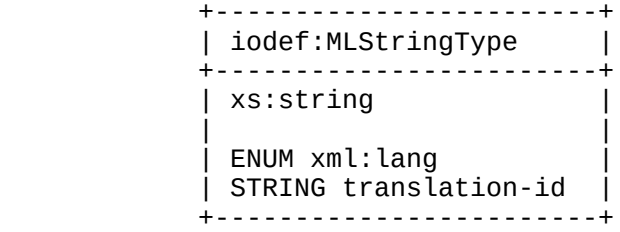

Figure 1: The iodef:MLStringType Type

The content of the class is a character string of type "xs:string" whose language MAY be specified by the xml:lang attribute.

The attributes of the iodef:MLStringType type are:

xml:lang
: Optional. ENUM. A language identifier per Section 2.12 of [W3C.XML] whose values and format are described in [RFC5646]. The interpretation of this code is described in Section 6.

translation-id
: Optional. STRING. An identifier to relate other instances of this class with the same parent as translations of this text. The scope of this identifier is limited to all of the direct, peer child classes of a given parent class.

Using this class enables representing translations of the same text in multiple languages. Each translation is a distinct instance of this class with a common parent. A group of classes each with a translated instance of text is related by setting a common identifier in the translation-id attribute. The language of a given class is set by the xml:lang attribute. See Section 6 for more details on representing translations of free-form text.

2.5. Binary Strings

Binary octets can be represented with two encodings.

2.5.1. Base64 Bytes

A binary octet encoded with Base64 is represented in the information model by the BYTE data type. A sequence of these octets is of the BYTE[] data type.

The BYTE and BYTE[] data types are implemented in the data model as a "xs:base64Binary" type per Section 3.2.16 of [W3C.SCHEMA.DTYPES].

2.5.2. Hexadecimal Bytes

A binary octet encoded as a character tuple consistent of two hexadecimal digits is represented in the information model by the HEXBIN data type. A sequence of these octets is of the HEXBIN[] data type.

The HEXBIN and HEXBIN[] data types are implemented in the data model as a "xs:hexBinary" type per Section 3.2.15 of [W3C.SCHEMA.DTYPES].

2.6. Enumerated Types

An enumerated type is represented in the information model by the ENUM data type. It is an ordered list of acceptable string values. Each value has a representative keyword. Within the data model, the enumerated type keywords are used as attribute values.

The ENUM data type is implemented in the data model as values of a "xs:NMTOKEN" type per Section 3.3.4 of [W3C.SCHEMA.DTYPES].

2.7. Date-Time String

A date-time strings that describes a particular instant in time is represented in the information model by the DATETIME data type. Ranges are not supported.

The DATETIME data type is implemented in the data model as a "xs:dateTime" type per Section 3.2.7 of [W3C.SCHEMA.DTYPES].

2.8. Timezone String

A timezone offset from UTC is represented in the information model by the TIMEZONE data type. It is formatted according to the following regular expression:
"Z|[\+\-](0[0-9]|1[0-4]):[0-5][0-9](:[0-5][0-9])?".

The TIMEZONE data type is implemented in the data model as an "iodef:TimezoneType" type.

2.9. Port Lists

A list of network ports is represented in the information model by the PORTLIST data type. A PORTLIST consists of a comma-separated list of numbers and ranges (N-M means ports N through M, inclusive). It is formatted according to the following regular expression:
"\d+(\-\d+)?(,\d+(\-\d+)?)*". For example,
"2,5-15,30,32,40-50,55-60".

The PORTLIST data type is implemented in the data model as an "iodef:PortlistType" type.

2.10. Postal Address

A postal address is represented in the information model by the POSTAL data type. The format of the POSTAL data type is documented in Section 2.23 of [RFC4519] as a free-form multi-line string separated by the "$" character.

The POSTAL data type is implemented in the data model as an "iodef:MLStringType" type.

2.11. Telephone Number

A telephone number is represented in the information model by the PHONE data type. The format of the PHONE data type is documented in [E.164].

The PHONE data type is implemented in the data model as a "xs:string" type per Section 3.2.1 of [W3C.SCHEMA.DTYPES].

2.12. Email String

An email address is represented in the information model by the EMAIL data type. The format of the EMAIL data type is documented in Section 3.4.1 of [RFC5322] and Section 3.3 of [RFC6531].

The EMAIL data type is implemented in the data model as a "xs:string" type per Section 3.2.1 of [W3C.SCHEMA.DTYPES].

2.13. Uniform Resource Locator strings

A uniform resource locator (URL) is represented in the information model by the URL data type. The format of the URL data type is documented in [RFC3986].

The URL data type is implemented as a "xs:anyURI" type per Section 3.2.17 of [W3C.SCHEMA.DTYPES].

2.14. Identifiers and Identifier References

An identifier unique to the IODEF document is represented in the information model by the ID data type. A reference to this identifier is represented by the IDREF data type.

The ID and IDREF data types are implemented in the model as "xs:ID" and "xs:IDREF" types per Sections 3.3.8 and 3.3.9 of [W3C.SCHEMA.DTYPES].

2.15. Software

A particular version of software is represented in the information model by the SOFTWARE data type. This software can be described by using a reference, a URL or with free-form text.

The SOFTWARE data type is implemented in the data model as the "iodef:SoftwareType" type.

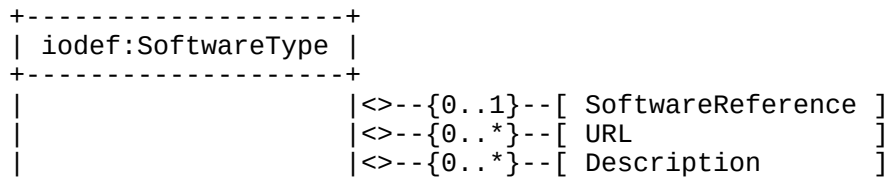

Figure 2: The SoftwareType Type

The aggregate classes of the SoftwareType type are:

SoftwareReference
: Zero or one. Reference to a software application. See Section 2.15.1.

URL
: Zero or more. URL. A URL to a resource describing the software.

Description
: Zero or more. ML_STRING. A free-form text description of the software.

At least one of these classes MUST be present.

The iodef:SoftwareType type has no attributes.

2.15.1. SoftwareReference Class

The SoftwareReference class is a reference to a particular version of software.

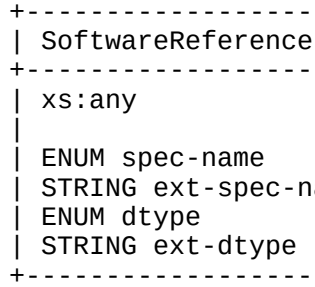

Figure 3: The SoftwareReference Class

The element content varies according to the value of the spec-name attribute. It is defined in the data model as "xs:any" per [W3C.SCHEMA].

The attributes of the SoftwareReference class are:

spec-name
: Required. ENUM. Identifies the format and semantics of the element body of this class. Formal standards and specifications can be referenced as well as a free-form text description with a user-provided data type. These values are maintained in the "SoftwareReference-spec-id" IANA registry per Section 10.2

1. custom. The element content is free-form and of the data type specified by the dtype attribute. If this value is selected, then the dtype attribute MUST be set.

2. cpe. The element content describes a Common Platform Enumeration (CPE) entry per [NIST.CPE].

3. swid. The element content describes a software identification (SWID) tag per [ISO19770].

4. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-spec-name
: Optional. STRING. A means by which to extend the spec-name attribute. See Section 5.1.1.

dtype
: Optional. ENUM. The data type of the element content. The permitted values for this attribute are shown below. The default value is "string". These values are maintained in the "SoftwareReference-dtype" IANA registry per Section 10.2.

1. bytes. The element content is of type HEXBIN.

2. integer. The element content is of type INTEGER.

3. real. The element content is of type REAL.

4. string. The element content is of type STRING.

5. xml. The element content is XML. See Section 5.2.

6. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-dtype

Optional. STRING. A means by which to extend the dtype attribute. See Section 5.1.1.

2.16. Extension

Information not otherwise represented in the IODEF can be added using the EXTENSION data type. This data type is a generic extension mechanism.

The EXTENSION data type is implemented in the data model as the "iodef:ExtensionType" type.

The data type of an EXTENSION is described by the dtype attribute. For simple information, atomic data types (e.g., integers, strings) are supported. Their semantics are further described by the meaning and formatid attributes. Encapsulating XML documents conforming to another schema is also supported. A detailed discussion of extending the schema can be found in Section 5. Additional coordination may be required to ensure that a recipient of a document using this type can parse and process it.

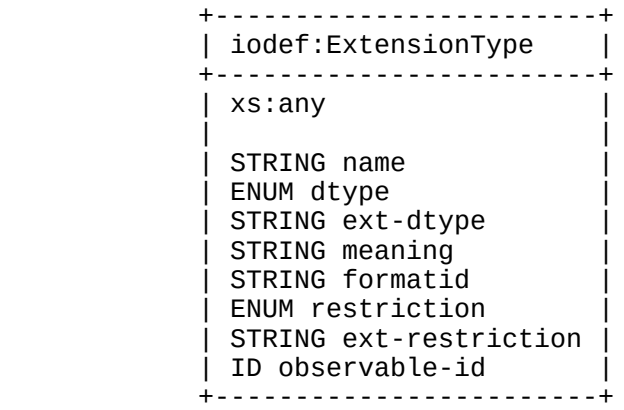

Figure 4: The iodef:ExtensionType Type

The element content of this type is the extension being added to the data model. This content is defined in the data model as "xs:any" per [W3C.SCHEMA].

The attributes of the iodef:ExtensionType type are:

name
Optional. STRING. A free-form name of the field or data element.

dtype

Required. ENUM. The data type of the element content. The default value is "string". These values are maintained in the "ExtensionType-dtype" IANA registry per Section 10.2.

1. boolean. The element content is of type BOOLEAN.

2. byte. The element content is of type BYTE.

3. bytes. The element content is of type HEXBIN.

4. character. The element content is of type CHARACTER.

5. date-time. The element content is of type DATETIME.

6. ntpstamp. Same as date-time.

7. integer. The element content is of type INTEGER.

8. portlist. The element content is of type PORTLIST.

9. real. The element content is of type REAL.

10. string. The element content is of type STRING.

11. file. The element content is a base64 encoded binary file encoded as a BYTE[] type.

12. path. The element content is a file-system path encoded as a STRING type.

13. frame. The element content is a layer-2 frame encoded as a HEXBIN type.

14. packet. The element content is a layer-3 packet encoded as a HEXBIN type.

15. ipv4-packet. The element content is an IPv4 packet encoded as a HEXBIN type.

16. ipv6-packet. The element content is an IPv6 packet encoded as a HEXBIN type.

17. url. The element content is of type URL.

18. csv. The element content is a common separated value (CSV) list per Section 2 of [RFC4180] encoded as a STRING type.

19. winreg. The element content is a Windows registry key encoded as a STRING type.

20. xml. The element content is XML. See Section 5.

21. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-dtype
Optional. STRING. A means by which to extend the dtype attribute. See Section 5.1.1.

meaning
Optional. STRING. A free-form text description of the element content.

formatid
Optional. STRING. An identifier referencing the format or semantics of the element content.

restriction
Optional. ENUM. See Section 3.3.1.

ext-restriction
Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

observable-id
Optional. ID. See Section 3.3.2.

3. The IODEF Information Model

The specifics of the IODEF information model are discussed in this section. Each class and its relationships with the other classes is described. When necessary, clarifications are made about translating this information model to the schema in Section 8.

3.1. IODEF-Document Class

The IODEF-Document class is the top level class in the IODEF data model. All IODEF documents are an instance of this class.

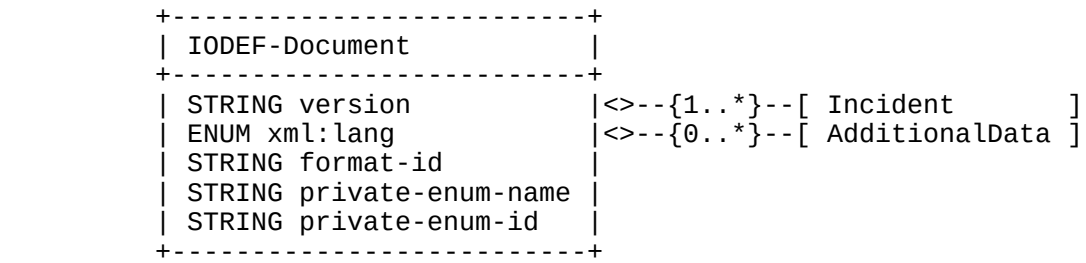

Figure 5: IODEF-Document Class

The aggregate classes of the IODEF-Document class are:

Incident
: One or more. The information related to a single incident. See Section 3.2.

AdditionalData
: Zero or more. EXTENSION. Mechanism by which to extend the data model.

The attributes of the IODEF-Document class are:

version
: Required. STRING. The IODEF specification version number to which this IODEF document conforms. The value of this attribute MUST be "2.00"

xml:lang
: Optional. ENUM. A language identifier per Section 2.12 of [W3C.XML] whose values and form are described in [RFC5646]. The interpretation of this code is described in Section 6.

format-id
: Optional. STRING. A free-form string to convey processing instructions to the recipient of the document. Its semantics must be negotiated out-of-band.

private-enum-name
: Optional. STRING. A globally unique identifier for the CSIRT generating the document to deconflict private extensions used in the document. The fully qualified domain name associated with the CSIRT MUST be used as the identifier. See Section 5.3.

private-enum-id

Optional. STRING. An organizationally unique identifier for an extension used in the document. If this attribute is set, the private-enum-name MUST also be set. See Section 5.3.

3.2. Incident Class

The Incident class describes commonly exchanged information when reporting or sharing derived analysis from security incidents.

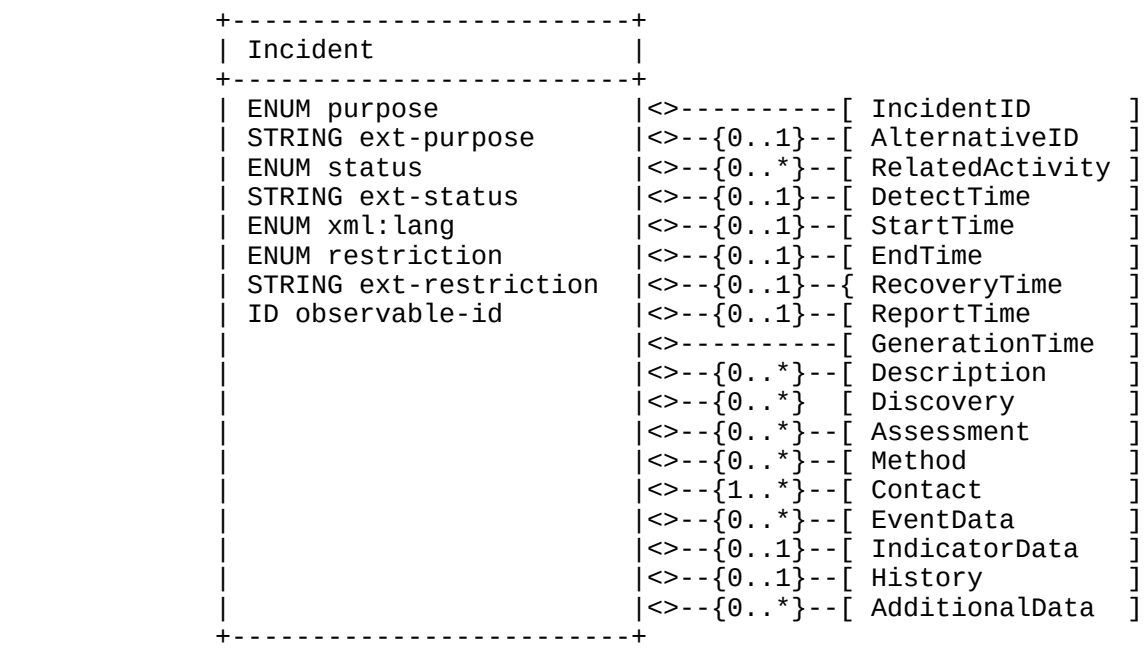

Figure 6: The Incident Class

The aggregate classes of the Incident class are:

IncidentID
: One. An incident tracking number assigned to this incident by the CSIRT that generated the IODEF document. See Section 3.4.

AlternativeID
: Zero or one. The incident tracking numbers used by other CSIRTs to refer to the incident described in the document. See Section 3.5.

RelatedActivity
: Zero or more. Related activity and attribution of this activity. See Section 3.6.

DetectTime
Zero or one. DATETIME. The time the incident was first detected.

StartTime
Zero or one. DATETIME. The time the incident started.

EndTime
Zero or one. DATETIME. The time the incident ended.

RecoveryTime
Zero or one. DATETIME. The time the site recovered from the incident.

ReportTime
Zero or one. DATETIME. The time the incident was reported.

GenerationTime
One. DATETIME. The time the content in this Incident class was generated.

Description
Zero or more. ML_STRING. A free-form text description of the incident.

Discovery
Zero or more. The means by which this incident was detected. See Section 3.10.

Assessment
Zero or more. A characterization of the impact of the incident. See Section 3.12.

Method
Zero or more. The techniques used by the threat actor in the incident. See Section 3.11.

Contact
One or more. Contact information for the parties involved in the incident. See Section 3.9.

EventData
Zero or more. Description of the events comprising the incident. See Section 3.14.

IndicatorData
Zero or one. Indicators from the analysis of an incident. See Section 3.28.

History
Zero or one. A log of significant events or actions that occurred during the course of handling the incident. See Section 3.13.

AdditionalData
Zero or more. EXTENSION. Mechanism by which to extend the data model.

The attributes of the Incident class are:

purpose
Required. ENUM. The purpose attribute represents describes the rational for document the information in this class. It is closely related to the Expectation class (Section 3.15). These values are maintained in the "Incident-purpose" IANA registry per Section 10.2. This attribute is defined as an enumerated list:

1. traceback. The Incident was sent for trace-back purposes.

2. mitigation. The Incident was sent to request aid in mitigating the described activity.

3. reporting. The Incident was sent to comply with reporting requirements.

4. watch. The Incident was sent to convey indicators that should be monitored.

5. other. The Incident was sent for purposes specified in the Expectation class.

6. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-purpose
Optional. STRING. A means by which to extend the purpose attribute. See Section 5.1.1.

status
Optional. ENUM. The status attribute conveys the state in a workflow where the incident is currently found. These values are maintained in the "Incident-status" IANA registry per Section 10.2. This attribute is defined as an enumerated list:

1. new. The Incident is newly reported and has not been actioned.

2. in-progress. The contents of this Incident are under investigation.

3. forwarded. The Incident has been forwarded to another party for handling.

4. resolved. The investigation into the activity in this Incident has concluded.

5. future. The described activity has not yet been detected.

6. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-status
Optional. STRING. A means by which to extend the status attribute. See Section 5.1.1.

xml:lang
Optional. ENUM. A language identifier per Section 2.12 of [W3C.XML] whose values and form are described in [RFC5646]. The interpretation of this code is described in Section 6.

restriction
Optional. ENUM. See Section 3.3.1. The default value is "private".

ext-restriction
Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

observable-id
Optional. ID. See Section 3.3.2.

3.3. Common Attributes

There are a number of recurring attributes used in the information model. They are documented in this section.

3.3.1. restriction Attribute

The restriction attribute indicates the disclosure guidelines to which the sender expects the recipient to adhere for the information represented in this class and its children. This guideline provides no security since there are no technical means to ensure that the recipient of the document handles the information as the sender requested.

The value of this attribute is logically inherited by the children of this class. That is to say, the disclosure rules applied to this class, also apply to its children.

It is possible to set a granular disclosure policy, since all of the high-level classes (i.e., children of the Incident class) have a restriction attribute. Therefore, a child can override the guidelines of a parent class, be it to restrict or relax the disclosure rules (e.g., a child has a weaker policy than an ancestor; or an ancestor has a weak policy, and the children selectively apply more rigid controls). The implicit value of the restriction attribute for a class that did not specify one can be found in the closest ancestor that did specify a value.

This attribute is defined as an enumerated value with a default value of "private". Note that the default value of the restriction attribute is only defined in the context of the Incident class. In other classes where this attribute is used, no default is specified.

These values are maintained in the "Restriction" IANA registry per Section 10.2.

1. public. The information can be freely distributed without restriction.

2. partner. The information may be shared within a closed community of peers, partners, or affected parties, but cannot be openly published.

3. need-to-know. The information may be shared only within the organization with individuals that have a need to know.

4. private. The information may not be shared.

5. default. The information can be shared according to an information disclosure policy pre-arranged by the communicating parties.

6. white. Same as ’public’.

7. green. Same as ’partner’.

8. amber. Same as ’need-to-know’.

9. red. Same as ’private’.

10. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

3.3.2. observable-id Attribute

The observable-id attribute tags information in the document as an observable so that it can be referenced later in the description of an indicator. The value of this attribute is a unique identifier in the scope of the document. It is used by the ObservableReference class to enumerate observables when defining an indicator with the IndicatorData class.

3.4. IncidentID Class

The IncidentID class represents a tracking number that is unique in the context of the CSIRT. It serves as an identifier for an incident or a document identifier when sharing indicators. This identifier would serve as an index into a CSIRT's incident handling or knowledge management system.

The combination of the name attribute and the string in the element content MUST be a globally unique identifier describing the activity. Documents generated by a given CSIRT MUST NOT reuse the same value unless they are referencing the same incident.

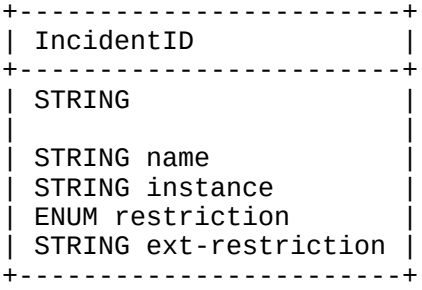

Figure 7: The IncidentID Class

The content of the class is an incident identifier of type STRING.

The attributes of the IncidentID class are:

name
Required. STRING. An identifier describing the CSIRT that created the document. In order to have a globally unique CSIRT name, the fully qualified domain name associated with the CSIRT MUST be used.

instance
Optional. STRING. An identifier referencing a subset of the named incident.

restriction
Optional. ENUM. See Section 3.3.1.

ext-restriction
Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

3.5. AlternativeID Class

The AlternativeID class lists the tracking numbers used by CSIRTs, other than the one generating the document, to refer to the identical activity described in the IODEF document. A tracking number listed as an AlternativeID references the same incident detected by another CSIRT. The tracking numbers of the CSIRT that generated the IODEF document must never be considered an AlternativeID.

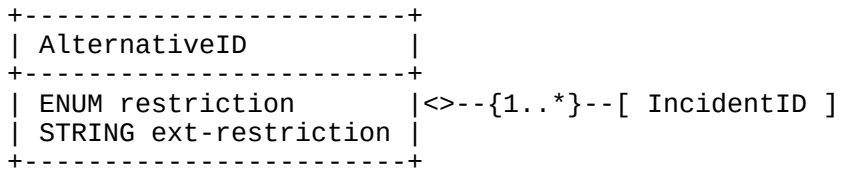

Figure 8: The AlternativeID Class

The aggregate class of the AlternativeID class is:

IncidentID
One or more. The tracking number of another CSIRT. See Section 3.4.

The attributes of the AlternativeID class are:

restriction
Optional. ENUM. See Section 3.3.1.

ext-restriction
Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

3.6. RelatedActivity Class

The RelatedActivity class relates the information described in the rest of the document to previously observed incidents or activity; and allows attribution to a specific actor or campaign.

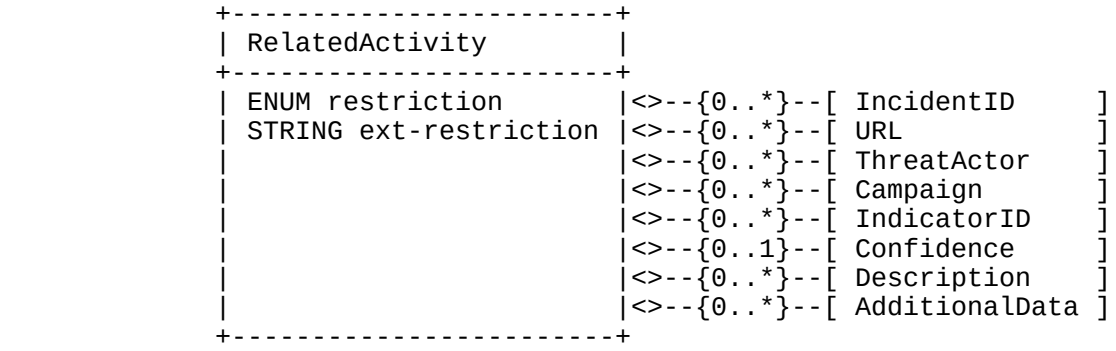

Figure 9: RelatedActivity Class

The aggregate classes of the RelatedActivity class are:

IncidentID
: Zero or more. The tracking number of a related incident. See Section 3.4.

URL
: Zero or more. URL. A URL to activity related to this incident.

ThreatActor
: Zero or more. The threat actor to whom the incident activity is attributed. See Section 3.7.

Campaign
: Zero or more. The campaign of a given threat actor to whom the described activity is attributed. See Section 3.8.

IndicatorID
: Zero or more. A reference to a related indicator. See Section 3.4.

Confidence
: Zero or one. An estimate of the confidence in attributing this RelatedActivity to the events described in the document. See Section 3.12.5.

Description

Zero or more. ML_STRING. A description of how these relationships were derived.

AdditionalData
Zero or more. EXTENSION. A mechanism by which to extend the data model.

The RelatedActivity class MUST have at least one instance of any of the following child classes: IncidentID, URL, ThreatActor, Campaign, Description or AdditionalData.

The attributes of the RelatedActivity class are:

restriction
Optional. ENUM. See Section 3.3.1.

ext-restriction
Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

3.7. ThreatActor Class

The ThreatActor class describes a threat actor.

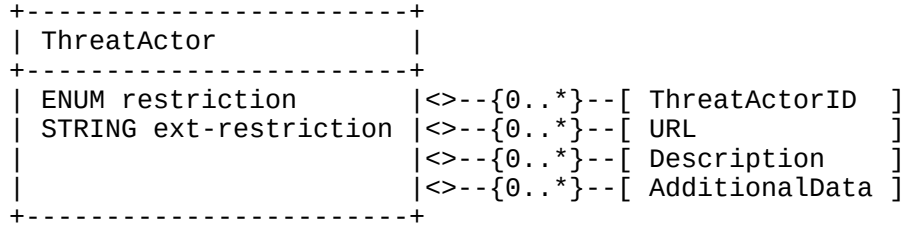

Figure 10: ThreatActor Class

The aggregate classes of the ThreatActor class are:

ThreatActorID
Zero or more. STRING. An identifier for the threat actor.

URL
Zero or more. URL. A URL to a reference describing the threat actor.

Description
Zero or more. ML_STRING. A description of the threat actor.

AdditionalData

Zero or more. EXTENSION. A mechanism by which to extend the data model.

The ThreatActor class MUST have at least one instance of a child class.

The attributes of the ThreatActor class are:

restriction
Optional. ENUM. See Section 3.3.1.

ext-restriction
Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

3.8. Campaign Class

The Campaign class describes a campaign of attacks by a threat actor.

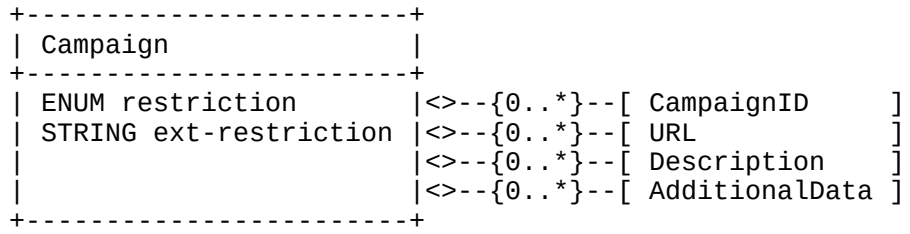

Figure 11: Campaign Class

The aggregate classes of the Campaign class are:

CampaignID
Zero or more. STRING. An identifier for the campaign.

URL
Zero or more. URL. A URL to a reference describing the campaign.

Description
Zero or more. ML_STRING. A description of the campaign.

AdditionalData
Zero or more. EXTENSION. A mechanism by which to extend the data model.

The Campaign class MUST have at least one instance of a child class.

The attributes of the Campaign class are:

restriction
Optional. ENUM. See Section 3.3.1.

ext-restriction
Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

3.9. Contact Class

The Contact class describes contact information for organizations and personnel involved in the incident. This class allows for the naming of the involved party, specifying contact information for them, and identifying their role in the incident.

People and organizations are treated interchangeably as contacts; one can be associated with the other using the recursive definition of the class (the Contact class is aggregated into the Contact class). The 'type' attribute disambiguates the type of contact information being provided.

The recursive definition of Contact provides a way to relate information without requiring the explicit use of identifiers or duplication of data. A complete point of contact is derived by a particular traversal from the root Contact class to the leaf Contact class. Each child Contact class logically inherits contact information from its ancestors.

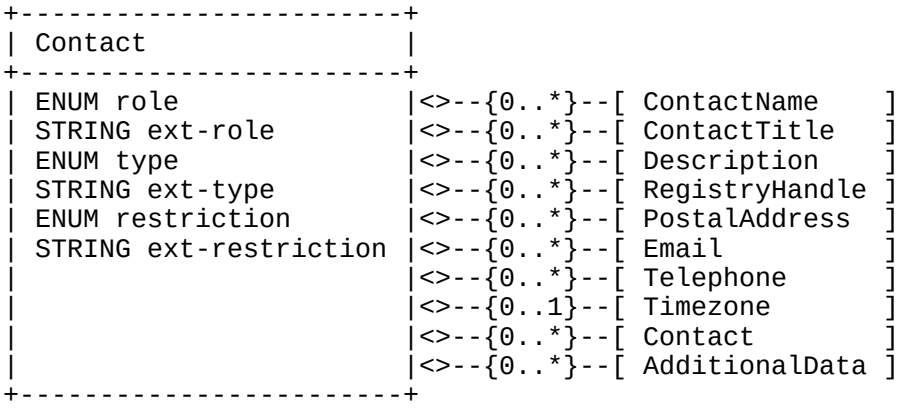

Figure 12: The Contact Class

The aggregate classes of the Contact class are:

ContactName

Zero or more. ML_STRING. The name of the contact. The contact may either be an organization or a person. The type attribute disambiguates the semantics.

ContactTitle
Zero or more. ML_STRING. The title for the individual named in the ContactName.

Description
Zero or more. ML_STRING. A free-form text description of the contact.

RegistryHandle
Zero or more. A handle name into the registry of the contact. See Section 3.9.1.

PostalAddress
Zero or more. The postal address of the contact. See Section 3.9.2.

Email
Zero or more. The email address of the contact. See Section 3.9.3.

Telephone
Zero or more. The telephone number of the contact. See Section 3.9.4.

Timezone
Zero or one. TIMEZONE. The timezone in which the contact resides.

Contact
Zero or more. A recursive definition of the Contact class. This definition can be used to group common data pertaining to multiple points of contact and is especially useful when listing multiple contacts at the same organization.

AdditionalData
Zero or more. EXTENSION. A mechanism by which to extend the data model.

At least one of the aggregate classes MUST be present in an instance of the Contact class.

The attributes of the Contact class are:

role

Required. ENUM. Indicates the role the contact fulfills. These values are maintained in the "Contact-role" IANA registry per Section 10.2.

1. creator. The entity that generate the document.

2. reporter. The entity that reported the information.

3. admin. An administrative contact or business owner for an asset or organization.

4. tech. An entity responsible for the day-to-day management of technical issues for an asset or organization.

5. provider. An external hosting provider for an asset.

6. user. An end-user of an asset or part of an organization.

7. billing. An entity responsible for billing issues for an asset or organization.

8. legal. An entity responsible for legal issue related to an asset or organization.

9. irt. An entity responsible for handling security issues for an asset or organization.

10. abuse. An entity responsible for handling abuse originating from an asset or organization.

11. cc. An entity that is to be kept informed about the events related to an asset or organization.

12. cc-irt. A CSIRT or information sharing organization coordinating activity related to an asset or organization.

13. leo. A law enforcement organization supporting the investigation of activity affecting an asset or organization.

14. vendor. The vendor that produces an asset.

15. vendor-support. A vendor that provides services.

16. victim. A victim in the incident.

17. victim-notified. A victim in the incident who has been notified.

18. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-role
Optional. STRING. A means by which to extend the role attribute. See Section 5.1.1.

type
Required. ENUM. Indicates the type of contact being described. This attribute is defined as an enumerated list. These values are maintained in the "Contact-type" IANA registry per Section 10.2.

1. person. The information for this contact references an individual.

2. organization. The information for this contact references an organization.

3. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-type
Optional. STRING. A means by which to extend the type attribute. See Section 5.1.1.

restriction
Optional. ENUM. See Section 3.3.1.

ext-restriction
Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

3.9.1. RegistryHandle Class

The RegistryHandle class represents a handle into an Internet registry or community-specific database.

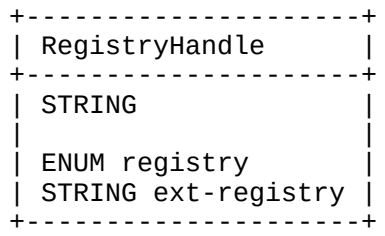

Figure 13: The RegistryHandle Class

The content of the class is a handle into a registry of type STRING.

The attributes of the RegistryHandle class are:

registry
: Required. ENUM. The database to which the handle belongs. These values are maintained in the "RegistryHandle-registry" IANA registry per Section 10.2. The possible values are:

1. internic. Internet Network Information Center
2. apnic. Asia Pacific Network Information Center
3. arin. American Registry for Internet Numbers
4. lacnic. Latin-American and Caribbean IP Address Registry
5. ripe. Reseaux IP Europeens
6. afrinic. African Internet Numbers Registry
7. local. A database local to the CSIRT
8. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-registry
: Optional. STRING. A means by which to extend the registry attribute. See Section 5.1.1.

3.9.2. PostalAddress Class

The PostalAddress class specifies an postal address and associated annotation.

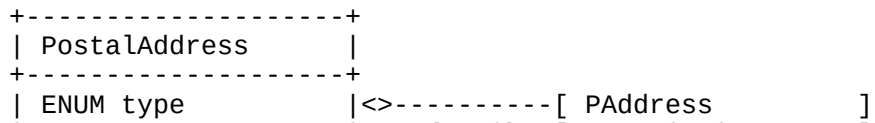

Figure 14: The PostalAddress Class

The aggregate classes of the PostalAddress class are:

PAddress
: One. POSTAL. A postal address.

Description
: Zero or more. ML_STRING. A free-form text description of the address.

The attributes of the PostalAddress class are:

type
: Optional. ENUM. Categorizes the type of address described in the PAddress class. These values are maintained in the "PostalAddress-type" IANA registry per Section 10.2.

  1. street. An address describing a physical location.

  2. mailing. An address to which correspondence should be sent.

  3. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-type
: Optional. STRING. A means by which to extend the type attribute. See Section 5.1.1.

3.9.3. Email Class

The Email class specifies an email address and associated annotation.

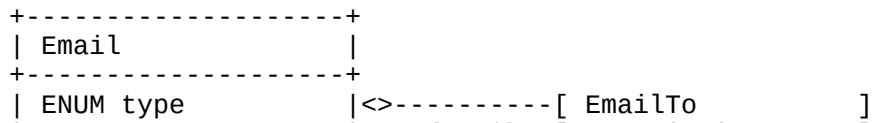

Figure 15: The Email Class

The aggregate classes of the Email class are:

EmailTo
: One. EMAIL. An email address.

Description
: Zero or more. ML_STRING. A free-form text description of the email address.

The attributes of the Email class are:

type
: Optional. ENUM. Categorizes the type of email address described in the EmailTo class. These values are maintained in the "Email-type" IANA registry per Section 10.2.

  1. direct. A email address of an individual.

  2. hotline. A email address regularly monitored for operational purposes.

  3. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-type
: Optional. STRING. A means by which to extend the type attribute. See Section 5.1.1.

3.9.4. Telephone Class

The Telephone class describes a telephone number and associated annotation.

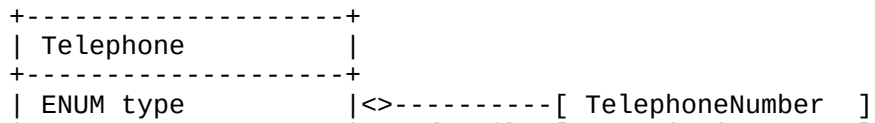

Figure 16: The Telephone Class

The aggregate classes of the Telephone class are:

TelephoneNumber
One. PHONE. A telephone number.

Description
Zero or more. ML_STRING. A free-form text description of the phone number.

The attributes of the Telephone class are:

type
Optional. ENUM. Categorizes the type of telephone number described in the TelephoneNumber class. These values are maintained in the "Telephone-type" IANA registry per Section 10.2.

1. wired. A number of a wire-line (land-line) phone.

2. mobile. A number of a mobile phone.

3. fax. A number to a fax machine.

4. hotline. A number to a regularly monitored operational hotline.

5. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-type
Optional. STRING. A means by which to extend the type attribute. See Section 5.1.1.

3.10. Discovery Class

The Discovery class describes how an incident was detected.

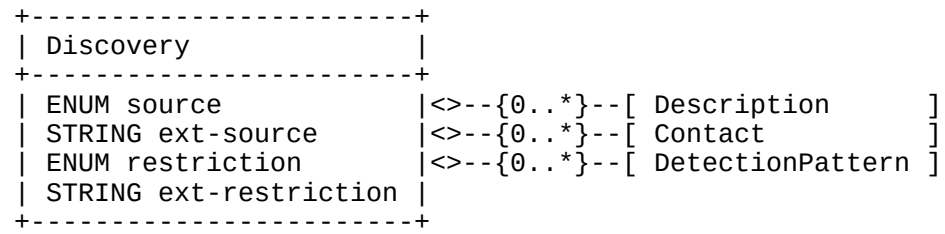

Figure 17: The Discovery Class

The aggregate classes of the Discovery class are:

Description
: Zero or more. ML_STRING. A free-form text description of how this incident was detected.

Contact
: Zero or more. Contact information for the party that discovered the incident. See Section 3.9.

DetectionPattern
: Zero or more. Describes an application-specific configuration that detected the incident. See Section 3.10.1.

The attributes of the Discovery class are:

source
: Optional. ENUM. Categorizes the techniques used to discover the incident. These values are partially derived from Table 3-1 of [NIST800.61rev2]. These values are maintained in the "Discovery-source" IANA registry per Section 10.2.

  1. nidps. Network Intrusion Detection or Prevention system.

  2. hips. Host-based Intrusion Prevention system.

  3. siem. Security Information and Event Management System.

  4. av. Antivirus or and antispam software.

  5. third-party-monitoring. Contracted third-party monitoring service.

  6. incident. The activity was discovered while investigating an unrelated incident.

  7. os-log. Operating system logs.

8. application-log. Application logs.

9. device-log. Network device logs.

10. network-flow. Network flow analysis.

11. passive-dns. Passive DNS analysis.

12. investigation. Manual investigation initiated based on notification of a new vulnerability or exploit.

13. audit. Security audit.

14. internal-notification. A party within the organization reported the activity

15. external-notification. A party outside of the organization reported the activity.

16. leo. A law enforcement organization notified the victim organization.

17. partner. A customer or business partner reported the activity to the victim organization.

18. actor. The threat actor directly or indirectly reported this activity to the victim organization.

19. unknown. Unknown detection approach.

20. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-source
Optional. STRING. A means by which to extend the source attribute. See Section 5.1.1.

restriction
Optional. ENUM. See Section 3.3.1.

ext-restriction
Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

3.10.1. DetectionPattern Class

The DetectionPattern class describes a configuration or signature that can be used by an IDS/IPS, SIEM, anti-virus, end-point protection, network analysis, malware analysis, or host forensics tool to identify a particular phenomenon. This class requires the identification of the target application and allows the configuration to be described in either free-form or machine readable form.

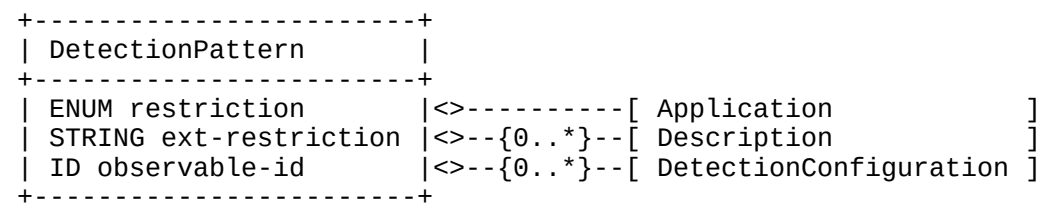

Figure 18: The DetectionPattern Class

The aggregate classes of the DetectionPattern class are:

Application
: One. SOFTWARE. The application for which the DetectionConfiguration or Description is being provided.

Description
: Zero or more. ML_STRING. A free-form text description of how to use the Application or provided DetectionConfiguration.

DetectionConfiguration
: Zero or more. STRING. A machine consumable configuration to find a pattern of activity.

Either an instance of the Description or DetectionConfiguration class MUST be present.

The attributes of the DetectionPattern class are:

restriction
: Optional. ENUM. See Section 3.3.1.

ext-restriction
: Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

observable-id
: Optional. ID. See Section 3.3.2.

3.11. Method Class

The Method class describes the tactics, techniques, procedures or weakness used by the threat actor in an incident. This class consists of both a list of references describing the attack methods and weaknesses and a free-form text description.

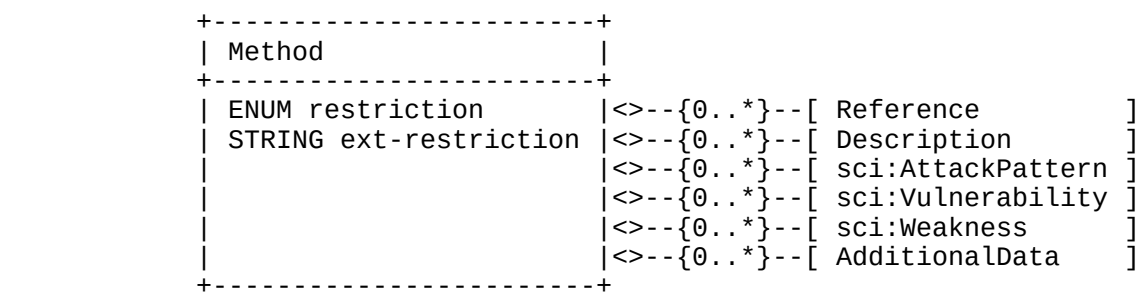

Figure 19: The Method Class

The aggregate classes of the Method class are:

Reference
: Zero or more. A reference to a vulnerability, malware sample, advisory, or analysis of an attack technique. See Section 3.11.1.

Description
: Zero or more. ML_STRING. A free-form text description of techniques, tactics, or procedures used by the threat actor.

sci:AttackPattern
: Zero or more. A reference to an pattern of attack or exploitation per [RFC7203]

sci:Vulnerability
: Zero or more. A reference to a vulnerability per [RFC7203]

sci:Weakness
: Zero or more. A reference to the exploited weakness per [RFC7203]

AdditionalData
: Zero or more. EXTENSION. A mechanism by which to extend the data model.

An instance of one of these child MUST be present.

The attributes of the Method class are:

restriction
Optional. ENUM. See Section 3.3.1.

ext-restriction
Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

3.11.1. Reference Class

The Reference class is an external reference to relevant information such a vulnerability, IDS alert, malware sample, advisory, or attack technique.

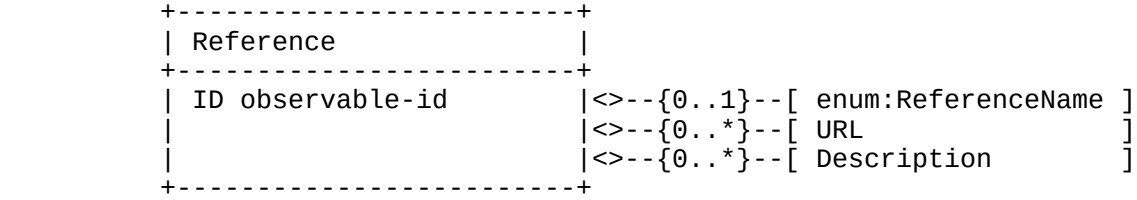

Figure 20: The Reference Class

The aggregate classes of the Reference class are:

enum:ReferenceName
Zero or one. Reference identifier per [RFC7495].

URL
Zero or more. URL. A URL to a reference.

Description
Zero or more. ML_STRING. A free-form text description of this reference.

At least one of these classes MUST be present.

The attribute of the Reference class is:

observable-id
Optional. ID. See Section 3.3.2.

3.12. Assessment Class

The Assessment class describes the repercussions of the incident to the victim.

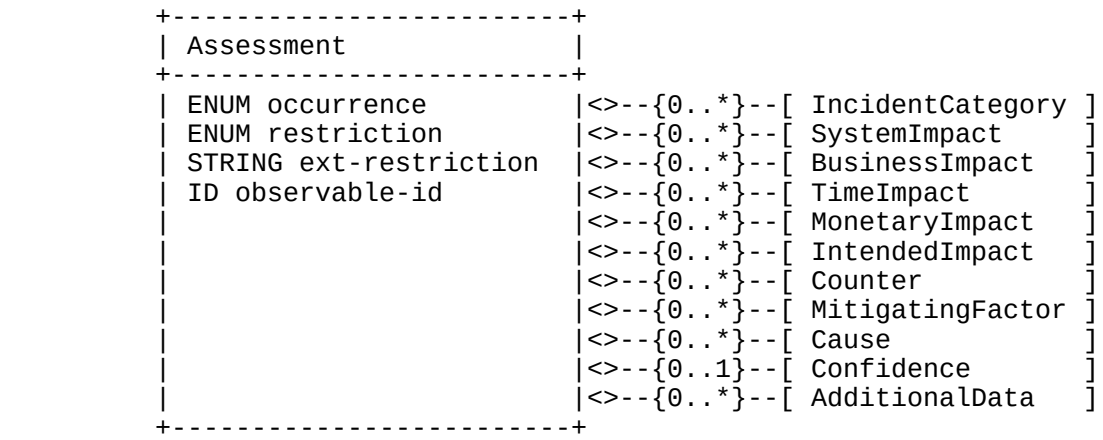

Figure 21: Assessment Class

The aggregate classes of the Assessment class are:

IncidentCategory
: Zero or more. ML_STRING. A free-form text description categorizing the type of Incident.

SystemImpact
: Zero or more. A technical characterization of the impact of the incident activity on the victim’s enterprise. See Section 3.12.1.

BusinessImpact
: Zero or more. Impact of the incident activity on the business functions of the victim organization. See Section 3.12.2.

TimeImpact
: Zero or more. A characterization of the victim organization due to the incident activity as a function of time. See Section 3.12.3.

MonetaryImpact
: Zero or more. The financial loss due to the incident activity. See Section 3.12.4.

IntendedImpact
: Zero or more. The intended outcome to the victim sought by the threat actor. Defined identically to the BusinessImpact defined in Section 3.12.2, but describes intent rather than the realized impact.

Counter

Zero or more. A counter with which to summarize the magnitude of the activity. See Section 3.18.3.

MitigatingFactor
Zero or more. ML_STRING. A description of a mitigating factor relative to the impact on the victim organization.

Cause
Zero or more. ML_STRING. A description of an underlying cause of the impact.

Confidence
Zero or one. An estimate of confidence in the impact assessment. See Section 3.12.5.

AdditionalData
Zero or more. EXTENSION. A mechanism by which to extend the data model.

A least one instance of the possible five impact classes (i.e., SystemImpact, BusinessImpact, TimeImpact, MonetaryImpact or IntendedImpact) MUST be present.

The attributes of the Assessment class are:

occurrence
Optional. ENUM. Specifies whether the assessment is describing actual or potential outcomes.

1. actual. This assessment describes activity that has occurred.

2. potential. This assessment describes potential activity that might occur.

restriction
Optional. ENUM. See Section 3.3.1.

ext-restriction
Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

observable-id
Optional. ID. See Section 3.3.2.

3.12.1. SystemImpact Class

The SystemImpact class describes the technical impact of the incident to the systems on the network.

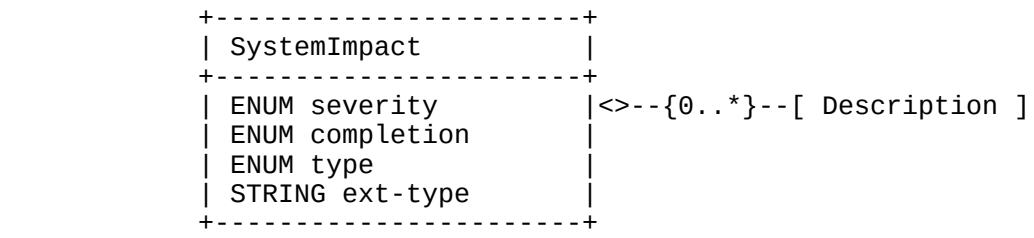

Figure 22: SystemImpact Class

The aggregate class of the SystemImpact class is:

Description
: Zero or more. ML_STRING. A free-form text description of the impact to the system.

The attributes of the SystemImpact class are:

severity
: Optional. ENUM. An estimate of the relative severity of the activity. The permitted values are shown below. There is no default value.

  1. low. Low severity

  2. medium. Medium severity

  3. high. High severity

completion
: Optional. ENUM. An indication whether the described activity was successful. The permitted values are shown below. There is no default value.

  1. failed. The attempted activity was not successful.

  2. succeeded. The attempted activity succeeded.

type
: Required. ENUM. Classifies the impact. The permitted values are shown below. The default value is "unknown". These values are

maintained in the "SystemImpact-type" IANA registry per Section 10.2.

1. takeover-account. Control was taken of a given account.

2. takeover-service. Control was taken of a given service.

3. takeover-system. Control was taken of a given system.

4. cps-manipulation. A cyber-physical system was manipulated.

5. cps-damage. A cyber-physical system was damaged.

6. availability-data. Access to particular data was degraded or denied.

7. availability-account. Access to an account was degraded or denied.

8. availability-service. Access to a service was degraded or denied.

9. availability-system. Access to a system was degraded or denied.

10. damaged-system. Hardware on a system was irreparably damaged.

11. damaged-data. Data on a system was deleted.

12. breach-proprietary. Sensitive or proprietary information was accessed or exfiltrated.

13. breach-privacy. Personally identifiable information was accessed or exfiltrated.

14. breach-credential. Credential information was accessed or exfiltrated.

15. breach-configuration. System configuration or data inventory was access or exfiltrated.

16. integrity-data. Data on the system was modified.

17. integrity-configuration. Application or system configuration was modified.

18. integrity-hardware. Firmware of a hardware component was modified.

19. traffic-redirection. Network traffic on the system was redirected

20. monitoring-traffic. Network traffic emerging from a host or enclave was monitored.

21. monitoring-host. System activity (e.g., running processes, keystrokes) were monitored.

22. policy. Activity violated the system owner's acceptable use policy.

23. unknown. The impact is unknown.

24. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-type
Optional. STRING. A means by which to extend the type attribute. See Section 5.1.1.

3.12.2. BusinessImpact Class

The BusinessImpact class describes and characterizes the degree to which the function of the organization was impacted by the Incident.

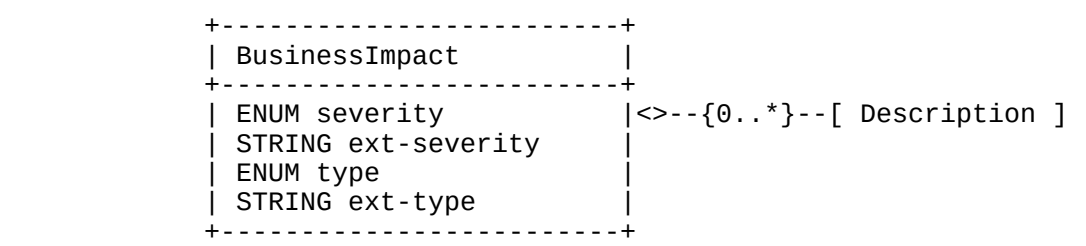

Figure 23: BusinessImpact Class

The aggregate class of the BusinessImpact class is:

Description
Zero or more. ML_STRING. A free-form text description of the impact to the organization.

The attributes of the BusinessImpact class are:

severity
Optional. ENUM. Characterizes the severity of the incident on business functions. The permitted values are shown below. They were derived from Table 3-2 of [NIST800.61rev2]. The default value is "unknown". These values are maintained in the "BusinessImpact-severity" IANA registry per Section 10.2.

1. none. No effect to the organization’s ability to provide all services to all users.

2. low. Minimal effect as the organization can still provide all critical services to all users but has lost efficiency.

3. medium. The organization has lost the ability to provide a critical service to a subset of system users.

4. high. The organization is no longer able to provide some critical services to any users.

5. unknown. The impact is not known.

6. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-severity
Optional. STRING. A means by which to extend the severity attribute. See Section 5.1.1.

type
Required. ENUM. Characterizes the effect this incident had on the business. The permitted values are shown below. The default value is "unknown". These values are maintained in the "BusinessImpact-type" IANA registry per Section 10.2.

1. breach-proprietary. Sensitive or proprietary information was accessed or exfiltrated.

2. breach-privacy. Personally identifiable information was accessed or exfiltrated.

3. breach-credential. Credential information was accessed or exfiltrated.

4. loss-of-integrity. Sensitive or proprietary information was changed or deleted.

5. loss-of-service. Service delivery was disrupted.

6. theft-financial. Money was stolen.

7. theft-service. Services were misappropriated.

8. degraded-reputation. The reputation of the organization's brand was diminished.

9. asset-damage. A cyber-physical system was damaged.

10. asset-manipulation. A cyber-physical system was manipulated.

11. legal. The incident resulted in legal or regulatory action.

12. extortion. The incident resulted in actors extorting the victim organization.

13. unknown. The impact is unknown.

14. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-type
Optional. STRING. A means by which to extend the type attribute. See Section 5.1.1.

3.12.3. TimeImpact Class

The TimeImpact class describes the impact of the incident on an organization as a function of time. It provides a way to convey down time and recovery time.

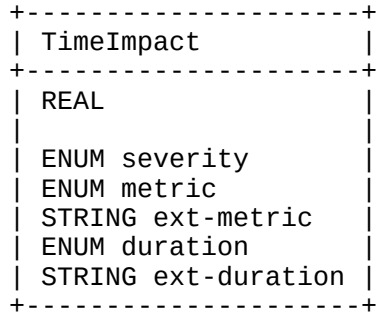

Figure 24: TimeImpact Class

The content of the class is of type REAL and specifies an amount of time. The duration attribute provides units for this content; and the metric attribute explains what this content is measuring.

The attributes of the TimeImpact class are:

severity
Optional. ENUM. An estimate of the relative severity of the activity. The permitted values are shown below. There is no default value.

1. low. Low severity

2. medium. Medium severity

3. high. High severity

metric
Required. ENUM. Defines the meaning of the value in the element content. These values are maintained in the "TimeImpact-metric" IANA registry per Section 10.2.

1. labor. Total staff-time to recovery from the activity (e.g., 2 employees working 4 hours each would be 8 hours).

2. elapsed. Elapsed time from the beginning of the recovery to its completion (i.e., wall-clock time).

3. downtime. Duration of time for which some provided service(s) was not available.

4. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-metric
Optional. STRING. A means by which to extend the metric attribute. See Section 5.1.1.

duration
Optional. ENUM. Defines the unit of time for the value in the element content. The default value is "hour". These values are maintained in the "TimeImpact-duration" IANA registry per Section 10.2.

1. second. The unit of the element content is seconds.

2. minute. The unit of the element content is minutes.

3. hour. The unit of the element content is hours.

4. day. The unit of the element content is days.

5. month. The unit of the element content is months.

6. quarter. The unit of the element content is quarters.

7. year. The unit of the element content is years.

8. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-duration
Optional. STRING. A means by which to extend the duration attribute. See Section 5.1.1.

3.12.4. MonetaryImpact Class

The MonetaryImpact class describes the financial impact of the activity on an organization. For example, this impact may consider losses due to the cost of the investigation or recovery, diminished productivity of the staff, or a tarnished reputation that will affect future opportunities.

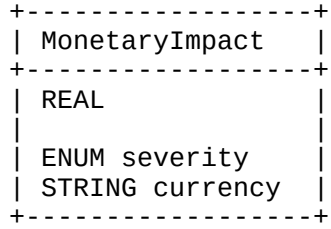

Figure 25: MonetaryImpact Class

The content of the class is of type REAL and specifies a quantity of money. The currency attribute defines the currently of this value.

The attributes of the MonetaryImpact class are:

severity
Optional. ENUM. An estimate of the relative severity of the activity. The permitted values are shown below. There is no default value.

1. low. Low severity

2. medium. Medium severity

3. high. High severity

currency
Optional. STRING. Defines the currency in which the value in the element content is expressed. The permitted values are defined in "Codes for the representation of currencies and funds" of [ISO4217]. There is no default value.

3.12.5. Confidence Class

The Confidence class represents an estimate of the validity and accuracy of data expressed in the document. This estimate can be expressed as a category or a numeric calculation.

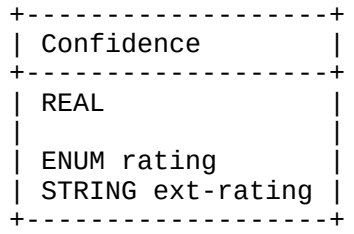

Figure 26: Confidence Class

The content of the class is of type REAL and specifies a numerical assessment in the confidence of the data when the value of the rating attribute is "numeric". Otherwise, this element MUST be empty.

The attributes of the Confidence class are:

rating
Required. ENUM. A qualitative assessment of confidence. These values are maintained in the "Confidence-rating" IANA registry per Section 10.2

1. low. Low confidence.

2. medium. Medium confidence.

3. high. High confidence.

4. numeric. The element content contains a number that conveys the confidence of the data. The semantics of this number outside the scope of this specification.

5. unknown. The confidence rating value is not known.

6. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-rating
Optional. STRING. A means by which to extend the rating attribute. See Section 5.1.1.

3.13. History Class

The History class is a log of the significant events or actions performed by the involved parties during the course of handling the incident.

The level of detail maintained in this log is left up to the discretion of those handling the incident.

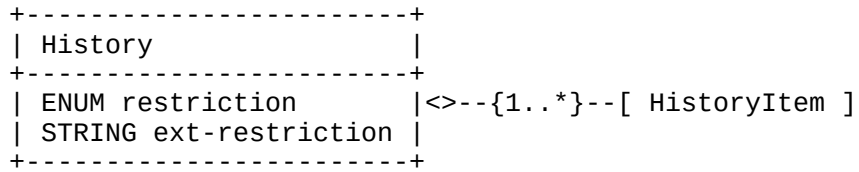

Figure 27: The History Class

The aggregate classes of the History class are:

HistoryItem
One or more. An entry in the history log of significant events or actions performed by the involved parties. See Section 3.13.1.

The attributes of the History class are:

restriction
Optional. ENUM. See Section 3.3.1.

ext-restriction
Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

3.13.1. HistoryItem Class

The HistoryItem class is an entry in the History (Section 3.13) log that documents a particular action or event that occurred in the course of handling the incident. The details of the entry are a

free-form text description, but each can be categorized with the type attribute.

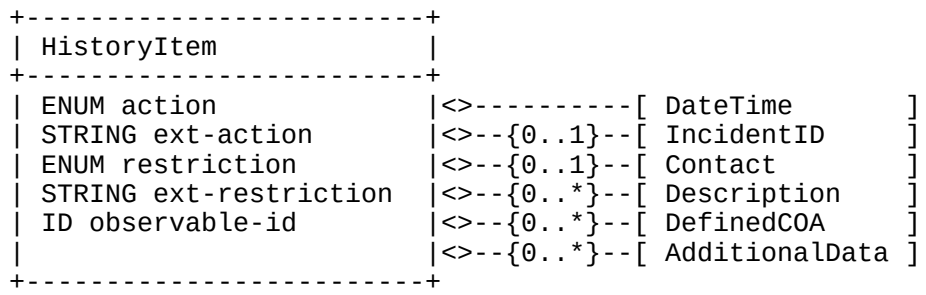

Figure 28: HistoryItem Class

The aggregate classes of the HistoryItem class are:

DateTime
: One. DATETIME. A timestamp of this entry in the history log.

IncidentID
: Zero or One. In a history log created by multiple parties, the IncidentID provides a mechanism to specify which CSIRT created a particular entry and references this organization's tracking number. When a single organization is maintaining the log, this class can be ignored. See Section 3.4.

Contact
: Zero or One. Provides contact information for the entity that performed the action documented in this class. See Section 3.9.

Description
: Zero or more. ML_STRING. A free-form text description of the action or event.

DefinedCOA
: Zero or more. STRING. An identifier meaningful to the sender and recipient of this document that references a course of action (COA). This class MUST be present if the action attribute is set to "defined-coa".

AdditionalData
: Zero or more. EXTENSION. A mechanism by which to extend the data model.

The attributes of the HistoryItem class are:

action
Required. ENUM. Classifies a performed action or occurrence documented in this history log entry. As activity will likely have been instigated either through a previously conveyed expectation or internal investigation. This attribute is identical to the action attribute of the Expectation class. The difference is only one of tense. When an action is in this class, it has been completed. See Section 3.15.

ext-action
Optional. STRING. A means by which to extend the action attribute. See Section 5.1.1.

restriction
Optional. ENUM. See Section 3.3.1.

ext-restriction
Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

observable-id
Optional. ID. See Section 3.3.2.

3.14. EventData Class

The EventData class is a container class to organize data about events that occurred during an incident.

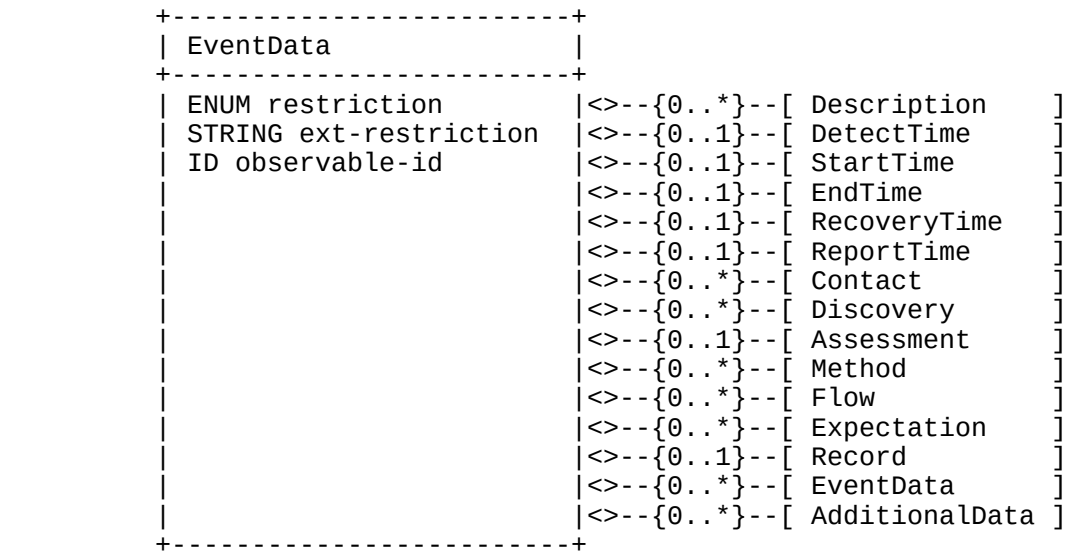

Figure 29: The EventData Class

The aggregate classes of the EventData class are:

Description
: Zero or more. ML_STRING. A free-form text description of the event.

DetectTime
: Zero or one. DATETIME. The time the event was detected.

StartTime
: Zero or one. DATETIME. The time the event started.

EndTime
: Zero or one. DATETIME. The time the event ended.

RecoveryTime
: Zero or one. DATETIME. The time the site recovered from the event.

ReportTime
: Zero or one. DATETIME. The time the event was reported.

Contact
: Zero or more. Contact information for the parties involved in the event. See Section 3.9.

Discovery
Zero or more. The means by which the event was detected. See Section 3.10.

Assessment
Zero or one. The impact of the event on the victim and the actions taken. See Section 3.12.

Method
Zero or more. The technique used by the threat actor in the event. See Section 3.11.

Flow
Zero or more. A description of the systems or networks involved. See Section 3.16.

Expectation
Zero or more. The expected action to be performed by the recipient for the described event. See Section 3.15.

Record
Zero or one. Supportive data (e.g., log files) that provides additional information about the event. See Section 3.22.

EventData
Zero or more. A recursive definition of the EventData class. See Section 3.14.2 for an explanation on using this class.

AdditionalData
Zero or more. EXTENSION. An extension mechanism for data not explicitly represented in the data model.

At least one of the aggregate classes MUST be present in an instance of the EventData class.

The attributes of the EventData class are:

restriction
Optional. ENUM. See Section 3.3.1. The default value is "default".

ext-restriction
Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

observable-id
Optional. ID. See Section 3.3.2.

3.14.1. Relating the Incident and EventData Classes

There is substantial overlap in the child classes aggregated in the Incident and EventData classes. Nevertheless, the semantics of these classes are quite different. The Incident class provides summary information about the entire incident, while the EventData class provides information about the individual events comprising the incident. In the common case, the EventData class will provide more specific information for the general description provided in the Incident class. However, in the case where the summarized information in the Incident class conflicts the detailed information in an EventData class the more specific EventData class MUST supersede the more generic information provided in Incident class.

3.14.2. Recursive Definition of EventData

The EventData class is container for the properties of an event in an incident. These properties include: the hosts involved, impact of the incident activity on the hosts, forensic logs, etc. The recursive definition of EventData allows for the grouping of related information with common properties. This approach eliminates the need for explicit identifiers to relate information or duplicate it. Instead, the relative depth (nesting) of a class is used to group (relate) information.

For example, consider a case where two hosts experience different impacts during an incident. However, these two hosts have common contact information. A depiction of how this situation would be represented can be found in Figure 30. EventData (2) and (3) group each of the two hosts with their unique impact. EventData (1) describes the common Contact class these two hosts share.

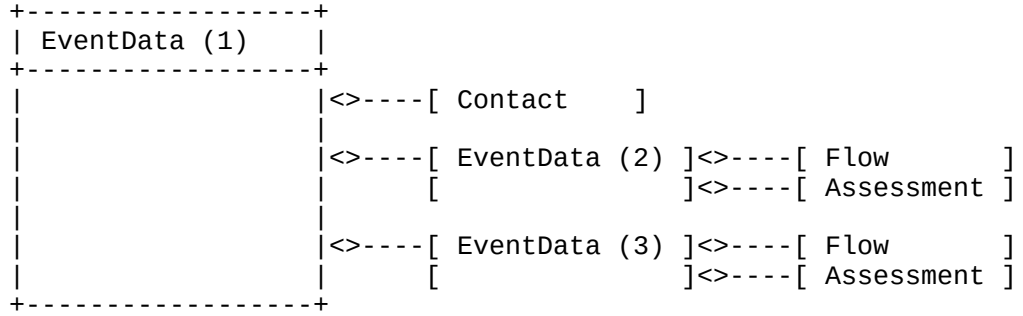

Figure 30: Recursion in the EventData Class

3.15. Expectation Class

The Expectation class conveys to the recipient of the IODEF document the actions the sender is requesting.

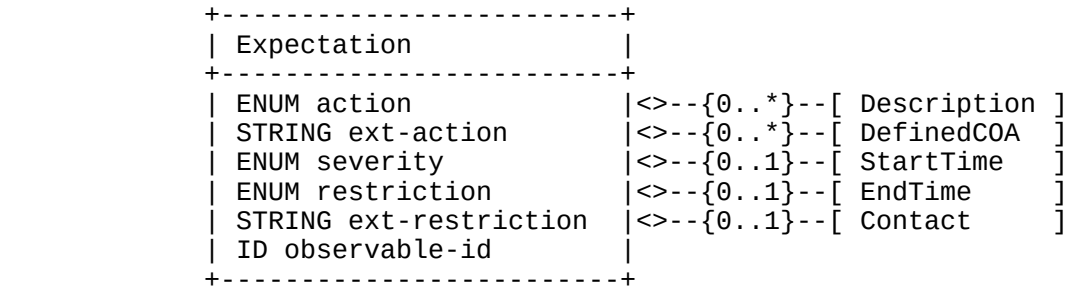

Figure 31: The Expectation Class

The aggregate classes of the Expectation class are:

Description
: Zero or more. ML_STRING. A free-form text description of the desired action(s).

DefinedCOA
: Zero or more. STRING. A unique identifier meaningful to the sender and recipient of this document that references a course of action. This class MUST be present if the action attribute is set to "defined-coa".

StartTime
: Zero or one. DATETIME. The time at which the sender would like the action performed. A timestamp that is earlier than the ReportTime specified in the Incident class denotes that the sender would like the action performed as soon as possible. The absence of this element indicates no expectations of when the recipient would like the action performed.

EndTime
: Zero or one. DATETIME. The time by which the sender expects the recipient to complete the action. If the recipient cannot complete the action before EndTime, the recipient MUST NOT carry out the action. Because of transit delays and clock drift the sender MUST be prepared for the recipient to have carried out the action, even if it completes past EndTime.

Contact

Zero or one. The entity expected to perform the action. See Section 3.9.

The attributes of the Expectation class are:

action
Optional. ENUM. Classifies the type of action requested. The default value of "other". These values are maintained in the "Expectation-action" IANA registry per Section 10.2.

1. nothing. No action is requested. Do nothing with the information.

2. contact-source-site. Contact the site(s) identified as the source of the activity.

3. contact-target-site. Contact the site(s) identified as the target of the activity.

4. contact-sender. Contact the originator of the document.

5. investigate. Investigate the systems(s) listed in the event.

6. block-host. Block traffic from the machine(s) listed as sources the event.

7. block-network. Block traffic from the network(s) lists as sources in the event.

8. block-port. Block the port listed as sources in the event.

9. rate-limit-host. Rate-limit the traffic from the machine(s) listed as sources in the event.

10. rate-limit-network. Rate-limit the traffic from the network(s) lists as sources in the event.

11. rate-limit-port. Rate-limit the port(s) listed as sources in the event.

12. redirect-traffic. Redirect traffic from the intended recipient for further analysis.

13. honeypot. Redirect traffic from systems listed in the event to a honeypot for further analysis.

14. upgrade-software. Upgrade or patch the software or firmware on an asset listed in the event.

15. rebuild-asset. Reinstall the operating system or applications on an asset listed in the event.

16. harden-asset. Change the configuration an asset listed in the event to reduce the attack surface.

17. remediate-other. Remediate the activity in a way other than by rate limiting or blocking.

18. status-triage. Confirm receipt and begin triaging the incident.

19. status-new-info. Notify the sender when new information is received for this incident.

20. watch-and-report. Watch for the described activity or indicators; and notify the sender when seen.

21. training. Train user to identify or mitigate the described threat.

22. defined-coa. Perform a predefined course of action (COA). The COA is named in the DefinedCOA class.

23. other. Perform a custom action described in the Description class.

24. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-action
Optional. STRING. A means by which to extend the action attribute. See Section 5.1.1.

severity
Optional. ENUM. Indicates the desired priority of the action. This attribute is an enumerated list with no default value, and the semantics of these relative measures are context dependent.

1. low. Low priority

2. medium. Medium priority

3. high. High priority

restriction

Optional. ENUM. See Section 3.3.1. The default value is "default".

ext-restriction
Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

observable-id
Optional. ID. See Section 3.3.2.

3.16. Flow Class

The Flow class describes the systems and networks involved in the incident; and the relationships between them.

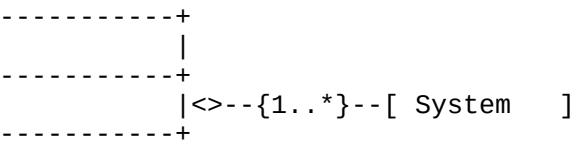

Figure 32: The Flow Class

The aggregate class of the Flow class is:

System
One or More. A host or network involved in an event. See Section 3.17.

The Flow class has no attributes.

3.17. System Class

The System class describes a system or network involved in an event.

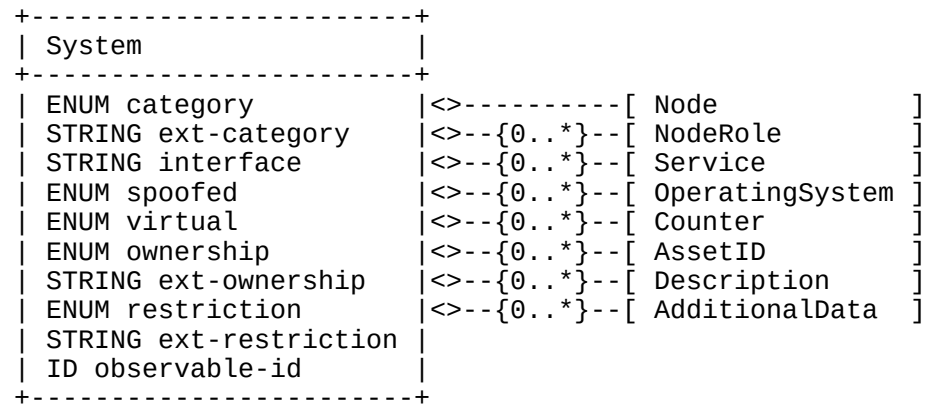

Figure 33: The System Class

The aggregate classes of the System class are:

Node
: One. A host or network involved in the incident. See Section 3.18.

NodeRole
: Zero or more. The intended purpose of the system. See Section 3.18.2.

Service
: Zero or more. A network service running on the system. See Section 3.20.

OperatingSystem
: Zero or more. SOFTWARE. The operating system running on the system.

Counter
: Zero or more. A counter with which to summarize properties of this host or network. See Section 3.18.3.

AssetID
: Zero or more. STRING. An asset identifier for the System.

Description
: Zero or more. ML_STRING. A free-form text description of the System.

AdditionalData

Zero or more. EXTENSION. A mechanism by which to extend the data model.

The attributes of the System class are:

category
Optional. ENUM. Classifies the role the host or network played in the incident. These values are maintained in the "System-category" IANA registry per Section 10.2.

1. source. The System was the source of the event.

2. target. The System was the target of the event.

3. intermediate. The System was an intermediary in the event.

4. sensor. The System was a sensor monitoring the event.

5. infrastructure. The System was an infrastructure node of IODEF document exchange.

6. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-category
Optional. STRING. A means by which to extend the category attribute. See Section 5.1.1.

interface
Optional. STRING. Specifies the interface on which the event(s) on this System originated. If the Node class specifies a network rather than a host, this attribute has no meaning.

spoofed
Optional. ENUM. An indication of confidence in whether this System was the true target or attacking host. The permitted values for this attribute are shown below. The default value is "unknown".

1. unknown. The accuracy of the category attribute value is unknown.

2. yes. The category attribute value is likely incorrect. In the case of a source, the System is likely a decoy; with a target, the System was likely not the intended victim.

3. no. The category attribute value is believed to be correct.

virtual
Optional. ENUM. Indicates whether this System is a virtual or physical device. The default value is "unknown".

1. yes. The System is a virtual device.

2. no. The System is a physical device.

3. unknown. It is not known if the System is virtual.

ownership
Optional. ENUM. Describes the ownership of this System relative to the victim in the incident. These values are maintained in the "System-ownership" IANA registry per Section 10.2.

1. organization. Corporate or enterprise-owned.

2. personal. Personally-owned by an employee or affiliate of the corporation or enterprise.

3. partner. Owned by a partner of the corporation or enterprise.

4. customer. Owned by a customer of the corporation or enterprise.

5. no-relationship. Owned by an entity that has no known relationship with victim organization.

6. unknown. Ownership is unknown.

7. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-ownership
Optional. STRING. A means by which to extend the ownership attribute. See Section 5.1.1.

restriction
Optional. ENUM. See Section 3.3.1.

ext-restriction
Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

observable-id
Optional. ID. See Section 3.3.2.

3.18. Node Class

The Node class identifies a system, asset or network; and its location.

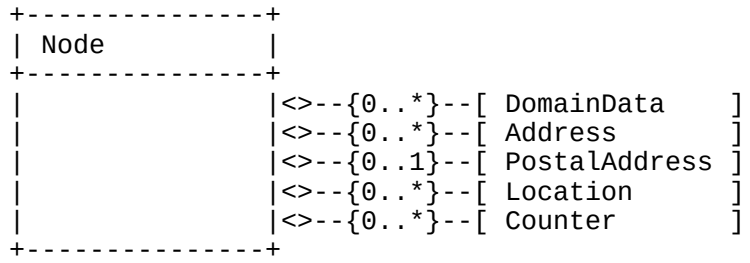

Figure 34: The Node Class

The aggregate classes of the Node class are:

DomainData
: Zero or more. The domain (DNS) information associated with this Node. If an Address is not provided, at least one DomainData MUST be specified. See Section 3.19.

Address
: Zero or more. The hardware, network, or application address of the Node. If a DomainData is not provided, at least one Address MUST be specified. See Section 3.18.1.

PostalAddress
: Zero or one. POSTAL. The postal address of the node.

Location
: Zero or more. ML_STRING. A free-form text description of the physical location of the Node. This description may provide a more detailed description of where in the PostalAddress this Node is found (e.g., room number, rack number, slot number in a chassis).

Counter
: Zero or more. A counter with which to summarizes properties of this host or network. See Section 3.18.3.

The Node class has no attributes.

3.18.1. Address Class

The Address class represents a hardware (layer-2), network (layer-3), or application (layer-7) address.

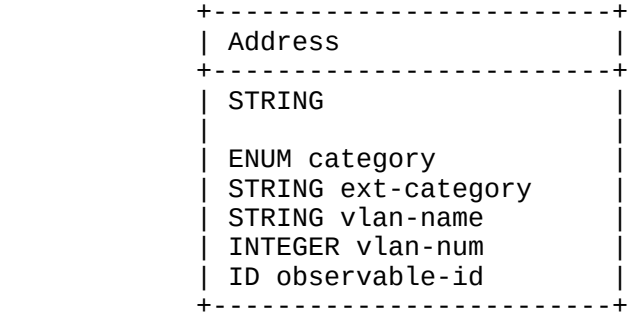

Figure 35: The Address Class

The content of the class is an address of type STRING whose semantics are determined by the category attribute.

The attributes of the Address class are:

category
: Required. ENUM. The type of address represented. The default value is "ipv6-addr". These values are maintained in the "Address-category" IANA registry per Section 10.2.

1. asn. Autonomous System Number.

2. atm. Asynchronous Transfer Mode (ATM) address.

3. e-mail. Email address, per the EMAIL data type.

4. ipv4-addr. IPv4 host address in dotted-decimal notation (a.b.c.d).

5. ipv4-net. IPv4 network address in dotted-decimal notation, slash, significant bits (i.e., a.b.c.d/nn).

6. ipv4-net-masked. A sanitized IPv4 address with significant bits per "ipv4-net" but with the character ’x’ replacing any digit(s) in the address or prefix.

7. ipv4-net-mask. IPv4 network address in dotted-decimal notation, slash, network mask in dotted-decimal notation (i.e., a.b.c.d/w.x.y.z).

8. ipv6-addr. IPv6 host address per Section 4 of [RFC5952].

9. ipv6-net. IPv6 network address, slash, prefix per Section 2.3 of [RFC4291].

10. ipv6-net-masked. A sanitized IPv6 address and prefix per "ipv6-net" but with the character 'x' replacing any hexadecimal digit(s) in the address or digit(s) in the prefix.

11. mac. Media Access Control (MAC) address (i.e., aa:bb:cc:dd:ee:ff).

12. site-uri. A URL or URI for a resource, per the URL data type.

13. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-category
Optional. STRING. A means by which to extend the category attribute. See Section 5.1.1.

vlan-name
Optional. STRING. The name of the Virtual LAN to which the address belongs.

vlan-num
Optional. INTEGER. The number of the Virtual LAN to which the address belongs.

observable-id
Optional. ID. See Section 3.3.2.

3.18.2. NodeRole Class

The NodeRole class describes the function performed by or role of a particular system, asset or network.

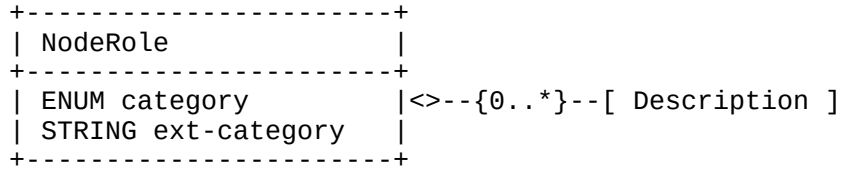

Figure 36: The NodeRole Class

The aggregate class of the NodeRole class is:

Description
: Zero or more. ML_STRING. A free-form text description of the role of the system.

The attributes of the NodeRole class are:

category
: Required. ENUM. Function or role of a node. These values are maintained in the "NodeRole-category" IANA registry per Section 10.2.

1. client. Client computer.
2. client-enterprise. Client computer on the enterprise network.
3. client-partner. Client computer on network of a partner.
4. client-remote. Client computer remotely connected to the enterprise network.
5. client-kiosk. Client computer serving as a kiosk.
6. client-mobile. Mobile device.
7. server-internal. Server with internal services.
8. server-public. Server with public services.
9. www. WWW server.
10. mail. Mail server.
11. webmail. Web mail server.
12. messaging. Messaging server (e.g., NNTP, IRC, IM).
13. streaming. Streaming-media server.
14. voice. Voice server (e.g., SIP, H.323).
15. file. File server.
16. ftp. FTP server.
17. p2p. Peer-to-peer node.

18. name. Name server (e.g., DNS, WINS).

19. directory. Directory server (e.g., LDAP, finger, whois).

20. credential. Credential server (e.g., domain controller, Kerberos).

21. print. Print server.

22. application. Application server.

23. database. Database server.

24. backup. Backup server.

25. dhcp. DHCP server.

26. assessment. Assessment server (e.g., vulnerability scanner, end-point assessment).

27. source-control. Source code control server.

28. config-management. Configuration management server.

29. monitoring. Security monitoring server (e.g., IDS).

30. infra. Infrastructure server (e.g., router, firewall, DHCP).

31. infra-firewall. Firewall.

32. infra-router. Router.

33. infra-switch. Switch.

34. camera. Camera and video system.

35. proxy. Proxy server.

36. remote-access. Remote access server.

37. log. Log server (e.g., syslog).

38. virtualization. Server running virtual machines.

39. pos. Point-of-sale device.

40. scada. Supervisory control and data acquisition (SCADA) system.

41. scada-supervisory. Supervisory system for a SCADA.

42. sinkhole. Traffic sinkhole destination.

43. honeypot. Honeypot server.

44. anonymization. Anonymization server (e.g., Tor node).

45. c2-server. Malicious command and control server.

46. malware-distribution. Server that distributes malware

47. drop-server. Server to which exfiltrated content is uploaded.

48. hop-point. Intermediary server used to get to a victim.

49. reflector. A system used in a reflector attack.

50. phishing-site. Site hosting phishing content.

51. spear-phishing-site. Site hosting spear-phishing content.

52. recruiting-site. Site to recruit.

53. fraudulent-site. Fraudulent site.

54. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-category
Optional. STRING. A means by which to extend the category attribute. See Section 5.1.1.

3.18.3. Counter Class

The Counter class summarizes multiple occurrences of an event or conveys counts or rates of various features.

The complete semantics of this class are context dependent based on the class in which it is aggregated.

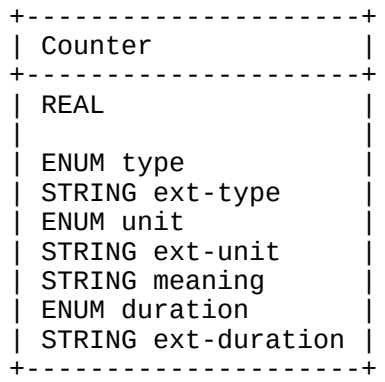

Figure 37: The Counter Class

The content of the class is a value of type REAL whose meaning and units are determined by the type and duration attributes, respectively. If the duration attribute is present, the element content is a rather. Otherwise, it is a simple counter.

The attributes of the Counter class are:

type
: Required. ENUM. Specifies the type of counter specified in the element content. These values are maintained in the "Counter-type" IANA registry per Section 10.2.

  1. count. The Counter class value is a counter.

  2. peak. The Counter class value is a peak value.

  3. average. The Counter class value is an average.

  4. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-type
: Optional. STRING. A means by which to extend the type attribute. See Section 5.1.1.

unit
: Required. ENUM. Specifies the units of the element content. These values are maintained in the "Counter-unit" IANA registry per Section 10.2.

  1. byte. Bytes transferred.

2. mbit. Megabits (Mbits) transfered.

3. packet. Packets.

4. flow. Network flow records.

5. session. Sessions.

6. alert. Notifications generated by another system (e.g., IDS or SIM).

7. message. Messages (e.g., mail messages).

8. event. Events.

9. host. Hosts.

10. site. Site.

11. organization. Organizations.

12. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-unit
Optional. STRING. A means by which to extend the unit attribute. See Section 5.1.1.

meaning
Optional. STRING. A free-form text description of the metric represented by the Counter.

duration
Optional. ENUM. If present, the Counter class represents a rate. This attribute specifies unit of time over which the rate whose units are specified in the unit attribute is being conveyed. This attribute is the the denominator of the rate (where the unit attribute specified the nominator). The possible values of this attribute are defined in the duration attribute of Section 3.12.3

ext-duration
Optional. STRING. A means by which to extend the duration attribute. See Section 5.1.1.

3.19. DomainData Class

The DomainData class describes a domain name and meta-data associated with this domain.

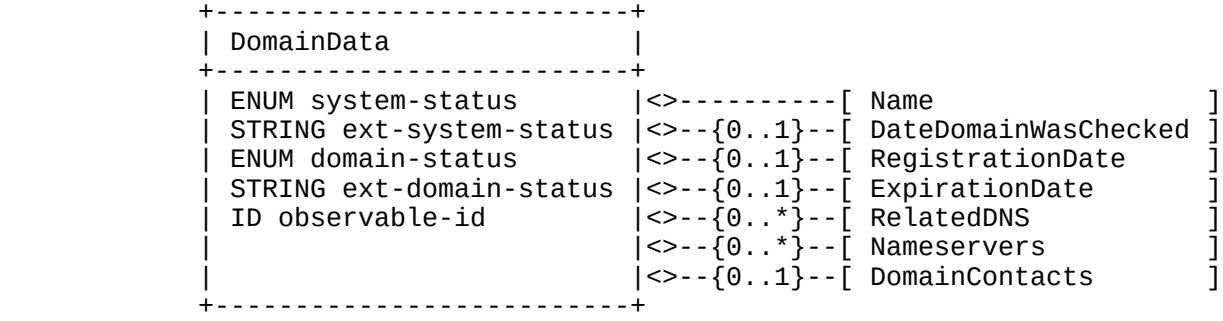

Figure 38: The DomainData Class

The aggregate classes of the DomainData class are:

Name
: One. STRING. The domain name of a system.

DateDomainWasChecked
: Zero or one. DATETIME. A timestamp of when the domain listed in the Name class was resolved.

RegistrationDate
: Zero or one. DATETIME. A timestamp of when domain listed in Name class was registered.

ExpirationDate
: Zero or one. DATETIME. A timestamp of when the domain listed in Name class is set to expire.

RelatedDNS
: Zero or more. EXTENSION. Additional DNS records associated with this domain.

Nameservers
: Zero or more. The name servers identified for the domain listed in Name class. See Section 3.19.1.

DomainContacts
: Zero or one. Contact information for the domain listed in Name class supplied by the registrar or through a whois query.

The attributes of the DomainData class are:

system-status
Required. ENUM. Assesses the domain's involvement in the event. These values are maintained in the "DomainData-system-status" IANA registry per Section 10.2.

1. spoofed. This domain was spoofed.

2. fraudulent. This domain was operated with fraudulent intentions.

3. innocent-hacked. This domain was compromised by a third party.

4. innocent-hijacked. This domain was deliberately hijacked.

5. unknown. No categorization for this domain known.

6. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-system-status
Optional. STRING. A means by which to extend the system-status attribute. See Section 5.1.1.

domain-status
Required. ENUM. Categorizes the registry status of the domain at the time the document was generated. These values and their associated descriptions are derived from Section 3.2.2 of [RFC3982]. These values are maintained in the "DomainData-domain-status" IANA registry per Section 10.2.

1. reservedDelegation. The domain is permanently inactive.

2. assignedAndActive. The domain is in a normal state.

3. assignedAndInactive. The domain has an assigned registration but the delegation is inactive.

4. assignedAndOnHold. The domain is in dispute.

5. revoked. The domain is in the process of being purged from the database.

6. transferPending. The domain is pending a change in authority.

7. registryLock. The domain is on hold by the registry.

8. registrarLock. Same as "registryLock".

9. other. The domain has a known status but it is not one of the redefined enumerated values.

10. unknown. The domain has an unknown status.

11. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-domain-status
Optional. STRING. A means by which to extend the domain-status attribute. See Section 5.1.1.

observable-id
Optional. ID. See Section 3.3.2.

3.19.1. Nameservers Class

The Nameservers class describes the name servers associated with a given domain.

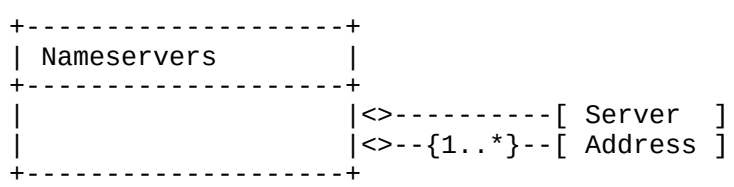

Figure 39: The Nameservers Class

The aggregate classes of the Nameservers class are:

Server
One. STRING. The domain name of the name server.

Address
One or more. The address of the name server. The value of the category attribute MUST be either "ipv4-addr" or "ipv6-addr". See Section 3.18.1.

The Nameservers class has no attributes.

3.19.2. DomainContacts Class

The DomainContacts class describes the contact information for a given domain provided either by the registrar or through a whois query.

This contact information can be explicitly described through a Contact class or a reference can be provided to a domain with identical contact information. Either a single SameDomainContact MUST be present or one or more Contact classes.

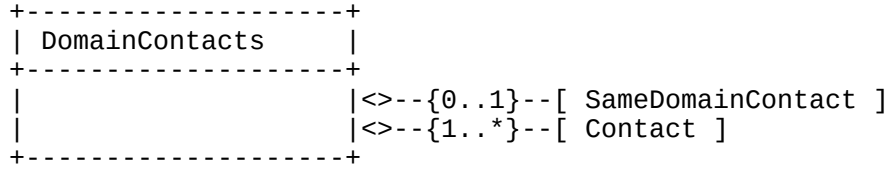

Figure 40: The DomainContacts Class

The aggregate classes of the DomainContacts class are:

SameDomainContact
: Zero or one. STRING. A domain name already cited in this document or through previous exchange that contains the identical contact information as the domain name in question. The domain contact information associated with this domain should be used instead of an explicit definition with the Contact class.

Contact
: One or more. Contact information for the domain. See Section 3.9.

The DomainContacts class has no attributes.

3.20. Service Class

The Service class describes a network service. The service is described by protocol, port, protocol header field and application providing or using the service.

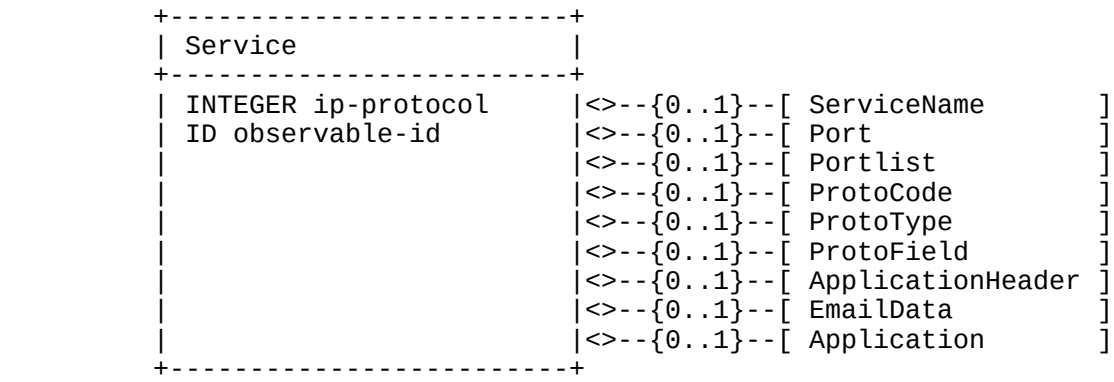

Figure 41: The Service Class

The aggregate classes of the Service class are:

ServiceName
: Zero or one. A protocol name.

Port
: Zero or one. INTEGER. A port number.

Portlist
: Zero or one. PORTLIST. A list of port numbers.

ProtoCode
: Zero or one. INTEGER. A transport layer (layer 4) protocol-specific code field (e.g., ICMP code field).

ProtoType
: Zero or one. INTEGER. A transport layer (layer 4) protocol specific type field (e.g., ICMP type field).

ProtoField
: Zero or one. INTEGER. A transport layer (layer 4) protocol specific flag field (e.g., TCP flag field).

ApplicationHeader
: Zero or one. A protocol header. See Section 3.20.2.

EmailData
: Zero or one. Headers associated with an email message. See Section 3.21.

Application

Zero or one. SOFTWARE. The application acting as either the client or server for the service.

At least one of these classes MUST be present.

When a given System classes with category="source" and another with category="target" are aggregated into a single Flow class, and each of these System classes has a Service and Portlist class, an implicit relationship between these Portlists exists. If N ports are listed for a System@category="source", and M ports are listed for System@category="target", the number of ports in N must be equal to M. Likewise, the ports MUST be listed in an identical sequence such that the n-th port in the source corresponds to the n-th port of the target. If N is greater than 1, a given instance of a Flow class MUST only have a single instance of a System@category="source" and System@category="target".

The attributes of the Service class are:

ip-protocol
Optional. INTEGER. The IANA assigned IP protocol number per [IANA.Protocols] The attribute MUST be set if a Port, Portlist, ProtoCode, ProtoType, ProtoField class is present.

observable-id
Optional. ID. See Section 3.3.2.

3.20.1. ServiceName Class

The ServiceName class identifies an application protocol. It can be described by referencing an IANA registered protocol, a URL or with free-form text.

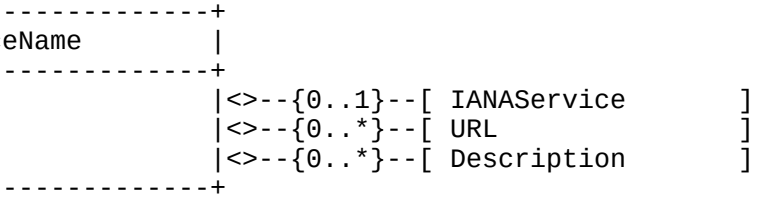

Figure 42: The ServiceName Class

The aggregate classes of the ServiceName class are:

IANAService
Zero or one. STRING. The name of the service per the "Service Name" field of the [IANA.Ports] registry.

URL
Zero or more. URL. A URL to a resource describing the service.

Description
Zero or more. ML_STRING. A free-form text description of the service.

At least one of these classes MUST be present.

The ServiceName class has no attributes.

3.20.2. ApplicationHeader Class

The ApplicationHeader class describes arbitrary fields from a protocol header and its corresponding value.

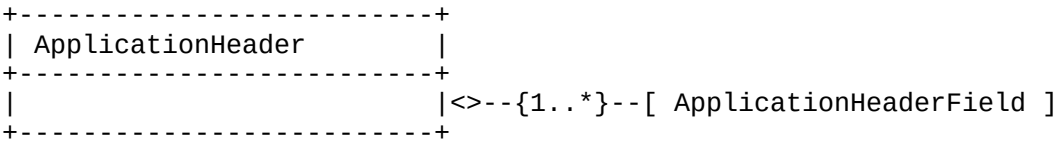

Figure 43: The ApplicationHeader Class

The aggregate class of the ApplicationHeader class is:

ApplicationHeaderField
One or more. EXTENSION. A field name and value in a protocol header. The 'name' attribute MUST be set to the field name. The field value MUST be set in the element content.

The ApplicationHeader class has no attributes.

3.21. EmailData Class

The EmailData class describes headers from an email message and cryptographic hash and signatures applied to it.

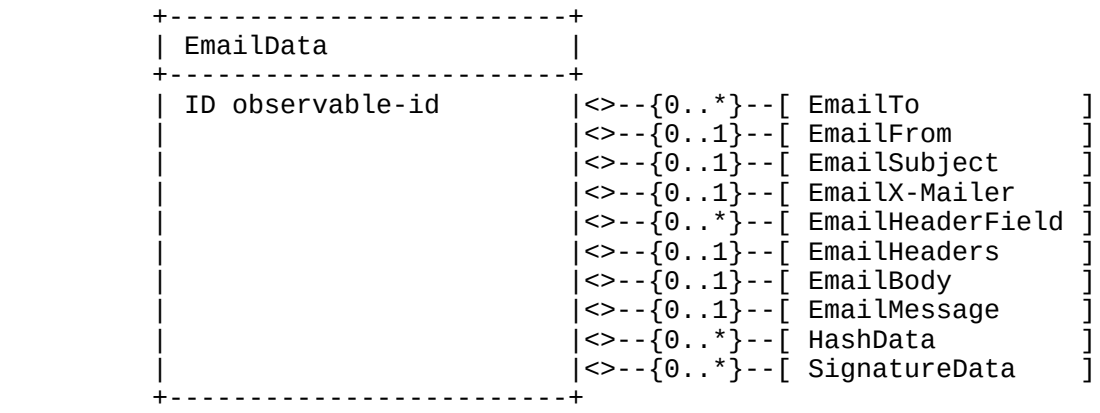

Figure 44: EmailData Class

The aggregate classes of the EmailData class are:

EmailTo
: Zero or more. EMAIL. The value of the "To:" header field (Section 3.6.3 of [RFC5322]) in an email.

EmailFrom
: Zero or one. EMAIL. The value of the "From:" header field (Section 3.6.2 of [RFC5322]) in an email.

EmailSubject
: Zero or one. STRING. The value of the "Subject:" header field in an email. See Section 3.6.4 of [RFC5322].

EmailX-Mailer
: Zero or one. STRING. The value of the "X-Mailer:" header field in an email.

EmailHeaderField
: Zero or more. EXTENSION. The header name and value of an arbitrary header field of the email message. The 'name' attribute MUST be set to header name. The header value MUST be set in the element body. The dtype attribute MUST be set to "string".

EmailHeaders
: Zero or one. STRING. The headers of an email message.

EmailBody
: Zero or one. STRING. The body of an email message.

EmailMessage

Zero or one. STRING. The headers and body of an email message.

HashData
Zero or more. Hash(es) associated with this email message. See Section 3.26.

SignatureData
Zero or more. Signature(s) associated with this email message. See Section 3.27.

The attribute of the EmailData class is:

observable-id
Optional. ID. See Section 3.3.2.

3.22. Record Class

The Record class is a container class for log and audit data that provides supportive information about the events in an incident. The source of this data will often be the output of monitoring tools. These logs substantiate the activity described in the document.

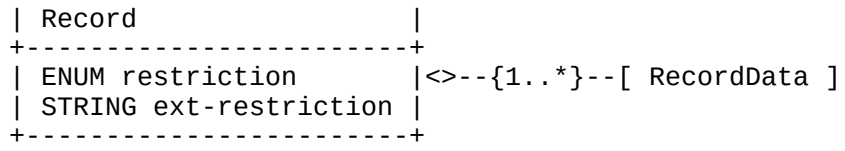

Figure 45: Record Class

The aggregate classes of the Record class are:

RecordData
One or more. Log or audit data generated by a particular tool. Separate instances of the RecordData class SHOULD be used for each type of log. See Section 3.22.1.

The attributes of the Record class are:

restriction
Optional. ENUM. See Section 3.3.1.

ext-restriction
Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

3.22.1. RecordData Class

The RecordData class describes or references log or audit data from a given type of tool and provides a means to annotate the output.

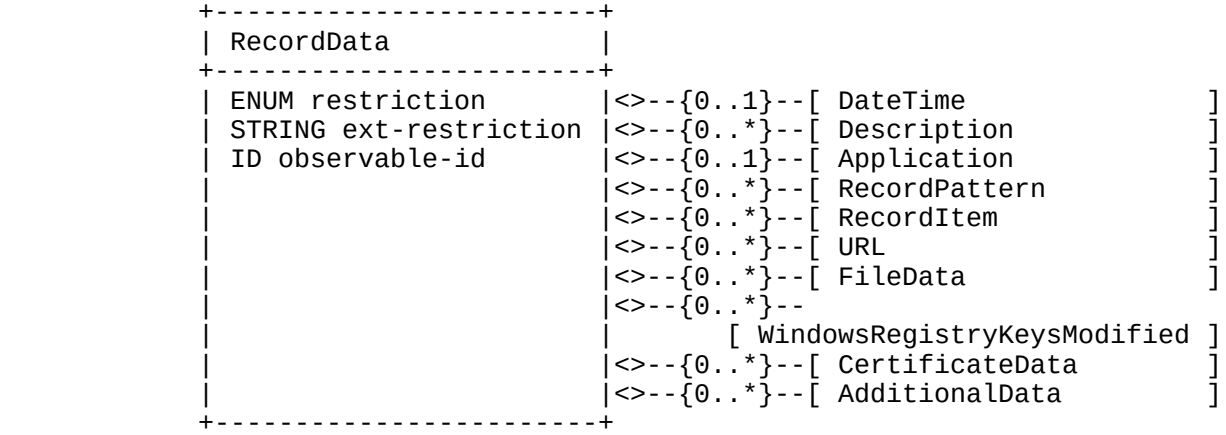

Figure 46: The RecordData Class

The aggregate classes of the RecordData class are:

DateTime
: Zero or one. DATETIME. A timestamp of the data found in the RecordItem or URL classes.

Description
: Zero or more. ML_STRING. A free-form text description of the data provided in the RecordItem or URL classes.

Application
: Zero or one. SOFTWARE. Identifies the tool used to generate the data in the RecordItem or URL classes.

RecordPattern
: Zero or more. A search string to precisely find the relevant data in the RecordItem or URL classes. See Section 3.22.2.

RecordItem
: Zero or more. EXTENSION. Log, audit, or forensic data to support the conclusions made during the course of analyzing the incident.

URL
: Zero or more. URL. A URL reference to a log or audit data.

FileData
Zero or one. The files involved in the incident. See Section 3.25.

WindowsRegistryKeysModified
Zero or more. The registry keys that were involved in the incident. See Section 3.23.

CertificateData
Zero or more. The certificates that were involved in the incident. See Section 3.24.

AdditionalData
Zero or more. EXTENSION. An extension mechanism for data not explicitly represented in the data model.

At least one of the following classes MUST be present: RecordItem, URL, FileData, WindowsRegistryKeysModified, CertificateData or AdditionalData.

The attributes of the RecordData class are:

restriction
Optional. ENUM. See Section 3.3.1.

ext-restriction
Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

observable-id
Optional. ID. See Section 3.3.2.

3.22.2. RecordPattern Class

The RecordPattern class describes where in the log data provided or referenced in RecordData class relevant information can be found. It provides a way to reference subsets of information, identified by a pattern, in a large log file, audit trail, or forensic data.

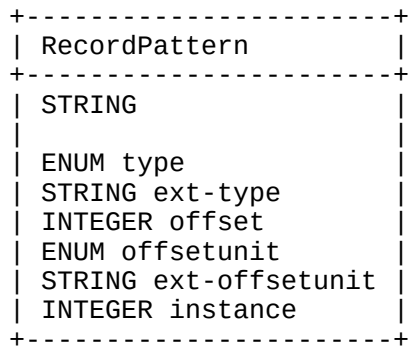

Figure 47: The RecordPattern Class

The content of the class is of type STRING and specifies a search pattern.

The attributes of the RecordPattern class are:

type
: Required. ENUM. Describes the type of pattern being specified in the element content. The default is "regex". These values are maintained in the "RecordPattern-type" IANA registry per Section 10.2.

  1. regex. regular expression as defined by POSIX Extended Regular Expressions (ERE) in Chapter 9 of [IEEE.POSIX].

  2. binary. Binhex encoded binary pattern, per the HEXBIN data type.

  3. xpath. XML Path (XPath) [W3C.XPATH]

  4. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-type
: Optional. STRING. A means by which to extend the type attribute. See Section 5.1.1.

offset
: Optional. INTEGER. Amount of units (determined by the offsetunit attribute) to seek into the RecordItem data before matching the pattern.

offsetunit

Optional. ENUM. Describes the units of the offset attribute. The default is "line". These values are maintained in the "RecordPattern-offsetunit" IANA registry per Section 10.2.

1. line. Offset is a count of lines.

2. byte. Offset is a count of bytes.

3. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-offsetunit
Optional. STRING. A means by which to extend the offsetunit attribute. See Section 5.1.1.

instance
Optional. INTEGER. Number of times to apply the specified pattern.

3.23. WindowsRegistryKeysModified Class

The WindowsRegistryKeysModified class describes Windows operating system registry keys and the operations that were performed on them. This class was derived from [RFC5901].

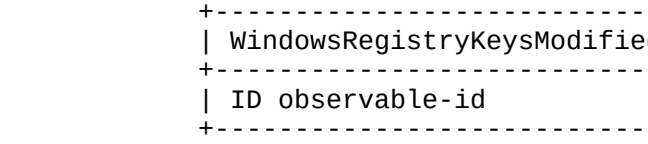

Figure 48: The WindowsRegistryKeysModified Class

The aggregate classes of the WindowsRegistryKeysModified class are:

Key
One or more. The Window registry key. See Section 3.23.1.

The attribute of the WindowsRegistryKeysModified class is:

observable-id
Optional. ID. See Section 3.3.2.

3.23.1. Key Class

The Key class describes a Windows operating system registry key name and value pair, and the operation performed on it.

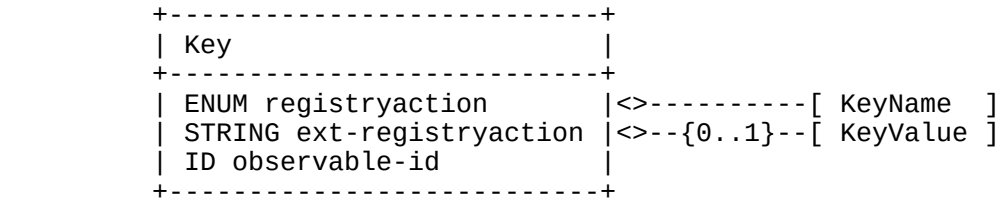

Figure 49: The Key Class

The aggregate classes of the Key class are:

KeyName
: One. STRING. The name of a Windows operating system registry key (e.g.,[HKEY_LOCAL_MACHINE\Software\Test\KeyName])

KeyValue
: Zero or one. STRING. The value of the registry key identified in the KeyName class encoded per the .reg file format [KB310516].

The attributes of the Key class are:

registryaction
: Optional. ENUM. The type of action taken on the registry key. These values are maintained in the "Key-registryaction" IANA registry per Section 10.2.

  1. add-key. Registry key added.

  2. add-value. Value added to a registry key.

  3. delete-key. Registry key deleted.

  4. delete-value. Value deleted from a registry key.

  5. modify-key. Registry key modified.

  6. modify-value. Value modified in a registry key.

  7. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-registryaction
Optional. STRING. A means by which to extend the registryaction attribute. See Section 5.1.1.

observable-id
Optional. ID. See Section 3.3.2.

3.24. CertificateData Class

The CertificateData class describes X.509 certificates.

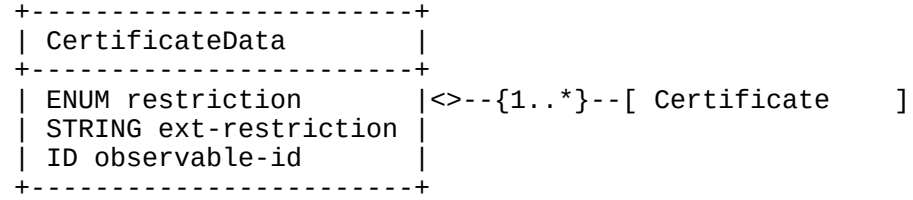

Figure 50: The CertificateData Class

The aggregate classes of the CertificateData class are:

Certificate
One or more. A description of an X.509 certificate or certificate chain. See Section 3.24.1.

The attributes of the CertificateData class are:

restriction
Optional. ENUM. See Section 3.3.1.

ext-restriction
Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

observable-id
Optional. ID. See Section 3.3.2.

3.24.1. Certificate Class

The Certificate class describes a given X.509 certificate or certificate chain.

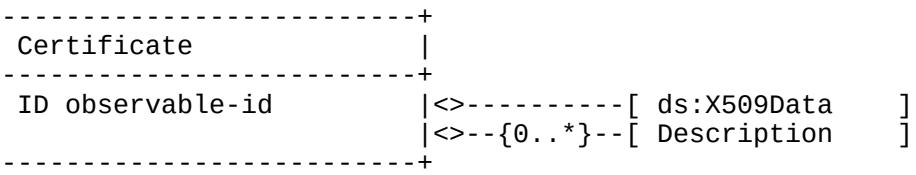

Figure 51: The Certificate Class

The aggregate classes of the Certificate class are:

ds:X509Data
: One. A given X.509 certificate or chain. See Section 4.4.4 of [W3C.XMLSIG].

Description
: Zero or more. ML_STRING. A free-form text description explaining the context of this certificate.

The attributes of the Certificate class are:

observable-id
: Optional. ID. See Section 3.3.2.

3.25. FileData Class

The FileData class describes a file or set of files.

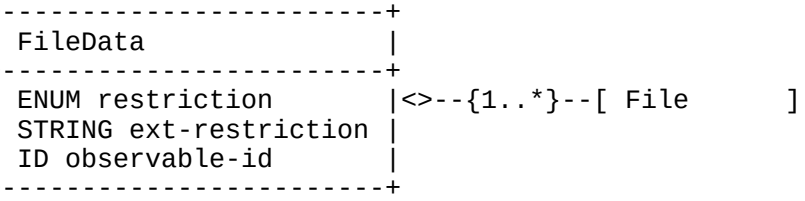

Figure 52: The FileData Class

The aggregate classes of the FileData class are:

File
: One or more. A description of a file. See Section 3.25.1.

The attributes of the FileData class are:

restriction
: Optional. ENUM. See Section 3.3.1.

ext-restriction
Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

observable-id
Optional. ID. See Section 3.3.2.

3.25.1. File Class

The File class describes a file; its associated meta data; and cryptographic hashes and signatures applied to it.

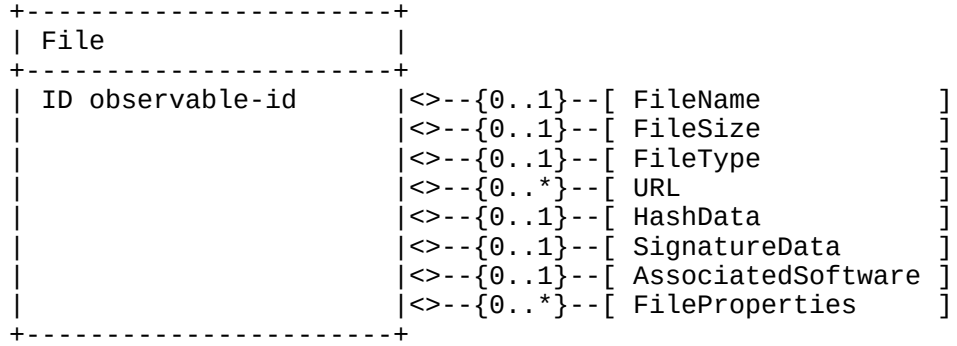

Figure 53: The File Class

The aggregate classes of the File class are:

FileName
Zero or One. STRING. The name of the file.

FileSize
Zero or One. INTEGER. The size of the file in bytes.

FileType
Zero or One. STRING. The type of file per the IANA Media Types Registry [IANA.Media]. Valid values correspond to the text in the "Template" column (e.g., "application/pdf").

URL
Zero or more. URL. A URL reference to the file.

HashData
Zero or One. Hash(es) associated with this file. See Section 3.26.

SignatureData

Zero or One. Signature(s) associated with this file. See Section 3.27.

AssociatedSoftware
Zero or One. SOFTWARE. The software application or operating system to which this file belongs or by which it can be processed.

FileProperties
Zero or more. EXTENSION. Mechanism by which to extend the data model to describe properties of the file.

The attributes of the File class are:

observable-id
Optional. ID. See Section 3.3.2.

3.26. HashData Class

The HashData class describes different types of hashes on an given object (e.g., file, part of a file, email).

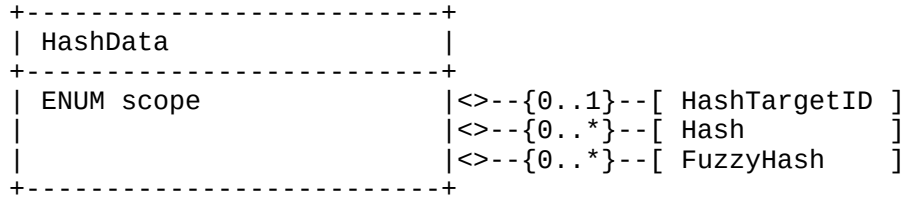

Figure 54: The HashData Class

The aggregate classes of the HashData class are:

HashTargetID
Zero or One. STRING. An identifier that references a subset of the object being hashed. The semantics of this identifier are specified by the scope attribute.

Hash
Zero or more. The hash of an object. See Section 3.26.1.

FuzzyHash
Zero or more. The fuzzy hash of an object. See Section 3.26.2.

At least one instance of either Hash or FuzzyHash MUST be present.

The attribute of the HashData class is:

scope
Required. ENUM. Describes on which part of the object the hash should be applied. These values are maintained in the "HashData-scope" IANA registry per Section 10.2.

1. file-contents. A hash computed over the entire contents of a file.

2. file-pe-section. A hash computed on a given section of a Windows Portable Executable (PE) file. If set to this value, the HashTargetID class MUST identify the section being hashed. A section is identified by an ordinal number (starting at 1) corresponding to the the order in which the given section header was defined in the Section Table of the PE file header.

3. file-pe-iat. A hash computed on the Import Address Table (IAT) of a PE file. As IAT hashes are often tool dependent, if this value is set, the Application class of either the Hash or FuzzyHash classes MUST specify the tool used to generate the hash.

4. file-pe-resource. A hash computed on a given resource in a PE file. If set to this value, the HashTargetID class MUST identify the resource being hashed. A resource is identified by an ordinal number (starting at 1) corresponding to the order in which the given resource is declared in the Resource Directory of the Data Dictionary in the PE file header.

5. file-pdf-object. A hash computed on a given object in a Portable Document Format (PDF) file. If set to this value, the HashTargetID class MUST identify the object being hashed. This object is identified by its offset in the PDF file.

6. email-hash. A hash computed over the headers and body of an email message.

7. email-headers-hash. A hash computed over all of the headers of an email message.

8. email-body-hash. A hash computed over the body of an email message.

9. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-scope

Optional. STRING. A means by which to extend the scope attribute. See Section 5.1.1.

3.26.1. Hash Class

The Hash class describes a cryptographic hash value; the algorithm and application used to generate it; and the canonicalization method applied to the object being hashed.

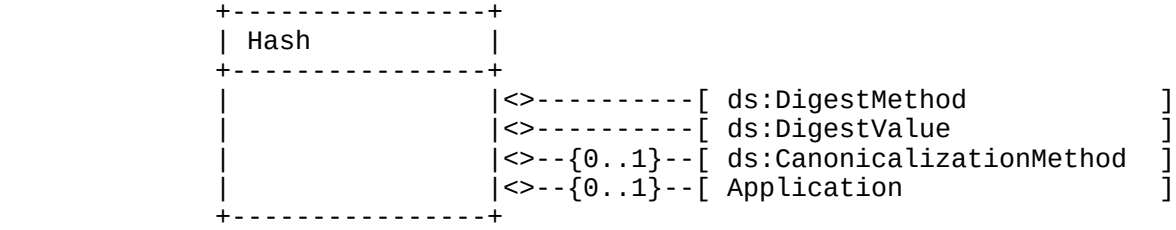

Figure 55: The Hash Class

The aggregate classes of the Hash class are:

ds:DigestMethod
One. The hash algorithm used to generate the hash. See Section 4.3.3.5 of [W3C.XMLSIG]

ds:DigestValue
One. The computed hash value. See Section 4.3.3.6 of [W3C.XMLSIG].

ds:CanonicalizationMethod
Zero or one. The canonicalization method used on the object being hashed. See Section 4.3.1 of [W3C.XMLSIG].

Application
Zero or One. SOFTWARE. The application used to calculate the hash.

The HashData class has no attributes.

3.26.2. FuzzyHash Class

The FuzzyHash class describes a fuzzy hash and the application used to generate it.

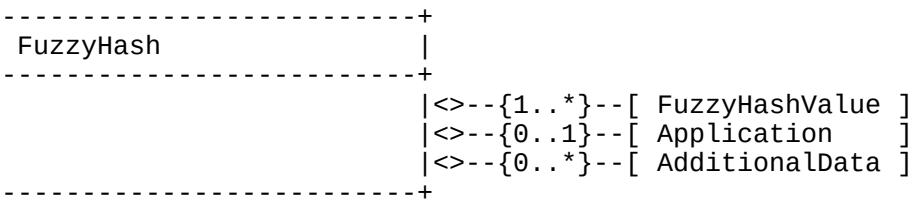

Figure 56: The FuzzyHash Class

The aggregate classes of the FuzzyHash class are:

FuzzyHashValue
: One or more. EXTENSION. The computed fuzzy hash value.

Application
: Zero or one. SOFTWARE. The application used to calculate the hash.

AdditionalData
: Zero or more. EXTENSION. Mechanism by which to extend the data model.

The FuzzyData class has no attributes.

3.27. SignatureData Class

The SignatureData class describes different types of digital signatures on an object.

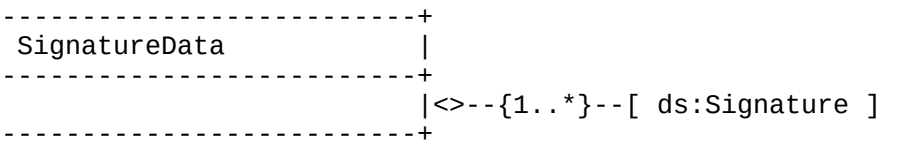

Figure 57: The SignatureData Class

The aggregate class of the SignatureData class is:

Signature
: One or more. An given signature. See Section 4.2 of [W3C.XMLSIG]

The SignatureData class has no attributes.

3.28. IndicatorData Class

The IndicatorData class describes indicators and meta-data associated with them.

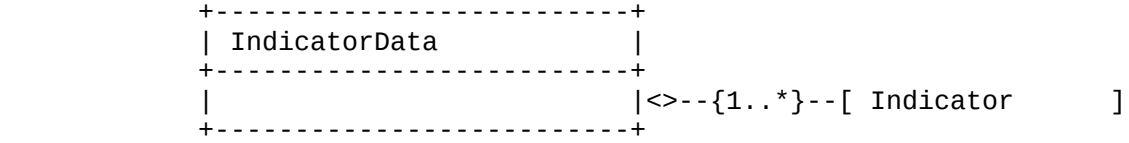

Figure 58: The IndicatorData Class

The aggregate class of the IndicatorData class is:

Indicator
: One or more. A description of an indicator. See Section 3.29.

The IndicatorData class has no attributes.

3.29. Indicator Class

The Indicator class describes an indicator. An indicator consists of observable features and phenomenon that aid in the forensic or proactive detection of malicious activity; and associated meta-data. An indicator can be described outright; by referencing or composing previously defined indicators; or by referencing observables described in the incident report found in this document.

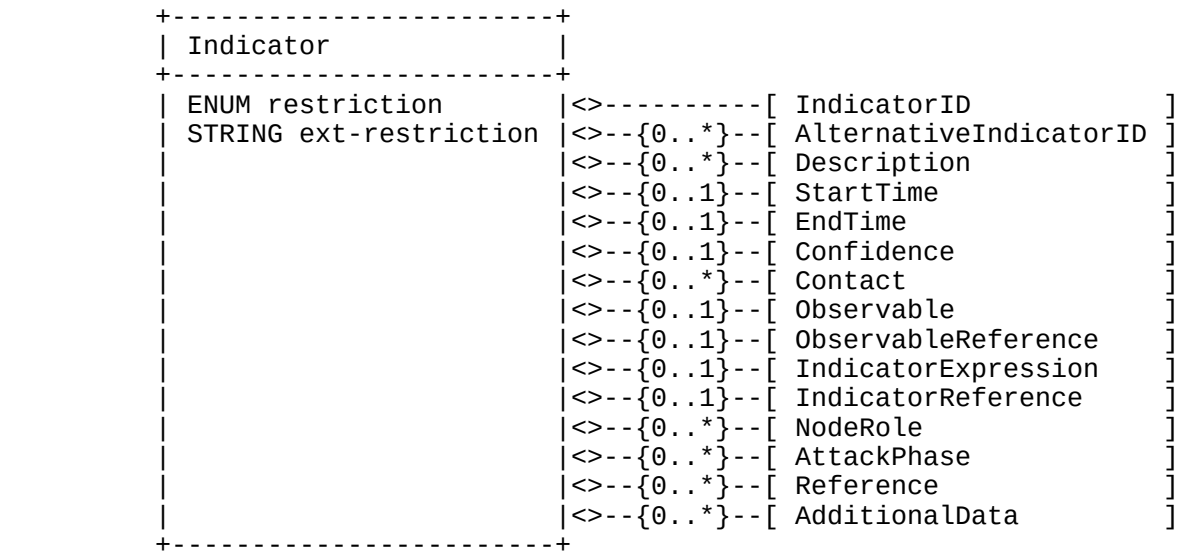

Figure 59: The Indicator Class

The aggregate classes of the Indicator class are:

IndicatorID
: One. An identifier for this indicator. See Section 3.29.1

AlternativeIndicatorID
: Zero or more. An alternative identifier for this indicator. See Section 3.29.2

Description
: Zero or more. ML_STRING. A free-form text description of the indicator.

StartTime
: Zero or one. DATETIME. A timestamp of the start of the time period during which this indicator is valid.

EndTime
: Zero or one. DATETIME. A timestamp of the end of the time period during which this indicator is valid.

Confidence
: Zero or one. An estimate of the confidence in the quality of the indicator. See Section 3.12.5.

Contact

Zero or more. Contact information for this indicator. See Section 3.9.

Observable
Zero or one. An observable feature or phenomenon of this indicator. See Section 3.29.3.

ObservableReference
Zero or one. A reference to an observable feature or phenomenon defined elsewhere in the document. See Section 3.29.6.

IndicatorExpression
Zero or one. A composition of observables. See Section 3.29.4.

IndicatorReference
Zero or one. A reference to an indicator. See Section 3.29.7.

NodeRole
Zero or more. The role of the system in the attack should this indicator be matched to it. See Section 3.18.2.

AttackPhase
Zero or more. The phase in an attack lifecycle during which this indicator might be seen. See Section 3.29.8.

Reference
Zero or more. A reference to additional information relevant to this indicator. See Section 3.11.1.

AdditionalData
Zero or more. EXTENSION. Mechanism by which to extend the data model.

The Indicator class MUST have exactly one instance of an Observable, IndicatorExpression, ObservableReference, or IndicatorReference class.

The StartTime and EndTime classes can be used to define an interval during which the indicator is valid. If both classes are present, the indicator is consider valid only during the described interval. If neither class is provided, the indicator is considered valid during any time interval. If only a StartTime is provided, the indicator is valid anytime after this timestamp. If only an EndTime is provided, the indicator is valid anytime prior to this timestamp.

The attributes of the Indicator class are:

restriction

Optional. ENUM. See Section 3.3.1.

ext-restriction
Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

3.29.1. IndicatorID Class

The IndicatorID class identifies an indicator with a globally unique identifier. The combination of the name and version attributes, and the element content form this identifier. Indicators generated by given CSIRT MUST NOT reuse the same value unless they are referencing the same indicator.

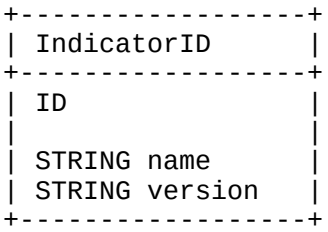

Figure 60: The IndicatorID Class

The content of the class is of type ID and specifies an identifier for an indicator.

The attributes of the IndicatorID class are:

name
Required. STRING. An identifier describing the CSIRT that created the indicator. In order to have a globally unique CSIRT name, the fully qualified domain name associated with the CSIRT MUST be used. This format is identical to the IncidentID@name attribute in Section 3.4.

version
Required. STRING. A version number of an indicator.

3.29.2. AlternativeIndicatorID Class

The AlternativeIndicatorID class lists alternative identifiers for an indicator.

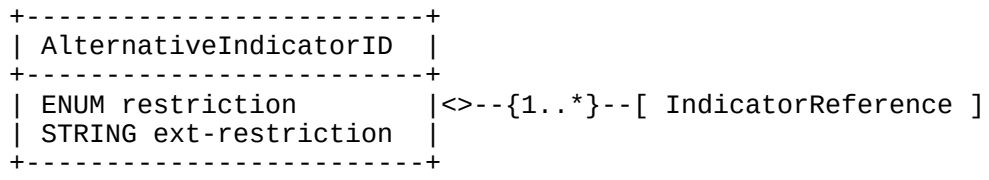

Figure 61: The AlternativeIndicatorID Class

The aggregate class of the AlternativeIndicatorID class is:

IndicatorReference
: One or more. A reference to an indicator. See Section 3.29.7

The attributes of the AlternativeIndicatorID class are:

restriction
: Optional. ENUM. See Section 3.3.1.

ext-restriction
: Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

3.29.3. Observable Class

The Observable class describes a feature and phenomenon that can be observed or measured for the purposes of detecting malicious behavior.

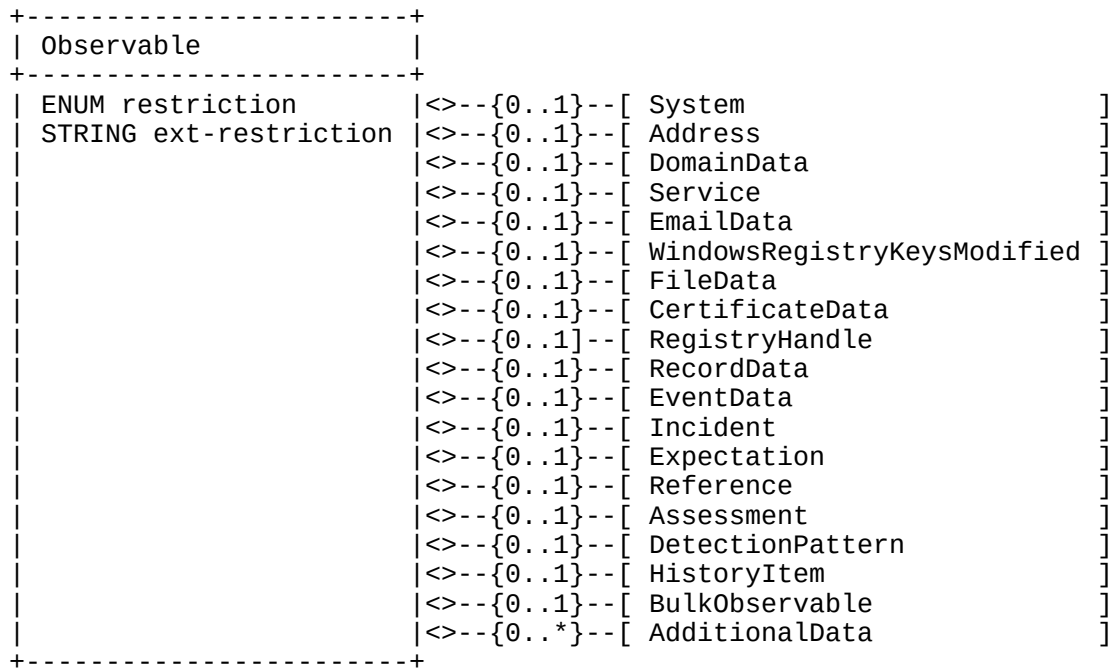

Figure 62: The Observable Class

The aggregate classes of the Observable class are:

System
: Zero or one. An System observable. See Section 3.17.

Address
: Zero or one. An Address observable. See Section 3.18.1.

DomainData
: Zero or one. A DomainData observable. See Section 3.19.

Service
: Zero or one. A Service observable. See Section 3.20.

EmailData
: Zero or one. A EmailData observable. See Section 3.21.

WindowsRegistryKeysModified
: Zero or one. A WindowsRegistryKeysModified observable. See Section 3.23.

FileData

Zero or one. A FileData observable. See Section 3.25.

CertificateData
Zero or one. A CertificateData observable. See Section 3.24.

RegistryHandle
Zero or one. A RegistryHandle observable. See Section 3.9.1.

RecordData
Zero or one. A RecordData observable. See Section 3.22.1.

EventData
Zero or one. An EventData observable. See Section 3.14.

Incident
Zero or one. An Incident observable. See Section 3.2.

Expectation
Zero or one. An Expectation observable. See Section 3.15.

Reference
Zero or one. A Reference observable. See Section 3.11.1.

Assessment
Zero or one. An Assessment observable. See Section 3.12.

DetectionPattern
Zero or one. A DetectionPattern observable. See Section 3.12.

HistoryItem
Zero or one. A HistoryItem observable. See Section 3.13.1.

BulkObservable
Zero or one. A bulk list of observables. See Section 3.29.3.1.

AdditionalData
Zero or more. EXTENSION. Mechanism by which to extend the data model.

The Observable class MUST have exactly one of the possible child classes.

The attributes of the Observable class are:

restriction
Optional. ENUM. See Section 3.3.1.

ext-restriction

Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

3.29.3.1. BulkObservable Class

The BulkObservable class allows the enumeration of a single type of observables without requiring each one to be encoded individually in multiple instances of the same class.

The type attribute describes the type of observable listed in the child BulkObservableList class. The BulkObservableFormat class optionally provides additional meta-data.

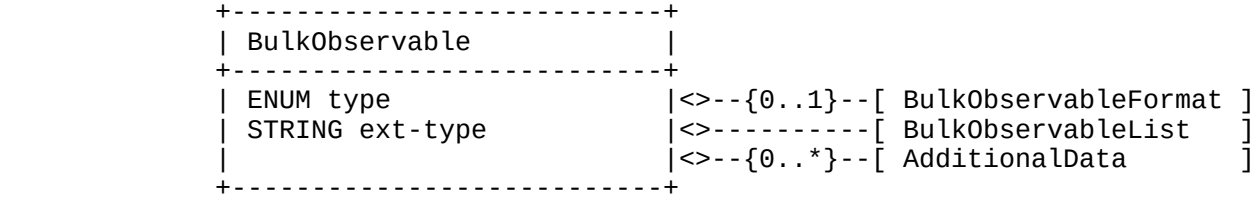

Figure 63: The BulkObservable Class

The aggregate classes of the BulkObservable class are:

BulkObservableFormat
: Zero or one. Provides additional meta-data about the observables enumerated in the BulkObservableList class. See Section 3.29.3.1.1.

BulkObservableList
: One. STRING. A list of observables, one per line. Each line is separated with either a LF character or CR-and-LF characters. The type attribute specifies which observables will be listed.

AdditionalData
: Zero or more. EXTENSION. Mechanism by which to extend the data model.

The attributes of the BulkObservable class are:

type
: Optional. ENUM. The type of the observable listed in the child ObservableList class. These values are maintained in the "BulkObservable-type" IANA registry per Section 10.2.

  1. asn. Autonomous System Number (per the Address@category attribute).

2. atm. Asynchronous Transfer Mode (ATM) address (per the Address@category attribute).

3. e-mail. Email address (per the Address@category attribute).

4. ipv4-addr. IPv4 host address in dotted-decimal notation (e.g., 192.0.2.1) (per the Address@category attribute).

5. ipv4-net. IPv4 network address in dotted-decimal notation, slash, significant bits (e.g., 192.0.2.0/24) (per the Address@category attribute).

6. ipv4-net-mask. IPv4 network address in dotted-decimal notation, slash, network mask in dotted-decimal notation (i.e., 192.0.2.0/255.255.255.0) (per the Address@category attribute).

7. ipv6-addr. IPv6 host address (e.g., 2001:DB8::3) (per the Address@category attribute).

8. ipv6-net. IPv6 network address, slash, significant bits (e.g., 2001:DB8::/32) (per the Address@category attribute).

9. ipv6-net-mask. IPv6 network address, slash, network mask (per the Address@category attribute).

10. mac. Media Access Control (MAC) address (i.e., a:b:c:d:e:f) (per the Address@category attribute).

11. site-uri. A URL or URI for a resource (per the Address@category attribute).

12. domain-name. A fully qualified domain name or part of a name. (e.g., fqdn.example.com, example.com).

13. domain-to-ipv4. A fqdn-to-IPv4 address mapping specified as a comma separated list (e.g., "fqdn.example.com, 192.0.2.1").

14. domain-to-ipv6. A fqdn-to-IPv6 address mapping specified as a comma separated list (e.g., "fqdn.example.com, 2001:DB8::3").

15. domain-to-ipv4-timestamp. Same as domain-to-ipv4 but with a timestamp (in the DATETIME format) of the resolution (e.g., "fqdn.example.com, 192.0.2.1, 2015-06-11T00:38:31-06:00").

16. domain-to-ipv6-timestamp. Same as domain-to-ipv6 but with a timestamp (in the DATETIME format) of the resolution (e.g., "fqdn.example.com, 2001:DB8::3, 2015-06-11T00:38:31-06:00").

17. ipv4-port. An IPv4 address, port and protocol tuple (e.g., 192.0.2.1, 80, tcp). The protocol name corresponds to the "Keyword" column in the [IANA.Protocols] registry.

18. ipv6-port. An IPv6 address, port and protocol tuple (e.g., 2001:DB8::3, 80, tcp). The protocol name corresponds to the "Keyword" column in the [IANA.Protocols] registry.

19. windows-reg-key. A Microsoft Windows Registry key.

20. file-hash. A file hash. The format of this hash is described in the Hash class that MUST be present in a sibling BulkObservableFormat class.

21. email-x-mailer. An X-Mailer field from an email.

22. email-subject. An email subject line.

23. http-user-agent. A User Agent field from an HTTP request header (e.g., "Mozilla/5.0 (Windows NT 6.3; WOW64; rv:38.0) Gecko/20100101 Firefox/38.0").

24. http-request-uri. The Request URI from an HTTP request header.

25. mutex. The name of a system mutex.

26. file-path. A file path (e.g., "/tmp/local/file", "c:\windows\system32\file.sys")

27. user-name. A username.

28. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-type
: Optional. STRING. A means by which to extend the type attribute. See Section 5.1.1.

3.29.3.1.1. BulkObservableFormat Class

The ObservableFormat class specifies meta-data about the format of an observable enumerated in a sibling BulkObservableList class.

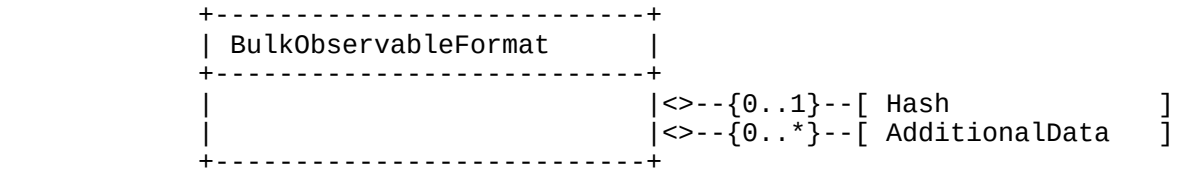

Figure 64: The BulkObservableFormat Class

The aggregate classes of the BulkObservableFormat class are:

Hash
: Zero or one. Describes the format of a hash. See Section 3.26.1.

AdditionalData
: Zero or more. EXTENSION. Mechanism by which to extend the data model.

The BulkObservableFormat class has no attributes.

Either Hash or AdditionalData MUST be present.

3.29.4. IndicatorExpression Class

The IndicatorExpression describes an expression composed of observed phenomenon or features, or indicators. Elements of the expression can be described directly, reference relevant data from other parts of a given IODEF document, or reference previously defined indicators.

All child classes of a given instance of IndicatorExpression form a boolean algebraic expression where the operator between them is determined by the operator attribute.

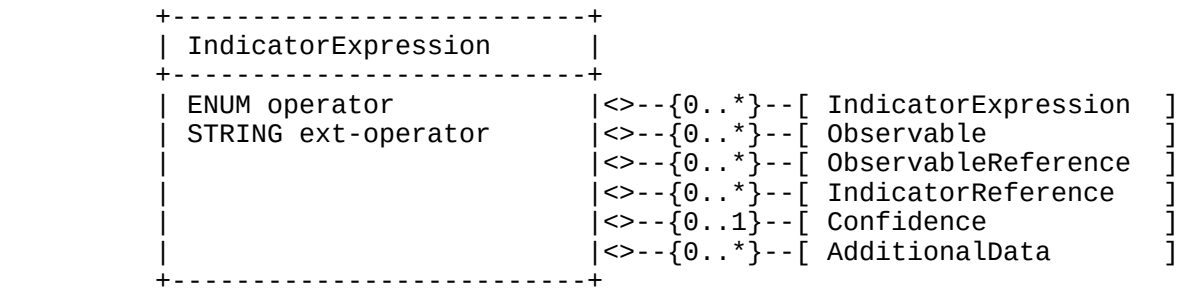

Figure 65: The IndicatorExpression Class

The aggregate classes of the IndicatorExpression class are:

IndicatorExpression
: Zero or more. An expression composed of other observables or indicators. See Section 3.29.4.

Observable
: Zero or more. A description of an observable. See Section 3.29.3.

ObservableReference
: Zero or more. A reference to an observable. See Section 3.29.6.

IndicatorReference
: Zero or more. A reference to an indicator. See Section 3.29.7.

Confidence
: Zero or one. An estimate of the confidence in the quality of the terms expressed in the expression. See Section 3.12.5.

AdditionalData
: Zero or more. EXTENSION. Mechanism by which to extend the data model.

The attributes of the IndicatorExpression class are:

operator
: Optional. ENUM. The operator to be applied between the child elements. See Section 3.29.5 for parsing guidance. The default value is "and". These values are maintained in the "IndicatorExpression-operator" IANA registry per Section 10.2.

  1. not. negation operator.

  2. and. conjunction operator.

3. or. disjunction operator.

4. xor. exclusive disjunction operator.

ext-operator
Optional. STRING. A means by which to extend the operator attribute. See Section 5.1.1.

3.29.5. Expressions with IndicatorExpression

Boolean algebraic expressions can be used to specify relationships between observables and indicator. These expressions are constructed through the use of the operator attribute and parent-child relationships in IndicatorExpressions. These expressions should be parsed as follows:

1. The operator specified by the operator attribute is applied between each of the child elements of the immediate parent IndicatorExpression element. If no operator attribute is specified, it should be assumed to be the conjunction operator (i.e., operator="and").

2. A nested IndicatorExpression element with a parent IndicatorExpression is the equivalent of a parentheses in the expression.

The following four examples in Figure 66 through Figure 70 illustrate these parsing rules:

```
1     : <IndicatorExpression>
2 [O1]:    <Observable>..</Observable>
3 [O2]:    <Observable>..</Observable>
4     : </IndicatorExpression>
```

Equivalent expression: (O1 AND O2)

Figure 66: Nested elements in an IndicatorExpression without an operator attribute specified

```
1     : <IndicatorExpression operator="or">
2 [O1]:    <Observable>..</Observable>
3 [O2]:    <Observable>..</Observable>
4     : </IndicatorExpression>
```

Equivalent expression: (O1 OR O2)

Figure 67: Nested elements in an IndicatorExpression with an operator attribute specified

```
1     : <IndicatorExpression operator="or">
2     :    <IndicatorExpression operator="or">
3 [O1]:      <Observable>..</Observable>
4 [O2]:      <Observable>..</Observable>
5     :    </IndicatorExpression>
6 [O3]:    <Observable>..</Observable>
7     : </IndicatorExpression>
```

Equivalent expression: ((O1 OR O2) OR O3)

Figure 68: Nested elements with a recursive IndicatorExpression with an operator attribute specified

```
1     : <IndicatorExpression operator="not">
2     :    <IndicatorExpression operator="and">
3 [O1]:      <Observable>..</Observable>
4 [O2]:      <Observable>..</Observable>
5     :    </IndicatorExpression>
6     : </IndicatorExpression>
```

Equivalent expression: (NOT (O1 AND O2))

Figure 69: A recursive IndicatorExpression with an operator attribute specified

```
 1                          :    <IndicatorExpression operator="or">
 2                          :      <IndicatorExpression>
 3 [O1 with low confidence] :        <Observable>..</Observable>
 4                          :        <Confidence rating="low" />
 5                          :      </IndicatorExpression>
 6                          :      <IndicatorExpression>
 7 [O2 with high confidence]:        <Observable>..</Observable>
 8                          :        <Confidence rating="high" />
 9                          :      </IndicatorExpression>
10                          :    </IndicatorExpression>
```

Equivalent expression: ((O1) OR (O2))

Figure 70: Varying confidence on particular Observables

Invalid algebraic expressions while valid XML, MUST NOT be specified.

3.29.6. ObservableReference Class

The ObservableReference describes a reference to an observable feature or phenomenon described elsewhere in the document.

The ObservableReference class has no content.

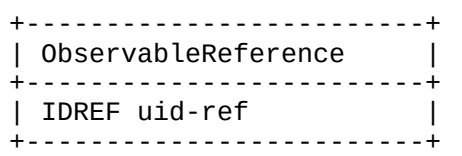

Figure 71: The ObservableReference Class

The ObservableReference class has no content.

The attribute of the ObservableReference class is:

uid-ref
: Required. IDREF. An identifier that serves as a reference to a class in the IODEF document. The referenced class will have this identifier set in its observable-id attribute.

3.29.7. IndicatorReference Class

The IndicatorReference describes a reference to an indicator. This reference may be to an indicator described in this IODEF document or in a previously exchanged IODEF document.

The IndicatorReference class has no content.

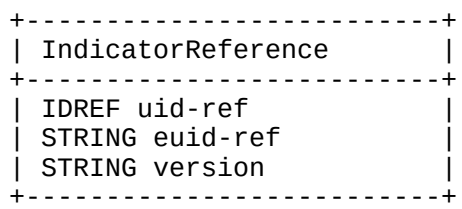

Figure 72: The IndicatorReference Class

The attributes of the IndicatorReference class are:

uid-ref
: Optional. IDREF. An identifier that references an Indicator class in the IODEF document. The referenced Indicator class will have this identifier set in its IndicatorID class.

euid-ref
: Optional. STRING. An identifier that references an IndicatorID not in this IODEF document.

version
Optional. STRING. A version number of an indicator.

Either the uid-ref or the euid-ref attribute MUST be set.

3.29.8. AttackPhase Class

The AttackPhase class describes a particular phase of an attack lifecycle.

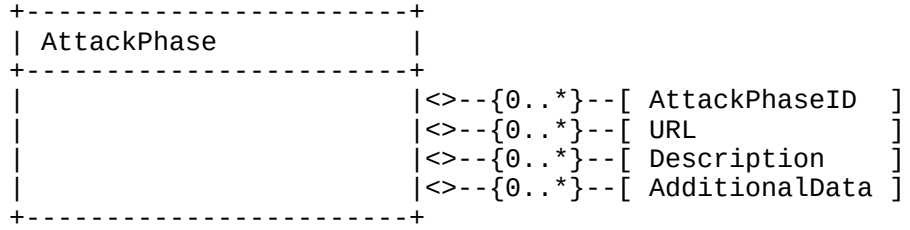

Figure 73: AttackPhase Class

The aggregate classes of the AttackPhase class are:

AttackPhaseID
Zero or more. STRING. An identifier for the phase of the attack.

URL
Zero or more. URL. A URL to a resource describing this phase of the attack.

Description
Zero or more. ML_STRING. A free-form text description of this phase of the attack.

AdditionalData
Zero or more. EXTENSION. A mechanism by which to extend the data model.

AttackPhase MUST have at least one instance of a child class.

The AttackPhase class has no attributes.

4. Processing Considerations

This section provides additional requirements and guidance on creating and processing IODEF documents.

4.1. Encoding

Every IODEF document MUST begin with an XML declaration and MUST specify the XML version used. The character encoding MUST also be explicitly specified. UTF-8 [RFC3629] SHOULD be used unless UTF-16 [RFC2781] is necessary. Encodings other than UTF-8 and UTF-16 SHOULD NOT be used. The IODEF conforms to all XML data encoding conventions and constraints.

The XML declaration with UTF-8 character encoding will read as follows:

```
<?xml version="1.0" encoding="UTF-8" ?>
```

Certain characters have special meaning in XML and MUST not appear in literal form. Per Section 2.4 of [W3C.XML], these characters MUST be escaped with a numeric character or entity reference.

4.2. IODEF Namespace

The IODEF schema declares a namespace of "urn:ietf:params:xml:ns:iodef-2.0" and registers it per [W3C.XMLNS]. Each IODEF document MUST include a valid reference to the IODEF schema using the "xsi:schemaLocation" attribute. An example of such a declaration would look as follows:

```
<IODEF-Document
   version="2.00" lang="en-US"
   xmlns:iodef="urn:ietf:params:xml:ns:iodef-2.0"
   xsi:schemaLocation="urn:ietf:params:xmls:schema:iodef-2.0" ...>
```

4.3. Validation

IODEF documents MUST be well-formed XML. It is RECOMMENDED that recipients validate the document against the schema described in Section 8. However, mere conformance to this schema is not sufficient for a semantically valid IODEF document. The text of Section 3 describes further formatting and constraints; some that cannot be conveniently encoded in the schema. These MUST also be considered by an IODEF implementation. Furthermore, the enumerated values present in this document are a static list that will be incomplete over time as select attributes can be extended by a corresponding IANA registry per Section 10.2. Therefore, IODEF implementations SHOULD periodically update their schema and MAY need to update their parsing algorithms to incorporate newly registered values.

4.4. Incompatibilities with v1

The IODEF data model in this document makes a number of changes to [RFC5070]. These changes were largely additive -- classes and enumerated values were added. However, some incompatibilities between [RFC5070] and this new specification were introduced. These incompatibilities are as follows:

- The IODEF-Document@version attribute is set to "2.0".
- Attributes with enumerated values can now also be extended with IANA registries.
- All iodef:MLStringType classes use xml:lang. IODEF-Document also uses xml:lang.
- The Service@ip_protocol attribute was renamed to @ip-protocol.
- The Node/NodeName class was removed in favor of representing domain names with Node/DomainData/Name class. The Node/DataTime class was also removed so that the Node/DomainData/ DateDomainWasChecked class can represent the time at which the name to address resolution occurred.
- The Node/NodeRole class was moved to System/NodeRole.
- The Reference class is now defined by [RFC7495].
- The data previously represented in the Impact class is now in the SystemImpact and IncidentCategory classes. The Impact class has been removed.
- The semantics of Counter@type are now represented in Counter@unit.
- The IODEF-Document@formatid attribute has been renamed to @format-id.
- Incident/ReportTime is no longer mandatory. However, GenerationTime is.
- The Fax class was removed and is now represented by a generic Telephone class.
- The Telephone, Email and PostalAddress classes were redefined from improved internationalization.
- The "ipv6-net-mask" value was remove from category attribute of Address.

5. Extending the IODEF

In order to support the dynamic nature of security operations, the IODEF data model will need to continue to evolve. This section discusses how new data elements can be incorporated into the IODEF. There is support to add additional enumerated values and new classes. Adding additional attributes to existing classes is not supported.

These extension mechanisms are designed so that adding new data elements is possible without requiring a modifications to this document. Extensions can be implemented publicly or privately. With proven value, well documented extensions can be incorporated into future versions of the specification.

5.1. Extending the Enumerated Values of Attributes

Additional enumerated values can be added to select attributes either through the use of specially marked attributes with the "ext-" prefix or through a set of corresponding IANA registries. The former approach allows for the extension to remain private. The latter approach is public.

5.1.1. Private Extension of Enumerated Values

The data model supports adding new enumerated values to an attribute without public registration. For each attribute that supports this extension technique, there is a corresponding attribute in the same element whose name is identical but with a prefix of "ext-". This special attribute is referred to as the extension attribute. The attribute being extended is referred to as an extensible attribute. For example, an extensible attribute named "foo" will have a corresponding extension attribute named "ext-foo". An element may have many extensible attributes.

In addition to a corresponding extension attribute, each extensible attribute has "ext-value" as one its possible enumerated values. Selection of this particular value in an extensible attribute signals that the extension attribute contains data. Otherwise, this "ext-value" value has no meaning.

In order to add a new enumerated value to an extensible attribute, the value of this attribute MUST be set to "ext-value", and the new desired value MUST be set in the corresponding extension attribute. For example, extending the type attribute of the SystemImpact class would look as follows:

```
 <SystemImpact type="ext-value" ext-type="new-attack-type">
```

A given extension attribute MUST NOT be set unless the corresponding extensible attribute has been set to "ext-value".

5.1.2. Public Extension of Enumerated Values

The data model also supports publicly extending select enumerated attributes. A new entry can be added by registering a new entry in the appropriate IANA registry. Section 10.2 provides a mapping between the extensible attributes and their corresponding registry. Section 4.3 discusses the XML Validation implications of this type of extension. All extensible attributes that support private extensions also support public extensions.

5.2. Extending Classes

Classes of the EXTENSION (iodef:ExtensionType) type can extend the data model. They provide the ability to have new atomic or XML-encoded data elements in all of the top-level classes of the Incident class and a few of the complex subordinate classes. As there are multiple instances of the extensible classes in the data model, there is discretion on where to add a new data element. It is RECOMMENDED that the extension be placed in the most closely related class to the new information.

Extensions using the atomic data types (i.e., all values of the dtype attributes other than "xml") MUST:

1. Set the element content to the desired value, and

2. Set the dtype attribute to correspond to the data type of the element content.

The following guidelines exist for extensions using XML (i.e., dtype="xml"):

1. The element content of the extensible class MUST be set to the desired value and the dtype attribute MUST be set to "xml".

2. The extension schema MUST declare a separate namespace. It is RECOMMENDED that these extensions have the prefix "iodef-". This recommendation makes readability of the document easier by allowing the reader to infer which namespaces relate to IODEF by inspection.

3. It is RECOMMENDED that extension schemas follow the naming convention of the IODEF data model. This too improves the readability of extended IODEF documents. The names of all elements SHOULD be capitalized. For elements with composed

names, a capital letter SHOULD be used for each word. Attribute names SHOULD be in lower case. Attributes with composed names SHOULD be separated by a hyphen.

4. Implementations that encounter an unrecognized element, attribute or attribute value in a supported namespace SHOULD reject the document as a syntax error.

5. There are security and performance implications in requiring implementations to dynamically download schemas at run time. Therefore, implementations MUST NOT download schemas at runtime unless the appropriate precautions are taken. Implementations also need to contend with the potential of significant network and processing issues.

6. Some adopters of the IODEF may have private schema definitions that are not publicly available. Thus implementations may encounter IODEF documents with references to private schemas that may not be resolvable. Hence, IODEF document recipients MUST be prepared for a schema definition in an IODEF document never to resolve.

The following schema and XML document excerpt provide a template for an extension schema and its use in the IODEF document.

This example schema defines a namespace of "iodef-extension1" and a single element named "newdata".

```
<xs:schema
   targetNamespace="iodef-extension1.xsd"
   xmlns:iodef-extension1="iodef-extension1.xsd"
   xmlns:xs="http://www.w3.org/2001/XMLSchema">
   attributeFormDefault="unqualified"
   elementFormDefault="qualified">
 <xs:import
      namespace="urn:ietf:params:xml:ns:iodef-2.0"
      schemaLocation=" urn:ietf:params:xml:schema:iodef-2.0"/>

   <xs:element name="newdata" type="xs:string" />
</xs:schema>
```

The following XML excerpt demonstrates the use of the above schema as an extension to the IODEF.

```
      <IODEF-Document
           version="2.00" lang="en-US"
           xmlns="urn:ietf:params:xml:ns:iodef-2.0"
           xmlns:iodef=" urn:ietf:params:xml:ns:iodef-2.0"
           xmlns:iodef-extension1="iodef-extension1.xsd"
           xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
           xsi:schemaLocation="iodef-extension1.xsd">
          <Incident purpose="reporting">
          ...
            <AdditionalData dtype="xml" meaning="xml">
              <iodef-extension1:newdata>
               Field that could not be represented elsewhere
              </iodef-extension1:newdata>
            </AdditionalData>
          </Incident>
    </IODEF-Document
```

5.3. Deconflicting Private Extensions

To disambiguate which private extension is used in an IODEF document, the data model provides a means to identify the source of an extension. Two attributes in the IODEF-Document class, private-enum-name and private-enum-id, are used to specify this attribution. Only a single private extension can be identified in a given IODEF-Document.

If an implementor has a single private extension, then only the private-enum-name attribute needs to be specified. Multiple distinct private extensions or versioning of a single extension can be attributed by also setting the corresponding private-num-id attribute.

The following XML excerpt demonstrates the specification of a private extension from "example.com" with an identifier of "13".

```
      <IODEF-Document
           version="2.00" lang="en-US"
           private-enum-name="example.com"
           private-enum-id="13"
          ...
    </IODEF-Document>
```

If an unrecognized private extension is encountered in processing, the recipient MAY reject the entire document as a syntax error.

6. Internationalization Issues

Internationalization and localization is of specific concern to the IODEF as it facilitates operational coordination with a diverse set of partners. The IODEF implements internationalization by relying on XML constructs and through explicit design choices in the data model.

Since the IODEF is implemented as an XML Schema, it supports different character encodings, such as UTF-8 and UTF-16, possible with XML. Additionally, each IODEF document MUST specify the language in which its content is encoded. The language can be specified with the attribute "xml:lang" (per Section 2.12 of [W3C.XML]) in the top-level element (i.e., IODEF-Document) and letting all other elements inherit that definition. All IODEF classes with a free-form text definition (i.e., all those defined with type iodef:MLStringType) can also specify a language different from the rest of the document.

The data model supports multiple translations of free-form text. All ML_STRING (iodef:MLStringType) classes have a one-to-many cardinality to their parent. This allows the identical text translated into different languages to be encoded in different instances of the same class with a common parent. This design also enables the creation of a single document containing all the translations. The IODEF implementation SHOULD extract the appropriate language relevant to the recipient.

Related instances of a given iodef:MLStringType class that are translations of each other are identified by a common identifier set in the translation-id attribute. The example below shows three instances of a Description class expressed in three different languages. The relationship between these three instances of the Description class is conveyed by the common value of "1" in the translation-id attribute.

```
<IODEF-Document version="2.00" xml:lang="en" ...
  <Incident purpose="reporting">
    ...
    <Description translation-id="1"
                 xml:lang="en">English</Description>
    <Description translation-id="1"
                 xml:lang="de">Englisch</Description>
    <Description translation-id="1"
                 xml:lang="fr">Anglais</Description>
```

The IODEF balances internationalization support with the need for interoperability. While the IODEF supports different languages, the

data model also relies heavily on standardized enumerated attributes that can crudely approximate the contents of the document. With this approach, a CSIRT should be able to make some sense of an IODEF document it receives even if the free-form text data elements are written in a language unfamiliar to the recipient.

7. Examples

This section provides example of IODEF documents. These examples do not represent the full capabilities of the data model or the the only way to encode particular information.

7.1. Minimal Example

A document containing only the mandatory elements and attributes.

```
<?xml version="1.0" encoding="UTF-8"?>
<!-- Minimum IODEF document -->
<IODEF-Document version="2.00" xml:lang="en"
   xmlns="urn:ietf:params:xml:ns:iodef-2.0"
   xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
   xsi:schemaLocation=
"http://www.iana.org/assignments/xmlregistry/schema/
iodef-2.0.xsd">
  <Incident purpose="reporting" restriction="private">
    <IncidentID name="csirt.example.com">492382</IncidentID>
    <GenerationTime>2015-07-18T09:00:00-05:00</GenerationTime>
    <Contact type="organization" role="creator">
      <Email>
        <EmailTo>contact@csirt.example.com</EmailTo>
      </Email>
    </Contact>
    <!-- Add more fields to make the document useful -->
  </Incident>
</IODEF-Document>
```

7.2. Indicators from a Campaign

An example of C2 domains from a given campaign.

```
<?xml version="1.0" encoding="UTF-8"?>
<!-- A list of C2 domains associated with a campaign -->
<IODEF-Document version="2.00" xml:lang="en"
   xmlns="urn:ietf:params:xml:ns:iodef-2.0"
   xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
   xsi:schemaLocation=
```

```
      "http://www.iana.org/assignments/xml-registry/schema/
       iodef-2.0.xsd">
     <Incident purpose="watch" restriction="green">
       <IncidentID name="csirt.example.com">897923</IncidentID>
         <RelatedActivity>
           <ThreatActor>
             <ThreatActorID>
             TA-12-AGGRESSIVE-BUTTERFLY
             </ThreatActorID>
             <Description>Aggressive Butterfly</Description>
           </ThreatActor>
           <Campaign>
             <CampaignID>C-2015-59405</CampaignID>
             <Description>Orange Giraffe</Description>
           </Campaign>
         </RelatedActivity>
         <GenerationTime>2015-10-02T11:18:00-05:00</GenerationTime>
         <Description>Summarizes the Indicators of Compromise
           for the Orange Giraffe campaign of the Aggressive
           Butterfly crime gang.
         </Description>
         <Assessment>
           <BusinessImpact type="breach-proprietary"/>
         </Assessment>
         <Contact type="organization" role="creator">
           <ContactName>CSIRT for example.com</ContactName>
           <Email>
             <EmailTo>contact@csirt.example.com</EmailTo>
           </Email>
         </Contact>
         <IndicatorData>
           <Indicator>
             <IndicatorID name="csirt.example.com" version="1">
             G90823490
             </IndicatorID>
             <Description>C2 domains</Description>
             <StartTime>2014-12-02T11:18:00-05:00</StartTime>
             <Observable>
               <BulkObservable type="fqdn">
               <BulkObservableList>
                 kj290023j09r34.example.com
                 09ijk23jfj0k8.example.net
                 klknjwfjiowjefr923.example.org
                 oimireik79msd.example.org
               </BulkObservableList>
             </BulkObservable>
           </Observable>
         </Indicator>
```

```
      </IndicatorData>
    </Incident>
  </IODEF-Document>
```

8. The IODEF Data Model (XML Schema)

```
<?xml version="1.0"?>
<xs:schema xmlns="urn:ietf:params:xml:ns:iodef-2.0"
           xmlns:iodef="urn:ietf:params:xml:ns:iodef-2.0"
           xmlns:enum="urn:ietf:params:xml:ns:iodef-enum-1.0"
           xmlns:sci="urn:ietf:params:xml:ns:iodef-sci-1.0"
           xmlns:xs="http://www.w3.org/2001/XMLSchema"
           xmlns:ds="http://www.w3.org/2000/09/xmldsig#"
           targetNamespace="urn:ietf:params:xml:ns:iodef-2.0"
           elementFormDefault="qualified"
           attributeFormDefault="unqualified">
  <xs:import namespace="http://www.w3.org/2000/09/xmldsig#"
             schemaLocation="http://www.w3.org/TR/2002/
REC-xmldsig-core-20020212/xmldsig-core-schema.xsd"/>
  <xs:import namespace="urn:ietf:params:xml:ns:iodef-enum-1.0"
             schemaLocation="http://www.iana.org/assignments/
xml-registry/schema/iodef-enum-1.0.xsd"/>
  <xs:import namespace="urn:ietf:params:xml:ns:iodef-sci-1.0"
             schemaLocation="http://www.iana.org/assignments/
xml-registry/schema/iodef-sci-1.0.xsd"/>
  <xs:import namespace="http://www.w3.org/XML/1998/namespace"
             schemaLocation="http://www.w3c.org/2001/xml.xsd"/>
  <xs:annotation>
    <xs:documentation>
       Incident Object Description Exchange Format v2.0
    </xs:documentation>
  </xs:annotation>
  <!--
   ================================================================
   == IODEF-Document class                                       ==
   ================================================================
  -->
  <xs:element name="IODEF-Document">
    <xs:complexType>
      <xs:sequence>
        <xs:element ref="iodef:Incident" maxOccurs="unbounded"/>
        <xs:element ref="iodef:AdditionalData"
                    minOccurs="0" maxOccurs="unbounded"/>
      </xs:sequence>
      <xs:attribute name="version" type="xs:string" fixed="2.00"/>
      <xs:attribute ref="xml:lang"/>
      <xs:attribute name="format-id" type="xs:string" use="optional"/>
      <xs:attribute name="private-enum-name"
```

```
                    type="xs:string" use="optional"/>
        <xs:attribute name="private-enum-id"
                    type="xs:string" use="optional"/>
      </xs:complexType>
    </xs:element>
    <!--
     ================================================================
     == Incident class                                             ==
     ================================================================
    -->
    <xs:element name="Incident">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:IncidentID"/>
          <xs:element ref="iodef:AlternativeID" minOccurs="0"/>
          <xs:element ref="iodef:RelatedActivity"
                    minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:DetectTime" minOccurs="0"/>
          <xs:element ref="iodef:StartTime" minOccurs="0"/>
          <xs:element ref="iodef:EndTime" minOccurs="0"/>
          <xs:element ref="iodef:RecoveryTime" minOccurs="0"/>
          <xs:element ref="iodef:ReportTime" minOccurs="0"/>
          <xs:element ref="iodef:GenerationTime"/>
          <xs:element ref="iodef:Description"
                    minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Discovery"
                    minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Assessment"
                    minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Method"
                    minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Contact" maxOccurs="unbounded"/>
          <xs:element ref="iodef:EventData"
                    minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:IndicatorData" minOccurs="0"/>
          <xs:element ref="iodef:History" minOccurs="0"/>
          <xs:element ref="iodef:AdditionalData"
                    minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="purpose"
                    type="incident-purpose-type" use="required"/>
        <xs:attribute name="ext-purpose"
                    type="xs:string" use="optional"/>
        <xs:attribute name="status" type="incident-status-type"/>
        <xs:attribute name="ext-status"
                    type="xs:string" use="optional"/>
        <xs:attribute ref="xml:lang"/>
        <xs:attribute name="restriction"
```

```
                    type="iodef:restriction-type" default="private"
                    use="optional"/>
      <xs:attribute name="ext-restriction"
                    type="xs:string" use="optional"/>
      <xs:attribute name="observable-id" type="xs:ID" use="optional"/>
    </xs:complexType>
  </xs:element>
  <xs:simpleType name="incident-purpose-type">
    <xs:restriction base="xs:NMTOKEN">
      <xs:enumeration value="traceback"/>
      <xs:enumeration value="mitigation"/>
      <xs:enumeration value="reporting"/>
      <xs:enumeration value="watch"/>
      <xs:enumeration value="other"/>
      <xs:enumeration value="ext-value"/>
    </xs:restriction>
  </xs:simpleType>
  <xs:simpleType name="incident-status-type">
    <xs:restriction base="xs:NMTOKEN">
      <xs:enumeration value="new"/>
      <xs:enumeration value="in-progress"/>
      <xs:enumeration value="forwarded"/>
      <xs:enumeration value="resolved"/>
      <xs:enumeration value="future"/>
      <xs:enumeration value="ext-value"/>
    </xs:restriction>
  </xs:simpleType>
  <!--
   ========================================================================
   ==  IncidentID class                                                  ==
   ========================================================================
  -->
  <xs:element name="IncidentID" type="iodef:IncidentIDType"/>
  <xs:complexType name="IncidentIDType">
    <xs:simpleContent>
      <xs:extension base="xs:string">
        <xs:attribute name="name" type="xs:string" use="required"/>
        <xs:attribute name="instance"
                      type="xs:string" use="optional"/>
        <xs:attribute name="restriction"
                      type="iodef:restriction-type" use="optional"/>
        <xs:attribute name="ext-restriction"
                      type="xs:string" use="optional"/>
      </xs:extension>
    </xs:simpleContent>
  </xs:complexType>
  <!--
   ========================================================================
```

```
     ==  AlternativeID class                                          ==
     ======================================================================
    -->
    <xs:element name="AlternativeID">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:IncidentID" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="restriction"
                      type="iodef:restriction-type" use="optional"/>
        <xs:attribute name="ext-restriction"
                      type="xs:string" use="optional"/>
      </xs:complexType>
    </xs:element>
    <!--
     ======================================================================
     ==  RelatedActivity class                                           ==
     ======================================================================
    -->
    <xs:element name="RelatedActivity">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:IncidentID"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:URL"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:ThreatActor"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Campaign"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:IndicatorID"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Confidence" minOccurs="0"/>
          <xs:element ref="iodef:Description"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:AdditionalData"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="restriction"
                      type="iodef:restriction-type" use="optional"/>
        <xs:attribute name="ext-restriction"
                      type="xs:string" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="ThreatActor">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:ThreatActorID"
```

```
                    minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:URL" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Description"
                    minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:AdditionalData"
                    minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="restriction"
                    type="iodef:restriction-type" use="optional"/>
        <xs:attribute name="ext-restriction"
                    type="xs:string" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="ThreatActorID" type="xs:string"/>
    <xs:element name="Campaign">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:CampaignID"
                    minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:URL"
                    minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Description"
                    minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:AdditionalData"
                    minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="restriction"
                    type="iodef:restriction-type" use="optional"/>
        <xs:attribute name="ext-restriction"
                    type="xs:string" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="CampaignID" type="xs:string"/>
    <!--
     ========================================================================
     ==   Contact class                                                    ==
     ========================================================================
    -->
    <xs:element name="Contact">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:ContactName"
                    minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:ContactTitle"
                    minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Description"
                    minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:RegistryHandle"
```

```
                    minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:PostalAddress"
                    minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Email"
                    minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Telephone"
                    minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Timezone" minOccurs="0"/>
          <xs:element ref="iodef:Contact"
                    minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:AdditionalData"
                    minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="role"
                    type="contact-role-type" use="required"/>
        <xs:attribute name="ext-role"
                    type="xs:string" use="optional"/>
        <xs:attribute name="type"
                    type="contact-type-type" use="required"/>
        <xs:attribute name="ext-type"
                    type="xs:string" use="optional"/>
        <xs:attribute name="restriction"
                    type="iodef:restriction-type" use="optional"/>
        <xs:attribute name="ext-restriction"
                    type="xs:string" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:simpleType name="contact-role-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="creator"/>
        <xs:enumeration value="reporter"/>
        <xs:enumeration value="admin"/>
        <xs:enumeration value="tech"/>
        <xs:enumeration value="provider"/>
        <xs:enumeration value="user"/>
        <xs:enumeration value="billing"/>
        <xs:enumeration value="legal"/>
        <xs:enumeration value="abuse"/>
        <xs:enumeration value="irt"/>
        <xs:enumeration value="cc"/>
        <xs:enumeration value="cc-irt"/>
        <xs:enumeration value="leo"/>
        <xs:enumeration value="vendor"/>
        <xs:enumeration value="vendor-services"/>
        <xs:enumeration value="victim"/>
        <xs:enumeration value="victim-notified"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
```

```
    </xs:simpleType>
    <xs:simpleType name="contact-type-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="person"/>
        <xs:enumeration value="organization"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:element name="ContactName" type="iodef:MLStringType"/>
    <xs:element name="ContactTitle" type="iodef:MLStringType"/>
    <xs:element name="RegistryHandle">
      <xs:complexType>
        <xs:simpleContent>
          <xs:extension base="xs:string">
            <xs:attribute name="registry"
                          type="registryhandle-registry-type"/>
            <xs:attribute name="ext-registry"
                          type="xs:string" use="optional"/>
          </xs:extension>
        </xs:simpleContent>
      </xs:complexType>
    </xs:element>
    <xs:simpleType name="registryhandle-registry-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="internic"/>
        <xs:enumeration value="apnic"/>
        <xs:enumeration value="arin"/>
        <xs:enumeration value="lacnic"/>
        <xs:enumeration value="ripe"/>
        <xs:enumeration value="afrinic"/>
        <xs:enumeration value="local"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:element name="PostalAddress">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:PAddress"/>
          <xs:element ref="iodef:Description"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="type"
                      type="postaladdress-type-type" use="optional"/>
        <xs:attribute name="ext-type" type="xs:string" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="PAddress" type="iodef:MLStringType"/>
    <xs:simpleType name="postaladdress-type-type">
```

```
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="street"/>
        <xs:enumeration value="mailing"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:element name="Telephone">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:TelephoneNumber"/>
          <xs:element ref="iodef:Description"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="type"
                      type="telephone-type-type" use="optional"/>
        <xs:attribute name="ext-type" type="xs:string" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="TelephoneNumber" type="xs:string"/>
    <xs:simpleType name="telephone-type-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="wired"/>
        <xs:enumeration value="mobile"/>
        <xs:enumeration value="fax"/>
        <xs:enumeration value="hotline"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:element name="Email">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:EmailTo"/>
          <xs:element ref="iodef:Description"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="type"
                      type="email-type-type" use="optional"/>
        <xs:attribute name="ext-type" type="xs:string" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:simpleType name="email-type-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="direct"/>
        <xs:enumeration value="hotline"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <!--
```

```
     ============================================================
     ==  Time-based classes                                    ==
     ============================================================
    -->
    <xs:element name="DateTime" type="xs:dateTime"/>
    <xs:element name="ReportTime" type="xs:dateTime"/>
    <xs:element name="DetectTime" type="xs:dateTime"/>
    <xs:element name="StartTime" type="xs:dateTime"/>
    <xs:element name="EndTime" type="xs:dateTime"/>
    <xs:element name="RecoveryTime" type="xs:dateTime"/>
    <xs:element name="GenerationTime" type="xs:dateTime"/>
    <xs:element name="Timezone" type="iodef:TimezoneType"/>
    <!--
     ============================================================
     ==  History class                                         ==
     ============================================================
    -->
    <xs:element name="History">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:HistoryItem" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="restriction"
                      type="iodef:restriction-type" use="optional"/>
        <xs:attribute name="ext-restriction"
                      type="xs:string" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="HistoryItem">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:DateTime"/>
          <xs:element ref="iodef:IncidentID" minOccurs="0"/>
          <xs:element ref="iodef:Contact" minOccurs="0"/>
          <xs:element ref="iodef:Description"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:DefinedCOA"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:AdditionalData"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="action"
                      type="iodef:action-type" use="required"/>
        <xs:attribute name="ext-action"
                      type="xs:string" use="optional"/>
        <xs:attribute name="restriction"
                      type="iodef:restriction-type" use="optional"/>
        <xs:attribute name="ext-restriction"
```

```
                    type="xs:string" use="optional"/>
        <xs:attribute name="observable-id" type="xs:ID" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="DefinedCOA" type="xs:string"/>
    <!--
     ========================================================================
     ==  Expectation class                                                 ==
     ========================================================================
    -->
    <xs:element name="Expectation">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:Description"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:DefinedCOA"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:StartTime" minOccurs="0"/>
          <xs:element ref="iodef:EndTime" minOccurs="0"/>
          <xs:element ref="iodef:Contact" minOccurs="0"/>
        </xs:sequence>
        <xs:attribute name="action"
                      type="iodef:action-type" default="other"/>
        <xs:attribute name="ext-action"
                      type="xs:string" use="optional"/>
        <xs:attribute name="severity" type="iodef:severity-type"/>
        <xs:attribute name="restriction"
                      type="iodef:restriction-type" use="optional"/>
        <xs:attribute name="ext-restriction"
                      type="xs:string" use="optional"/>
        <xs:attribute name="observable-id" type="xs:ID" use="optional"/>
      </xs:complexType>
    </xs:element>
    <!--
     ========================================================================
     ==  Discovery class                                                   ==
     ========================================================================
    -->
    <xs:element name="Discovery">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:Description"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Contact"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:DetectionPattern"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
```

```
        <xs:attribute name="source"
                      type="discovery-source-type" use="optional"
                      default="unknown"/>
        <xs:attribute name="ext-source"
                      type="xs:string" use="optional"/>
        <xs:attribute name="restriction"
                      type="iodef:restriction-type" use="optional"/>
        <xs:attribute name="ext-restriction"
                      type="xs:string" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:simpleType name="discovery-source-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="nidps"/>
        <xs:enumeration value="hips"/>
        <xs:enumeration value="siem"/>
        <xs:enumeration value="av"/>
        <xs:enumeration value="third-party-monitoring"/>
        <xs:enumeration value="incident"/>
        <xs:enumeration value="os-log"/>
        <xs:enumeration value="application-log"/>
        <xs:enumeration value="device-log"/>
        <xs:enumeration value="network-flow"/>
        <xs:enumeration value="passive-dns"/>
        <xs:enumeration value="investigation"/>
        <xs:enumeration value="audit"/>
        <xs:enumeration value="internal-notification"/>
        <xs:enumeration value="external-notification"/>
        <xs:enumeration value="leo"/>
        <xs:enumeration value="partner"/>
        <xs:enumeration value="actor"/>
        <xs:enumeration value="unknown"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:element name="DetectionPattern">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:Application"/>
          <xs:element ref="iodef:Description"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element name="DetectionConfiguration"
                      type="xs:string"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="restriction"
                      type="iodef:restriction-type" use="optional"/>
        <xs:attribute name="ext-restriction"
```

```
                    type="xs:string" use="optional"/>
        <xs:attribute name="observable-id" type="xs:ID" use="optional"/>
      </xs:complexType>
    </xs:element>
    <!--
     ================================================================
     ==  Method class                                               ==
     ================================================================
    -->
    <xs:element name="Method">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:Reference"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Description"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="sci:AttackPattern"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="sci:Vulnerability"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="sci:Weakness"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:AdditionalData"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="restriction"
                      type="iodef:restriction-type" use="optional"/>
        <xs:attribute name="ext-restriction"
                      type="xs:string" use="optional"/>
      </xs:complexType>
    </xs:element>
    <!--
     ================================================================
     ==  Reference class                                            ==
     ================================================================
    -->
    <xs:element name="Reference">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="enum:ReferenceName" minOccurs="0"/>
          <xs:element ref="iodef:URL"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Description"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="observable-id" type="xs:ID" use="optional"/>
      </xs:complexType>
    </xs:element>
```

```
    <!--
     ========================================================================
     ==  Assessment class                                                  ==
     ========================================================================
    -->
    <xs:element name="Assessment">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:IncidentCategory"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:choice maxOccurs="unbounded">
            <xs:element ref="iodef:SystemImpact"/>
            <xs:element ref="iodef:BusinessImpact"/>
            <xs:element ref="iodef:TimeImpact"/>
            <xs:element ref="iodef:MonetaryImpact"/>
            <xs:element ref="iodef:IntendedImpact"/>
          </xs:choice>
          <xs:element ref="iodef:Counter"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:MitigatingFactor"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Cause"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Confidence" minOccurs="0"/>
          <xs:element ref="iodef:AdditionalData"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="occurrence">
          <xs:simpleType>
            <xs:restriction base="xs:NMTOKEN">
              <xs:enumeration value="actual"/>
              <xs:enumeration value="potential"/>
            </xs:restriction>
          </xs:simpleType>
        </xs:attribute>
        <xs:attribute name="restriction"
                      type="iodef:restriction-type" use="optional"/>
        <xs:attribute name="ext-restriction"
                      type="xs:string" use="optional"/>
        <xs:attribute name="observable-id" type="xs:ID" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="IncidentCategory" type="iodef:MLStringType"/>
    <xs:element name="BusinessImpact" type="iodef:BusinessImpactType"/>
    <xs:element name="IntendedImpact" type="iodef:BusinessImpactType"/>
    <xs:element name="MitigatingFactor" type="iodef:MLStringType"/>
    <xs:element name="Cause" type="iodef:MLStringType"/>
    <xs:element name="SystemImpact">
```

```
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:Description"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="severity"
                      type="iodef:severity-type" use="optional"/>
        <xs:attribute name="completion"
                      type="iodef:systemimpact-completion-type"
                      use="optional"/>
        <xs:attribute name="type"
                      type="systemimpact-type-type"
                      use="optional" default="unknown"/>
        <xs:attribute name="ext-type" type="xs:string" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:simpleType name="systemimpact-completion-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="failed"/>
        <xs:enumeration value="succeeded"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:simpleType name="systemimpact-type-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="takeover-account"/>
        <xs:enumeration value="takeover-service"/>
        <xs:enumeration value="takeover-system"/>
        <xs:enumeration value="cps-manipulation"/>
        <xs:enumeration value="cps-damage"/>
        <xs:enumeration value="availability-data"/>
        <xs:enumeration value="availability-account"/>
        <xs:enumeration value="availability-service"/>
        <xs:enumeration value="availability-system"/>
        <xs:enumeration value="damaged-system"/>
        <xs:enumeration value="damaged-data"/>
        <xs:enumeration value="breach-proprietary"/>
        <xs:enumeration value="breach-privacy"/>
        <xs:enumeration value="breach-credential"/>
        <xs:enumeration value="breach-configuration"/>
        <xs:enumeration value="integrity-data"/>
        <xs:enumeration value="integrity-configuration"/>
        <xs:enumeration value="integrity-hardware"/>
        <xs:enumeration value="traffic-redirection"/>
        <xs:enumeration value="monitoring-traffic"/>
        <xs:enumeration value="monitoring-host"/>
        <xs:enumeration value="policy"/>
        <xs:enumeration value="unknown"/>
        <xs:enumeration value="ext-value"/>
```

```
      </xs:restriction>
    </xs:simpleType>
    <xs:complexType name="BusinessImpactType">
      <xs:sequence>
        <xs:element ref="iodef:Description"
                    minOccurs="0" maxOccurs="unbounded"/>
      </xs:sequence>
      <xs:attribute name="severity"
                    type="businessimpact-severity-type" use="optional"/>
      <xs:attribute name="ext-severity"
                    type="xs:string" use="optional"/>
      <xs:attribute name="type"
                    type="businessimpact-type-type"
                    use="optional" default="unknown"/>
      <xs:attribute name="ext-type" type="xs:string" use="optional"/>
    </xs:complexType>
    <xs:simpleType name="businessimpact-severity-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="none"/>
        <xs:enumeration value="low"/>
        <xs:enumeration value="medium"/>
        <xs:enumeration value="high"/>
        <xs:enumeration value="unknown"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:simpleType name="businessimpact-type-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="breach-proprietary"/>
        <xs:enumeration value="breach-privacy"/>
        <xs:enumeration value="breach-credential"/>
        <xs:enumeration value="loss-of-integrity"/>
        <xs:enumeration value="loss-of-service"/>
        <xs:enumeration value="theft-financial"/>
        <xs:enumeration value="theft-service"/>
        <xs:enumeration value="degraded-reputation"/>
        <xs:enumeration value="asset-damage"/>
        <xs:enumeration value="asset-manipulation"/>
        <xs:enumeration value="legal"/>
        <xs:enumeration value="extortion"/>
        <xs:enumeration value="unknown"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:element name="TimeImpact">
      <xs:complexType>
        <xs:simpleContent>
          <xs:extension base="iodef:PositiveFloatType">
```

```
            <xs:attribute name="severity" type="iodef:severity-type"/>
            <xs:attribute name="metric"
                          type="timeimpact-metric-type" use="required"/>
            <xs:attribute name="ext-metric"
                          type="xs:string" use="optional"/>
            <xs:attribute name="duration" type="iodef:duration-type"/>
            <xs:attribute name="ext-duration"
                          type="xs:string" use="optional"/>
          </xs:extension>
        </xs:simpleContent>
      </xs:complexType>
    </xs:element>
    <xs:simpleType name="timeimpact-metric-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="labor"/>
        <xs:enumeration value="elapsed"/>
        <xs:enumeration value="downtime"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:element name="MonetaryImpact">
      <xs:complexType>
        <xs:simpleContent>
          <xs:extension base="iodef:PositiveFloatType">
            <xs:attribute name="severity" type="iodef:severity-type"/>
            <xs:attribute name="currency" type="xs:string"/>
          </xs:extension>
        </xs:simpleContent>
      </xs:complexType>
    </xs:element>
    <xs:element name="Confidence">
      <xs:complexType>
        <xs:attribute name="rating"
                      type="confidence-rating-type" use="required"/>
        <xs:attribute name="ext-rating"
                      type="xs:string" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:simpleType name="confidence-rating-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="low"/>
        <xs:enumeration value="medium"/>
        <xs:enumeration value="high"/>
        <xs:enumeration value="numeric"/>
        <xs:enumeration value="unknown"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
```

```
    <!--
     ====================================================================
     == EventData class                                                ==
     ====================================================================
    -->
    <xs:element name="EventData">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:Description"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:DetectTime" minOccurs="0"/>
          <xs:element ref="iodef:StartTime" minOccurs="0"/>
          <xs:element ref="iodef:EndTime" minOccurs="0"/>
          <xs:element ref="iodef:RecoveryTime" minOccurs="0"/>
          <xs:element ref="iodef:ReportTime" minOccurs="0"/>
          <xs:element ref="iodef:Contact"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Discovery"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Assessment" minOccurs="0"/>
          <xs:element ref="iodef:Method"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Flow"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Expectation"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Record" minOccurs="0"/>
          <xs:element ref="iodef:EventData"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:AdditionalData"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="restriction"
                      type="iodef:restriction-type" use="optional"/>
        <xs:attribute name="ext-restriction"
                      type="xs:string" use="optional"/>
        <xs:attribute name="observable-id" type="xs:ID" use="optional"/>
      </xs:complexType>
    </xs:element>
    <!--
     ====================================================================
     ==  Flow class                                                    ==
     ====================================================================
    -->
    <xs:element name="Flow">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:System" maxOccurs="unbounded"/>
```

```
      </xs:sequence>
    </xs:complexType>
  </xs:element>
  <!--
   ================================================================
   ==  System class                                               ==
   ================================================================
  -->
  <xs:element name="System">
    <xs:complexType>
      <xs:sequence>
        <xs:element ref="iodef:Node"/>
        <xs:element ref="iodef:NodeRole"
                    minOccurs="0" maxOccurs="unbounded"/>
        <xs:element ref="iodef:Service"
                    minOccurs="0" maxOccurs="unbounded"/>
        <xs:element ref="iodef:OperatingSystem"
                    minOccurs="0" maxOccurs="unbounded"/>
        <xs:element ref="iodef:Counter"
                    minOccurs="0" maxOccurs="unbounded"/>
        <xs:element name="AssetID"
                    type="xs:string"
                    minOccurs="0" maxOccurs="unbounded"/>
        <xs:element ref="iodef:Description"
                    minOccurs="0" maxOccurs="unbounded"/>
        <xs:element ref="iodef:AdditionalData"
                    minOccurs="0" maxOccurs="unbounded"/>
      </xs:sequence>
      <xs:attribute name="category" type="system-category-type"/>
      <xs:attribute name="ext-category"
                    type="xs:string" use="optional"/>
      <xs:attribute name="interface" type="xs:string"/>
      <xs:attribute name="spoofed"
                    type="yes-no-unknown-type" default="unknown"/>
      <xs:attribute name="virtual"
                    type="yes-no-unknown-type" use="optional"
                    default="unknown"/>
      <xs:attribute name="ownership" type="system-ownership-type"
                    use="optional"/>
      <xs:attribute name="ext-ownership"
                    type="xs:string" use="optional"/>
      <xs:attribute name="restriction"
                    type="iodef:restriction-type" use="optional"/>
      <xs:attribute name="ext-restriction"
                    type="xs:string" use="optional"/>
      <xs:attribute name="observable-id" type="xs:ID" use="optional"/>
    </xs:complexType>
  </xs:element>
```

```
    <xs:element name="OperatingSystem" type="iodef:SoftwareType"/>
    <xs:simpleType name="system-category-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="source"/>
        <xs:enumeration value="target"/>
        <xs:enumeration value="intermediate"/>
        <xs:enumeration value="sensor"/>
        <xs:enumeration value="infrastructure"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:simpleType name="system-ownership-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="organization"/>
        <xs:enumeration value="personal"/>
        <xs:enumeration value="partner"/>
        <xs:enumeration value="customer"/>
        <xs:enumeration value="no-relationship"/>
        <xs:enumeration value="unknown"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <!--
     ================================================================
     == Node class                                                 ==
     ================================================================
    -->
    <xs:element name="Node">
      <xs:complexType>
        <xs:sequence>
          <xs:choice maxOccurs="unbounded">
            <xs:element ref="iodef:DomainData"
                        minOccurs="0" maxOccurs="unbounded"/>
            <xs:element ref="iodef:Address"
                        minOccurs="0" maxOccurs="unbounded"/>
          </xs:choice>
          <xs:element ref="iodef:PostalAddress" minOccurs="0"/>
          <xs:element ref="iodef:Location"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Counter"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
      </xs:complexType>
    </xs:element>
    <xs:element name="Address">
      <xs:complexType>
        <xs:simpleContent>
          <xs:extension base="xs:string">
```

```
            <xs:attribute name="category"
                          type="address-category-type"
                          default="ipv6-addr"/>
            <xs:attribute name="ext-category"
                          type="xs:string" use="optional"/>
            <xs:attribute name="vlan-name" type="xs:string"/>
            <xs:attribute name="vlan-num" type="xs:integer"/>
            <xs:attribute name="observable-id"
                          type="xs:ID" use="optional"/>
          </xs:extension>
        </xs:simpleContent>
      </xs:complexType>
    </xs:element>
    <xs:simpleType name="address-category-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="asn"/>
        <xs:enumeration value="atm"/>
        <xs:enumeration value="e-mail"/>
        <xs:enumeration value="mac"/>
        <xs:enumeration value="ipv4-addr"/>
        <xs:enumeration value="ipv4-net"/>
        <xs:enumeration value="ipv4-net-masked"/>
        <xs:enumeration value="ipv4-net-mask"/>
        <xs:enumeration value="ipv6-addr"/>
        <xs:enumeration value="ipv6-net"/>
        <xs:enumeration value="ipv6-net-masked"/>
        <xs:enumeration value="site-uri"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:element name="Location" type="iodef:MLStringType"/>
    <xs:element name="NodeRole">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:Description"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="category"
                      type="noderole-category-type" use="required"/>
        <xs:attribute name="ext-category"
                      type="xs:string" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:simpleType name="noderole-category-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="client"/>
        <xs:enumeration value="client-enterprise"/>
        <xs:enumeration value="client-partner"/>
```

```
        <xs:enumeration value="client-remote"/>
        <xs:enumeration value="client-kiosk"/>
        <xs:enumeration value="client-mobile"/>
        <xs:enumeration value="server-internal"/>
        <xs:enumeration value="server-public"/>
        <xs:enumeration value="www"/>
        <xs:enumeration value="mail"/>
        <xs:enumeration value="webmail"/>
        <xs:enumeration value="messaging"/>
        <xs:enumeration value="streaming"/>
        <xs:enumeration value="voice"/>
        <xs:enumeration value="file"/>
        <xs:enumeration value="ftp"/>
        <xs:enumeration value="p2p"/>
        <xs:enumeration value="name"/>
        <xs:enumeration value="directory"/>
        <xs:enumeration value="credential"/>
        <xs:enumeration value="print"/>
        <xs:enumeration value="application"/>
        <xs:enumeration value="database"/>
        <xs:enumeration value="backup"/>
        <xs:enumeration value="dhcp"/>
        <xs:enumeration value="assessment"/>
        <xs:enumeration value="source-control"/>
        <xs:enumeration value="config-management"/>
        <xs:enumeration value="monitoring"/>
        <xs:enumeration value="infra"/>
        <xs:enumeration value="infra-firewall"/>
        <xs:enumeration value="infra-router"/>
        <xs:enumeration value="infra-switch"/>
        <xs:enumeration value="camera"/>
        <xs:enumeration value="proxy"/>
        <xs:enumeration value="remote-access"/>
        <xs:enumeration value="log"/>
        <xs:enumeration value="virtualization"/>
        <xs:enumeration value="pos"/>
        <xs:enumeration value="scada"/>
        <xs:enumeration value="scada-supervisory"/>
        <xs:enumeration value="sinkhole"/>
        <xs:enumeration value="honeypot"/>
        <xs:enumeration value="anonymization"/>
        <xs:enumeration value="c2-server"/>
        <xs:enumeration value="malware-distribution"/>
        <xs:enumeration value="drop-server"/>
        <xs:enumeration value="hop-point"/>
        <xs:enumeration value="reflector"/>
        <xs:enumeration value="phishing-site"/>
        <xs:enumeration value="spear-phishing-site"/>
```

```
        <xs:enumeration value="recruiting-site"/>
        <xs:enumeration value="fraudulent-site"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <!--
     ========================================================================
     ==  Service Class                                                     ==
     ========================================================================
    -->
    <xs:element name="Service">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:ServiceName" minOccurs="0"/>
          <xs:element ref="iodef:Port" minOccurs="0"/>
          <xs:element ref="iodef:Portlist" minOccurs="0"/>
          <xs:element ref="iodef:ProtoType" minOccurs="0"/>
          <xs:element ref="iodef:ProtoCode" minOccurs="0"/>
          <xs:element ref="iodef:ProtoField" minOccurs="0"/>
          <xs:element ref="iodef:ApplicationHeader" minOccurs="0"/>
          <xs:element ref="iodef:EmailData" minOccurs="0"/>
          <xs:element ref="iodef:Application" minOccurs="0"/>
        </xs:sequence>
        <xs:attribute name="ip-protocol"
                      type="xs:integer" use="optional"/>
        <xs:attribute name="observable-id" type="xs:ID" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="Port" type="xs:integer"/>
    <xs:element name="Portlist" type="iodef:PortlistType"/>
    <xs:element name="ProtoType" type="xs:integer"/>
    <xs:element name="ProtoCode" type="xs:integer"/>
    <xs:element name="ProtoField" type="xs:integer"/>
    <xs:element name="ApplicationHeader">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:ApplicationHeaderField"
                      maxOccurs="unbounded"/>
        </xs:sequence>
      </xs:complexType>
    </xs:element>
    <xs:element name="ApplicationHeaderField"
                type="iodef:ExtensionType"/>
    <xs:element name="ServiceName">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:IANAService"
                      minOccurs="0"/>
```

```
          <xs:element ref="iodef:URL"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Description"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
      </xs:complexType>
    </xs:element>
    <xs:element name="IANAService" type="xs:string"/>
    <xs:element name="Application" type="iodef:SoftwareType"/>
    <!--
     ========================================================================
     ==  Counter class                                                     ==
     ========================================================================
    -->
    <xs:element name="Counter">
      <xs:complexType>
        <xs:simpleContent>
          <xs:extension base="xs:float">
            <xs:attribute name="type"
                          type="counter-type-type" use="required"/>
            <xs:attribute name="ext-type"
                          type="xs:string" use="optional"/>
            <xs:attribute name="unit"
                          type="counter-unit-type" use="required"/>
            <xs:attribute name="ext-unit"
                          type="xs:string" use="optional"/>
            <xs:attribute name="meaning"
                          type="xs:string" use="optional"/>
            <xs:attribute name="duration" type="iodef:duration-type"/>
            <xs:attribute name="ext-duration"
                          type="xs:string" use="optional"/>
          </xs:extension>
        </xs:simpleContent>
      </xs:complexType>
    </xs:element>
    <xs:simpleType name="counter-type-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="counter"/>
        <xs:enumeration value="rate"/>
        <xs:enumeration value="average"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:simpleType name="counter-unit-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="byte"/>
        <xs:enumeration value="mbit"/>
        <xs:enumeration value="packet"/>
```

```
        <xs:enumeration value="flow"/>
        <xs:enumeration value="session"/>
        <xs:enumeration value="event"/>
        <xs:enumeration value="alert"/>
        <xs:enumeration value="message"/>
        <xs:enumeration value="host"/>
        <xs:enumeration value="site"/>
        <xs:enumeration value="organization"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <!--
     ================================================================
     ==  EmailData class                                           ==
     ================================================================
    -->
    <xs:element name="EmailData">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:EmailTo"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:EmailFrom" minOccurs="0"/>
          <xs:element ref="iodef:EmailSubject" minOccurs="0"/>
          <xs:element ref="iodef:EmailX-Mailer" minOccurs="0"/>
          <xs:element ref="iodef:EmailHeaderField"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:EmailHeaders" minOccurs="0"/>
          <xs:element ref="iodef:EmailBody" minOccurs="0"/>
          <xs:element ref="iodef:EmailMessage" minOccurs="0"/>
          <xs:element ref="iodef:HashData"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="SignatureData"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="observable-id" type="xs:ID" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="EmailTo" type="xs:string"/>
    <xs:element name="EmailFrom" type="xs:string"/>
    <xs:element name="EmailSubject" type="xs:string"/>
    <xs:element name="EmailX-Mailer" type="xs:string"/>
    <xs:element name="EmailHeaderField" type="iodef:ExtensionType"/>
    <xs:element name="EmailHeaders" type="xs:string"/>
    <xs:element name="EmailBody" type="xs:string"/>
    <xs:element name="EmailMessage" type="xs:string"/>
    <!--
     ================================================================
     ==   DomainData class                                         ==
```

```
     ============================================================
    -->
    <xs:element name="DomainData">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:Name"/>
          <xs:element ref="iodef:DateDomainWasChecked"
                      minOccurs="0"/>
          <xs:element ref="iodef:RegistrationDate"
                      minOccurs="0"/>
          <xs:element ref="iodef:ExpirationDate"
                      minOccurs="0"/>
          <xs:element ref="iodef:RelatedDNS"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Nameservers"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:DomainContacts"
                      minOccurs="0"/>
        </xs:sequence>
        <xs:attribute name="system-status"
                      type="domaindata-system-status-type"/>
        <xs:attribute name="ext-system-status"
                      type="xs:string" use="optional"/>
        <xs:attribute name="domain-status"
                      type="domaindata-domain-status-type"/>
        <xs:attribute name="ext-domain-status"
                      type="xs:string" use="optional"/>
        <xs:attribute name="observable-id" type="xs:ID" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="Name" type="xs:string"/>
    <xs:element name="DateDomainWasChecked" type="xs:dateTime"/>
    <xs:element name="RegistrationDate" type="xs:dateTime"/>
    <xs:element name="ExpirationDate" type="xs:dateTime"/>
    <xs:simpleType name="domaindata-system-status-type">
      <xs:restriction base="xs:string">
        <xs:enumeration value="spoofed"/>
        <xs:enumeration value="fraudulent"/>
        <xs:enumeration value="innocent-hacked"/>
        <xs:enumeration value="innocent-hijacked"/>
        <xs:enumeration value="unknown"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:simpleType name="domaindata-domain-status-type">
      <xs:restriction base="xs:string">
        <xs:enumeration value="reservedDelegation"/>
        <xs:enumeration value="assignedAndActive"/>
```

```
        <xs:enumeration value="assignedAndInactive"/>
        <xs:enumeration value="assignedAndOnHold"/>
        <xs:enumeration value="revoked"/>
        <xs:enumeration value="transferPending"/>
        <xs:enumeration value="registryLock"/>
        <xs:enumeration value="registrarLock"/>
        <xs:enumeration value="other"/>
        <xs:enumeration value="unknown"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:element name="RelatedDNS" type="iodef:ExtensionType"/>
    <xs:element name="Nameservers">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:Server"/>
          <xs:element ref="iodef:Address" maxOccurs="unbounded"/>
        </xs:sequence>
      </xs:complexType>
    </xs:element>
    <xs:element name="Server" type="xs:string"/>
    <xs:element name="DomainContacts">
      <xs:complexType>
        <xs:choice>
          <xs:element ref="iodef:SameDomainContact"/>
          <xs:element ref="iodef:Contact"
                      minOccurs="1" maxOccurs="unbounded"/>
        </xs:choice>
      </xs:complexType>
    </xs:element>
    <xs:element name="SameDomainContact" type="xs:string"/>
    <!--
     ========================================================================
     ==  Record class                                                      ==
     ========================================================================
    -->
    <xs:element name="Record">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:RecordData" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="restriction"
                      type="iodef:restriction-type" use="optional"/>
        <xs:attribute name="ext-restriction"
                      type="xs:string" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="RecordData">
```

```
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:DateTime" minOccurs="0"/>
          <xs:element ref="iodef:Description"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Application" minOccurs="0"/>
          <xs:element ref="iodef:RecordPattern"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:RecordItem"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:URL"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:FileData"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:WindowsRegistryKeysModified"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:CertificateData"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:AdditionalData"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="restriction"
                      type="iodef:restriction-type" use="optional"/>
        <xs:attribute name="ext-restriction"
                      type="xs:string" use="optional"/>
        <xs:attribute name="observable-id" type="xs:ID" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="RecordPattern">
      <xs:complexType>
        <xs:simpleContent>
          <xs:extension base="xs:string">
            <xs:attribute name="type"
                          type="recordpattern-type-type"
                          use="required"/>
            <xs:attribute name="ext-type"
                          type="xs:string" use="optional"/>
            <xs:attribute name="offset"
                          type="xs:integer" use="optional"/>
            <xs:attribute name="offsetunit"
                          type="recordpattern-offsetunit-type"
                          use="optional" default="line"/>
            <xs:attribute name="ext-offsetunit"
                          type="xs:string" use="optional"/>
            <xs:attribute name="instance"
                          type="xs:integer" use="optional"/>
          </xs:extension>
        </xs:simpleContent>
```

```
      </xs:complexType>
    </xs:element>
    <xs:simpleType name="recordpattern-type-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="regex"/>
        <xs:enumeration value="binary"/>
        <xs:enumeration value="xpath"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:simpleType name="recordpattern-offsetunit-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="line"/>
        <xs:enumeration value="byte"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:element name="RecordItem" type="iodef:ExtensionType"/>
    <!--
     ========================================================================
     ==  WindowsRegistryKeysModified Class                                 ==
     ========================================================================
    -->
    <xs:element name="WindowsRegistryKeysModified">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:Key" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="observable-id" type="xs:ID" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="Key">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:KeyName"/>
          <xs:element ref="iodef:Value" minOccurs="0"/>
        </xs:sequence>
        <xs:attribute name="registryaction"
                      type="key-registryaction-type"/>
        <xs:attribute name="ext-registryaction"
                      type="xs:string" use="optional"/>
        <xs:attribute name="observable-id" type="xs:ID" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="KeyName" type="xs:string"/>
    <xs:element name="Value" type="xs:string"/>
    <xs:simpleType name="key-registryaction-type">
      <xs:restriction base="xs:NMTOKEN">
```

```
        <xs:enumeration value="add-key"/>
        <xs:enumeration value="add-value"/>
        <xs:enumeration value="delete-key"/>
        <xs:enumeration value="delete-value"/>
        <xs:enumeration value="modify-key"/>
        <xs:enumeration value="modify-value"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <!--
    ========================================================================
    ==  FileData Class                                                    ==
    ========================================================================
    -->
    <xs:element name="FileData">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:File"
                      minOccurs="1" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="restriction"
                      type="iodef:restriction-type" use="optional"/>
        <xs:attribute name="ext-restriction"
                      type="xs:string" use="optional"/>
        <xs:attribute name="observable-id" type="xs:ID" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="File">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:FileName" minOccurs="0"/>
          <xs:element ref="iodef:FileSize" minOccurs="0"/>
          <xs:element ref="FileType" minOccurs="0"/>
          <xs:element ref="iodef:URL"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:HashData" minOccurs="0"/>
          <xs:element ref="iodef:SignatureData" minOccurs="0"/>
          <xs:element ref="iodef:AssociatedSoftware" minOccurs="0"/>
          <xs:element ref="iodef:FileProperties"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="observable-id" type="xs:ID" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="FileName" type="xs:string"/>
    <xs:element name="FileSize" type="xs:integer"/>
    <xs:element name="FileType" type="xs:string"/>
    <xs:element name="AssociatedSoftware" type="iodef:SoftwareType"/>
```

```
    <xs:element name="FileProperties" type="iodef:ExtensionType"/>
    <!--
    ========================================================================
    ==  HashData Class                                                    ==
    ========================================================================
    -->
    <xs:element name="HashData">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:HashTargetID" minOccurs="0"/>
          <xs:element ref="iodef:Hash"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:FuzzyHash"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="scope"
                      type="hashdata-scope-type" use="required"/>
        <xs:attribute name="ext-scope" type="xs:string" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="HashTargetID" type="xs:string"/>
    <xs:simpleType name="hashdata-scope-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="file-contents"/>
        <xs:enumeration value="file-pe-section"/>
        <xs:enumeration value="file-pe-iat"/>
        <xs:enumeration value="file-pe-resource"/>
        <xs:enumeration value="file-pdf-object"/>
        <xs:enumeration value="email-hash"/>
        <xs:enumeration value="email-headers-hash"/>
        <xs:enumeration value="email-body-hash"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:element name="Hash">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="ds:DigestMethod"/>
          <xs:element ref="ds:DigestValue"/>
          <xs:element ref="ds:CanonicalizationMethod"
                      minOccurs="0"/>
          <xs:element ref="iodef:Application" minOccurs="0"/>
        </xs:sequence>
      </xs:complexType>
    </xs:element>
    <xs:element name="FuzzyHash">
      <xs:complexType>
        <xs:sequence>
```

```
          <xs:element ref="iodef:FuzzyHashValue"
                      maxOccurs="unbounded"/>
          <xs:element ref="iodef:Application" minOccurs="0"/>
          <xs:element ref="iodef:AdditionalData"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
      </xs:complexType>
    </xs:element>
    <xs:element name="FuzzyHashValue" type="iodef:ExtensionType"/>
    <!--
     ========================================================================
     ==  SignatureData Class                                               ==
     ========================================================================
    -->
    <xs:element name="SignatureData">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="ds:Signature" maxOccurs="unbounded"/>
        </xs:sequence>
      </xs:complexType>
    </xs:element>
    <!--
     ========================================================================
     ==  CertificateData                                                   ==
     ========================================================================
    -->
    <xs:element name="CertificateData">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:Certificate" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="restriction"
                      type="iodef:restriction-type" use="optional"/>
        <xs:attribute name="ext-restriction"
                      type="xs:string" use="optional"/>
        <xs:attribute name="observable-id" type="xs:ID" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="Certificate">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="ds:X509Data"/>
          <xs:element ref="iodef:Description"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="observable-id" type="xs:ID" use="optional"/>
      </xs:complexType>
    </xs:element>
```

```
    <!--
     ====================================================================
     == IndicatorData Class                                            ==
     ====================================================================
    -->
    <xs:element name="IndicatorData">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:Indicator"
                      minOccurs="1" maxOccurs="unbounded"/>
        </xs:sequence>
      </xs:complexType>
    </xs:element>
    <xs:element name="Indicator">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:IndicatorID"/>
          <xs:element ref="iodef:AlternativeIndicatorID"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Description"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:StartTime" minOccurs="0"/>
          <xs:element ref="iodef:EndTime" minOccurs="0"/>
          <xs:element ref="iodef:Confidence" minOccurs="0"/>
          <xs:element ref="iodef:Contact"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:choice>
            <xs:element ref="iodef:Observable"/>
            <xs:element ref="iodef:ObservableReference"/>
            <xs:element ref="iodef:IndicatorExpression"/>
            <xs:element ref="iodef:IndicatorReference"/>
          </xs:choice>
          <xs:element ref="iodef:NodeRole"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:AttackPhase"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Reference"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:AdditionalData"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="restriction"
                      type="iodef:restriction-type" use="optional"/>
        <xs:attribute name="ext-restriction"
                      type="xs:string" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="IndicatorID">
```

```
      <xs:complexType>
        <xs:simpleContent>
          <xs:extension base="xs:ID">
            <xs:attribute name="name" type="xs:string" use="required"/>
            <xs:attribute name="version"
                          type="xs:string" use="required"/>
          </xs:extension>
        </xs:simpleContent>
      </xs:complexType>
    </xs:element>
    <xs:element name="AlternativeIndicatorID">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:IndicatorID" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="restriction"
                      type="iodef:restriction-type" use="optional"/>
        <xs:attribute name="ext-restriction"
                      type="xs:string" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="Observable">
      <xs:complexType>
        <xs:choice>
          <xs:element ref="iodef:System" minOccurs="0"/>
          <xs:element ref="iodef:Address" minOccurs="0"/>
          <xs:element ref="iodef:DomainData" minOccurs="0"/>
          <xs:element ref="iodef:Service" minOccurs="0"/>
          <xs:element ref="iodef:EmailData" minOccurs="0"/>
          <xs:element ref="iodef:WindowsRegistryKeysModified"
                           minOccurs="0"/>
          <xs:element ref="iodef:FileData" minOccurs="0"/>
          <xs:element ref="iodef:CertificateData" minOccurs="0"/>
          <xs:element ref="iodef:RegistryHandle" minOccurs="0"/>
          <xs:element ref="iodef:RecordData" minOccurs="0"/>
          <xs:element ref="iodef:EventData" minOccurs="0"/>
          <xs:element ref="iodef:Incident" minOccurs="0"/>
          <xs:element ref="iodef:Expectation" minOccurs="0"/>
          <xs:element ref="iodef:Reference" minOccurs="0"/>
          <xs:element ref="iodef:Assessment" minOccurs="0"/>
          <xs:element ref="iodef:DetectionPattern" minOccurs="0"/>
          <xs:element ref="iodef:HistoryItem" minOccurs="0"/>
          <xs:element ref="iodef:BulkObservable" minOccurs="0"/>
          <xs:element ref="iodef:AdditionalData"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:choice>
        <xs:attribute name="restriction"
                      type="iodef:restriction-type" use="optional"/>
```

```
        <xs:attribute name="ext-restriction"
                      type="xs:string" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="BulkObservable">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:BulkObservableFormat" minOccurs="0"/>
          <xs:element name="BulkObservableList"/>
          <xs:element ref="iodef:AdditionalData"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="type"
                      type="bulkobservable-type-type" use="required"/>
        <xs:attribute name="ext-type" type="xs:string" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:simpleType name="bulkobservable-type-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="asn"/>
        <xs:enumeration value="atm"/>
        <xs:enumeration value="e-mail"/>
        <xs:enumeration value="ipv4-addr"/>
        <xs:enumeration value="ipv4-net"/>
        <xs:enumeration value="ipv4-net-mask"/>
        <xs:enumeration value="ipv6-addr"/>
        <xs:enumeration value="ipv6-net"/>
        <xs:enumeration value="ipv6-net-mask"/>
        <xs:enumeration value="mac"/>
        <xs:enumeration value="site-uri"/>
        <xs:enumeration value="domain-name"/>
        <xs:enumeration value="domain-to-ipv4"/>
        <xs:enumeration value="domain-to-ipv6"/>
        <xs:enumeration value="domain-to-ipv4-timestamp"/>
        <xs:enumeration value="domain-to-ipv6-timestamp"/>
        <xs:enumeration value="ipv4-port"/>
        <xs:enumeration value="ipv6-port"/>
        <xs:enumeration value="windows-reg-key"/>
        <xs:enumeration value="file-hash"/>
        <xs:enumeration value="email-x-mailer"/>
        <xs:enumeration value="email-subject"/>
        <xs:enumeration value="http-user-agent"/>
        <xs:enumeration value="http-request-uri"/>
        <xs:enumeration value="mutex"/>
        <xs:enumeration value="file-path"/>
        <xs:enumeration value="user-name"/>
      </xs:restriction>
    </xs:simpleType>
```

```
    <xs:element name="BulkObservableFormat">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:Hash" minOccurs="0"/>
          <xs:element ref="iodef:AdditionalData"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
      </xs:complexType>
    </xs:element>
    <xs:element name="BulkObservableList" type="xs:string"/>
    <xs:element name="IndicatorExpression">
      <xs:complexType>
        <xs:sequence maxOccurs="unbounded">
          <xs:choice>
            <xs:element ref="iodef:IndicatorExpression"/>
            <xs:element ref="iodef:Observable"/>
            <xs:element ref="iodef:ObservableReference"/>
            <xs:element ref="iodef:IndicatorReference"/>
          </xs:choice>
          <xs:element ref="iodef:Confidence" minOccurs="0"/>
          <xs:element ref="iodef:AdditionalData"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="operator"
                      type="indicatorexpression-operator-type"
                      use="optional" default="and"/>
        <xs:attribute name="ext-operator"
                      type="xs:string" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:simpleType name="indicatorexpression-operator-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="not"/>
        <xs:enumeration value="and"/>
        <xs:enumeration value="or"/>
        <xs:enumeration value="xor"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:element name="ObservableReference">
      <xs:complexType>
        <xs:attribute name="uid-ref" type="xs:IDREF" use="required"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="IndicatorReference">
      <xs:complexType>
        <xs:attribute name="uid-ref" type="xs:IDREF" use="optional"/>
        <xs:attribute name="euid-ref" type="xs:string" use="optional"/>
        <xs:attribute name="version" type="xs:string" use="optional"/>
```

```
      </xs:complexType>
    </xs:element>
    <xs:element name="AttackPhase">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:AttackPhaseID"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:URL" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Description"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:AdditionalData"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
      </xs:complexType>
    </xs:element>
    <xs:element name="AttackPhaseID" type="xs:string"/>
    <!--
     ========================================================================
     == Miscellaneous Classes                                              ==
     ========================================================================
    -->
    <xs:element name="AdditionalData" type="iodef:ExtensionType"/>
    <xs:element name="Description" type="iodef:MLStringType"/>
    <xs:element name="URL" type="xs:anyURI"/>
    <!--
     ========================================================================
     == IODEF Data Types                                                   ==
     ========================================================================
    -->
    <xs:simpleType name="PositiveFloatType">
      <xs:restriction base="xs:float">
        <xs:minExclusive value="0"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:complexType name="MLStringType">
      <xs:simpleContent>
        <xs:extension base="xs:string">
          <xs:attribute name="translation-id"
                        type="xs:string" use="optional"/>
          <xs:attribute ref="xml:lang"/>
        </xs:extension>
      </xs:simpleContent>
    </xs:complexType>
    <xs:simpleType name="PortlistType">
      <xs:restriction base="xs:string">
        <xs:pattern value="\d+(\-\d+)?(,\d+(\-\d+)?)*"/>
      </xs:restriction>
    </xs:simpleType>
```

```
    <xs:simpleType name="TimezoneType">
      <xs:restriction base="xs:string">
        <xs:pattern
         value="Z|[\+\-](0[0-9]|1[0-4]):[0-5][0-9](:[0-5][0-9])?"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:complexType name="ExtensionType" mixed="true">
      <xs:sequence>
        <xs:any namespace="##any" processContents="lax"
                minOccurs="0" maxOccurs="unbounded"/>
      </xs:sequence>

      <xs:attribute name="name" type="xs:string" use="optional"/>
      <xs:attribute name="dtype"
                    type="iodef:dtype-type" use="required"/>
      <xs:attribute name="ext-dtype" type="xs:string" use="optional"/>
      <xs:attribute name="meaning" type="xs:string" use="optional"/>
      <xs:attribute name="formatid" type="xs:string" use="optional"/>
      <xs:attribute name="restriction"
                    type="iodef:restriction-type" use="optional"/>
      <xs:attribute name="ext-restriction"
                    type="xs:string" use="optional"/>
      <xs:attribute name="observable-id" type="xs:ID" use="optional"/>
    </xs:complexType>
    <xs:complexType name="SoftwareType">
      <xs:sequence>
        <xs:element ref="iodef:SoftwareReference" minOccurs="0"/>
        <xs:element ref="iodef:URL"
                    minOccurs="0" maxOccurs="unbounded"/>
        <xs:element ref="iodef:Description"
                    minOccurs="0" maxOccurs="unbounded"/>
      </xs:sequence>
    </xs:complexType>
    <xs:element name="SoftwareReference">
      <xs:complexType>
        <xs:sequence>
          <xs:any namespace="##any" processContents="lax"
                  minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="spec-name"
                      type="softwarereference-spec-name-type"
                      use="required"/>
        <xs:attribute name="ext-spec-name"
                      type="xs:string" use="optional"/>
        <xs:attribute name="dtype"
                      type="softwarereference-dtype-type"
                      use="optional"/>
        <xs:attribute name="ext-dtype" type="xs:string" use="optional"/>
```

```
      </xs:complexType>
    </xs:element>
    <xs:simpleType name="softwarereference-spec-name-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="custom"/>
        <xs:enumeration value="cpe"/>
        <xs:enumeration value="swid"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:simpleType name="softwarereference-dtype-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="bytes"/>
        <xs:enumeration value="integer"/>
        <xs:enumeration value="real"/>
        <xs:enumeration value="string"/>
        <xs:enumeration value="xml"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <!--
     ========================================================================
     == Global attribute type declarations                                 ==
     ========================================================================
    -->
    <xs:simpleType name="yes-no-unknown-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="yes"/>
        <xs:enumeration value="no"/>
        <xs:enumeration value="unknown"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:simpleType name="restriction-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="default"/>
        <xs:enumeration value="public"/>
        <xs:enumeration value="partner"/>
        <xs:enumeration value="need-to-know"/>
        <xs:enumeration value="private"/>
        <xs:enumeration value="white"/>
        <xs:enumeration value="green"/>
        <xs:enumeration value="amber"/>
        <xs:enumeration value="red"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:simpleType name="severity-type">
      <xs:restriction base="xs:NMTOKEN">
```

```
        <xs:enumeration value="low"/>
        <xs:enumeration value="medium"/>
        <xs:enumeration value="high"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:simpleType name="duration-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="second"/>
        <xs:enumeration value="minute"/>
        <xs:enumeration value="hour"/>
        <xs:enumeration value="day"/>
        <xs:enumeration value="month"/>
        <xs:enumeration value="quarter"/>
        <xs:enumeration value="year"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:simpleType name="action-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="nothing"/>
        <xs:enumeration value="contact-source-site"/>
        <xs:enumeration value="contact-target-site"/>
        <xs:enumeration value="contact-sender"/>
        <xs:enumeration value="investigate"/>
        <xs:enumeration value="block-host"/>
        <xs:enumeration value="block-network"/>
        <xs:enumeration value="block-port"/>
        <xs:enumeration value="rate-limit-host"/>
        <xs:enumeration value="rate-limit-network"/>
        <xs:enumeration value="rate-limit-port"/>
        <xs:enumeration value="redirect-traffic"/>
        <xs:enumeration value="honeypot"/>
        <xs:enumeration value="upgrade-software"/>
        <xs:enumeration value="rebuild-asset"/>
        <xs:enumeration value="harden-asset"/>
        <xs:enumeration value="remediate-other"/>
        <xs:enumeration value="status-triage"/>
        <xs:enumeration value="status-new-info"/>
        <xs:enumeration value="watch-and-report"/>
        <xs:enumeration value="defined-coa"/>
        <xs:enumeration value="other"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:simpleType name="dtype-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="boolean"/>
        <xs:enumeration value="byte"/>
```

```
        <xs:enumeration value="bytes"/>
        <xs:enumeration value="character"/>
        <xs:enumeration value="date-time"/>
        <xs:enumeration value="integer"/>
        <xs:enumeration value="ntpstamp"/>
        <xs:enumeration value="portlist"/>
        <xs:enumeration value="real"/>
        <xs:enumeration value="string"/>
        <xs:enumeration value="file"/>
        <xs:enumeration value="path"/>
        <xs:enumeration value="frame"/>
        <xs:enumeration value="packet"/>
        <xs:enumeration value="ipv4-packet"/>
        <xs:enumeration value="ipv6-packet"/>
        <xs:enumeration value="url"/>
        <xs:enumeration value="csv"/>
        <xs:enumeration value="winreg"/>
        <xs:enumeration value="xml"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
  </xs:schema>
```

9. Security Considerations

The IODEF data model does not directly introduce security or privacy issues. However, as the data encoded by the IODEF might be considered sensitive by the parties exchanging it or by those described by it, care needs to be taken to ensure appropriate handling during the document construction, exchange, processing, archiving, subsequent retrieval and analysis.

9.1. Security

The underlying messaging format and protocol used to exchange instances of the IODEF MUST provide appropriate guarantees of confidentiality, integrity, and authenticity. The use of a standardized security protocol is encouraged. The Real-time Inter-network Defense (RID) protocol [RFC6545] and its associated transport binding IODEF/RID over HTTP/TLS [RFC6546] provide such security.

An IODEF implementation may act on the data in the document. These actions might be explicitly requested in the document or the result of analytical logic that triggered on data in the document. For this reason, care must be taken by IODEF implementations to properly authenticate the sender and receiver of the document. The sender needs confidence that sensitive information and timely requests for action are sent to the correct recipient. The recipient may

interpret the contents of the document differently based on who sent it; or vary actions based on the sender. While the sender of the document may explicitly convey confidence in the data in a granular way using the Confidence class, the recipient is free to ignore or refine this information to make its own assessment. Ambiguous Confidence elements (where it is unclear to which of a set of other elements the Confidence element relates) in a document MUST be ignored by the recipient.

Certain classes may require out-of-band coordination to agree upon their semantics (e.g., Confidence@rating="low" or DefinedCOA). This coordination MUST occur prior to operational data exchange to prevent the incorrect interpretation of these select data elements. When parsing these data elements, implementations should validate, when possible, that they conform to the agreed upon semantics. These semantics may need to be periodically reevaluated.

Executable content of various forms could be embedded into the IODEF document directly or through an extension. Implementation MUST handle this content with care to prevent unintentional automated execution. The following classes are explicitly intended to represent content that might be executable:

- All classes of type iodef:ExtensionType and the RecordPattern class can represent arbitrary binary strings such as legitimate software programs or malware.

- The EmailMessage and EmailBody classes can represent email attachments that can contain arbitrary content.

- The DetectionPattern class could specify a machine-readable configuration that directs the execution of the corresponding tool.

Per Section 4.3, IODEF implementations will need to periodically consult the IANA registries specified in Section 10.2 to discover newly registered enumerated attribute values. These implementations MUST communicate with IANA in a way that ensures the integrity of the values and the authenticity of the source. HTTPS over TLS [RFC2818][RFC5246] provides such security.

9.2. Privacy

The IODEF contains numerous fields that are identifiers which could be linked to an individual or organization. IODEF documents may contain sensitive information about these identified parties; and repeated document exchanges about the same and related parties may

enable the correlation of data about them. Likewise, a party may report on another to a third party without their knowledge.

When creating an IODEF document, careful consideration must be given to what information is shared. Personal identifiers and attributable sensitive information should only be shared when necessary.

When exchanging documents, transport security MUST provide document-level confidentiality. XML element-level confidentiality can also be provided by using [W3C.XMLENC].

In order to suggest data processing and handling guidelines of the encoded information, the IODEF allows a document sender to convey a privacy policy using the restriction attribute. The various instances of this attribute allow different data elements of the document to be covered by dissimilar policies. While flexible, it must be stressed that this approach only serves as a guideline from the sender, as the recipient is free to ignore it.

Although outside of the scope of an IODEF implementation, the contents of IODEF documents and any derived analysis should be archived with at appropriate confidentiality controls. Likewise, access to retrieve and analyze this data should be restricted to authorized users.

10. IANA Considerations

This document registers a namespace, an XML schema, and a number of registries that map to enumerated values defined in the data model. It also defines an expert review process for IODEF-related XML registry entries.

10.1. Namespace and Schema

This document uses URNs to describe an XML namespace and schema conforming to a registry mechanism described in [RFC3688]

Registration for the IODEF namespace:

- URI: urn:ietf:params:xml:ns:iodef-2.0
- Registrant Contact: See the first author of the "Author's Address" section of this document.
- XML: None. Namespace URIs do not represent an XML specification.

Registration for the IODEF XML schema:

- URI: urn:ietf:params:xml:schema:iodef-2.0
- Registrant Contact: See the first author of the "Author's Address" section of this document.
- XML: See Section 8 of this document.

10.2. Enumerated Value Registries

This document creates 34 identically structured registries to be managed by IANA:

- Name of the parent registry: "Incident Object Description Exchange Format v2 (IODEF)"
- URL of the registry: http://www.iana.org/assignments/iodef2
- Namespace format: A registry entry consists of:
  - Value. A value for a given IODEF attribute. It MUST conform to the formatting specified by the IODEF ENUM data type which is implemented as an "xs:NMTOKEN" type per Section 3.3.4 of [W3C.SCHEMA.DTYPES]. The value SHOULD conform to the convention specified in Section 5.2.
  - Description. A short description of the enumerated value.
  - Reference. An optional list of URIs to further describe the value.
- Allocation policy: Expert Review per [RFC5226]. This reviewer will ensure that the requested registry entry conforms to the prescribed formatting. The reviewer will also ensure that the entry is an appropriate value for the attribute per the information model (Section 3).

The registries to be created are named in the "Registry Name" column of Table 1. Each registry is initially populated with values and descriptions that come from an attribute specified in the IODEF schema (Section 8) whose description is found in a sub-section of the information model (Section 3). The initial values for the Value and Description fields of a given registry are listed in the "IV (Value)" and "IV (Description)" columns respectively. The "IV (Value)" points to a given schema type per Section 8. Each enumerated value in the schema gets a corresponding entry in a given registry. The "IV (Description)" points to a section in the text of this document that describes each enumerated value. The initial value of the Reference

field of every registry entry described below should be this document.

Registry Name	IV (Value)	IV (Description)
Restriction	iodef-restriction-type	Section 3.3.1
Incident-purpose	incident-purpose-type	Section 3.2
Incident-status	incident-status-type	Section 3.2
Contact-role	contact-role-type	Section 3.9
Contact-type	contact-type-type	Section 3.9
RegistryHandle-registry	registryhandle-registry-type	Section 3.9.1
PostalAddress-type	postaladdress-type-type	Section 3.9.2
Telephone-type	telephone-type-type	Section 3.9.4
Email-type	email-type-type	Section 3.9.3
Expectation-action	action-type	Section 3.15
Discovery-source	discovery-source-type	Section 3.10
SystemImpact-type	systemimpact-type-type	Section 3.12.1
BusinessImpact-severity	businessimpact-severity-type	Section 3.12.2
BusinessImpact-type	businessimpact-type-type	Section 3.12.2
TimeImpact-metric	timeimpact-metric-type	Section 3.12.3
TimeImpact-duration	duration-type	Section 3.12.3
Confidence-rating	confidence-rating-type	Section 3.12.5

NodeRole-category	noderole-category-type	Section 3.18.2
System-category	system-category-type	Section 3.17
System-ownership	system-ownership-type	Section 3.17
Address-category	address-category-type	Section 3.18.1
Counter-type	counter-type-type	Section 3.18.3
Counter-unit	counter-unit-type	Section 3.18.3
DomainData-system-status	domaindata-system-status-type	Section 3.19
DomainData-domain-status	domaindata-domain-status-type	Section 3.19
RecordPattern-type	recordpattern-type-type	Section 3.22.2
RecordPattern-offsetunit	recordpattern-offsetunit-type	Section 3.22.2
Key-registryaction	key-registryaction-type	Section 3.23.1
HashData-scope	hashdata-scope-type	Section 3.26
BulkObservable-type	bulkobservable-type-type	Section 3.29.3.1
IndicatorExpression-operator	indicatorexpression-operator-type	Section 3.29.4
ExtensionType-dtype	dtype-type	Section 2.16
SoftwareReference-spec-id	softwarereference-spec-id-type	Section 2.15.1
SoftwareReference-dtype	softwarereference-dtype-type	Section 2.15.1

Table 1: IANA Enumerated Value Registries

10.3. Expert Review of IODEF-Related XML Registry Entries

IODEF class extensions, per Section 5.2, could register their namespaces and schemas with the IANA XML Namespace ("ns", http://www.iana.org/assignments/xml-registry/xml-registry.xhtml#ns) and Schema registries ("schema", http://www.iana.org/assignments/xml-registry/xml-registry.xhtml#schema) described in [RFC3688]. In addition to any reviews required by IANA, changes to the XML Schema registry for schema names beginning with "urn:ietf:params:xml:schema:iodef" are subject to an additional IODEF Expert Review [RFC5226] to ensure compatibility with IODEF and other existing IODEF extensions.

The IODEF expert(s) for these reviews will be designated by the IETF Security Area Directors.

This document obsoletes [RFC6685].

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The Incident Object Description Exchange Format v2
draft-ietf-mile-rfc5070-bis-26

Abstract

The Incident Object Description Exchange Format (IODEF) defines a data representation for security incident reports and indicators commonly exchanged by operational security teams for mitigation and watch and warning. This document describes an updated information model for the IODEF and provides an associated data model specified with XML Schema. This new information and data model obsoletes Request for Comment (RFC) 5070 and 6685.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

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Table of Contents

1. Introduction

Organizations require help from other parties to mitigate malicious activity targeting their network and to gain insight into potential threats. This coordination might entail working with an ISP to filter attack traffic, contacting a remote site to take down a botnet, or sharing watch-lists of known malicious indicators in a consortium.

The Incident Object Description Exchange Format (IODEF) is a format for representing computer security information commonly exchanged between Computer Security Incident Response Teams (CSIRTs) or other operational security teams. It provides an XML representation for conveying:

- indicators to characterize a threat;
- security incident reports to document attacks against an organization;
- response activity taken or that could be taken in response to an incident; and
- meta-data so that these various classes of information can be exchanged among parties.

The purpose of the IODEF is to enhance the operational capabilities of CSIRTs. Adoption of the IODEF will improve the ability of a CSIRT to resolve security incidents; understand threats; and coordinate response activities and proactive mitigations by simplifying collaboration and data sharing with its partners. This structured format provided by the IODEF allows for:

- machine-to-machine exchange of incident and indicator data;
- automated processing of this data whereby allowing more rapid execution of appropriate courses of action; and
- the development of an ecosystem of interoperable tools enabling security operations.

Sharing and coordinating with other organizations is not strictly a technical problem. There are numerous procedural, cultural, legal and trust-related barriers to overcome. The IODEF does not attempt to address them directly. However, operational implementations of the IODEF will need to consider these challenges.

Section 1 provides the background for the IODEF. Sections 3 and 8 specify the IODEF information and data model respectively. The data types used in this document are described in Section 2. Processing considerations, extending the specification, internationalization and security issues are covered in Sections 4, 5, 6 and 9 respectively. Examples are listed in Section 7.

1.1. Terminology

The key words "MUST," "MUST NOT," "REQUIRED," "SHALL," "SHALL NOT," "SHOULD," "SHOULD NOT," "RECOMMENDED," "MAY," and "OPTIONAL" in this document are to be interpreted as described in [RFC2119].

1.2. Notations

The IODEF is specified as an Extensible Markup Language (XML) [W3C.XML] Schema [W3C.SCHEMA]. The normative IODEF data model is found in the XML schema in Section 8. To aid in the understanding of the data elements, Section 3 also depicts the underlying information model using Unified Modeling Language (UML). This abstract presentation of the IODEF is not normative.

For clarity in this document, the term "XML document" will be used when referring generically to any instance of an XML document. The term "IODEF document" will be used to refer to an XML document conforming to the IODEF specification. The terms "schema" will be used to refer to Section 8 of this document. The terms "data model" and "schema" will be used interchangeably. The terms "class" and "element" will be used to reference either the corresponding data element in the UML-based information or XML Schema-based data models, respectively.

1.3. About the IODEF Data Model

A number of considerations were made in the design of the IODEF data model.

- The data model found in this document is an evolution of the one previously specified in [RFC5070]. New fields were added to represent additional information. [RFC5070] was developed primarily to represent incident reports. This document builds upon it by adding support for indicators and revising it to reflect the current challenges faced by CSIRTs. An attempt was made to preserve backward compatibility but this was not possible in all cases. See Section 4.4. This document obsoletes [RFC5070].

- The IODEF is a transport format. Therefore, the data model may not be the optimal archival or in-memory processing format.

- The IODEF is intended to be a framework to convey only commonly exchanged information. It ensures that there are mechanisms for extensibility to support organization-specific information and techniques to reference information kept outside of the data model.

- Not all commonly exchanged information has a well-defined format or taxonomy. The IODEF attempts to strike a balance between enforcing sufficient structure to allow automated processing and supporting free-form content that enables maximum flexibility.

- The IODEF fits into a broader ecosystem of standards and conventions. An attempt was made to harmonize the data model with this context.

1.4. Changelog

A detailed list of additions made to the [RFC5070] data model are enumerated in this section. See Section 4.4 for a list of incompatible changes.

- Updated the data types (Section 2) to improve internationalization, clarify ambiguity, and ensure consistency in extensions.

- Added the observable-id attribute (Section 3.3.2) and IndicatorData (Section 3.28) class (Section 3.28) to represent indicators.

- Added the private-enum-name and -id attributes to the IODEF-Document class (Section 3.1) to disambiguate private extensions.

- Updated the Incident class (Section 3.2) to represent additional timing and workflow information.

- Added the ThreatActor (Section 3.7) and Campaign (Section 3.8) classes to represent attack attribution information.

- Updated the Contact class (Section 3.9) and its children to improve internationalization and represent additional information about an entity.

- Updated the Method class (Section 3.11) to improve extensibility through externally referenced resources.

- Added the Discovery class (Section 3.10) to describe how an incident was discovered.
- Updated the Assessment class (Section 3.12) to enable more descriptive characterizations of the impact of an incident.
- Updated the HistoryItem (Section 3.13.1) and Expectation (Section 3.15) classes to support a reference to a course of action.
- Updated the EventData class (Section 3.14) with additional meta-data added to the Incident class.
- Updated the System (Section 3.17) class with additional meta-data.
- Updated the Counter class (Section 3.18.3) to support additional rate metrics.
- Added the DomainData (Section 3.19), EmailData (Section 3.21), WindowsRegistryKeysModified (Section 3.23), CertificateData (Section 3.24) and FileData (Section 3.25) to improve the description of an incident and support this data as indicators.
- Added the SignatureData (Section 3.27) and HashData classes (Section 3.26) to represent digital signatures and hashes.
- Added support for public enumerated attribute extensions using IANA registries (Section 5.1.2).
- Updated numerous enumerated attributes for completeness.

2. IODEF Data Types

The IODEF uses a number of simple and complex types. This section describes these data types.

2.1. Integers

An integer is represented in the information model by the INTEGER data type. Integer data MUST be encoded in Base 10.

The INTEGER data type is implemented in the data model as a "xs:integer" type per Section 3.3.13 of [W3C.SCHEMA.DTYPES].

2.2. Real Numbers

A real (floating-point) number is represented in the information model by the REAL data type. Real data MUST be encoded in Base 10.

The REAL data type is implemented in the data model as a "xs:float" type per Section 3.2.4 of [W3C.SCHEMA.DTYPES].

2.3. Characters and Strings

A single character is represented in the information model by the CHARACTER data type. A string is represented by the STRING data type. Special characters MUST be encoded using entity references. See Section 4.1.

The CHARACTER and STRING data types are implemented in the data model as a "xs:string" type per Section 3.2.1 of [W3C.SCHEMA.DTYPES].

2.4. Multilingual Strings

A string that needs to be represented in a human-readable language different than the default encoding of the document is represented in the information model by the ML_STRING data type.

The ML_STRING data type is implemented in the data model as the "iodef:MLStringType" type. This type extends the "xs:string" to include two attributes.

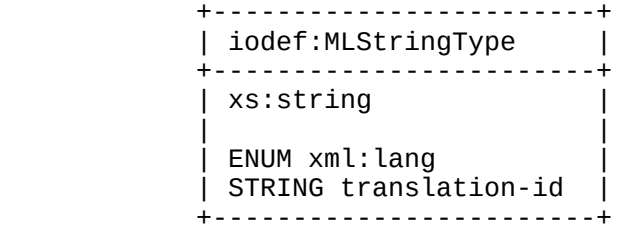

Figure 1: The iodef:MLStringType Type

The content of the class is a character string of type "xs:string" whose language MAY be specified by the xml:lang attribute.

The attributes of the iodef:MLStringType type are:

xml:lang
: Optional. ENUM. A language identifier per Section 2.12 of [W3C.XML] whose values and format are described in [RFC5646]. The interpretation of this code is described in Section 6.

translation-id
: Optional. STRING. An identifier to relate other instances of this class with the same parent as translations of this text. The scope of this identifier is limited to all of the direct, peer child classes of a given parent class.

Using this class enables representing translations of the same text in multiple languages. Each translation is a distinct instance of this class with a common parent. A group of classes each with a translated instance of text is related by setting a common identifier in the translation-id attribute. The language of a given class is set by the xml:lang attribute. See Section 6 for more details on representing translations of free-form text.

2.5. Binary Strings

Binary octets can be represented with two encodings.

2.5.1. Base64 Bytes

A binary octet encoded with Base64 is represented in the information model by the BYTE data type. A sequence of these octets is of the BYTE[] data type.

The BYTE and BYTE[] data types are implemented in the data model as a "xs:base64Binary" type per Section 3.2.16 of [W3C.SCHEMA.DTYPES].

2.5.2. Hexadecimal Bytes

A binary octet encoded as a character tuple consistent of two hexadecimal digits is represented in the information model by the HEXBIN data type. A sequence of these octets is of the HEXBIN[] data type.

The HEXBIN and HEXBIN[] data types are implemented in the data model as a "xs:hexBinary" type per Section 3.2.15 of [W3C.SCHEMA.DTYPES].

2.6. Enumerated Types

An enumerated type is represented in the information model by the ENUM data type. It is an ordered list of acceptable string values. Each value has a representative keyword. Within the data model, the enumerated type keywords are used as attribute values.

The ENUM data type is implemented in the data model as values of a "xs:NMTOKEN" type per Section 3.3.4 of [W3C.SCHEMA.DTYPES].

2.7. Date-Time String

A date-time strings that describes a particular instant in time is represented in the information model by the DATETIME data type. Ranges are not supported.

The DATETIME data type is implemented in the data model as a "xs:dateTime" type per Section 3.2.7 of [W3C.SCHEMA.DTYPES].

2.8. Timezone String

A timezone offset from UTC is represented in the information model by the TIMEZONE data type. It is formatted according to the following regular expression: "Z|[\+\-](0[0-9]|1[0-4]):[0-5][0-9]".

The TIMEZONE data type is implemented in the data model as an "iodef:TimezoneType" type.

2.9. Port Lists

A list of network ports is represented in the information model by the PORTLIST data type. A PORTLIST consists of a comma-separated list of numbers and ranges (N-M means ports N through M, inclusive). It is formatted according to the following regular expression: "\d+(\-\d+)?(,\d+(\-\d+)?)*". For example, "2,5-15,30,32,40-50,55-60".

The PORTLIST data type is implemented in the data model as an "iodef:PortlistType" type.

2.10. Postal Address

A postal address is represented in the information model by the POSTAL data type. The format of the POSTAL data type is documented in Section 2.23 of [RFC4519] as a free-form multi-line string separated by the "$" character.

The POSTAL data type is implemented in the data model as an "iodef:MLStringType" type.

2.11. Telephone Number

A telephone number is represented in the information model by the PHONE data type. The format of the PHONE data type is documented in [E.164].

The PHONE data type is implemented in the data model as a "xs:string" type per Section 3.2.1 of [W3C.SCHEMA.DTYPES].

2.12. Email String

An email address is represented in the information model by the EMAIL data type. The format of the EMAIL data type is documented in Section 3.4.1 of [RFC5322] and Section 3.3 of [RFC6531].

The EMAIL data type is implemented in the data model as a "xs:string" type per Section 3.2.1 of [W3C.SCHEMA.DTYPES].

2.13. Uniform Resource Locator strings

A uniform resource locator (URL) is represented in the information model by the URL data type. The format of the URL data type is documented in [RFC3986].

The URL data type is implemented as a "xs:anyURI" type per Section 3.2.17 of [W3C.SCHEMA.DTYPES].

2.14. Identifiers and Identifier References

An identifier unique to the IODEF document is represented in the information model by the ID data type. A reference to this identifier is represented by the IDREF data type.

The ID and IDREF data types are implemented in the model as "xs:ID" and "xs:IDREF" types per Sections 3.3.8 and 3.3.9 of [W3C.SCHEMA.DTYPES].

2.15. Software

A particular version of software is represented in the information model by the SOFTWARE data type. This software can be described by using a reference, a URL or with free-form text.

The SOFTWARE data type is implemented in the data model as the "iodef:SoftwareType" type.

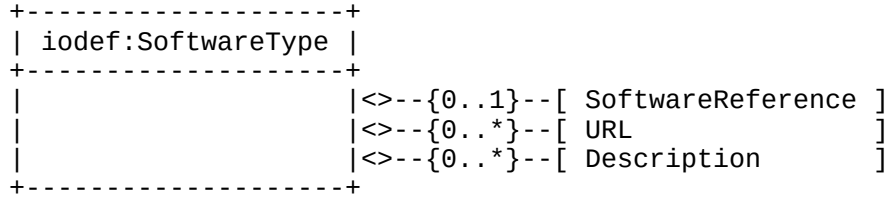

Figure 2: The SoftwareType Type

The aggregate classes of the SoftwareType type are:

SoftwareReference
Zero or one. Reference to a software application. See Section 2.15.1.

URL
Zero or more. URL. A URL to a resource describing the software.

Description
Zero or more. ML_STRING. A free-form text description of the software.

At least one of these classes MUST be present.

The iodef:SoftwareType type has no attributes.

2.15.1. SoftwareReference Class

The SoftwareReference class is a reference to a particular version of software.

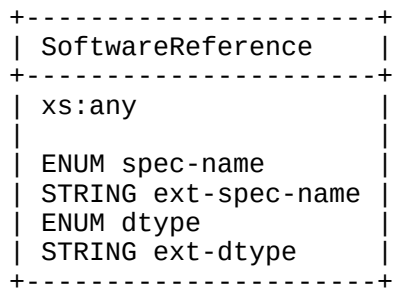

Figure 3: The SoftwareReference Class

The element content varies according to the value of the spec-name attribute. It is defined in the data model as "xs:any" per [W3C.SCHEMA].

The attributes of the SoftwareReference class are:

spec-name
Required. ENUM. Identifies the format and semantics of the element body of this class. Formal standards and specifications can be referenced as well as a free-form text description with a user-provided data type. These values are maintained in the "SoftwareReference-spec-id" IANA registry per Section 10.2

1. custom. The element content is free-form and of the data type specified by the dtype attribute. If this value is selected, then the dtype attribute MUST be set.

2. cpe. The element content describes a Common Platform Enumeration (CPE) entry per [NIST.CPE].

3. swid. The element content describes a software identification (SWID) tag per [ISO19770].

4. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-spec-name
Optional. STRING. A means by which to extend the spec-name attribute. See Section 5.1.1.

dtype
Optional. ENUM. The data type of the element content. The permitted values for this attribute are shown below. The default value is "string". These values are maintained in the "SoftwareReference-dtype" IANA registry per Section 10.2.

1. bytes. The element content is of type HEXBIN.

2. integer. The element content is of type INTEGER.

3. real. The element content is of type REAL.

4. string. The element content is of type STRING.

5. xml. The element content is XML. See Section 5.2.

6. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-dtype
Optional. STRING. A means by which to extend the dtype attribute. See Section 5.1.1.

2.16. Extension

Information not otherwise represented in the IODEF can be added using the EXTENSION data type. This data type is a generic extension mechanism.

The EXTENSION data type is implemented in the data model as the "iodef:ExtensionType" type.

The data type of an EXTENSION is described by the dtype attribute. For simple information, atomic data types (e.g., integers, strings) are supported. Their semantics are further described by the meaning and formatid attributes. Encapsulating XML documents conforming to another schema is also supported. A detailed discussion of extending the schema can be found in Section 5. Additional coordination may be required to ensure that a recipient of a document using this type can parse and process it.

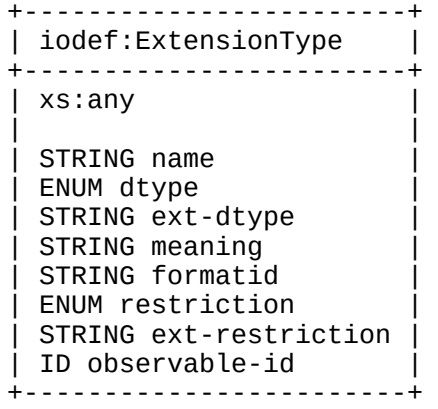

Figure 4: The iodef:ExtensionType Type

The element content of this type is the extension being added to the data model. This content is defined in the data model as "xs:any" per [W3C.SCHEMA].

The attributes of the iodef:ExtensionType type are:

name
: Optional. STRING. A free-form name of the field or data element.

dtype
: Required. ENUM. The data type of the element content. The default value is "string". These values are maintained in the "ExtensionType-dtype" IANA registry per Section 10.2.

1. boolean. The element content is of type BOOLEAN.

2. byte. The element content is of type BYTE.

3. bytes. The element content is of type HEXBIN.

4. character. The element content is of type CHARACTER.

5. date-time. The element content is of type DATETIME.

6. ntpstamp. Same as date-time.

7. integer. The element content is of type INTEGER.

8. portlist. The element content is of type PORTLIST.

9. real. The element content is of type REAL.

10. string. The element content is of type STRING.

11. file. The element content is a base64 encoded binary file encoded as a BYTE[] type.

12. path. The element content is a file-system path encoded as a STRING type.

13. frame. The element content is a layer-2 frame encoded as a HEXBIN type.

14. packet. The element content is a layer-3 packet encoded as a HEXBIN type.

15. ipv4-packet. The element content is an IPv4 packet encoded as a HEXBIN type.

16. ipv6-packet. The element content is an IPv6 packet encoded as a HEXBIN type.

17. url. The element content is of type URL.

18. csv. The element content is a common separated value (CSV) list per Section 2 of [RFC4180] encoded as a STRING type.

19. winreg. The element content is a Windows registry key encoded as a STRING type.

20. xml. The element content is XML. See Section 5.

21. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-dtype

Optional. STRING. A means by which to extend the dtype attribute. See Section 5.1.1.

meaning
Optional. STRING. A free-form text description of the element content.

formatid
Optional. STRING. An identifier referencing the format or semantics of the element content.

restriction
Optional. ENUM. See Section 3.3.1.

ext-restriction
Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

observable-id
Optional. ID. See Section 3.3.2.

3. The IODEF Information Model

The specifics of the IODEF information model are discussed in this section. Each class and its relationships with the other classes is described. When necessary, clarifications are made about translating this information model to the schema in Section 8.

3.1. IODEF-Document Class

The IODEF-Document class is the top level class in the IODEF data model. All IODEF documents are an instance of this class.

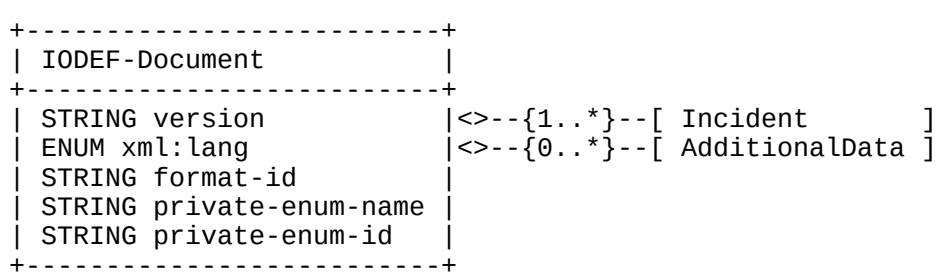

Figure 5: IODEF-Document Class

The aggregate classes of the IODEF-Document class are:

Incident

One or more. The information related to a single incident. See Section 3.2.

AdditionalData
Zero or more. EXTENSION. Mechanism by which to extend the data model.

The attributes of the IODEF-Document class are:

version
Required. STRING. The IODEF specification version number to which this IODEF document conforms. The value of this attribute MUST be "2.00"

xml:lang
Optional. ENUM. A language identifier per Section 2.12 of [W3C.XML] whose values and form are described in [RFC5646]. The interpretation of this code is described in Section 6.

format-id
Optional. STRING. A free-form string to convey processing instructions to the recipient of the document. Its semantics must be negotiated out-of-band.

private-enum-name
Optional. STRING. A globally unique identifier for the CSIRT generating the document to deconflict private extensions used in the document. The fully qualified domain name associated with the CSIRT MUST be used as the identifier. See Section 5.3.

private-enum-id
Optional. STRING. An organizationally unique identifier for an extension used in the document. If this attribute is set, the private-enum-name MUST also be set. See Section 5.3.

3.2. Incident Class

The Incident class describes commonly exchanged information when reporting or sharing derived analysis from security incidents.

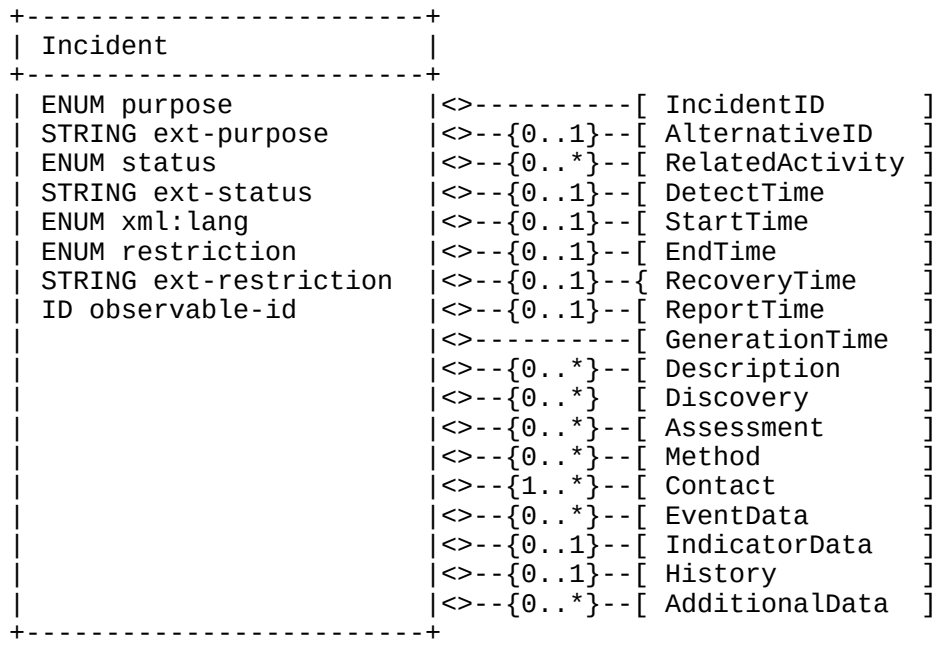

Figure 6: The Incident Class

The aggregate classes of the Incident class are:

IncidentID
: One. An incident tracking number assigned to this incident by the CSIRT that generated the IODEF document. See Section 3.4.

AlternativeID
: Zero or one. The incident tracking numbers used by other CSIRTs to refer to the incident described in the document. See Section 3.5.

RelatedActivity
: Zero or more. Related activity and attribution of this activity. See Section 3.6.

DetectTime
: Zero or one. DATETIME. The time the incident was first detected.

StartTime
: Zero or one. DATETIME. The time the incident started.

EndTime
: Zero or one. DATETIME. The time the incident ended.

RecoveryTime
Zero or one. DATETIME. The time the site recovered from the incident.

ReportTime
Zero or one. DATETIME. The time the incident was reported.

GenerationTime
One. DATETIME. The time the content in this Incident class was generated.

Description
Zero or more. ML_STRING. A free-form text description of the incident.

Discovery
Zero or more. The means by which this incident was detected. See Section 3.10.

Assessment
Zero or more. A characterization of the impact of the incident. See Section 3.12.

Method
Zero or more. The techniques used by the threat actor in the incident. See Section 3.11.

Contact
One or more. Contact information for the parties involved in the incident. See Section 3.9.

EventData
Zero or more. Description of the events comprising the incident. See Section 3.14.

IndicatorData
Zero or one. Indicators from the analysis of an incident. See Section 3.28.

History
Zero or one. A log of significant events or actions that occurred during the course of handling the incident. See Section 3.13.

AdditionalData
Zero or more. EXTENSION. Mechanism by which to extend the data model.

The attributes of the Incident class are:

purpose
Required. ENUM. The purpose attribute represents describes the rational for document the information in this class. It is closely related to the Expectation class (Section 3.15). These values are maintained in the "Incident-purpose" IANA registry per Section 10.2. This attribute is defined as an enumerated list:

1. traceback. The Incident was sent for trace-back purposes.

2. mitigation. The Incident was sent to request aid in mitigating the described activity.

3. reporting. The Incident was sent to comply with reporting requirements.

4. watch. The Incident was sent to convey indicators that should be monitored.

5. other. The Incident was sent for purposes specified in the Expectation class.

6. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-purpose
Optional. STRING. A means by which to extend the purpose attribute. See Section 5.1.1.

status
Optional. ENUM. The status attribute conveys the state in a workflow where the incident is currently found. These values are maintained in the "Incident-status" IANA registry per Section 10.2. This attribute is defined as an enumerated list:

1. new. The Incident is newly reported and has not been actioned.

2. in-progress. The contents of this Incident are under investigation.

3. forwarded. The Incident has been forwarded to another party for handling.

4. resolved. The investigation into the activity in this Incident has concluded.

5. future. The described activity has not yet been detected.

6. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-status
Optional. STRING. A means by which to extend the status attribute. See Section 5.1.1.

xml:lang
Optional. ENUM. A language identifier per Section 2.12 of [W3C.XML] whose values and form are described in [RFC5646]. The interpretation of this code is described in Section 6.

restriction
Optional. ENUM. See Section 3.3.1. The default value is "private".

ext-restriction
Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

observable-id
Optional. ID. See Section 3.3.2.

3.3. Common Attributes

There are a number of recurring attributes used in the information model. They are documented in this section.

3.3.1. restriction Attribute

The restriction attribute indicates the disclosure guidelines to which the sender expects the recipient to adhere for the information represented in this class and its children. This guideline provides no security since there are no technical means to ensure that the recipient of the document handles the information as the sender requested.

The value of this attribute is logically inherited by the children of this class. That is to say, the disclosure rules applied to this class, also apply to its children.

It is possible to set a granular disclosure policy, since all of the high-level classes (i.e., children of the Incident class) have a restriction attribute. Therefore, a child can override the guidelines of a parent class, be it to restrict or relax the disclosure rules (e.g., a child has a weaker policy than an ancestor; or an ancestor has a weak policy, and the children selectively apply

more rigid controls). The implicit value of the restriction attribute for a class that did not specify one can be found in the closest ancestor that did specify a value.

This attribute is defined as an enumerated value with a default value of "private". Note that the default value of the restriction attribute is only defined in the context of the Incident class. In other classes where this attribute is used, no default is specified.

These values are maintained in the "Restriction" IANA registry per Section 10.2.

1. public. The information can be freely distributed without restriction.

2. partner. The information may be shared within a closed community of peers, partners, or affected parties, but cannot be openly published.

3. need-to-know. The information may be shared only within the organization with individuals that have a need to know.

4. private. The information may not be shared.

5. default. The information can be shared according to an information disclosure policy pre-arranged by the communicating parties.

6. white. Same as ’public’.

7. green. Same as ’partner’.

8. amber. Same as ’need-to-know’.

9. red. Same as ’private’.

10. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

3.3.2. observable-id Attribute

The observable-id attribute tags information in the document as an observable so that it can be referenced later in the description of an indicator. The value of this attribute is a unique identifier in the scope of the document. It is used by the ObservableReference class to enumerate observables when defining an indicator with the IndicatorData class.

3.4. IncidentID Class

The IncidentID class represents a tracking number that is unique in the context of the CSIRT. It serves as an identifier for an incident or a document identifier when sharing indicators. This identifier would serve as an index into a CSIRT's incident handling or knowledge management system.

The combination of the name attribute and the string in the element content MUST be a globally unique identifier describing the activity. Documents generated by a given CSIRT MUST NOT reuse the same value unless they are referencing the same incident.

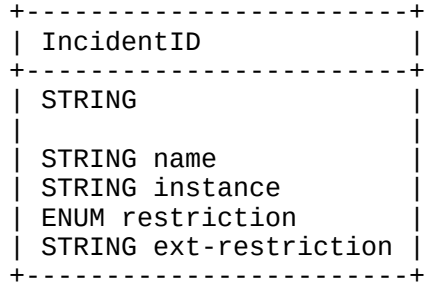

Figure 7: The IncidentID Class

The content of the class is an incident identifier of type STRING.

The attributes of the IncidentID class are:

name
: Required. STRING. An identifier describing the CSIRT that created the document. In order to have a globally unique CSIRT name, the fully qualified domain name associated with the CSIRT MUST be used.

instance
: Optional. STRING. An identifier referencing a subset of the named incident.

restriction
: Optional. ENUM. See Section 3.3.1.

ext-restriction
: Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

3.5. AlternativeID Class

The AlternativeID class lists the tracking numbers used by CSIRTs, other than the one generating the document, to refer to the identical activity described in the IODEF document. A tracking number listed as an AlternativeID references the same incident detected by another CSIRT. The tracking numbers of the CSIRT that generated the IODEF document must never be considered an AlternativeID.

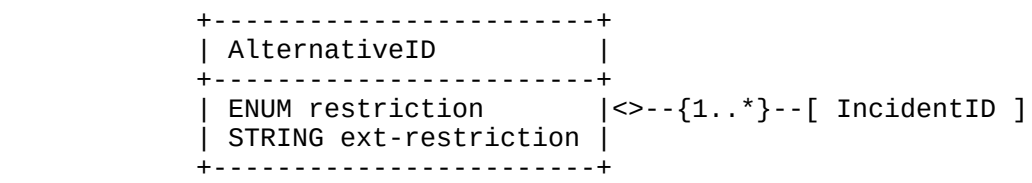

Figure 8: The AlternativeID Class

The aggregate class of the AlternativeID class is:

IncidentID
: One or more. The tracking number of another CSIRT. See Section 3.4.

The attributes of the AlternativeID class are:

restriction
: Optional. ENUM. See Section 3.3.1.

ext-restriction
: Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

3.6. RelatedActivity Class

The RelatedActivity class relates the information described in the rest of the document to previously observed incidents or activity; and allows attribution to a specific actor or campaign.

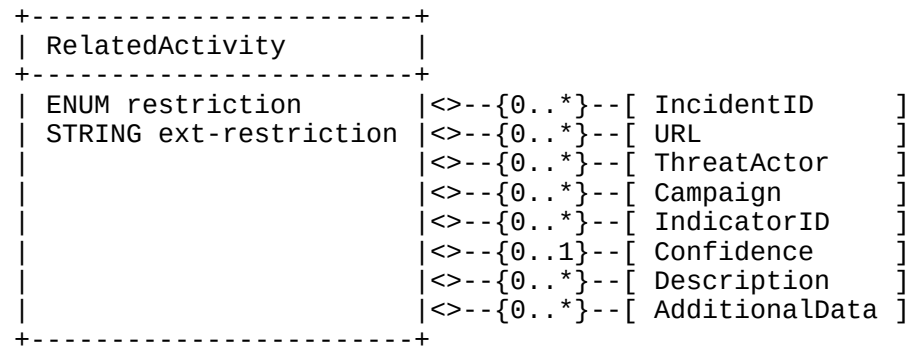

Figure 9: RelatedActivity Class

The aggregate classes of the RelatedActivity class are:

IncidentID
: Zero or more. The tracking number of a related incident. See Section 3.4.

URL
: Zero or more. URL. A URL to activity related to this incident.

ThreatActor
: Zero or more. The threat actor to whom the incident activity is attributed. See Section 3.7.

Campaign
: Zero or more. The campaign of a given threat actor to whom the described activity is attributed. See Section 3.8.

IndicatorID
: Zero or more. A reference to a related indicator. See Section 3.4.

Confidence
: Zero or one. An estimate of the confidence in attributing this RelatedActivity to the events described in the document. See Section 3.12.5.

Description
: Zero or more. ML_STRING. A description of how these relationships were derived.

AdditionalData
: Zero or more. EXTENSION. A mechanism by which to extend the data model.

The RelatedActivity class MUST have at least one instance of any of the following child classes: IncidentID, URL, ThreatActor, Campaign, Description or AdditionalData.

The attributes of the RelatedActivity class are:

restriction
: Optional. ENUM. See Section 3.3.1.

ext-restriction
: Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

3.7. ThreatActor Class

The ThreatActor class describes a threat actor.

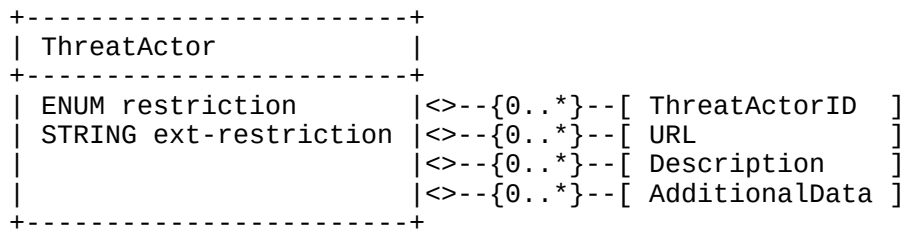

Figure 10: ThreatActor Class

The aggregate classes of the ThreatActor class are:

ThreatActorID
: Zero or more. STRING. An identifier for the threat actor.

URL
: Zero or more. URL. A URL to a reference describing the threat actor.

Description
: Zero or more. ML_STRING. A description of the threat actor.

AdditionalData
: Zero or more. EXTENSION. A mechanism by which to extend the data model.

The ThreatActor class MUST have at least one instance of a child class.

The attributes of the ThreatActor class are:

restriction
Optional. ENUM. See Section 3.3.1.

ext-restriction
Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

3.8. Campaign Class

The Campaign class describes a campaign of attacks by a threat actor.

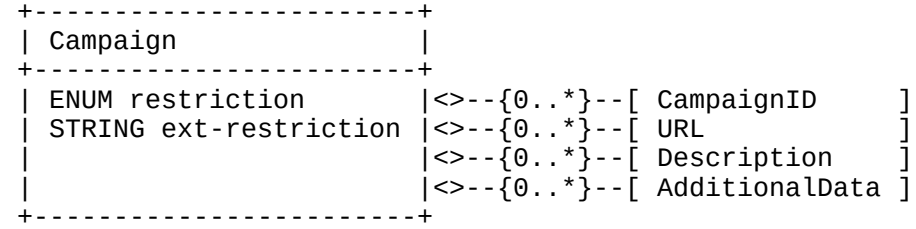

Figure 11: Campaign Class

The aggregate classes of the Campaign class are:

CampaignID
Zero or more. STRING. An identifier for the campaign.

URL
Zero or more. URL. A URL to a reference describing the campaign.

Description
Zero or more. ML_STRING. A description of the campaign.

AdditionalData
Zero or more. EXTENSION. A mechanism by which to extend the data model.

The Campaign class MUST have at least one instance of a child class.

The attributes of the Campaign class are:

restriction
Optional. ENUM. See Section 3.3.1.

ext-restriction
Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

3.9. Contact Class

The Contact class describes contact information for organizations and personnel involved in the incident. This class allows for the naming of the involved party, specifying contact information for them, and identifying their role in the incident.

People and organizations are treated interchangeably as contacts; one can be associated with the other using the recursive definition of the class (the Contact class is aggregated into the Contact class). The 'type' attribute disambiguates the type of contact information being provided.

The recursive definition of Contact provides a way to relate information without requiring the explicit use of identifiers or duplication of data. A complete point of contact is derived by a particular traversal from the root Contact class to the leaf Contact class. Each child Contact class logically inherits contact information from its ancestors.

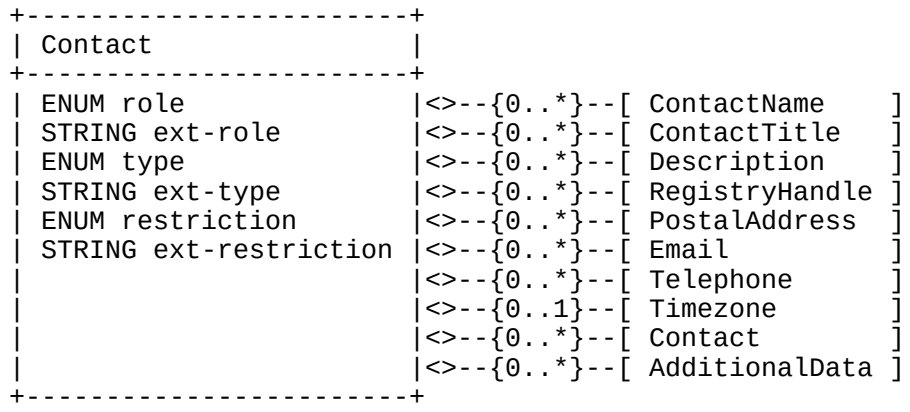

Figure 12: The Contact Class

The aggregate classes of the Contact class are:

ContactName
: Zero or more. ML_STRING. The name of the contact. The contact may either be an organization or a person. The type attribute disambiguates the semantics.

ContactTitle
: Zero or more. ML_STRING. The title for the individual named in the ContactName.

Description
Zero or more. ML_STRING. A free-form text description of the contact.

RegistryHandle
Zero or more. A handle name into the registry of the contact. See Section 3.9.1.

PostalAddress
Zero or more. The postal address of the contact. See Section 3.9.2.

Email
Zero or more. The email address of the contact. See Section 3.9.3.

Telephone
Zero or more. The telephone number of the contact. See Section 3.9.4.

Timezone
Zero or one. TIMEZONE. The timezone in which the contact resides.

Contact
Zero or more. A recursive definition of the Contact class. This definition can be used to group common data pertaining to multiple points of contact and is especially useful when listing multiple contacts at the same organization.

AdditionalData
Zero or more. EXTENSION. A mechanism by which to extend the data model.

At least one of the aggregate classes MUST be present in an instance of the Contact class.

The attributes of the Contact class are:

role
Required. ENUM. Indicates the role the contact fulfills. These values are maintained in the "Contact-role" IANA registry per Section 10.2.

1. creator. The entity that generate the document.

2. reporter. The entity that reported the information.

3. admin. An administrative contact or business owner for an asset or organization.

4. tech. An entity responsible for the day-to-day management of technical issues for an asset or organization.

5. provider. An external hosting provider for an asset.

6. user. An end-user of an asset or part of an organization.

7. billing. An entity responsible for billing issues for an asset or organization.

8. legal. An entity responsible for legal issue related to an asset or organization.

9. irt. An entity responsible for handling security issues for an asset or organization.

10. abuse. An entity responsible for handling abuse originating from an asset or organization.

11. cc. An entity that is to be kept informed about the events related to an asset or organization.

12. cc-irt. A CSIRT or information sharing organization coordinating activity related to an asset or organization.

13. leo. A law enforcement organization supporting the investigation of activity affecting an asset or organization.

14. vendor. The vendor that produces an asset.

15. vendor-support. A vendor that provides services.

16. victim. A victim in the incident.

17. victim-notified. A victim in the incident who has been notified.

18. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-role
: Optional. STRING. A means by which to extend the role attribute. See Section 5.1.1.

type
Required. ENUM. Indicates the type of contact being described. This attribute is defined as an enumerated list. These values are maintained in the "Contact-type" IANA registry per Section 10.2.

1. person. The information for this contact references an individual.

2. organization. The information for this contact references an organization.

3. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-type
Optional. STRING. A means by which to extend the type attribute. See Section 5.1.1.

restriction
Optional. ENUM. See Section 3.3.1.

ext-restriction
Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

3.9.1. RegistryHandle Class

The RegistryHandle class represents a handle into an Internet registry or community-specific database.

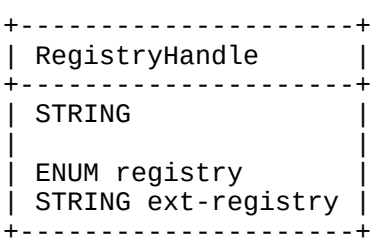

Figure 13: The RegistryHandle Class

The content of the class is a handle into a registry of type STRING.

The attributes of the RegistryHandle class are:

registry

Required. ENUM. The database to which the handle belongs. These values are maintained in the "RegistryHandle-registry" IANA registry per Section 10.2. The possible values are:

1. internic. Internet Network Information Center

2. apnic. Asia Pacific Network Information Center

3. arin. American Registry for Internet Numbers

4. lacnic. Latin-American and Caribbean IP Address Registry

5. ripe. Reseaux IP Europeens

6. afrinic. African Internet Numbers Registry

7. local. A database local to the CSIRT

8. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-registry
Optional. STRING. A means by which to extend the registry attribute. See Section 5.1.1.

3.9.2. PostalAddress Class

The PostalAddress class specifies an postal address and associated annotation.

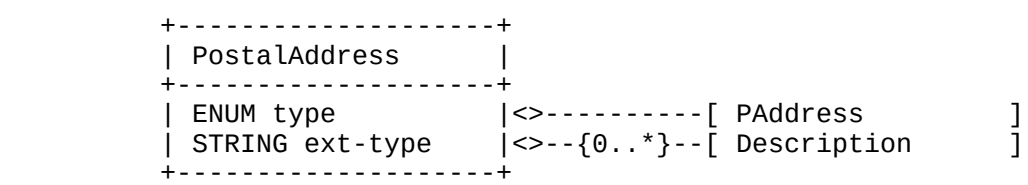

Figure 14: The PostalAddress Class

The aggregate classes of the PostalAddress class are:

PAddress
One. POSTAL. A postal address.

Description
Zero or more. ML_STRING. A free-form text description of the address.

The attributes of the PostalAddress class are:

type
: Optional. ENUM. Categorizes the type of address described in the PAddress class. These values are maintained in the "PostalAddress-type" IANA registry per Section 10.2.

  1. street. An address describing a physical location.

  2. mailing. An address to which correspondence should be sent.

  3. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-type
: Optional. STRING. A means by which to extend the type attribute. See Section 5.1.1.

3.9.3. Email Class

The Email class specifies an email address and associated annotation.

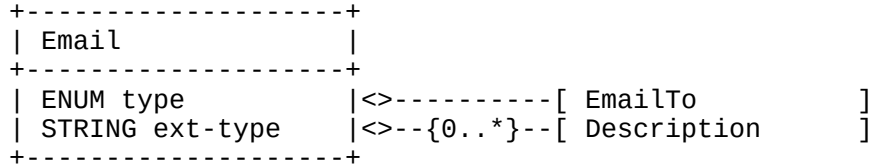

Figure 15: The Email Class

The aggregate classes of the Email class are:

EmailTo
: One. EMAIL. An email address.

Description
: Zero or more. ML_STRING. A free-form text description of the email address.

The attributes of the Email class are:

type
: Optional. ENUM. Categorizes the type of email address described in the EmailTo class. These values are maintained in the "Email-type" IANA registry per Section 10.2.

1. direct. A email address of an individual.

2. hotline. A email address regularly monitored for operational purposes.

3. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-type
Optional. STRING. A means by which to extend the type attribute. See Section 5.1.1.

3.9.4. Telephone Class

The Telephone class describes a telephone number and associated annotation.

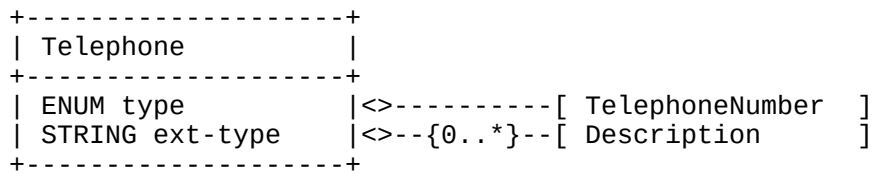

Figure 16: The Telephone Class

The aggregate classes of the Telephone class are:

TelephoneNumber
One. PHONE. A telephone number.

Description
Zero or more. ML_STRING. A free-form text description of the phone number.

The attributes of the Telephone class are:

type
Optional. ENUM. Categorizes the type of telephone number described in the TelephoneNumber class. These values are maintained in the "Telephone-type" IANA registry per Section 10.2.

1. wired. A number of a wire-line (land-line) phone.

2. mobile. A number of a mobile phone.

3. fax. A number to a fax machine.

4. hotline. A number to a regularly monitored operational hotline.

5. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-type
Optional. STRING. A means by which to extend the type attribute. See Section 5.1.1.

3.10. Discovery Class

The Discovery class describes how an incident was detected.

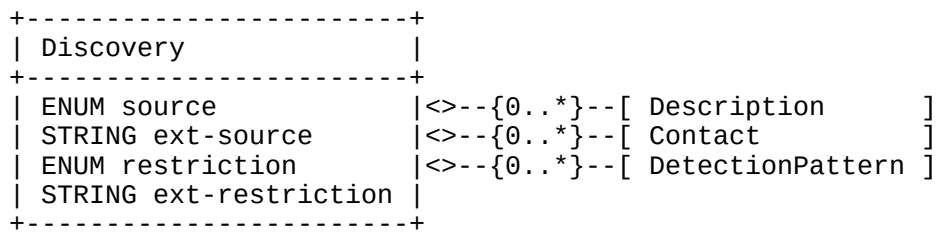

Figure 17: The Discovery Class

The aggregate classes of the Discovery class are:

Description
Zero or more. ML_STRING. A free-form text description of how this incident was detected.

Contact
Zero or more. Contact information for the party that discovered the incident. See Section 3.9.

DetectionPattern
Zero or more. Describes an application-specific configuration that detected the incident. See Section 3.10.1.

The attributes of the Discovery class are:

source
Optional. ENUM. Categorizes the techniques used to discover the incident. These values are partially derived from Table 3-1 of [NIST800.61rev2]. These values are maintained in the "Discovery-source" IANA registry per Section 10.2.

1. nidps. Network Intrusion Detection or Prevention system.

2. hips. Host-based Intrusion Prevention system.

3. siem. Security Information and Event Management System.

4. av. Antivirus or and antispam software.

5. third-party-monitoring. Contracted third-party monitoring service.

6. incident. The activity was discovered while investigating an unrelated incident.

7. os-log. Operating system logs.

8. application-log. Application logs.

9. device-log. Network device logs.

10. network-flow. Network flow analysis.

11. passive-dns. Passive DNS analysis.

12. investigation. Manual investigation initiated based on notification of a new vulnerability or exploit.

13. audit. Security audit.

14. internal-notification. A party within the organization reported the activity

15. external-notification. A party outside of the organization reported the activity.

16. leo. A law enforcement organization notified the victim organization.

17. partner. A customer or business partner reported the activity to the victim organization.

18. actor. The threat actor directly or indirectly reported this activity to the victim organization.

19. unknown. Unknown detection approach.

20. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-source
Optional. STRING. A means by which to extend the source attribute. See Section 5.1.1.

restriction
Optional. ENUM. See Section 3.3.1.

ext-restriction
Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

3.10.1. DetectionPattern Class

The DetectionPattern class describes a configuration or signature that can be used by an IDS/IPS, SIEM, anti-virus, end-point protection, network analysis, malware analysis, or host forensics tool to identify a particular phenomenon. This class requires the identification of the target application and allows the configuration to be described in either free-form or machine readable form.

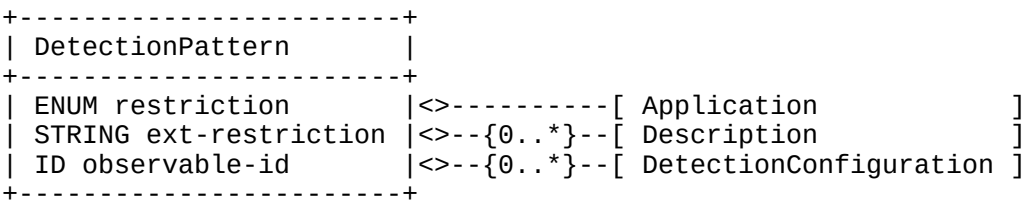

Figure 18: The DetectionPattern Class

The aggregate classes of the DetectionPattern class are:

Application
One. SOFTWARE. The application for which the DetectionConfiguration or Description is being provided.

Description
Zero or more. ML_STRING. A free-form text description of how to use the Application or provided DetectionConfiguration.

DetectionConfiguration
Zero or more. STRING. A machine consumable configuration to find a pattern of activity.

Either an instance of the Description or DetectionConfiguration class MUST be present.

The attributes of the DetectionPattern class are:

restriction
Optional. ENUM. See Section 3.3.1.

ext-restriction
Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

observable-id
Optional. ID. See Section 3.3.2.

3.11. Method Class

The Method class describes the tactics, techniques, procedures or weakness used by the threat actor in an incident. This class consists of both a list of references describing the attack methods and weaknesses and a free-form text description.

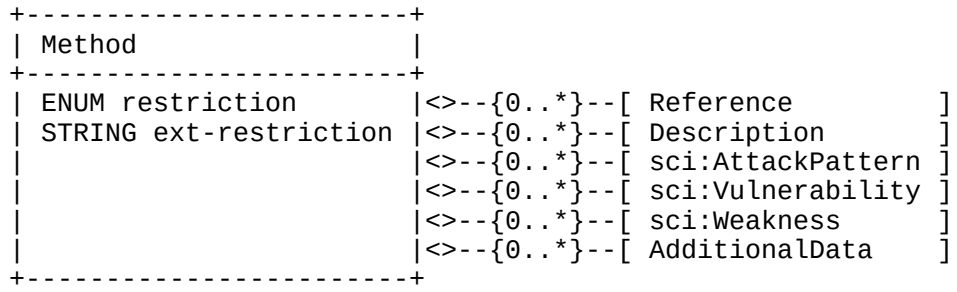

Figure 19: The Method Class

The aggregate classes of the Method class are:

Reference
Zero or more. A reference to a vulnerability, malware sample, advisory, or analysis of an attack technique. See Section 3.11.1.

Description
Zero or more. ML_STRING. A free-form text description of techniques, tactics, or procedures used by the threat actor.

sci:AttackPattern
Zero or more. A reference to an pattern of attack or exploitation per [RFC7203]

sci:Vulnerability
Zero or more. A reference to a vulnerability per [RFC7203]

sci:Weakness
Zero or more. A reference to the exploited weakness per [RFC7203]

AdditionalData
Zero or more. EXTENSION. A mechanism by which to extend the data model.

An instance of one of these child MUST be present.

The attributes of the Method class are:

restriction
Optional. ENUM. See Section 3.3.1.

ext-restriction
Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

3.11.1. Reference Class

The Reference class is an external reference to relevant information such a vulnerability, IDS alert, malware sample, advisory, or attack technique.

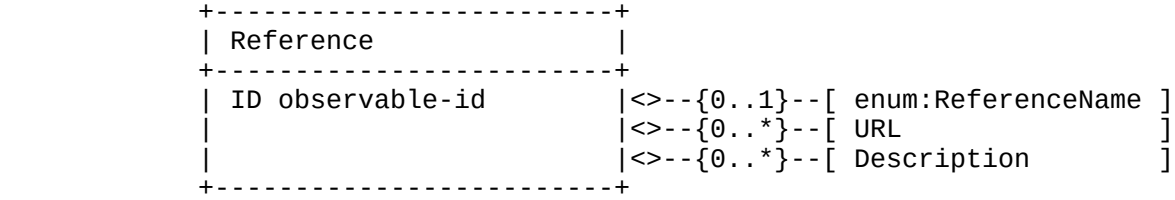

Figure 20: The Reference Class

The aggregate classes of the Reference class are:

enum:ReferenceName
Zero or one. Reference identifier per [RFC7495].

URL
Zero or more. URL. A URL to a reference.

Description
Zero or more. ML_STRING. A free-form text description of this reference.

At least one of these classes MUST be present.

The attribute of the Reference class is:

observable-id
Optional. ID. See Section 3.3.2.

3.12. Assessment Class

The Assessment class describes the repercussions of the incident to the victim.

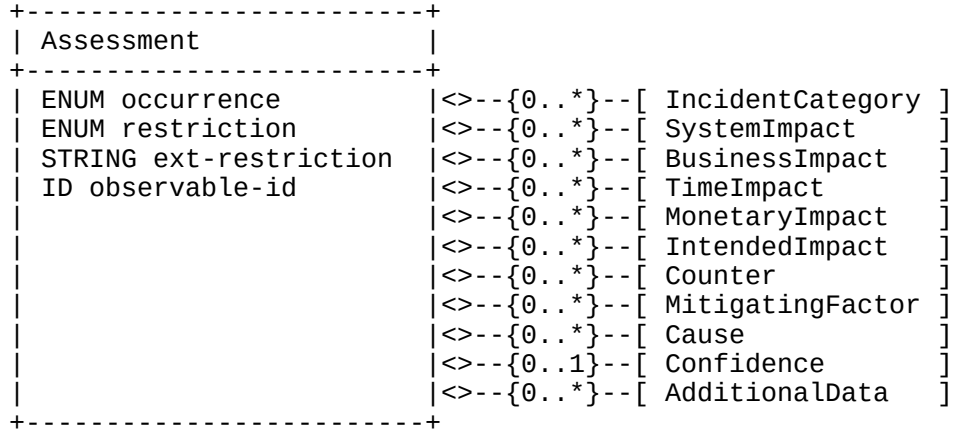

Figure 21: Assessment Class

The aggregate classes of the Assessment class are:

IncidentCategory
Zero or more. ML_STRING. A free-form text description categorizing the type of Incident.

SystemImpact
Zero or more. A technical characterization of the impact of the incident activity on the victim's enterprise. See Section 3.12.1.

BusinessImpact
Zero or more. Impact of the incident activity on the business functions of the victim organization. See Section 3.12.2.

TimeImpact
Zero or more. A characterization of the victim organization due to the incident activity as a function of time. See Section 3.12.3.

MonetaryImpact
Zero or more. The financial loss due to the incident activity. See Section 3.12.4.

IntendedImpact
Zero or more. The intended outcome to the victim sought by the threat actor. Defined identically to the BusinessImpact defined in Section 3.12.2, but describes intent rather than the realized impact.

Counter
Zero or more. A counter with which to summarize the magnitude of the activity. See Section 3.18.3.

MitigatingFactor
Zero or more. ML_STRING. A description of a mitigating factor relative to the impact on the victim organization.

Cause
Zero or more. ML_STRING. A description of an underlying cause of the impact.

Confidence
Zero or one. An estimate of confidence in the impact assessment. See Section 3.12.5.

AdditionalData
Zero or more. EXTENSION. A mechanism by which to extend the data model.

A least one instance of the possible five impact classes (i.e., SystemImpact, BusinessImpact, TimeImpact, MonetaryImpact or IntendedImpact) MUST be present.

The attributes of the Assessment class are:

occurrence
Optional. ENUM. Specifies whether the assessment is describing actual or potential outcomes.

1. actual. This assessment describes activity that has occurred.

2. potential. This assessment describes potential activity that might occur.

restriction
Optional. ENUM. See Section 3.3.1.

ext-restriction
Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

observable-id
Optional. ID. See Section 3.3.2.

3.12.1. SystemImpact Class

The SystemImpact class describes the technical impact of the incident to the systems on the network.

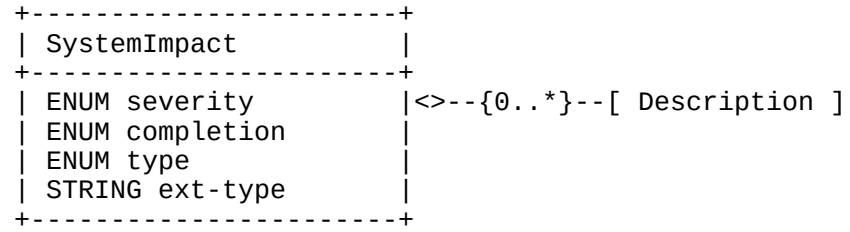

Figure 22: SystemImpact Class

The aggregate class of the SystemImpact class is:

Description
Zero or more. ML_STRING. A free-form text description of the impact to the system.

The attributes of the SystemImpact class are:

severity
Optional. ENUM. An estimate of the relative severity of the activity. The permitted values are shown below. There is no default value.

1. low. Low severity

2. medium. Medium severity

3. high. High severity

completion
Optional. ENUM. An indication whether the described activity was successful. The permitted values are shown below. There is no default value.

1. failed. The attempted activity was not successful.

2. succeeded. The attempted activity succeeded.

type
Required. ENUM. Classifies the impact. The permitted values are shown below. The default value is "unknown". These values are maintained in the "SystemImpact-type" IANA registry per Section 10.2.

1. takeover-account. Control was taken of a given account.

2. takeover-service. Control was taken of a given service.

3. takeover-system. Control was taken of a given system.

4. cps-manipulation. A cyber-physical system was manipulated.

5. cps-damage. A cyber-physical system was damaged.

6. availability-data. Access to particular data was degraded or denied.

7. availability-account. Access to an account was degraded or denied.

8. availability-service. Access to a service was degraded or denied.

9. availability-system. Access to a system was degraded or denied.

10. damaged-system. Hardware on a system was irreparably damaged.

11. damaged-data. Data on a system was deleted.

12. breach-proprietary. Sensitive or proprietary information was accessed or exfiltrated.

13. breach-privacy. Personally identifiable information was accessed or exfiltrated.

14. breach-credential. Credential information was accessed or exfiltrated.

15. breach-configuration. System configuration or data inventory was access or exfiltrated.

16. integrity-data. Data on the system was modified.

17. integrity-configuration. Application or system configuration was modified.

18. integrity-hardware. Firmware of a hardware component was modified.

19. traffic-redirection. Network traffic on the system was redirected

20. monitoring-traffic. Network traffic emerging from a host or enclave was monitored.

21. monitoring-host. System activity (e.g., running processes, keystrokes) were monitored.

22. policy. Activity violated the system owner's acceptable use policy.

23. unknown. The impact is unknown.

24. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-type
Optional. STRING. A means by which to extend the type attribute. See Section 5.1.1.

3.12.2. BusinessImpact Class

The BusinessImpact class describes and characterizes the degree to which the function of the organization was impacted by the Incident.

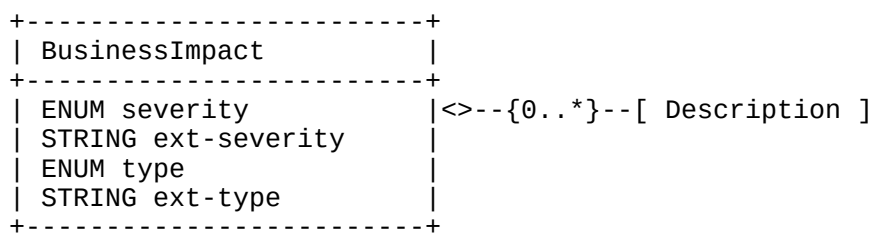

Figure 23: BusinessImpact Class

The aggregate class of the BusinessImpact class is:

Description
Zero or more. ML_STRING. A free-form text description of the impact to the organization.

The attributes of the BusinessImpact class are:

severity
Optional. ENUM. Characterizes the severity of the incident on business functions. The permitted values are shown below. They were derived from Table 3-2 of [NIST800.61rev2]. The default value is "unknown". These values are maintained in the "BusinessImpact-severity" IANA registry per Section 10.2.

1. none. No effect to the organization’s ability to provide all services to all users.

2. low. Minimal effect as the organization can still provide all critical services to all users but has lost efficiency.

3. medium. The organization has lost the ability to provide a critical service to a subset of system users.

4. high. The organization is no longer able to provide some critical services to any users.

5. unknown. The impact is not known.

6. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-severity
Optional. STRING. A means by which to extend the severity attribute. See Section 5.1.1.

type
Required. ENUM. Characterizes the effect this incident had on the business. The permitted values are shown below. The default value is "unknown". These values are maintained in the "BusinessImpact-type" IANA registry per Section 10.2.

1. breach-proprietary. Sensitive or proprietary information was accessed or exfiltrated.

2. breach-privacy. Personally identifiable information was accessed or exfiltrated.

3. breach-credential. Credential information was accessed or exfiltrated.

4. loss-of-integrity. Sensitive or proprietary information was changed or deleted.

5. loss-of-service. Service delivery was disrupted.

6. theft-financial. Money was stolen.

7. theft-service. Services were misappropriated.

8. degraded-reputation. The reputation of the organization's brand was diminished.

9. asset-damage. A cyber-physical system was damaged.

10. asset-manipulation. A cyber-physical system was manipulated.

11. legal. The incident resulted in legal or regulatory action.

12. extortion. The incident resulted in actors extorting the victim organization.

13. unknown. The impact is unknown.

14. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-type
Optional. STRING. A means by which to extend the type attribute. See Section 5.1.1.

3.12.3. TimeImpact Class

The TimeImpact class describes the impact of the incident on an organization as a function of time. It provides a way to convey down time and recovery time.

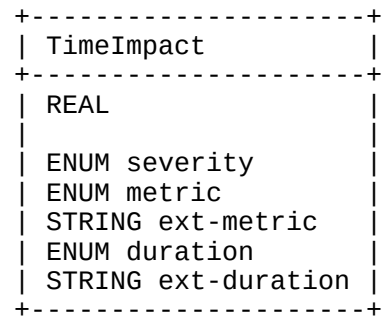

Figure 24: TimeImpact Class

The content of the class is of type REAL and specifies an amount of time. The duration attribute provides units for this content; and the metric attribute explains what this content is measuring.

The attributes of the TimeImpact class are:

severity
: Optional. ENUM. An estimate of the relative severity of the activity. The permitted values are shown below. There is no default value.

  1. low. Low severity

  2. medium. Medium severity

  3. high. High severity

metric
: Required. ENUM. Defines the meaning of the value in the element content. These values are maintained in the "TimeImpact-metric" IANA registry per Section 10.2.

  1. labor. Total staff-time to recovery from the activity (e.g., 2 employees working 4 hours each would be 8 hours).

  2. elapsed. Elapsed time from the beginning of the recovery to its completion (i.e., wall-clock time).

  3. downtime. Duration of time for which some provided service(s) was not available.

  4. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-metric
Optional. STRING. A means by which to extend the metric attribute. See Section 5.1.1.

duration
Optional. ENUM. Defines the unit of time for the value in the element content. The default value is "hour". These values are maintained in the "TimeImpact-duration" IANA registry per Section 10.2.

1. second. The unit of the element content is seconds.

2. minute. The unit of the element content is minutes.

3. hour. The unit of the element content is hours.

4. day. The unit of the element content is days.

5. month. The unit of the element content is months.

6. quarter. The unit of the element content is quarters.

7. year. The unit of the element content is years.

8. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-duration
Optional. STRING. A means by which to extend the duration attribute. See Section 5.1.1.

3.12.4. MonetaryImpact Class

The MonetaryImpact class describes the financial impact of the activity on an organization. For example, this impact may consider losses due to the cost of the investigation or recovery, diminished productivity of the staff, or a tarnished reputation that will affect future opportunities.

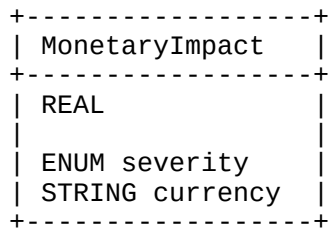

Figure 25: MonetaryImpact Class

The content of the class is of type REAL and specifies a quantity of money. The currency attribute defines the currently of this value.

The attributes of the MonetaryImpact class are:

severity
: Optional. ENUM. An estimate of the relative severity of the activity. The permitted values are shown below. There is no default value.

  1. low. Low severity

  2. medium. Medium severity

  3. high. High severity

currency
: Optional. STRING. Defines the currency in which the value in the element content is expressed. The permitted values are defined in "Codes for the representation of currencies and funds" of [ISO4217]. There is no default value.

3.12.5. Confidence Class

The Confidence class represents an estimate of the validity and accuracy of data expressed in the document. This estimate can be expressed as a category or a numeric calculation.

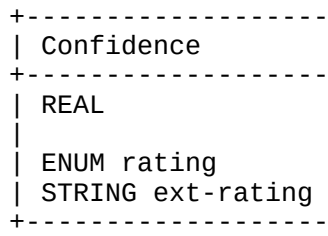

Figure 26: Confidence Class

The content of the class is of type REAL and specifies a numerical assessment in the confidence of the data when the value of the rating attribute is "numeric". Otherwise, this element MUST be empty.

The attributes of the Confidence class are:

rating
: Required. ENUM. A qualitative assessment of confidence. These values are maintained in the "Confidence-rating" IANA registry per Section 10.2

1. low. Low confidence.

2. medium. Medium confidence.

3. high. High confidence.

4. numeric. The element content contains a number that conveys the confidence of the data. The semantics of this number outside the scope of this specification.

5. unknown. The confidence rating value is not known.

6. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-rating
: Optional. STRING. A means by which to extend the rating attribute. See Section 5.1.1.

3.13. History Class

The History class is a log of the significant events or actions performed by the involved parties during the course of handling the incident.

The level of detail maintained in this log is left up to the discretion of those handling the incident.

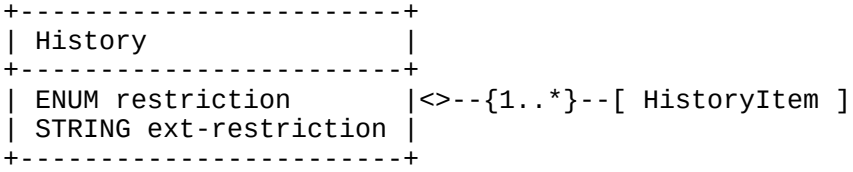

Figure 27: The History Class

The aggregate classes of the History class are:

HistoryItem
: One or more. An entry in the history log of significant events or actions performed by the involved parties. See Section 3.13.1.

The attributes of the History class are:

restriction
: Optional. ENUM. See Section 3.3.1.

ext-restriction
: Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

3.13.1. HistoryItem Class

The HistoryItem class is an entry in the History (Section 3.13) log that documents a particular action or event that occurred in the course of handling the incident. The details of the entry are a free-form text description, but each can be categorized with the type attribute.

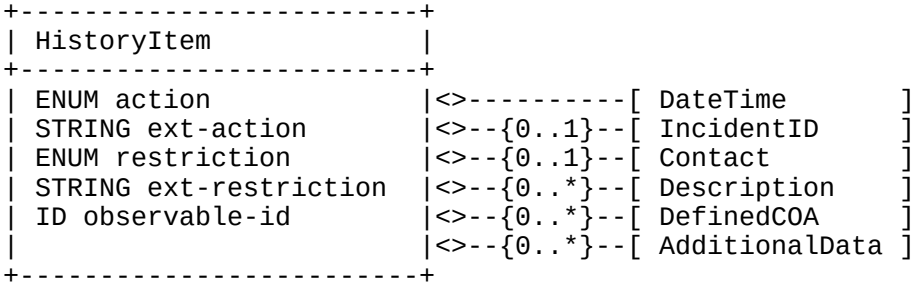

Figure 28: HistoryItem Class

The aggregate classes of the HistoryItem class are:

DateTime
One. DATETIME. A timestamp of this entry in the history log.

IncidentID
Zero or One. In a history log created by multiple parties, the IncidentID provides a mechanism to specify which CSIRT created a particular entry and references this organization's tracking number. When a single organization is maintaining the log, this class can be ignored. See Section 3.4.

Contact
Zero or One. Provides contact information for the entity that performed the action documented in this class. See Section 3.9.

Description
Zero or more. ML_STRING. A free-form text description of the action or event.

DefinedCOA
Zero or more. STRING. An identifier meaningful to the sender and recipient of this document that references a course of action (COA). This class MUST be present if the action attribute is set to "defined-coa".

AdditionalData
Zero or more. EXTENSION. A mechanism by which to extend the data model.

The attributes of the HistoryItem class are:

action
Required. ENUM. Classifies a performed action or occurrence documented in this history log entry. As activity will likely have been instigated either through a previously conveyed expectation or internal investigation. This attribute is identical to the action attribute of the Expectation class. The difference is only one of tense. When an action is in this class, it has been completed. See Section 3.15.

ext-action
Optional. STRING. A means by which to extend the action attribute. See Section 5.1.1.

restriction
Optional. ENUM. See Section 3.3.1.

ext-restriction
Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

observable-id
Optional. ID. See Section 3.3.2.

3.14. EventData Class

The EventData class is a container class to organize data about events that occurred during an incident.

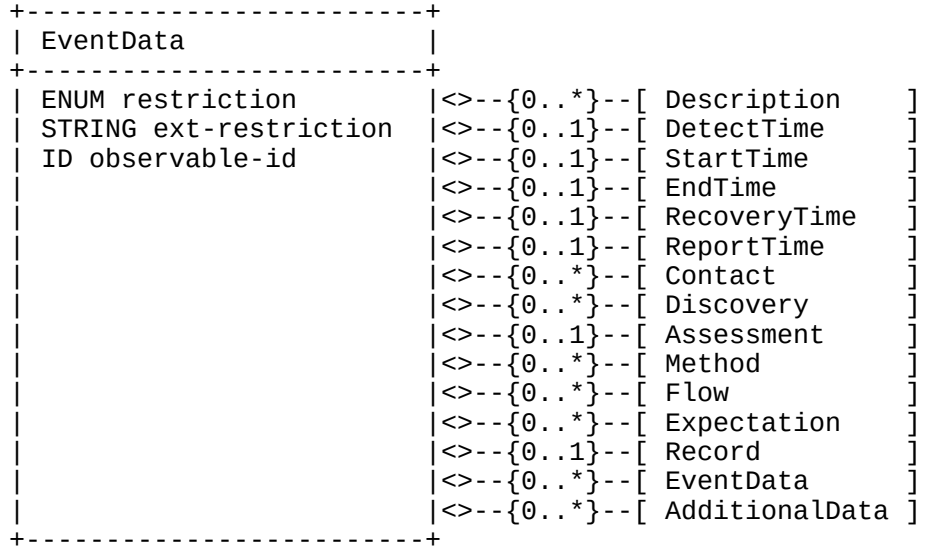

Figure 29: The EventData Class

The aggregate classes of the EventData class are:

Description
Zero or more. ML_STRING. A free-form text description of the event.

DetectTime
Zero or one. DATETIME. The time the event was detected.

StartTime
Zero or one. DATETIME. The time the event started.

EndTime
Zero or one. DATETIME. The time the event ended.

RecoveryTime
Zero or one. DATETIME. The time the site recovered from the event.

ReportTime
Zero or one. DATETIME. The time the event was reported.

Contact
Zero or more. Contact information for the parties involved in the event. See Section 3.9.

Discovery
Zero or more. The means by which the event was detected. See Section 3.10.

Assessment
Zero or one. The impact of the event on the victim and the actions taken. See Section 3.12.

Method
Zero or more. The technique used by the threat actor in the event. See Section 3.11.

Flow
Zero or more. A description of the systems or networks involved. See Section 3.16.

Expectation
Zero or more. The expected action to be performed by the recipient for the described event. See Section 3.15.

Record
Zero or one. Supportive data (e.g., log files) that provides additional information about the event. See Section 3.22.

EventData
Zero or more. A recursive definition of the EventData class. See Section 3.14.2 for an explanation on using this class.

AdditionalData
Zero or more. EXTENSION. An extension mechanism for data not explicitly represented in the data model.

At least one of the aggregate classes MUST be present in an instance of the EventData class.

The attributes of the EventData class are:

restriction
Optional. ENUM. See Section 3.3.1. The default value is "default".

ext-restriction
Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

observable-id
Optional. ID. See Section 3.3.2.

3.14.1. Relating the Incident and EventData Classes

There is substantial overlap in the child classes aggregated in the Incident and EventData classes. Nevertheless, the semantics of these classes are quite different. The Incident class provides summary information about the entire incident, while the EventData class provides information about the individual events comprising the incident. In the common case, the EventData class will provide more specific information for the general description provided in the Incident class. However, in the case where the summarized information in the Incident class conflicts the detailed information in an EventData class the more specific EventData class MUST supersede the more generic information provided in Incident class.

3.14.2. Recursive Definition of EventData

The EventData class is container for the properties of an event in an incident. These properties include: the hosts involved, impact of the incident activity on the hosts, forensic logs, etc. The recursive definition of EventData allows for the grouping of related information with common properties. This approach eliminates the need for explicit identifiers to relate information or duplicate it. Instead, the relative depth (nesting) of a class is used to group (relate) information.

For example, consider a case where two hosts experience different impacts during an incident. However, these two hosts have common contact information. A depiction of how this situation would be represented can be found in Figure 30. EventData (2) and (3) group each of the two hosts with their unique impact. EventData (1) describes the common Contact class these two hosts share.

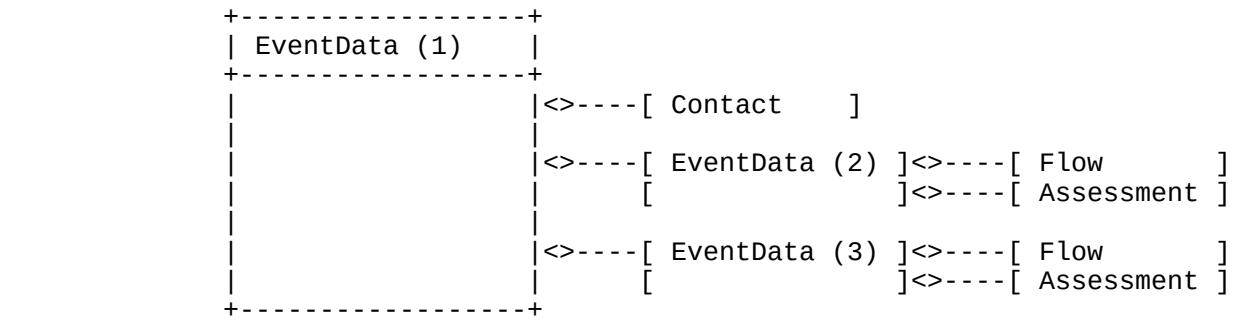

Figure 30: Recursion in the EventData Class

3.15. Expectation Class

The Expectation class conveys to the recipient of the IODEF document the actions the sender is requesting.

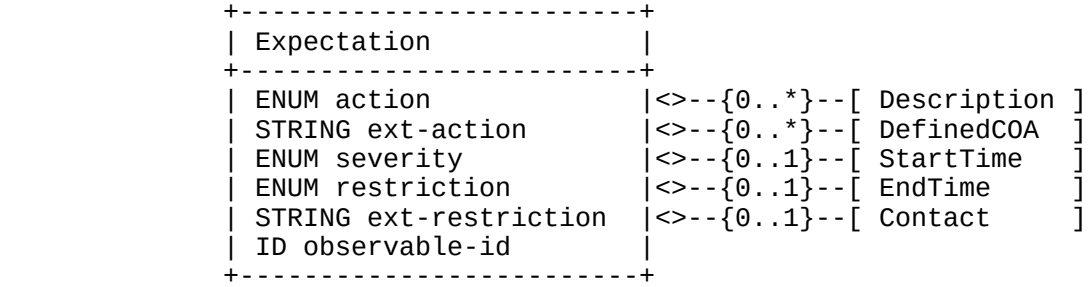

Figure 31: The Expectation Class

The aggregate classes of the Expectation class are:

Description
: Zero or more. ML_STRING. A free-form text description of the desired action(s).

DefinedCOA
: Zero or more. STRING. A unique identifier meaningful to the sender and recipient of this document that references a course of action. This class MUST be present if the action attribute is set to "defined-coa".

StartTime
: Zero or one. DATETIME. The time at which the sender would like the action performed. A timestamp that is earlier than the ReportTime specified in the Incident class denotes that the sender

would like the action performed as soon as possible. The absence of this element indicates no expectations of when the recipient would like the action performed.

EndTime
Zero or one. DATETIME. The time by which the sender expects the recipient to complete the action. If the recipient cannot complete the action before EndTime, the recipient MUST NOT carry out the action. Because of transit delays and clock drift the sender MUST be prepared for the recipient to have carried out the action, even if it completes past EndTime.

Contact
Zero or one. The entity expected to perform the action. See Section 3.9.

The attributes of the Expectation class are:

action
Optional. ENUM. Classifies the type of action requested. The default value of "other". These values are maintained in the "Expectation-action" IANA registry per Section 10.2.

1. nothing. No action is requested. Do nothing with the information.

2. contact-source-site. Contact the site(s) identified as the source of the activity.

3. contact-target-site. Contact the site(s) identified as the target of the activity.

4. contact-sender. Contact the originator of the document.

5. investigate. Investigate the systems(s) listed in the event.

6. block-host. Block traffic from the machine(s) listed as sources the event.

7. block-network. Block traffic from the network(s) lists as sources in the event.

8. block-port. Block the port listed as sources in the event.

9. rate-limit-host. Rate-limit the traffic from the machine(s) listed as sources in the event.

10. rate-limit-network. Rate-limit the traffic from the network(s) lists as sources in the event.

11. rate-limit-port. Rate-limit the port(s) listed as sources in the event.

12. redirect-traffic. Redirect traffic from the intended recipient for further analysis.

13. honeypot. Redirect traffic from systems listed in the event to a honeypot for further analysis.

14. upgrade-software. Upgrade or patch the software or firmware on an asset listed in the event.

15. rebuild-asset. Reinstall the operating system or applications on an asset listed in the event.

16. harden-asset. Change the configuration an asset listed in the event to reduce the attack surface.

17. remediate-other. Remediate the activity in a way other than by rate limiting or blocking.

18. status-triage. Confirm receipt and begin triaging the incident.

19. status-new-info. Notify the sender when new information is received for this incident.

20. watch-and-report. Watch for the described activity or indicators; and notify the sender when seen.

21. training. Train user to identify or mitigate the described threat.

22. defined-coa. Perform a predefined course of action (COA). The COA is named in the DefinedCOA class.

23. other. Perform a custom action described in the Description class.

24. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-action

Optional. STRING. A means by which to extend the action attribute. See Section 5.1.1.

severity
Optional. ENUM. Indicates the desired priority of the action. This attribute is an enumerated list with no default value, and the semantics of these relative measures are context dependent.

1. low. Low priority

2. medium. Medium priority

3. high. High priority

restriction
Optional. ENUM. See Section 3.3.1. The default value is "default".

ext-restriction
Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

observable-id
Optional. ID. See Section 3.3.2.

3.16. Flow Class

The Flow class describes the systems and networks involved in the incident; and the relationships between them.

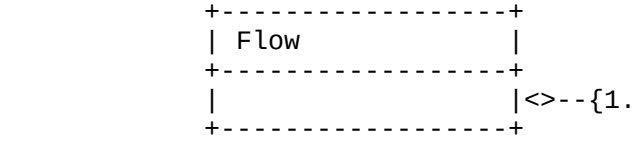

Figure 32: The Flow Class

The aggregate class of the Flow class is:

System
One or More. A host or network involved in an event. See Section 3.17.

The Flow class has no attributes.

3.17. System Class

The System class describes a system or network involved in an event.

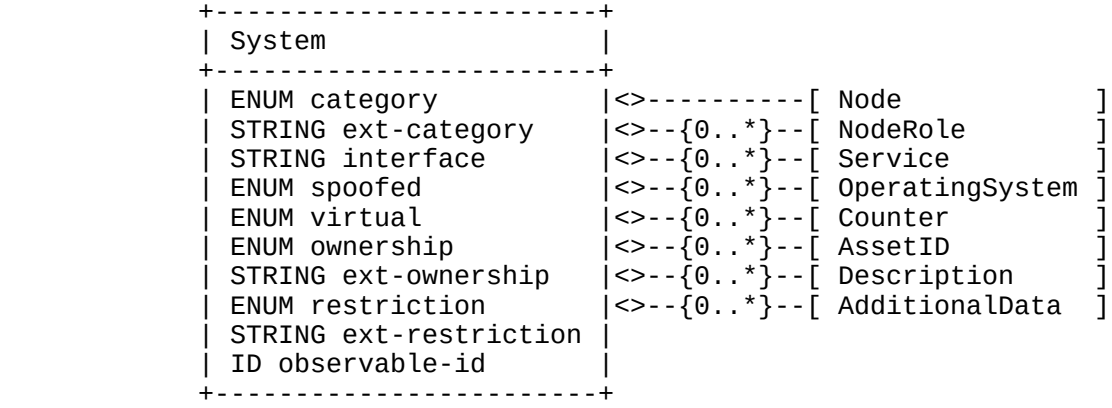

Figure 33: The System Class

The aggregate classes of the System class are:

Node
: One. A host or network involved in the incident. See Section 3.18.

NodeRole
: Zero or more. The intended purpose of the system. See Section 3.18.2.

Service
: Zero or more. A network service running on the system. See Section 3.20.

OperatingSystem
: Zero or more. SOFTWARE. The operating system running on the system.

Counter
: Zero or more. A counter with which to summarize properties of this host or network. See Section 3.18.3.

AssetID
: Zero or more. STRING. An asset identifier for the System.

Description

Zero or more. ML_STRING. A free-form text description of the System.

AdditionalData
Zero or more. EXTENSION. A mechanism by which to extend the data model.

The attributes of the System class are:

category
Optional. ENUM. Classifies the role the host or network played in the incident. These values are maintained in the "System-category" IANA registry per Section 10.2.

1. source. The System was the source of the event.

2. target. The System was the target of the event.

3. intermediate. The System was an intermediary in the event.

4. sensor. The System was a sensor monitoring the event.

5. infrastructure. The System was an infrastructure node of IODEF document exchange.

6. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-category
Optional. STRING. A means by which to extend the category attribute. See Section 5.1.1.

interface
Optional. STRING. Specifies the interface on which the event(s) on this System originated. If the Node class specifies a network rather than a host, this attribute has no meaning.

spoofed
Optional. ENUM. An indication of confidence in whether this System was the true target or attacking host. The permitted values for this attribute are shown below. The default value is "unknown".

1. unknown. The accuracy of the category attribute value is unknown.

2. yes. The category attribute value is likely incorrect. In the case of a source, the System is likely a decoy; with a target, the System was likely not the intended victim.

3. no. The category attribute value is believed to be correct.

virtual
Optional. ENUM. Indicates whether this System is a virtual or physical device. The default value is "unknown".

1. yes. The System is a virtual device.

2. no. The System is a physical device.

3. unknown. It is not known if the System is virtual.

ownership
Optional. ENUM. Describes the ownership of this System relative to the victim in the incident. These values are maintained in the "System-ownership" IANA registry per Section 10.2.

1. organization. Corporate or enterprise-owned.

2. personal. Personally-owned by an employee or affiliate of the corporation or enterprise.

3. partner. Owned by a partner of the corporation or enterprise.

4. customer. Owned by a customer of the corporation or enterprise.

5. no-relationship. Owned by an entity that has no known relationship with victim organization.

6. unknown. Ownership is unknown.

7. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-ownership
Optional. STRING. A means by which to extend the ownership attribute. See Section 5.1.1.

restriction
Optional. ENUM. See Section 3.3.1.

ext-restriction

Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

observable-id
Optional. ID. See Section 3.3.2.

3.18. Node Class

The Node class identifies a system, asset or network; and its location.

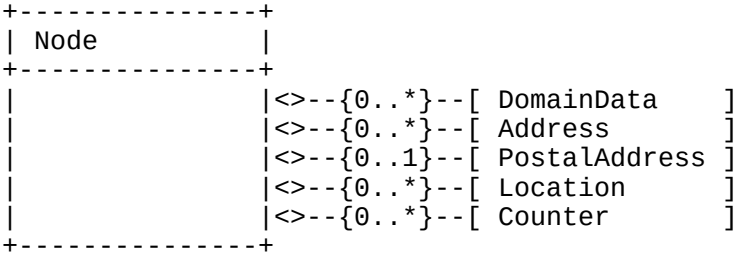

Figure 34: The Node Class

The aggregate classes of the Node class are:

DomainData
Zero or more. The domain (DNS) information associated with this Node. If an Address is not provided, at least one DomainData MUST be specified. See Section 3.19.

Address
Zero or more. The hardware, network, or application address of the Node. If a DomainData is not provided, at least one Address MUST be specified. See Section 3.18.1.

PostalAddress
Zero or one. POSTAL. The postal address of the node.

Location
Zero or more. ML_STRING. A free-form text description of the physical location of the Node. This description may provide a more detailed description of where in the PostalAddress this Node is found (e.g., room number, rack number, slot number in a chassis).

Counter
Zero or more. A counter with which to summarizes properties of this host or network. See Section 3.18.3.

The Node class has no attributes.

3.18.1. Address Class

The Address class represents a hardware (layer-2), network (layer-3), or application (layer-7) address.

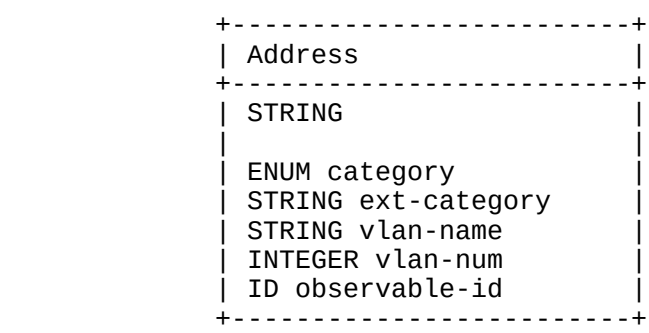

Figure 35: The Address Class

The content of the class is an address of type STRING whose semantics are determined by the category attribute.

The attributes of the Address class are:

category
: Required. ENUM. The type of address represented. The default value is "ipv6-addr". These values are maintained in the "Address-category" IANA registry per Section 10.2.

1. asn. Autonomous System Number.

2. atm. Asynchronous Transfer Mode (ATM) address.

3. e-mail. Email address, per the EMAIL data type.

4. ipv4-addr. IPv4 host address in dotted-decimal notation (a.b.c.d).

5. ipv4-net. IPv4 network address in dotted-decimal notation, slash, significant bits (i.e., a.b.c.d/nn).

6. ipv4-net-masked. A sanitized IPv4 address with significant bits per "ipv4-net" but with the character ’x’ replacing any digit(s) in the address or prefix.

7. ipv4-net-mask. IPv4 network address in dotted-decimal notation, slash, network mask in dotted-decimal notation (i.e., a.b.c.d/w.x.y.z).

8. ipv6-addr. IPv6 host address per Section 4 of [RFC5952].

9. ipv6-net. IPv6 network address, slash, prefix per Section 2.3 of [RFC4291].

10. ipv6-net-masked. A sanitized IPv6 address and prefix per "ipv6-net" but with the character 'x' replacing any hexadecimal digit(s) in the address or digit(s) in the prefix.

11. mac. Media Access Control (MAC) address (i.e., aa:bb:cc:dd:ee:ff).

12. site-uri. A URL or URI for a resource, per the URL data type.

13. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-category
Optional. STRING. A means by which to extend the category attribute. See Section 5.1.1.

vlan-name
Optional. STRING. The name of the Virtual LAN to which the address belongs.

vlan-num
Optional. INTEGER. The number of the Virtual LAN to which the address belongs.

observable-id
Optional. ID. See Section 3.3.2.

3.18.2. NodeRole Class

The NodeRole class describes the function performed by or role of a particular system, asset or network.

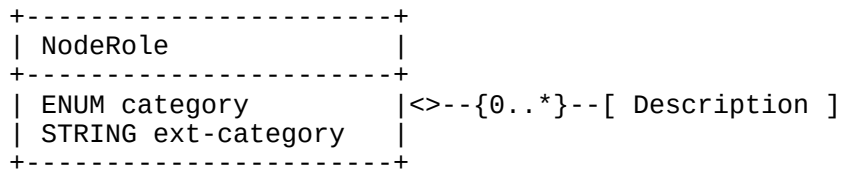

Figure 36: The NodeRole Class

The aggregate class of the NodeRole class is:

Description
: Zero or more. ML_STRING. A free-form text description of the role of the system.

The attributes of the NodeRole class are:

category
: Required. ENUM. Function or role of a node. These values are maintained in the "NodeRole-category" IANA registry per Section 10.2.

1. client. Client computer.
2. client-enterprise. Client computer on the enterprise network.
3. client-partner. Client computer on network of a partner.
4. client-remote. Client computer remotely connected to the enterprise network.
5. client-kiosk. Client computer serving as a kiosk.
6. client-mobile. Mobile device.
7. server-internal. Server with internal services.
8. server-public. Server with public services.
9. www. WWW server.
10. mail. Mail server.
11. webmail. Web mail server.
12. messaging. Messaging server (e.g., NNTP, IRC, IM).

13. streaming. Streaming-media server.

14. voice. Voice server (e.g., SIP, H.323).

15. file. File server.

16. ftp. FTP server.

17. p2p. Peer-to-peer node.

18. name. Name server (e.g., DNS, WINS).

19. directory. Directory server (e.g., LDAP, finger, whois).

20. credential. Credential server (e.g., domain controller, Kerberos).

21. print. Print server.

22. application. Application server.

23. database. Database server.

24. backup. Backup server.

25. dhcp. DHCP server.

26. assessment. Assessment server (e.g., vulnerability scanner, end-point assessment).

27. source-control. Source code control server.

28. config-management. Configuration management server.

29. monitoring. Security monitoring server (e.g., IDS).

30. infra. Infrastructure server (e.g., router, firewall, DHCP).

31. infra-firewall. Firewall.

32. infra-router. Router.

33. infra-switch. Switch.

34. camera. Camera and video system.

35. proxy. Proxy server.

36. remote-access. Remote access server.

37. log. Log server (e.g., syslog).

38. virtualization. Server running virtual machines.

39. pos. Point-of-sale device.

40. scada. Supervisory control and data acquisition (SCADA) system.

41. scada-supervisory. Supervisory system for a SCADA.

42. sinkhole. Traffic sinkhole destination.

43. honeypot. Honeypot server.

44. anonymization. Anonymization server (e.g., Tor node).

45. c2-server. Malicious command and control server.

46. malware-distribution. Server that distributes malware

47. drop-server. Server to which exfiltrated content is uploaded.

48. hop-point. Intermediary server used to get to a victim.

49. reflector. A system used in a reflector attack.

50. phishing-site. Site hosting phishing content.

51. spear-phishing-site. Site hosting spear-phishing content.

52. recruiting-site. Site to recruit.

53. fraudulent-site. Fraudulent site.

54. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-category
: Optional. STRING. A means by which to extend the category attribute. See Section 5.1.1.

3.18.3. Counter Class

The Counter class summarizes multiple occurrences of an event or conveys counts or rates of various features.

The complete semantics of this class are context dependent based on the class in which it is aggregated.

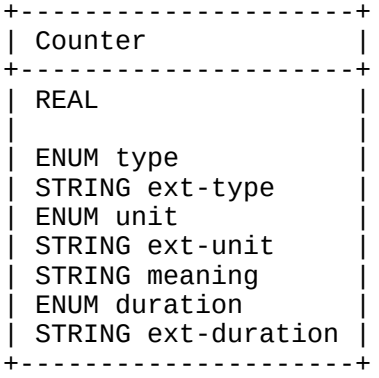

Figure 37: The Counter Class

The content of the class is a value of type REAL whose meaning and units are determined by the type and duration attributes, respectively. If the duration attribute is present, the element content is a rather. Otherwise, it is a simple counter.

The attributes of the Counter class are:

type
: Required. ENUM. Specifies the type of counter specified in the element content. These values are maintained in the "Counter-type" IANA registry per Section 10.2.

  1. count. The Counter class value is a counter.

  2. peak. The Counter class value is a peak value.

  3. average. The Counter class value is an average.

  4. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-type

Optional. STRING. A means by which to extend the type attribute. See Section 5.1.1.

unit
Required. ENUM. Specifies the units of the element content. These values are maintained in the "Counter-unit" IANA registry per Section 10.2.

1. byte. Bytes transferred.

2. mbit. Megabits (Mbits) transfered.

3. packet. Packets.

4. flow. Network flow records.

5. session. Sessions.

6. alert. Notifications generated by another system (e.g., IDS or SIM).

7. message. Messages (e.g., mail messages).

8. event. Events.

9. host. Hosts.

10. site. Site.

11. organization. Organizations.

12. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-unit
Optional. STRING. A means by which to extend the unit attribute. See Section 5.1.1.

meaning
Optional. STRING. A free-form text description of the metric represented by the Counter.

duration
Optional. ENUM. If present, the Counter class represents a rate. This attribute specifies unit of time over which the rate whose units are specified in the unit attribute is being conveyed. This attribute is the the denominator of the rate (where the unit

attribute specified the nominator). The possible values of this attribute are defined in the duration attribute of Section 3.12.3

ext-duration
Optional. STRING. A means by which to extend the duration attribute. See Section 5.1.1.

3.19. DomainData Class

The DomainData class describes a domain name and meta-data associated with this domain.

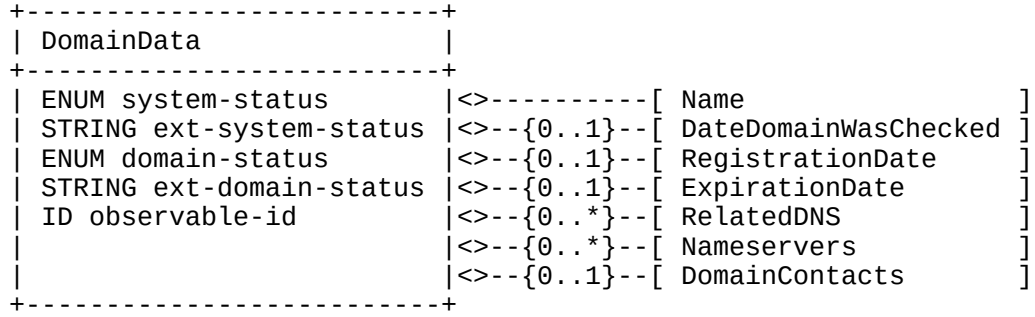

Figure 38: The DomainData Class

The aggregate classes of the DomainData class are:

Name
One. STRING. The domain name of a system.

DateDomainWasChecked
Zero or one. DATETIME. A timestamp of when the domain listed in the Name class was resolved.

RegistrationDate
Zero or one. DATETIME. A timestamp of when domain listed in Name class was registered.

ExpirationDate
Zero or one. DATETIME. A timestamp of when the domain listed in Name class is set to expire.

RelatedDNS
Zero or more. EXTENSION. Additional DNS records associated with this domain.

Nameservers

Zero or more. The name servers identified for the domain listed in Name class. See Section 3.19.1.

DomainContacts
Zero or one. Contact information for the domain listed in Name class supplied by the registrar or through a whois query.

The attributes of the DomainData class are:

system-status
Required. ENUM. Assesses the domain's involvement in the event. These values are maintained in the "DomainData-system-status" IANA registry per Section 10.2.

1. spoofed. This domain was spoofed.

2. fraudulent. This domain was operated with fraudulent intentions.

3. innocent-hacked. This domain was compromised by a third party.

4. innocent-hijacked. This domain was deliberately hijacked.

5. unknown. No categorization for this domain known.

6. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-system-status
Optional. STRING. A means by which to extend the system-status attribute. See Section 5.1.1.

domain-status
Required. ENUM. Categorizes the registry status of the domain at the time the document was generated. These values and their associated descriptions are derived from Section 3.2.2 of [RFC3982]. These values are maintained in the "DomainData-domain-status" IANA registry per Section 10.2.

1. reservedDelegation. The domain is permanently inactive.

2. assignedAndActive. The domain is in a normal state.

3. assignedAndInactive. The domain has an assigned registration but the delegation is inactive.

4. assignedAndOnHold. The domain is in dispute.

5. revoked. The domain is in the process of being purged from the database.

6. transferPending. The domain is pending a change in authority.

7. registryLock. The domain is on hold by the registry.

8. registrarLock. Same as "registryLock".

9. other. The domain has a known status but it is not one of the redefined enumerated values.

10. unknown. The domain has an unknown status.

11. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-domain-status
Optional. STRING. A means by which to extend the domain-status attribute. See Section 5.1.1.

observable-id
Optional. ID. See Section 3.3.2.

3.19.1. Nameservers Class

The Nameservers class describes the name servers associated with a given domain.

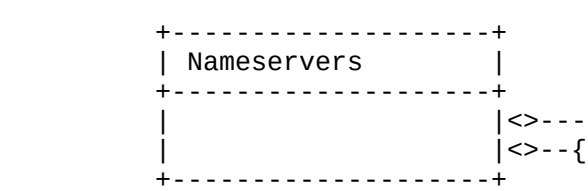

Figure 39: The Nameservers Class

The aggregate classes of the Nameservers class are:

Server
One. STRING. The domain name of the name server.

Address

One or more. The address of the name server. The value of the category attribute MUST be either "ipv4-addr" or "ipv6-addr". See Section 3.18.1.

The Nameservers class has no attributes.

3.19.2. DomainContacts Class

The DomainContacts class describes the contact information for a given domain provided either by the registrar or through a whois query.

This contact information can be explicitly described through a Contact class or a reference can be provided to a domain with identical contact information. Either a single SameDomainContact MUST be present or one or more Contact classes.

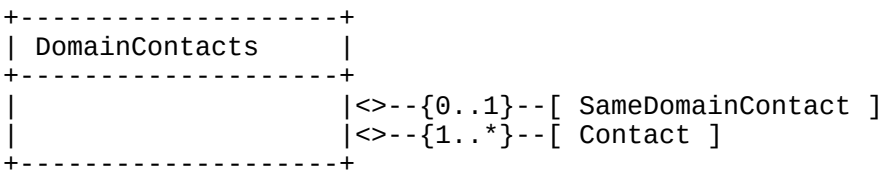

Figure 40: The DomainContacts Class

The aggregate classes of the DomainContacts class are:

SameDomainContact
: Zero or one. STRING. A domain name already cited in this document or through previous exchange that contains the identical contact information as the domain name in question. The domain contact information associated with this domain should be used instead of an explicit definition with the Contact class.

Contact
: One or more. Contact information for the domain. See Section 3.9.

The DomainContacts class has no attributes.

3.20. Service Class

The Service class describes a network service. The service is described by protocol, port, protocol header field and application providing or using the service.

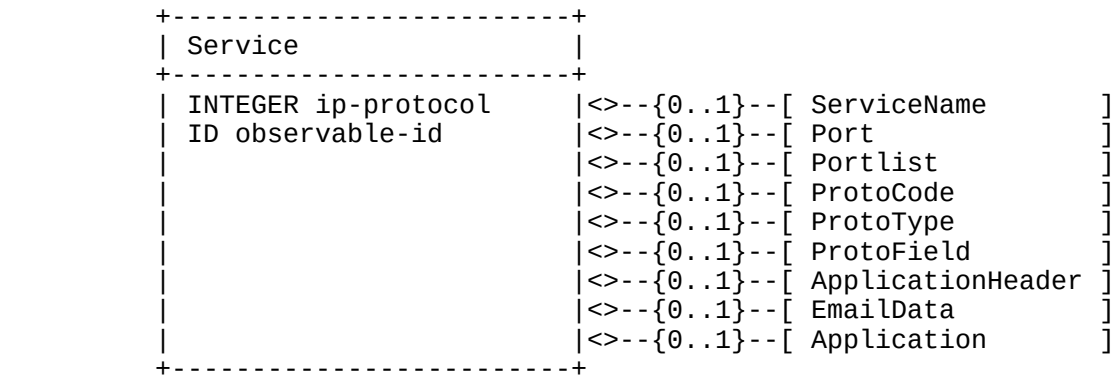

Figure 41: The Service Class

The aggregate classes of the Service class are:

ServiceName
: Zero or one. A protocol name.

Port
: Zero or one. INTEGER. A port number.

Portlist
: Zero or one. PORTLIST. A list of port numbers.

ProtoCode
: Zero or one. INTEGER. A transport layer (layer 4) protocol-specific code field (e.g., ICMP code field).

ProtoType
: Zero or one. INTEGER. A transport layer (layer 4) protocol specific type field (e.g., ICMP type field).

ProtoField
: Zero or one. INTEGER. A transport layer (layer 4) protocol specific flag field (e.g., TCP flag field).

ApplicationHeader
: Zero or one. A protocol header. See Section 3.20.2.

EmailData
: Zero or one. Headers associated with an email message. See Section 3.21.

Application

Zero or one. SOFTWARE. The application acting as either the client or server for the service.

At least one of these classes MUST be present.

When a given System classes with category="source" and another with category="target" are aggregated into a single Flow class, and each of these System classes has a Service and Portlist class, an implicit relationship between these Portlists exists. If N ports are listed for a System@category="source", and M ports are listed for System@category="target", the number of ports in N must be equal to M. Likewise, the ports MUST be listed in an identical sequence such that the n-th port in the source corresponds to the n-th port of the target. If N is greater than 1, a given instance of a Flow class MUST only have a single instance of a System@category="source" and System@category="target".

The attributes of the Service class are:

ip-protocol
Optional. INTEGER. The IANA assigned IP protocol number per [IANA.Protocols] The attribute MUST be set if a Port, Portlist, ProtoCode, ProtoType, ProtoField class is present.

observable-id
Optional. ID. See Section 3.3.2.

3.20.1. ServiceName Class

The ServiceName class identifies an application protocol. It can be described by referencing an IANA registered protocol, a URL or with free-form text.

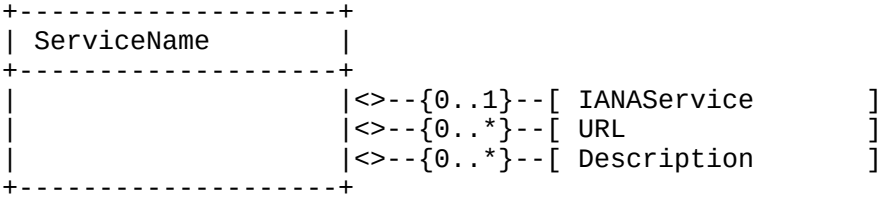

Figure 42: The ServiceName Class

The aggregate classes of the ServiceName class are:

IANAService
Zero or one. STRING. The name of the service per the "Service Name" field of the [IANA.Ports] registry.

URL
Zero or more. URL. A URL to a resource describing the service.

Description
Zero or more. ML_STRING. A free-form text description of the service.

At least one of these classes MUST be present.

The ServiceName class has no attributes.

3.20.2. ApplicationHeader Class

The ApplicationHeader class describes arbitrary fields from a protocol header and its corresponding value.

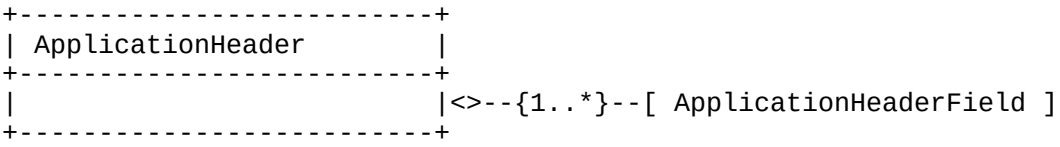

Figure 43: The ApplicationHeader Class

The aggregate class of the ApplicationHeader class is:

ApplicationHeaderField
One or more. EXTENSION. A field name and value in a protocol header. The 'name' attribute MUST be set to the field name. The field value MUST be set in the element content.

The ApplicationHeader class has no attributes.

3.21. EmailData Class

The EmailData class describes headers from an email message and cryptographic hash and signatures applied to it.

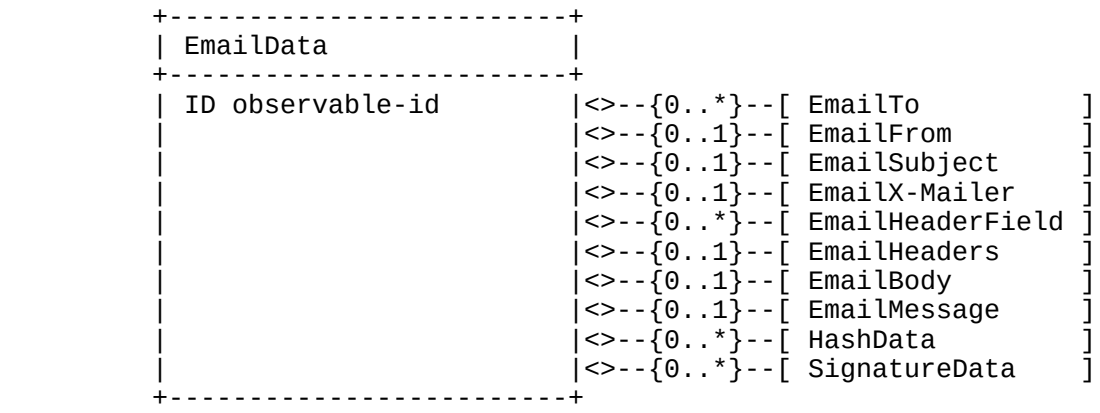

Figure 44: EmailData Class

The aggregate classes of the EmailData class are:

EmailTo
: Zero or more. EMAIL. The value of the "To:" header field (Section 3.6.3 of [RFC5322]) in an email.

EmailFrom
: Zero or one. EMAIL. The value of the "From:" header field (Section 3.6.2 of [RFC5322]) in an email.

EmailSubject
: Zero or one. STRING. The value of the "Subject:" header field in an email. See Section 3.6.4 of [RFC5322].

EmailX-Mailer
: Zero or one. STRING. The value of the "X-Mailer:" header field in an email.

EmailHeaderField
: Zero or more. EXTENSION. The header name and value of an arbitrary header field of the email message. The 'name' attribute MUST be set to header name. The header value MUST be set in the element body. The dtype attribute MUST be set to "string".

EmailHeaders
: Zero or one. STRING. The headers of an email message.

EmailBody
: Zero or one. STRING. The body of an email message.

EmailMessage

Zero or one. STRING. The headers and body of an email message.

HashData
Zero or more. Hash(es) associated with this email message. See Section 3.26.

SignatureData
Zero or more. Signature(s) associated with this email message. See Section 3.27.

The attribute of the EmailData class is:

observable-id
Optional. ID. See Section 3.3.2.

3.22. Record Class

The Record class is a container class for log and audit data that provides supportive information about the events in an incident. The source of this data will often be the output of monitoring tools. These logs substantiate the activity described in the document.

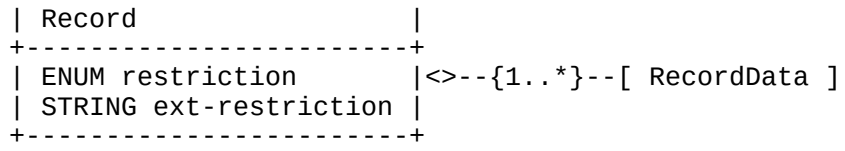

Figure 45: Record Class

The aggregate classes of the Record class are:

RecordData
One or more. Log or audit data generated by a particular tool. Separate instances of the RecordData class SHOULD be used for each type of log. See Section 3.22.1.

The attributes of the Record class are:

restriction
Optional. ENUM. See Section 3.3.1.

ext-restriction
Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

3.22.1. RecordData Class

The RecordData class describes or references log or audit data from a given type of tool and provides a means to annotate the output.

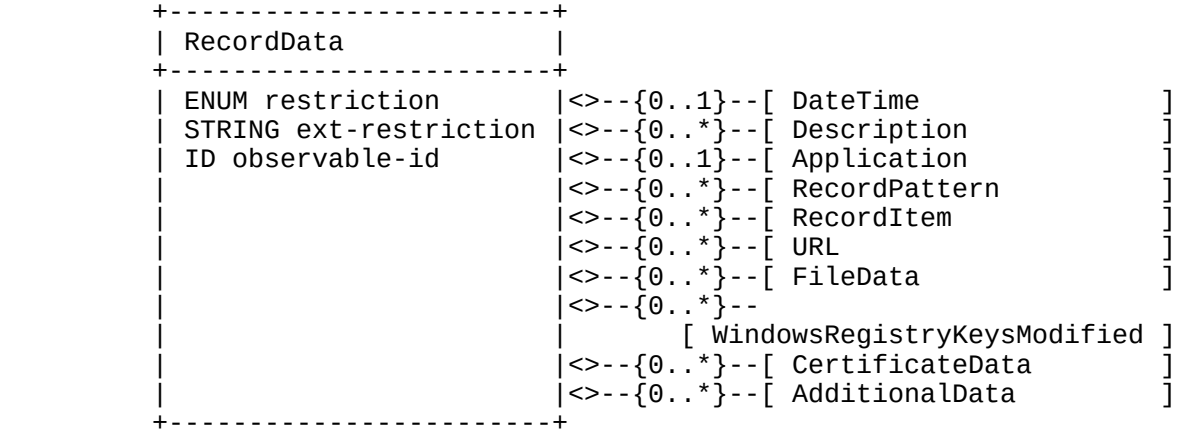

Figure 46: The RecordData Class

The aggregate classes of the RecordData class are:

DateTime
: Zero or one. DATETIME. A timestamp of the data found in the RecordItem or URL classes.

Description
: Zero or more. ML_STRING. A free-form text description of the data provided in the RecordItem or URL classes.

Application
: Zero or one. SOFTWARE. Identifies the tool used to generate the data in the RecordItem or URL classes.

RecordPattern
: Zero or more. A search string to precisely find the relevant data in the RecordItem or URL classes. See Section 3.22.2.

RecordItem
: Zero or more. EXTENSION. Log, audit, or forensic data to support the conclusions made during the course of analyzing the incident.

URL
: Zero or more. URL. A URL reference to a log or audit data.

FileData
Zero or one. The files involved in the incident. See Section 3.25.

WindowsRegistryKeysModified
Zero or more. The registry keys that were involved in the incident. See Section 3.23.

CertificateData
Zero or more. The certificates that were involved in the incident. See Section 3.24.

AdditionalData
Zero or more. EXTENSION. An extension mechanism for data not explicitly represented in the data model.

At least one of the following classes MUST be present: RecordItem, URL, FileData, WindowsRegistryKeysModified, CertificateData or AdditionalData.

The attributes of the RecordData class are:

restriction
Optional. ENUM. See Section 3.3.1.

ext-restriction
Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

observable-id
Optional. ID. See Section 3.3.2.

3.22.2. RecordPattern Class

The RecordPattern class describes where in the log data provided or referenced in RecordData class relevant information can be found. It provides a way to reference subsets of information, identified by a pattern, in a large log file, audit trail, or forensic data.

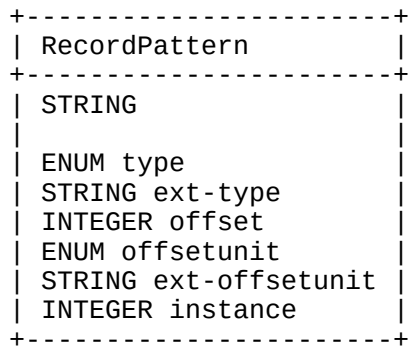

Figure 47: The RecordPattern Class

The content of the class is of type STRING and specifies a search pattern.

The attributes of the RecordPattern class are:

type
: Required. ENUM. Describes the type of pattern being specified in the element content. The default is "regex". These values are maintained in the "RecordPattern-type" IANA registry per Section 10.2.

  1. regex. regular expression as defined by POSIX Extended Regular Expressions (ERE) in Chapter 9 of [IEEE.POSIX].

  2. binary. Binhex encoded binary pattern, per the HEXBIN data type.

  3. xpath. XML Path (XPath) [W3C.XPATH]

  4. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-type
: Optional. STRING. A means by which to extend the type attribute. See Section 5.1.1.

offset
: Optional. INTEGER. Amount of units (determined by the offsetunit attribute) to seek into the RecordItem data before matching the pattern.

offsetunit

Optional. ENUM. Describes the units of the offset attribute. The default is "line". These values are maintained in the "RecordPattern-offsetunit" IANA registry per Section 10.2.

1. line. Offset is a count of lines.

2. byte. Offset is a count of bytes.

3. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-offsetunit
Optional. STRING. A means by which to extend the offsetunit attribute. See Section 5.1.1.

instance
Optional. INTEGER. Number of times to apply the specified pattern.

3.23. WindowsRegistryKeysModified Class

The WindowsRegistryKeysModified class describes Windows operating system registry keys and the operations that were performed on them. This class was derived from [RFC5901].

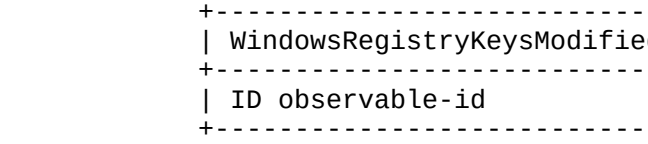

Figure 48: The WindowsRegistryKeysModified Class

The aggregate classes of the WindowsRegistryKeysModified class are:

Key
One or more. The Window registry key. See Section 3.23.1.

The attribute of the WindowsRegistryKeysModified class is:

observable-id
Optional. ID. See Section 3.3.2.

3.23.1. Key Class

The Key class describes a Windows operating system registry key name and value pair, and the operation performed on it.

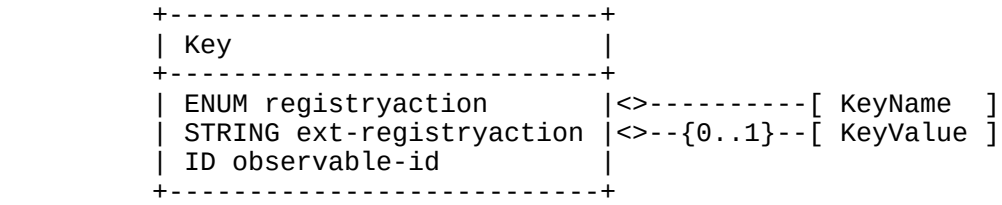

Figure 49: The Key Class

The aggregate classes of the Key class are:

KeyName
: One. STRING. The name of a Windows operating system registry key (e.g.,[HKEY_LOCAL_MACHINE\Software\Test\KeyName])

KeyValue
: Zero or one. STRING. The value of the registry key identified in the KeyName class encoded per the .reg file format [KB310516].

The attributes of the Key class are:

registryaction
: Optional. ENUM. The type of action taken on the registry key. These values are maintained in the "Key-registryaction" IANA registry per Section 10.2.

  1. add-key. Registry key added.

  2. add-value. Value added to a registry key.

  3. delete-key. Registry key deleted.

  4. delete-value. Value deleted from a registry key.

  5. modify-key. Registry key modified.

  6. modify-value. Value modified in a registry key.

  7. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-registryaction
Optional. STRING. A means by which to extend the registryaction attribute. See Section 5.1.1.

observable-id
Optional. ID. See Section 3.3.2.

3.24. CertificateData Class

The CertificateData class describes X.509 certificates.

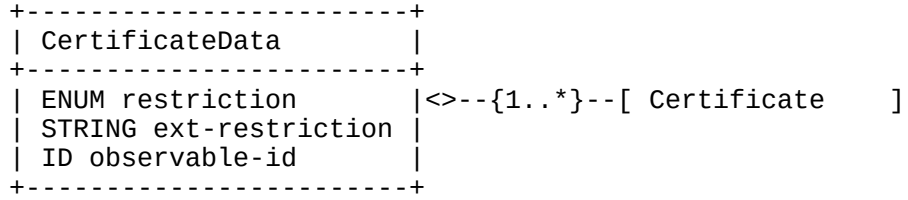

Figure 50: The CertificateData Class

The aggregate classes of the CertificateData class are:

Certificate
One or more. A description of an X.509 certificate or certificate chain. See Section 3.24.1.

The attributes of the CertificateData class are:

restriction
Optional. ENUM. See Section 3.3.1.

ext-restriction
Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

observable-id
Optional. ID. See Section 3.3.2.

3.24.1. Certificate Class

The Certificate class describes a given X.509 certificate or certificate chain.

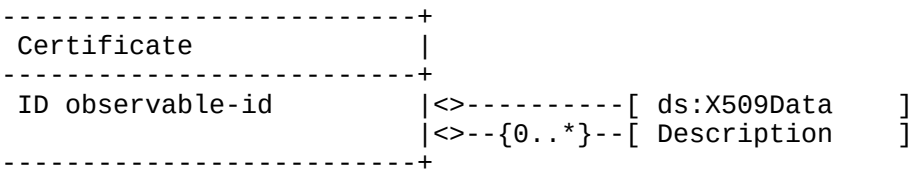

Figure 51: The Certificate Class

The aggregate classes of the Certificate class are:

ds:X509Data
: One. A given X.509 certificate or chain. See Section 4.4.4 of [W3C.XMLSIG].

Description
: Zero or more. ML_STRING. A free-form text description explaining the context of this certificate.

The attributes of the Certificate class are:

observable-id
: Optional. ID. See Section 3.3.2.

3.25. FileData Class

The FileData class describes a file or set of files.

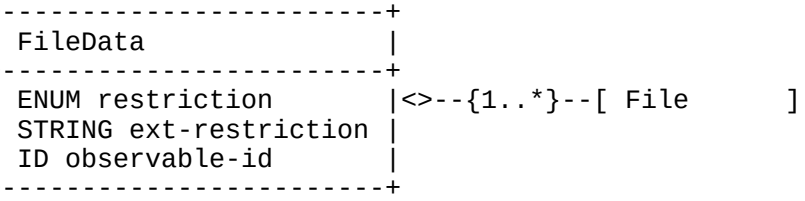

Figure 52: The FileData Class

The aggregate classes of the FileData class are:

File
: One or more. A description of a file. See Section 3.25.1.

The attributes of the FileData class are:

restriction
: Optional. ENUM. See Section 3.3.1.

ext-restriction
Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

observable-id
Optional. ID. See Section 3.3.2.

3.25.1. File Class

The File class describes a file; its associated meta data; and cryptographic hashes and signatures applied to it.

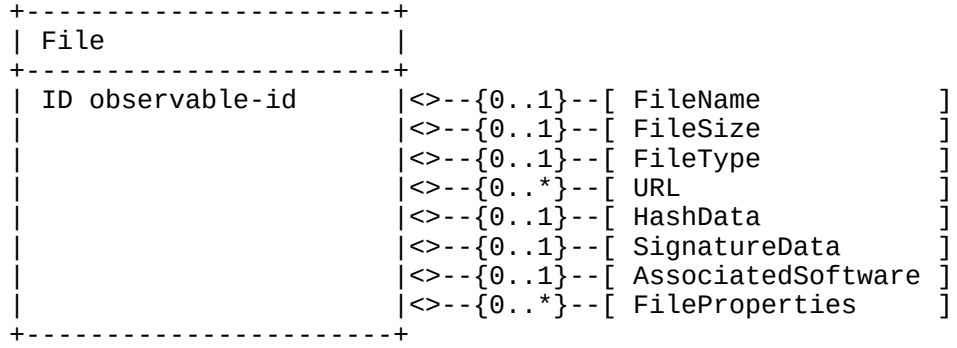

Figure 53: The File Class

The aggregate classes of the File class are:

FileName
Zero or One. STRING. The name of the file.

FileSize
Zero or One. INTEGER. The size of the file in bytes.

FileType
Zero or One. STRING. The type of file per the IANA Media Types Registry [IANA.Media]. Valid values correspond to the text in the "Template" column (e.g., "application/pdf").

URL
Zero or more. URL. A URL reference to the file.

HashData
Zero or One. Hash(es) associated with this file. See Section 3.26.

SignatureData

Zero or One. Signature(s) associated with this file. See Section 3.27.

AssociatedSoftware
Zero or One. SOFTWARE. The software application or operating system to which this file belongs or by which it can be processed.

FileProperties
Zero or more. EXTENSION. Mechanism by which to extend the data model to describe properties of the file.

The attributes of the File class are:

observable-id
Optional. ID. See Section 3.3.2.

3.26. HashData Class

The HashData class describes different types of hashes on an given object (e.g., file, part of a file, email).

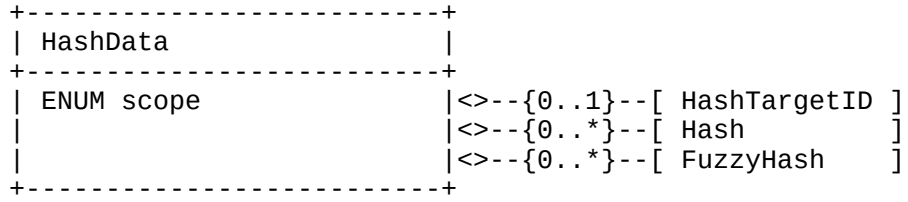

Figure 54: The HashData Class

The aggregate classes of the HashData class are:

HashTargetID
Zero or One. STRING. An identifier that references a subset of the object being hashed. The semantics of this identifier are specified by the scope attribute.

Hash
Zero or more. The hash of an object. See Section 3.26.1.

FuzzyHash
Zero or more. The fuzzy hash of an object. See Section 3.26.2.

At least one instance of either Hash or FuzzyHash MUST be present.

The attribute of the HashData class is:

scope
Required. ENUM. Describes on which part of the object the hash should be applied. These values are maintained in the "HashData-scope" IANA registry per Section 10.2.

1. file-contents. A hash computed over the entire contents of a file.

2. file-pe-section. A hash computed on a given section of a Windows Portable Executable (PE) file. If set to this value, the HashTargetID class MUST identify the section being hashed. A section is identified by an ordinal number (starting at 1) corresponding to the the order in which the given section header was defined in the Section Table of the PE file header.

3. file-pe-iat. A hash computed on the Import Address Table (IAT) of a PE file. As IAT hashes are often tool dependent, if this value is set, the Application class of either the Hash or FuzzyHash classes MUST specify the tool used to generate the hash.

4. file-pe-resource. A hash computed on a given resource in a PE file. If set to this value, the HashTargetID class MUST identify the resource being hashed. A resource is identified by an ordinal number (starting at 1) corresponding to the order in which the given resource is declared in the Resource Directory of the Data Dictionary in the PE file header.

5. file-pdf-object. A hash computed on a given object in a Portable Document Format (PDF) file. If set to this value, the HashTargetID class MUST identify the object being hashed. This object is identified by its offset in the PDF file.

6. email-hash. A hash computed over the headers and body of an email message.

7. email-headers-hash. A hash computed over all of the headers of an email message.

8. email-body-hash. A hash computed over the body of an email message.

9. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-scope

Optional. STRING. A means by which to extend the scope attribute. See Section 5.1.1.

3.26.1. Hash Class

The Hash class describes a cryptographic hash value; the algorithm and application used to generate it; and the canonicalization method applied to the object being hashed.

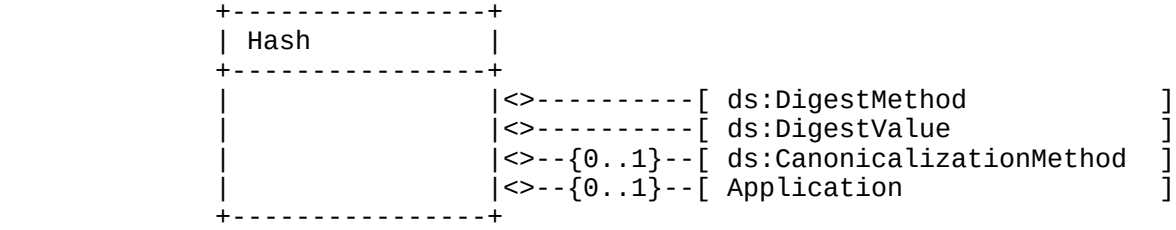

Figure 55: The Hash Class

The aggregate classes of the Hash class are:

ds:DigestMethod
One. The hash algorithm used to generate the hash. See Section 4.3.3.5 of [W3C.XMLSIG]

ds:DigestValue
One. The computed hash value. See Section 4.3.3.6 of [W3C.XMLSIG].

ds:CanonicalizationMethod
Zero or one. The canonicalization method used on the object being hashed. See Section 4.3.1 of [W3C.XMLSIG].

Application
Zero or One. SOFTWARE. The application used to calculate the hash.

The HashData class has no attributes.

3.26.2. FuzzyHash Class

The FuzzyHash class describes a fuzzy hash and the application used to generate it.

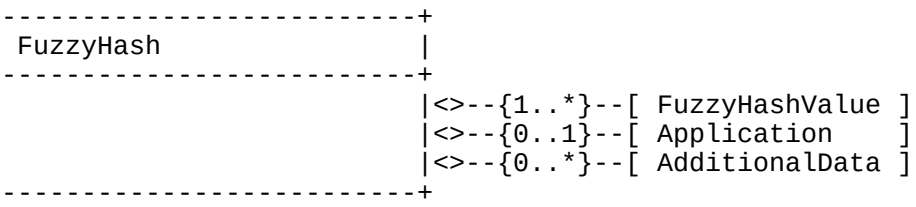

Figure 56: The FuzzyHash Class

The aggregate classes of the FuzzyHash class are:

FuzzyHashValue
: One or more. EXTENSION. The computed fuzzy hash value.

Application
: Zero or one. SOFTWARE. The application used to calculate the hash.

AdditionalData
: Zero or more. EXTENSION. Mechanism by which to extend the data model.

The FuzzyData class has no attributes.

3.27. SignatureData Class

The SignatureData class describes different types of digital signatures on an object.

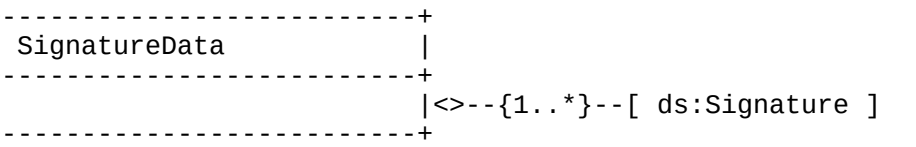

Figure 57: The SignatureData Class

The aggregate class of the SignatureData class is:

Signature
: One or more. An given signature. See Section 4.2 of [W3C.XMLSIG]

The SignatureData class has no attributes.

3.28. IndicatorData Class

The IndicatorData class describes indicators and meta-data associated with them.

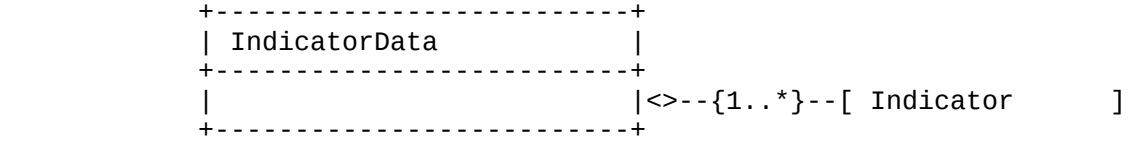

Figure 58: The IndicatorData Class

The aggregate class of the IndicatorData class is:

Indicator
One or more. A description of an indicator. See Section 3.29.

The IndicatorData class has no attributes.

3.29. Indicator Class

The Indicator class describes an indicator. An indicator consists of observable features and phenomenon that aid in the forensic or proactive detection of malicious activity; and associated meta-data. An indicator can be described outright; by referencing or composing previously defined indicators; or by referencing observables described in the incident report found in this document.

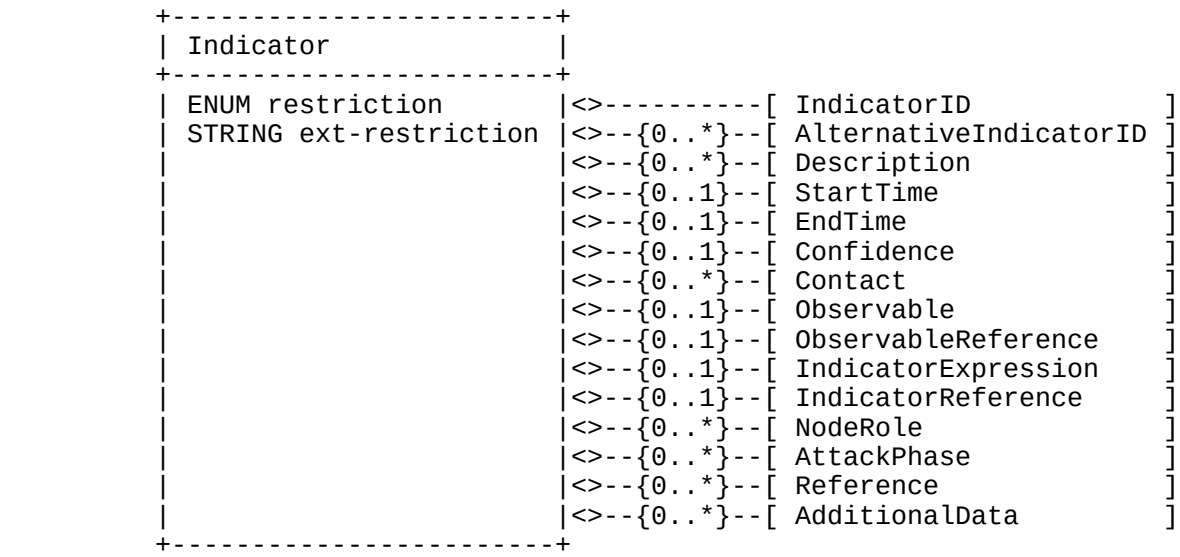

Figure 59: The Indicator Class

The aggregate classes of the Indicator class are:

IndicatorID
: One. An identifier for this indicator. See Section 3.29.1

AlternativeIndicatorID
: Zero or more. An alternative identifier for this indicator. See Section 3.29.2

Description
: Zero or more. ML_STRING. A free-form text description of the indicator.

StartTime
: Zero or one. DATETIME. A timestamp of the start of the time period during which this indicator is valid.

EndTime
: Zero or one. DATETIME. A timestamp of the end of the time period during which this indicator is valid.

Confidence
: Zero or one. An estimate of the confidence in the quality of the indicator. See Section 3.12.5.

Contact

Zero or more. Contact information for this indicator. See Section 3.9.

Observable
Zero or one. An observable feature or phenomenon of this indicator. See Section 3.29.3.

ObservableReference
Zero or one. A reference to an observable feature or phenomenon defined elsewhere in the document. See Section 3.29.6.

IndicatorExpression
Zero or one. A composition of observables. See Section 3.29.4.

IndicatorReference
Zero or one. A reference to an indicator. See Section 3.29.7.

NodeRole
Zero or more. The role of the system in the attack should this indicator be matched to it. See Section 3.18.2.

AttackPhase
Zero or more. The phase in an attack lifecycle during which this indicator might be seen. See Section 3.29.8.

Reference
Zero or more. A reference to additional information relevant to this indicator. See Section 3.11.1.

AdditionalData
Zero or more. EXTENSION. Mechanism by which to extend the data model.

The Indicator class MUST have exactly one instance of an Observable, IndicatorExpression, ObservableReference, or IndicatorReference class.

The StartTime and EndTime classes can be used to define an interval during which the indicator is valid. If both classes are present, the indicator is consider valid only during the described interval. If neither class is provided, the indicator is considered valid during any time interval. If only a StartTime is provided, the indicator is valid anytime after this timestamp. If only an EndTime is provided, the indicator is valid anytime prior to this timestamp.

The attributes of the Indicator class are:

restriction

Optional. ENUM. See Section 3.3.1.

ext-restriction
Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

3.29.1. IndicatorID Class

The IndicatorID class identifies an indicator with a globally unique identifier. The combination of the name and version attributes, and the element content form this identifier. Indicators generated by given CSIRT MUST NOT reuse the same value unless they are referencing the same indicator.

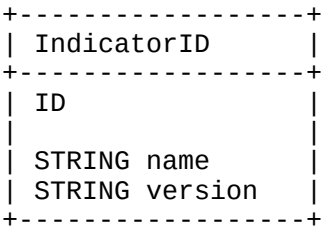

Figure 60: The IndicatorID Class

The content of the class is of type ID and specifies an identifier for an indicator.

The attributes of the IndicatorID class are:

name
Required. STRING. An identifier describing the CSIRT that created the indicator. In order to have a globally unique CSIRT name, the fully qualified domain name associated with the CSIRT MUST be used. This format is identical to the IncidentID@name attribute in Section 3.4.

version
Required. STRING. A version number of an indicator.

3.29.2. AlternativeIndicatorID Class

The AlternativeIndicatorID class lists alternative identifiers for an indicator.

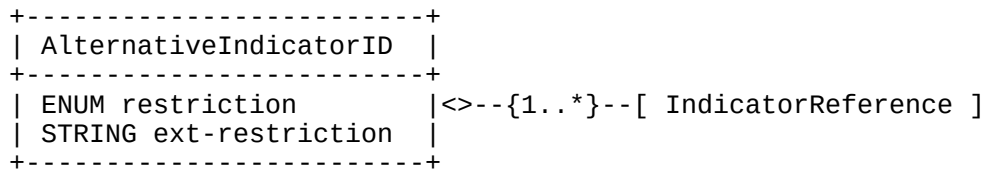

Figure 61: The AlternativeIndicatorID Class

The aggregate class of the AlternativeIndicatorID class is:

IndicatorReference
: One or more. A reference to an indicator. See Section 3.29.7

The attributes of the AlternativeIndicatorID class are:

restriction
: Optional. ENUM. See Section 3.3.1.

ext-restriction
: Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

3.29.3. Observable Class

The Observable class describes a feature and phenomenon that can be observed or measured for the purposes of detecting malicious behavior.

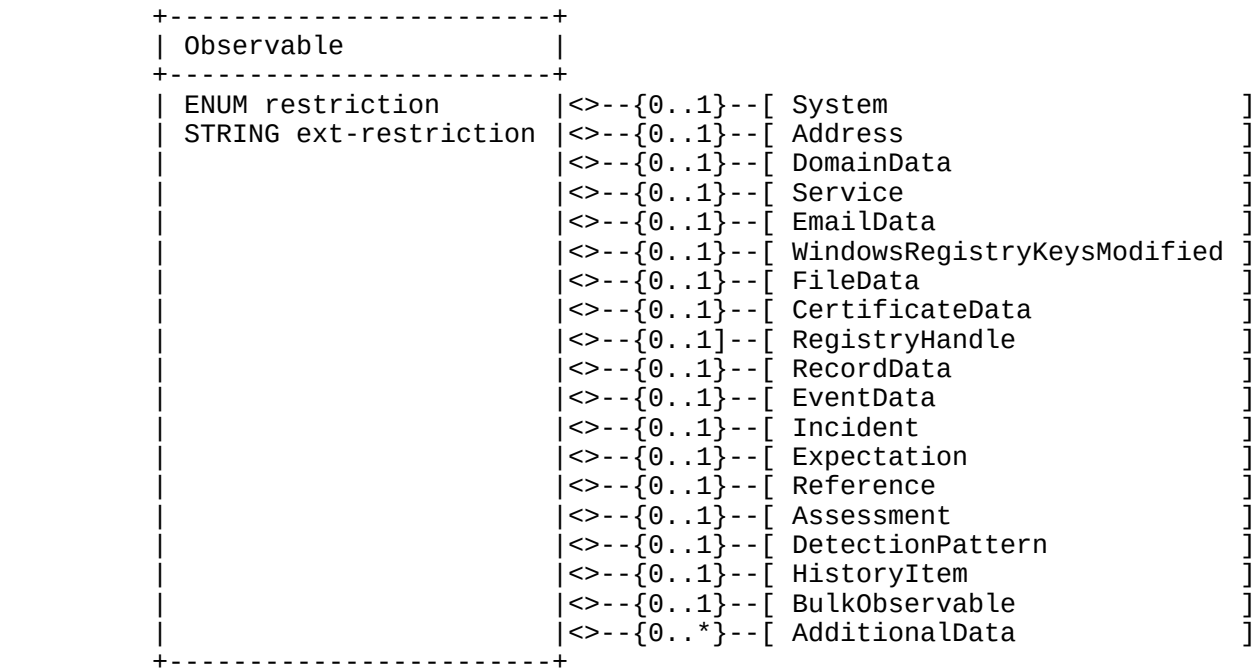

Figure 62: The Observable Class

The aggregate classes of the Observable class are:

System
: Zero or one. An System observable. See Section 3.17.

Address
: Zero or one. An Address observable. See Section 3.18.1.

DomainData
: Zero or one. A DomainData observable. See Section 3.19.

Service
: Zero or one. A Service observable. See Section 3.20.

EmailData
: Zero or one. A EmailData observable. See Section 3.21.

WindowsRegistryKeysModified
: Zero or one. A WindowsRegistryKeysModified observable. See Section 3.23.

FileData

Zero or one. A FileData observable. See Section 3.25.

CertificateData
Zero or one. A CertificateData observable. See Section 3.24.

RegistryHandle
Zero or one. A RegistryHandle observable. See Section 3.9.1.

RecordData
Zero or one. A RecordData observable. See Section 3.22.1.

EventData
Zero or one. An EventData observable. See Section 3.14.

Incident
Zero or one. An Incident observable. See Section 3.2.

Expectation
Zero or one. An Expectation observable. See Section 3.15.

Reference
Zero or one. A Reference observable. See Section 3.11.1.

Assessment
Zero or one. An Assessment observable. See Section 3.12.

DetectionPattern
Zero or one. A DetectionPattern observable. See Section 3.12.

HistoryItem
Zero or one. A HistoryItem observable. See Section 3.13.1.

BulkObservable
Zero or one. A bulk list of observables. See Section 3.29.3.1.

AdditionalData
Zero or more. EXTENSION. Mechanism by which to extend the data model.

The Observable class MUST have exactly one of the possible child classes.

The attributes of the Observable class are:

restriction
Optional. ENUM. See Section 3.3.1.

ext-restriction

Optional. STRING. A means by which to extend the restriction attribute. See Section 5.1.1.

3.29.3.1. BulkObservable Class

The BulkObservable class allows the enumeration of a single type of observables without requiring each one to be encoded individually in multiple instances of the same class.

The type attribute describes the type of observable listed in the child BulkObservableList class. The BulkObservableFormat class optionally provides additional meta-data.

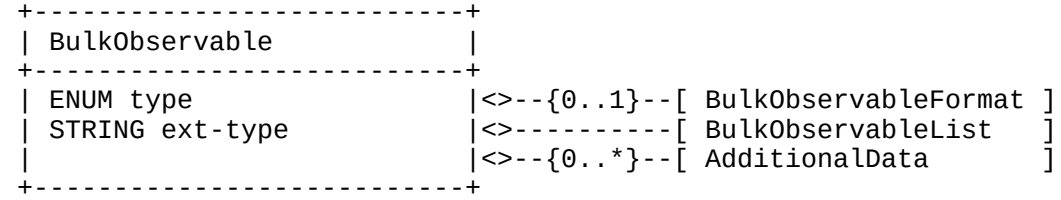

Figure 63: The BulkObservable Class

The aggregate classes of the BulkObservable class are:

BulkObservableFormat
: Zero or one. Provides additional meta-data about the observables enumerated in the BulkObservableList class. See Section 3.29.3.1.1.

BulkObservableList
: One. STRING. A list of observables, one per line. Each line is separated with either a LF character or CR-and-LF characters. The type attribute specifies which observables will be listed.

AdditionalData
: Zero or more. EXTENSION. Mechanism by which to extend the data model.

The attributes of the BulkObservable class are:

type
: Optional. ENUM. The type of the observable listed in the child ObservableList class. These values are maintained in the "BulkObservable-type" IANA registry per Section 10.2.

  1. asn. Autonomous System Number (per the Address@category attribute).

2. atm. Asynchronous Transfer Mode (ATM) address (per the Address@category attribute).

3. e-mail. Email address (per the Address@category attribute).

4. ipv4-addr. IPv4 host address in dotted-decimal notation (e.g., 192.0.2.1) (per the Address@category attribute).

5. ipv4-net. IPv4 network address in dotted-decimal notation, slash, significant bits (e.g., 192.0.2.0/24) (per the Address@category attribute).

6. ipv4-net-mask. IPv4 network address in dotted-decimal notation, slash, network mask in dotted-decimal notation (i.e., 192.0.2.0/255.255.255.0) (per the Address@category attribute).

7. ipv6-addr. IPv6 host address (e.g., 2001:DB8::3) (per the Address@category attribute).

8. ipv6-net. IPv6 network address, slash, significant bits (e.g., 2001:DB8::/32) (per the Address@category attribute).

9. ipv6-net-mask. IPv6 network address, slash, network mask (per the Address@category attribute).

10. mac. Media Access Control (MAC) address (i.e., a:b:c:d:e:f) (per the Address@category attribute).

11. site-uri. A URL or URI for a resource (per the Address@category attribute).

12. domain-name. A fully qualified domain name or part of a name. (e.g., fqdn.example.com, example.com).

13. domain-to-ipv4. A fqdn-to-IPv4 address mapping specified as a comma separated list (e.g., "fqdn.example.com, 192.0.2.1").

14. domain-to-ipv6. A fqdn-to-IPv6 address mapping specified as a comma separated list (e.g., "fqdn.example.com, 2001:DB8::3").

15. domain-to-ipv4-timestamp. Same as domain-to-ipv4 but with a timestamp (in the DATETIME format) of the resolution (e.g., "fqdn.example.com, 192.0.2.1, 2015-06-11T00:38:31-06:00").

16. domain-to-ipv6-timestamp. Same as domain-to-ipv6 but with a timestamp (in the DATETIME format) of the resolution (e.g., "fqdn.example.com, 2001:DB8::3, 2015-06-11T00:38:31-06:00").

17. ipv4-port. An IPv4 address, port and protocol tuple (e.g., 192.0.2.1, 80, tcp). The protocol name corresponds to the "Keyword" column in the [IANA.Protocols] registry.

18. ipv6-port. An IPv6 address, port and protocol tuple (e.g., 2001:DB8::3, 80, tcp). The protocol name corresponds to the "Keyword" column in the [IANA.Protocols] registry.

19. windows-reg-key. A Microsoft Windows Registry key.

20. file-hash. A file hash. The format of this hash is described in the Hash class that MUST be present in a sibling BulkObservableFormat class.

21. email-x-mailer. An X-Mailer field from an email.

22. email-subject. An email subject line.

23. http-user-agent. A User Agent field from an HTTP request header (e.g., "Mozilla/5.0 (Windows NT 6.3; WOW64; rv:38.0) Gecko/20100101 Firefox/38.0").

24. http-request-uri. The Request URI from an HTTP request header.

25. mutex. The name of a system mutex.

26. file-path. A file path (e.g., "/tmp/local/file", "c:\windows\system32\file.sys")

27. user-name. A username.

28. ext-value. A value used to indicate that this attribute is extended and the actual value is provided using the corresponding ext-* attribute. See Section 5.1.1.

ext-type
: Optional. STRING. A means by which to extend the type attribute. See Section 5.1.1.

3.29.3.1.1. BulkObservableFormat Class

The ObservableFormat class specifies meta-data about the format of an observable enumerated in a sibling BulkObservableList class.

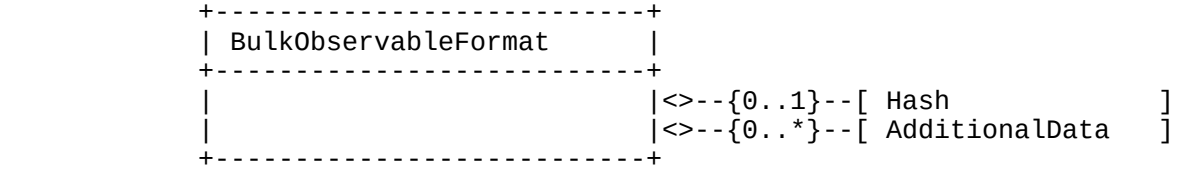

Figure 64: The BulkObservableFormat Class

The aggregate classes of the BulkObservableFormat class are:

Hash
: Zero or one. Describes the format of a hash. See Section 3.26.1.

AdditionalData
: Zero or more. EXTENSION. Mechanism by which to extend the data model.

The BulkObservableFormat class has no attributes.

Either Hash or AdditionalData MUST be present.

3.29.4. IndicatorExpression Class

The IndicatorExpression describes an expression composed of observed phenomenon or features, or indicators. Elements of the expression can be described directly, reference relevant data from other parts of a given IODEF document, or reference previously defined indicators.

All child classes of a given instance of IndicatorExpression form a boolean algebraic expression where the operator between them is determined by the operator attribute.

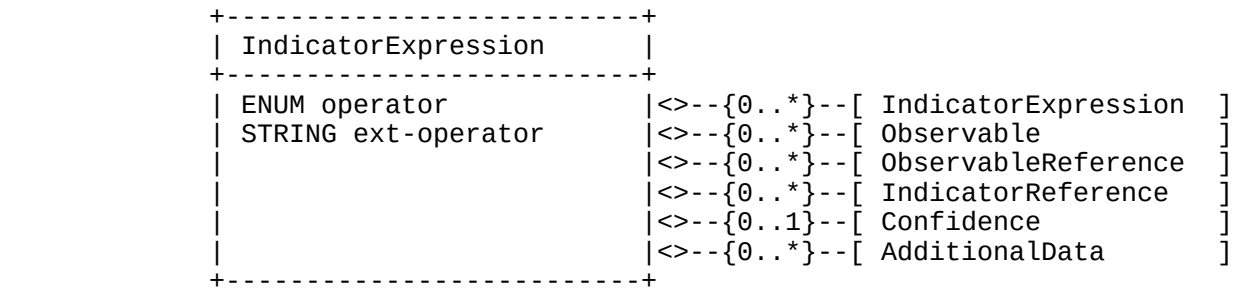

Figure 65: The IndicatorExpression Class

The aggregate classes of the IndicatorExpression class are:

IndicatorExpression
: Zero or more. An expression composed of other observables or indicators. See Section 3.29.4.

Observable
: Zero or more. A description of an observable. See Section 3.29.3.

ObservableReference
: Zero or more. A reference to an observable. See Section 3.29.6.

IndicatorReference
: Zero or more. A reference to an indicator. See Section 3.29.7.

Confidence
: Zero or one. An estimate of the confidence in the quality of the terms expressed in the expression. See Section 3.12.5.

AdditionalData
: Zero or more. EXTENSION. Mechanism by which to extend the data model.

The attributes of the IndicatorExpression class are:

operator
: Optional. ENUM. The operator to be applied between the child elements. See Section 3.29.5 for parsing guidance. The default value is "and". These values are maintained in the "IndicatorExpression-operator" IANA registry per Section 10.2.

  1. not. negation operator.

  2. and. conjunction operator.

3. or. disjunction operator.

4. xor. exclusive disjunction operator.

ext-operator
Optional. STRING. A means by which to extend the operator attribute. See Section 5.1.1.

3.29.5. Expressions with IndicatorExpression

Boolean algebraic expressions can be used to specify relationships between observables and indicator. These expressions are constructed through the use of the operator attribute and parent-child relationships in IndicatorExpressions. These expressions should be parsed as follows:

1. The operator specified by the operator attribute is applied between each of the child elements of the immediate parent IndicatorExpression element. If no operator attribute is specified, it should be assumed to be the conjunction operator (i.e., operator="and").

2. A nested IndicatorExpression element with a parent IndicatorExpression is the equivalent of a parentheses in the expression.

The following four examples in Figure 66 through Figure 70 illustrate these parsing rules:

```
1     : <IndicatorExpression>
2 [O1]:    <Observable>..</Observable>
3 [O2]:    <Observable>..</Observable>
4     : </IndicatorExpression>
```

Equivalent expression: (O1 AND O2)

Figure 66: Nested elements in an IndicatorExpression without an operator attribute specified

```
1     : <IndicatorExpression operator="or">
2 [O1]:    <Observable>..</Observable>
3 [O2]:    <Observable>..</Observable>
4     : </IndicatorExpression>
```

Equivalent expression: (O1 OR O2)

Figure 67: Nested elements in an IndicatorExpression with an operator attribute specified

```
1     : <IndicatorExpression operator="or">
2     :    <IndicatorExpression operator="or">
3 [O1]:      <Observable>..</Observable>
4 [O2]:      <Observable>..</Observable>
5     :    </IndicatorExpression>
6 [O3]:    <Observable>..</Observable>
7     : </IndicatorExpression>
```

Equivalent expression: ((O1 OR O2) OR O3)

Figure 68: Nested elements with a recursive IndicatorExpression with an operator attribute specified

```
1     : <IndicatorExpression operator="not">
2     :    <IndicatorExpression operator="and">
3 [O1]:      <Observable>..</Observable>
4 [O2]:      <Observable>..</Observable>
5     :    </IndicatorExpression>
6     : </IndicatorExpression>
```

Equivalent expression: (NOT (O1 AND O2))

Figure 69: A recursive IndicatorExpression with an operator attribute specified

```
 1                          :    <IndicatorExpression operator="or">
 2                          :      <IndicatorExpression>
 3 [O1 with low confidence] :        <Observable>..</Observable>
 4                          :        <Confidence rating="low" />
 5                          :      </IndicatorExpression>
 6                          :      <IndicatorExpression>
 7 [O2 with high confidence]:        <Observable>..</Observable>
 8                          :        <Confidence rating="high" />
 9                          :      </IndicatorExpression>
10                          :    </IndicatorExpression>
```

Equivalent expression: ((O1) OR (O2))

Figure 70: Varying confidence on particular Observables

Invalid algebraic expressions while valid XML, MUST NOT be specified.

3.29.6. ObservableReference Class

The ObservableReference describes a reference to an observable feature or phenomenon described elsewhere in the document.

The ObservableReference class has no content.

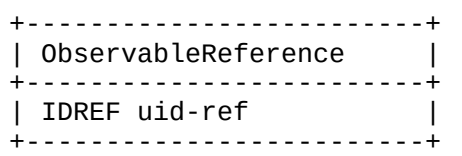

Figure 71: The ObservableReference Class

The ObservableReference class has no content.

The attribute of the ObservableReference class is:

uid-ref
: Required. IDREF. An identifier that serves as a reference to a class in the IODEF document. The referenced class will have this identifier set in its observable-id attribute.

3.29.7. IndicatorReference Class

The IndicatorReference describes a reference to an indicator. This reference may be to an indicator described in this IODEF document or in a previously exchanged IODEF document.

The IndicatorReference class has no content.

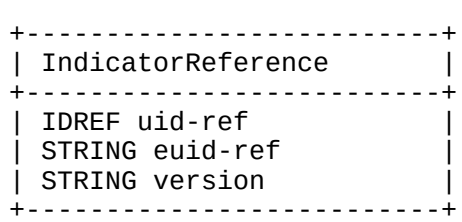

Figure 72: The IndicatorReference Class

The attributes of the IndicatorReference class are:

uid-ref
: Optional. IDREF. An identifier that references an Indicator class in the IODEF document. The referenced Indicator class will have this identifier set in its IndicatorID class.

euid-ref
: Optional. STRING. An identifier that references an IndicatorID not in this IODEF document.

version
Optional. STRING. A version number of an indicator.

Either the uid-ref or the euid-ref attribute MUST be set.

3.29.8. AttackPhase Class

The AttackPhase class describes a particular phase of an attack lifecycle.

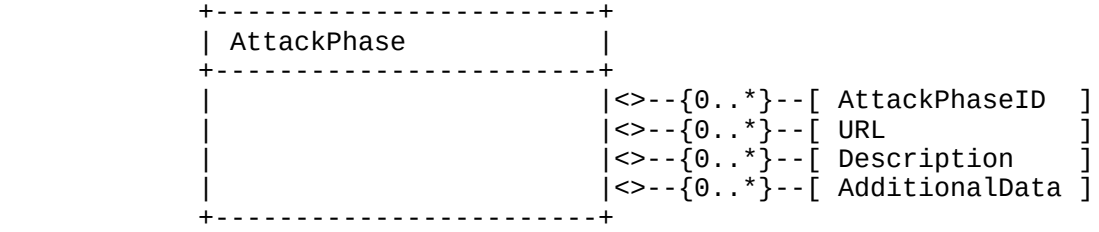

Figure 73: AttackPhase Class

The aggregate classes of the AttackPhase class are:

AttackPhaseID
Zero or more. STRING. An identifier for the phase of the attack.

URL
Zero or more. URL. A URL to a resource describing this phase of the attack.

Description
Zero or more. ML_STRING. A free-form text description of this phase of the attack.

AdditionalData
Zero or more. EXTENSION. A mechanism by which to extend the data model.

AttackPhase MUST have at least one instance of a child class.

The AttackPhase class has no attributes.

4. Processing Considerations

This section provides additional requirements and guidance on creating and processing IODEF documents.

4.1. Encoding

Every IODEF document MUST begin with an XML declaration and MUST specify the XML version used. The character encoding MUST also be explicitly specified. UTF-8 [RFC3629] SHOULD be used unless UTF-16 [RFC2781] is necessary. Encodings other than UTF-8 and UTF-16 SHOULD NOT be used. The IODEF conforms to all XML data encoding conventions and constraints.

The XML declaration with UTF-8 character encoding will read as follows:

```
<?xml version="1.0" encoding="UTF-8" ?>
```

Certain characters have special meaning in XML and MUST not appear in literal form. Per Section 2.4 of [W3C.XML], these characters MUST be escaped with a numeric character or entity reference.

4.2. IODEF Namespace

The IODEF schema declares a namespace of "urn:ietf:params:xml:ns:iodef-2.0" and registers it per [W3C.XMLNS]. Each IODEF document MUST include a valid reference to the IODEF schema using the "xsi:schemaLocation" attribute. An example of such a declaration would look as follows:

```
<IODEF-Document
   version="2.00" lang="en-US"
   xmlns:iodef="urn:ietf:params:xml:ns:iodef-2.0"
   xsi:schemaLocation="urn:ietf:params:xmls:schema:iodef-2.0" ...>
```

4.3. Validation

IODEF documents MUST be well-formed XML. It is RECOMMENDED that recipients validate the document against the schema described in Section 8. However, mere conformance to this schema is not sufficient for a semantically valid IODEF document. The text of Section 3 describes further formatting and constraints; some that cannot be conveniently encoded in the schema. These MUST also be considered by an IODEF implementation. Furthermore, the enumerated values present in this document are a static list that will be incomplete over time as select attributes can be extended by a corresponding IANA registry per Section 10.2. Therefore, IODEF implementations SHOULD periodically update their schema and MAY need to update their parsing algorithms to incorporate newly registered values.

4.4. Incompatibilities with v1

The IODEF data model in this document makes a number of changes to [RFC5070]. These changes were largely additive -- classes and enumerated values were added. However, some incompatibilities between [RFC5070] and this new specification were introduced. These incompatibilities are as follows:

- The IODEF-Document@version attribute is set to "2.0".
- Attributes with enumerated values can now also be extended with IANA registries.
- All iodef:MLStringType classes use xml:lang. IODEF-Document also uses xml:lang.
- The Service@ip_protocol attribute was renamed to @ip-protocol.
- The Node/NodeName class was removed in favor of representing domain names with Node/DomainData/Name class. The Node/DataTime class was also removed so that the Node/DomainData/ DateDomainWasChecked class can represent the time at which the name to address resolution occurred.
- The Node/NodeRole class was moved to System/NodeRole.
- The Reference class is now defined by [RFC7495].
- The data previously represented in the Impact class is now in the SystemImpact and IncidentCategory classes. The Impact class has been removed.
- The semantics of Counter@type are now represented in Counter@unit.
- The IODEF-Document@formatid attribute has been renamed to @format-id.
- Incident/ReportTime is no longer mandatory. However, GenerationTime is.
- The Fax class was removed and is now represented by a generic Telephone class.
- The Telephone, Email and PostalAddress classes were redefined from improved internationalization.
- The "ipv6-net-mask" value was remove from category attribute of Address.

5. Extending the IODEF

In order to support the dynamic nature of security operations, the IODEF data model will need to continue to evolve. This section discusses how new data elements can be incorporated into the IODEF. There is support to add additional enumerated values and new classes. Adding additional attributes to existing classes is not supported.

These extension mechanisms are designed so that adding new data elements is possible without requiring a modifications to this document. Extensions can be implemented publicly or privately. With proven value, well documented extensions can be incorporated into future versions of the specification.

5.1. Extending the Enumerated Values of Attributes

Additional enumerated values can be added to select attributes either through the use of specially marked attributes with the "ext-" prefix or through a set of corresponding IANA registries. The former approach allows for the extension to remain private. The latter approach is public.

5.1.1. Private Extension of Enumerated Values

The data model supports adding new enumerated values to an attribute without public registration. For each attribute that supports this extension technique, there is a corresponding attribute in the same element whose name is identical but with a prefix of "ext-". This special attribute is referred to as the extension attribute. The attribute being extended is referred to as an extensible attribute. For example, an extensible attribute named "foo" will have a corresponding extension attribute named "ext-foo". An element may have many extensible attributes.

In addition to a corresponding extension attribute, each extensible attribute has "ext-value" as one its possible enumerated values. Selection of this particular value in an extensible attribute signals that the extension attribute contains data. Otherwise, this "ext-value" value has no meaning.

In order to add a new enumerated value to an extensible attribute, the value of this attribute MUST be set to "ext-value", and the new desired value MUST be set in the corresponding extension attribute. For example, extending the type attribute of the SystemImpact class would look as follows:

```
 <SystemImpact type="ext-value" ext-type="new-attack-type">
```

A given extension attribute MUST NOT be set unless the corresponding extensible attribute has been set to "ext-value".

5.1.2. Public Extension of Enumerated Values

The data model also supports publicly extending select enumerated attributes. A new entry can be added by registering a new entry in the appropriate IANA registry. Section 10.2 provides a mapping between the extensible attributes and their corresponding registry. Section 4.3 discusses the XML Validation implications of this type of extension. All extensible attributes that support private extensions also support public extensions.

5.2. Extending Classes

Classes of the EXTENSION (iodef:ExtensionType) type can extend the data model. They provide the ability to have new atomic or XML-encoded data elements in all of the top-level classes of the Incident class and a few of the complex subordinate classes. As there are multiple instances of the extensible classes in the data model, there is discretion on where to add a new data element. It is RECOMMENDED that the extension be placed in the most closely related class to the new information.

Extensions using the atomic data types (i.e., all values of the dtype attributes other than "xml") MUST:

1. Set the element content to the desired value, and

2. Set the dtype attribute to correspond to the data type of the element content.

The following guidelines exist for extensions using XML (i.e., dtype="xml"):

1. The element content of the extensible class MUST be set to the desired value and the dtype attribute MUST be set to "xml".

2. The extension schema MUST declare a separate namespace. It is RECOMMENDED that these extensions have the prefix "iodef-". This recommendation makes readability of the document easier by allowing the reader to infer which namespaces relate to IODEF by inspection.

3. It is RECOMMENDED that extension schemas follow the naming convention of the IODEF data model. This too improves the readability of extended IODEF documents. The names of all elements SHOULD be capitalized. For elements with composed

names, a capital letter SHOULD be used for each word. Attribute names SHOULD be in lower case. Attributes with composed names SHOULD be separated by a hyphen.

4. Implementations that encounter an unrecognized element, attribute or attribute value in a supported namespace SHOULD reject the document as a syntax error.

5. There are security and performance implications in requiring implementations to dynamically download schemas at run time. Therefore, implementations MUST NOT download schemas at runtime unless the appropriate precautions are taken. Implementations also need to contend with the potential of significant network and processing issues.

6. Some adopters of the IODEF may have private schema definitions that are not publicly available. Thus implementations may encounter IODEF documents with references to private schemas that may not be resolvable. Hence, IODEF document recipients MUST be prepared for a schema definition in an IODEF document never to resolve.

The following schema and XML document excerpt provide a template for an extension schema and its use in the IODEF document.

This example schema defines a namespace of "iodef-extension1" and a single element named "newdata".

```
<xs:schema
   targetNamespace="iodef-extension1.xsd"
   xmlns:iodef-extension1="iodef-extension1.xsd"
   xmlns:xs="http://www.w3.org/2001/XMLSchema">
   attributeFormDefault="unqualified"
   elementFormDefault="qualified">
 <xs:import
      namespace="urn:ietf:params:xml:ns:iodef-2.0"
      schemaLocation=" urn:ietf:params:xml:schema:iodef-2.0"/>

   <xs:element name="newdata" type="xs:string" />
</xs:schema>
```

The following XML excerpt demonstrates the use of the above schema as an extension to the IODEF.

```
      <IODEF-Document
           version="2.00" lang="en-US"
           xmlns="urn:ietf:params:xml:ns:iodef-2.0"
           xmlns:iodef=" urn:ietf:params:xml:ns:iodef-2.0"
           xmlns:iodef-extension1="iodef-extension1.xsd"
           xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
           xsi:schemaLocation="iodef-extension1.xsd">
          <Incident purpose="reporting">
          ...
            <AdditionalData dtype="xml" meaning="xml">
              <iodef-extension1:newdata>
               Field that could not be represented elsewhere
              </iodef-extension1:newdata>
            </AdditionalData>
          </Incident>
    </IODEF-Document
```

5.3. Deconflicting Private Extensions

To disambiguate which private extension is used in an IODEF document, the data model provides a means to identify the source of an extension. Two attributes in the IODEF-Document class, private-enum-name and private-enum-id, are used to specify this attribution. Only a single private extension can be identified in a given IODEF-Document.

If an implementor has a single private extension, then only the private-enum-name attribute needs to be specified. Multiple distinct private extensions or versioning of a single extension can be attributed by also setting the corresponding private-num-id attribute.

The following XML excerpt demonstrates the specification of a private extension from "example.com" with an identifier of "13".

```
      <IODEF-Document
           version="2.00" lang="en-US"
           private-enum-name="example.com"
           private-enum-id="13"
          ...
    </IODEF-Document>
```

If an unrecognized private extension is encountered in processing, the recipient MAY reject the entire document as a syntax error.

6. Internationalization Issues

Internationalization and localization is of specific concern to the IODEF as it facilitates operational coordination with a diverse set of partners. The IODEF implements internationalization by relying on XML constructs and through explicit design choices in the data model.

Since the IODEF is implemented as an XML Schema, it supports different character encodings, such as UTF-8 and UTF-16, possible with XML. Additionally, each IODEF document MUST specify the language in which its content is encoded. The language can be specified with the attribute "xml:lang" (per Section 2.12 of [W3C.XML]) in the top-level element (i.e., IODEF-Document) and letting all other elements inherit that definition. All IODEF classes with a free-form text definition (i.e., all those defined with type iodef:MLStringType) can also specify a language different from the rest of the document.

The data model supports multiple translations of free-form text. All ML_STRING (iodef:MLStringType) classes have a one-to-many cardinality to their parent. This allows the identical text translated into different languages to be encoded in different instances of the same class with a common parent. This design also enables the creation of a single document containing all the translations. The IODEF implementation SHOULD extract the appropriate language relevant to the recipient.

Related instances of a given iodef:MLStringType class that are translations of each other are identified by a common identifier set in the translation-id attribute. The example below shows three instances of a Description class expressed in three different languages. The relationship between these three instances of the Description class is conveyed by the common value of "1" in the translation-id attribute.

```
<IODEF-Document version="2.00" xml:lang="en" ...
  <Incident purpose="reporting">
    ...
    <Description translation-id="1"
                 xml:lang="en">English</Description>
    <Description translation-id="1"
                 xml:lang="de">Englisch</Description>
    <Description translation-id="1"
                 xml:lang="fr">Anglais</Description>
```

The IODEF balances internationalization support with the need for interoperability. While the IODEF supports different languages, the

data model also relies heavily on standardized enumerated attributes that can crudely approximate the contents of the document. With this approach, a CSIRT should be able to make some sense of an IODEF document it receives even if the free-form text data elements are written in a language unfamiliar to the recipient.

7. Examples

This section provides example of IODEF documents. These examples do not represent the full capabilities of the data model or the the only way to encode particular information.

7.1. Minimal Example

A document containing only the mandatory elements and attributes.

```
<?xml version="1.0" encoding="UTF-8"?>
<!-- Minimum IODEF document -->
<IODEF-Document version="2.00" xml:lang="en"
   xmlns="urn:ietf:params:xml:ns:iodef-2.0"
   xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
   xsi:schemaLocation=
"http://www.iana.org/assignments/xmlregistry/schema/
iodef-2.0.xsd">
  <Incident purpose="reporting" restriction="private">
    <IncidentID name="csirt.example.com">492382</IncidentID>
    <GenerationTime>2015-07-18T09:00:00-05:00</GenerationTime>
    <Contact type="organization" role="creator">
      <Email>
        <EmailTo>contact@csirt.example.com</EmailTo>
      </Email>
    </Contact>
    <!-- Add more fields to make the document useful -->
  </Incident>
</IODEF-Document>
```

7.2. Indicators from a Campaign

An example of C2 domains from a given campaign.

```
<?xml version="1.0" encoding="UTF-8"?>
<!-- A list of C2 domains associated with a campaign -->
<IODEF-Document version="2.00" xml:lang="en"
   xmlns="urn:ietf:params:xml:ns:iodef-2.0"
   xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
   xsi:schemaLocation=
```

```
      "http://www.iana.org/assignments/xml-registry/schema/
       iodef-2.0.xsd">
     <Incident purpose="watch" restriction="green">
       <IncidentID name="csirt.example.com">897923</IncidentID>
         <RelatedActivity>
           <ThreatActor>
             <ThreatActorID>
             TA-12-AGGRESSIVE-BUTTERFLY
             </ThreatActorID>
             <Description>Aggressive Butterfly</Description>
           </ThreatActor>
           <Campaign>
             <CampaignID>C-2015-59405</CampaignID>
             <Description>Orange Giraffe</Description>
           </Campaign>
         </RelatedActivity>
         <GenerationTime>2015-10-02T11:18:00-05:00</GenerationTime>
         <Description>Summarizes the Indicators of Compromise
           for the Orange Giraffe campaign of the Aggressive
           Butterfly crime gang.
         </Description>
         <Assessment>
           <BusinessImpact type="breach-proprietary"/>
         </Assessment>
         <Contact type="organization" role="creator">
           <ContactName>CSIRT for example.com</ContactName>
           <Email>
             <EmailTo>contact@csirt.example.com</EmailTo>
           </Email>
         </Contact>
         <IndicatorData>
           <Indicator>
             <IndicatorID name="csirt.example.com" version="1">
             G90823490
             </IndicatorID>
             <Description>C2 domains</Description>
             <StartTime>2014-12-02T11:18:00-05:00</StartTime>
             <Observable>
               <BulkObservable type="fqdn">
               <BulkObservableList>
                 kj290023j09r34.example.com
                 09ijk23jfj0k8.example.net
                 klknjwfjiowjefr923.example.org
                 oimireik79msd.example.org
               </BulkObservableList>
             </BulkObservable>
           </Observable>
         </Indicator>
```

```
      </IndicatorData>
    </Incident>
  </IODEF-Document>
```

8. The IODEF Data Model (XML Schema)

```
<?xml version="1.0"?>
<xs:schema xmlns="urn:ietf:params:xml:ns:iodef-2.0"
           xmlns:iodef="urn:ietf:params:xml:ns:iodef-2.0"
           xmlns:enum="urn:ietf:params:xml:ns:iodef-enum-1.0"
           xmlns:sci="urn:ietf:params:xml:ns:iodef-sci-1.0"
           xmlns:xs="http://www.w3.org/2001/XMLSchema"
           xmlns:ds="http://www.w3.org/2000/09/xmldsig#"
           targetNamespace="urn:ietf:params:xml:ns:iodef-2.0"
           elementFormDefault="qualified"
           attributeFormDefault="unqualified">
  <xs:import namespace="http://www.w3.org/2000/09/xmldsig#"
             schemaLocation="http://www.w3.org/TR/2002/
REC-xmldsig-core-20020212/xmldsig-core-schema.xsd"/>
  <xs:import namespace="urn:ietf:params:xml:ns:iodef-enum-1.0"
             schemaLocation="http://www.iana.org/assignments/
xml-registry/schema/iodef-enum-1.0.xsd"/>
  <xs:import namespace="urn:ietf:params:xml:ns:iodef-sci-1.0"
             schemaLocation="http://www.iana.org/assignments/
xml-registry/schema/iodef-sci-1.0.xsd"/>
  <xs:import namespace="http://www.w3.org/XML/1998/namespace"
             schemaLocation="http://www.w3c.org/2001/xml.xsd"/>
  <xs:annotation>
    <xs:documentation>
       Incident Object Description Exchange Format v2.0
    </xs:documentation>
  </xs:annotation>
  <!--
   ================================================================
   == IODEF-Document class                                       ==
   ================================================================
  -->
  <xs:element name="IODEF-Document">
    <xs:complexType>
      <xs:sequence>
        <xs:element ref="iodef:Incident" maxOccurs="unbounded"/>
        <xs:element ref="iodef:AdditionalData"
                    minOccurs="0" maxOccurs="unbounded"/>
      </xs:sequence>
      <xs:attribute name="version" type="xs:string" fixed="2.00"/>
      <xs:attribute ref="xml:lang"/>
      <xs:attribute name="format-id" type="xs:string" use="optional"/>
      <xs:attribute name="private-enum-name"
```

```
                    type="xs:string" use="optional"/>
      <xs:attribute name="private-enum-id"
                    type="xs:string" use="optional"/>
    </xs:complexType>
  </xs:element>
  <!--
   ================================================================
   == Incident class                                             ==
   ================================================================
  -->
  <xs:element name="Incident">
    <xs:complexType>
      <xs:sequence>
        <xs:element ref="iodef:IncidentID"/>
        <xs:element ref="iodef:AlternativeID" minOccurs="0"/>
        <xs:element ref="iodef:RelatedActivity"
                    minOccurs="0" maxOccurs="unbounded"/>
        <xs:element ref="iodef:DetectTime" minOccurs="0"/>
        <xs:element ref="iodef:StartTime" minOccurs="0"/>
        <xs:element ref="iodef:EndTime" minOccurs="0"/>
        <xs:element ref="iodef:RecoveryTime" minOccurs="0"/>
        <xs:element ref="iodef:ReportTime" minOccurs="0"/>
        <xs:element ref="iodef:GenerationTime"/>
        <xs:element ref="iodef:Description"
                    minOccurs="0" maxOccurs="unbounded"/>
        <xs:element ref="iodef:Discovery"
                    minOccurs="0" maxOccurs="unbounded"/>
        <xs:element ref="iodef:Assessment"
                    minOccurs="0" maxOccurs="unbounded"/>
        <xs:element ref="iodef:Method"
                    minOccurs="0" maxOccurs="unbounded"/>
        <xs:element ref="iodef:Contact" maxOccurs="unbounded"/>
        <xs:element ref="iodef:EventData"
                    minOccurs="0" maxOccurs="unbounded"/>
        <xs:element ref="iodef:IndicatorData" minOccurs="0"/>
        <xs:element ref="iodef:History" minOccurs="0"/>
        <xs:element ref="iodef:AdditionalData"
                    minOccurs="0" maxOccurs="unbounded"/>
      </xs:sequence>
      <xs:attribute name="purpose"
                    type="incident-purpose-type" use="required"/>
      <xs:attribute name="ext-purpose"
                    type="xs:string" use="optional"/>
      <xs:attribute name="status" type="incident-status-type"/>
      <xs:attribute name="ext-status"
                    type="xs:string" use="optional"/>
      <xs:attribute ref="xml:lang"/>
      <xs:attribute name="restriction"
```

```
                    type="iodef:restriction-type" default="private"
                    use="optional"/>
      <xs:attribute name="ext-restriction"
                    type="xs:string" use="optional"/>
      <xs:attribute name="observable-id" type="xs:ID" use="optional"/>
    </xs:complexType>
  </xs:element>
  <xs:simpleType name="incident-purpose-type">
    <xs:restriction base="xs:NMTOKEN">
      <xs:enumeration value="traceback"/>
      <xs:enumeration value="mitigation"/>
      <xs:enumeration value="reporting"/>
      <xs:enumeration value="watch"/>
      <xs:enumeration value="other"/>
      <xs:enumeration value="ext-value"/>
    </xs:restriction>
  </xs:simpleType>
  <xs:simpleType name="incident-status-type">
    <xs:restriction base="xs:NMTOKEN">
      <xs:enumeration value="new"/>
      <xs:enumeration value="in-progress"/>
      <xs:enumeration value="forwarded"/>
      <xs:enumeration value="resolved"/>
      <xs:enumeration value="future"/>
      <xs:enumeration value="ext-value"/>
    </xs:restriction>
  </xs:simpleType>
  <!--
   ========================================================================
   ==  IncidentID class                                                  ==
   ========================================================================
  -->
  <xs:element name="IncidentID" type="iodef:IncidentIDType"/>
  <xs:complexType name="IncidentIDType">
    <xs:simpleContent>
      <xs:extension base="xs:string">
        <xs:attribute name="name" type="xs:string" use="required"/>
        <xs:attribute name="instance"
                      type="xs:string" use="optional"/>
        <xs:attribute name="restriction"
                      type="iodef:restriction-type" use="optional"/>
        <xs:attribute name="ext-restriction"
                      type="xs:string" use="optional"/>
      </xs:extension>
    </xs:simpleContent>
  </xs:complexType>
  <!--
   ========================================================================
```

```
     ==  AlternativeID class                                          ==
     ======================================================================
    -->
    <xs:element name="AlternativeID">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:IncidentID" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="restriction"
                      type="iodef:restriction-type" use="optional"/>
        <xs:attribute name="ext-restriction"
                      type="xs:string" use="optional"/>
      </xs:complexType>
    </xs:element>
    <!--
     ======================================================================
     ==  RelatedActivity class                                           ==
     ======================================================================
    -->
    <xs:element name="RelatedActivity">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:IncidentID"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:URL"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:ThreatActor"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Campaign"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:IndicatorID"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Confidence" minOccurs="0"/>
          <xs:element ref="iodef:Description"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:AdditionalData"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="restriction"
                      type="iodef:restriction-type" use="optional"/>
        <xs:attribute name="ext-restriction"
                      type="xs:string" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="ThreatActor">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:ThreatActorID"
```

```
                    minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:URL" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Description"
                    minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:AdditionalData"
                    minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="restriction"
                    type="iodef:restriction-type" use="optional"/>
        <xs:attribute name="ext-restriction"
                    type="xs:string" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="ThreatActorID" type="xs:string"/>
    <xs:element name="Campaign">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:CampaignID"
                    minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:URL"
                    minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Description"
                    minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:AdditionalData"
                    minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="restriction"
                    type="iodef:restriction-type" use="optional"/>
        <xs:attribute name="ext-restriction"
                    type="xs:string" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="CampaignID" type="xs:string"/>
    <!--
     ========================================================================
     ==   Contact class                                                    ==
     ========================================================================
    -->
    <xs:element name="Contact">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:ContactName"
                    minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:ContactTitle"
                    minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Description"
                    minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:RegistryHandle"
```

```
                    minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:PostalAddress"
                    minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Email"
                    minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Telephone"
                    minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Timezone" minOccurs="0"/>
          <xs:element ref="iodef:Contact"
                    minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:AdditionalData"
                    minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="role"
                    type="contact-role-type" use="required"/>
        <xs:attribute name="ext-role"
                    type="xs:string" use="optional"/>
        <xs:attribute name="type"
                    type="contact-type-type" use="required"/>
        <xs:attribute name="ext-type"
                    type="xs:string" use="optional"/>
        <xs:attribute name="restriction"
                    type="iodef:restriction-type" use="optional"/>
        <xs:attribute name="ext-restriction"
                    type="xs:string" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:simpleType name="contact-role-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="creator"/>
        <xs:enumeration value="reporter"/>
        <xs:enumeration value="admin"/>
        <xs:enumeration value="tech"/>
        <xs:enumeration value="provider"/>
        <xs:enumeration value="user"/>
        <xs:enumeration value="billing"/>
        <xs:enumeration value="legal"/>
        <xs:enumeration value="abuse"/>
        <xs:enumeration value="irt"/>
        <xs:enumeration value="cc"/>
        <xs:enumeration value="cc-irt"/>
        <xs:enumeration value="leo"/>
        <xs:enumeration value="vendor"/>
        <xs:enumeration value="vendor-services"/>
        <xs:enumeration value="victim"/>
        <xs:enumeration value="victim-notified"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
```

```
    </xs:simpleType>
    <xs:simpleType name="contact-type-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="person"/>
        <xs:enumeration value="organization"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:element name="ContactName" type="iodef:MLStringType"/>
    <xs:element name="ContactTitle" type="iodef:MLStringType"/>
    <xs:element name="RegistryHandle">
      <xs:complexType>
        <xs:simpleContent>
          <xs:extension base="xs:string">
            <xs:attribute name="registry"
                          type="registryhandle-registry-type"/>
            <xs:attribute name="ext-registry"
                          type="xs:string" use="optional"/>
          </xs:extension>
        </xs:simpleContent>
      </xs:complexType>
    </xs:element>
    <xs:simpleType name="registryhandle-registry-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="internic"/>
        <xs:enumeration value="apnic"/>
        <xs:enumeration value="arin"/>
        <xs:enumeration value="lacnic"/>
        <xs:enumeration value="ripe"/>
        <xs:enumeration value="afrinic"/>
        <xs:enumeration value="local"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:element name="PostalAddress">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:PAddress"/>
          <xs:element ref="iodef:Description"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="type"
                      type="postaladdress-type-type" use="optional"/>
        <xs:attribute name="ext-type" type="xs:string" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="PAddress" type="iodef:MLStringType"/>
    <xs:simpleType name="postaladdress-type-type">
```

```
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="street"/>
        <xs:enumeration value="mailing"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:element name="Telephone">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:TelephoneNumber"/>
          <xs:element ref="iodef:Description"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="type"
                      type="telephone-type-type" use="optional"/>
        <xs:attribute name="ext-type" type="xs:string" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="TelephoneNumber" type="xs:string"/>
    <xs:simpleType name="telephone-type-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="wired"/>
        <xs:enumeration value="mobile"/>
        <xs:enumeration value="fax"/>
        <xs:enumeration value="hotline"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:element name="Email">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:EmailTo"/>
          <xs:element ref="iodef:Description"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="type"
                      type="email-type-type" use="optional"/>
        <xs:attribute name="ext-type" type="xs:string" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:simpleType name="email-type-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="direct"/>
        <xs:enumeration value="hotline"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <!--
```

```
     ============================================================
     ==  Time-based classes                                    ==
     ============================================================
    -->
    <xs:element name="DateTime" type="xs:dateTime"/>
    <xs:element name="ReportTime" type="xs:dateTime"/>
    <xs:element name="DetectTime" type="xs:dateTime"/>
    <xs:element name="StartTime" type="xs:dateTime"/>
    <xs:element name="EndTime" type="xs:dateTime"/>
    <xs:element name="RecoveryTime" type="xs:dateTime"/>
    <xs:element name="GenerationTime" type="xs:dateTime"/>
    <xs:element name="Timezone" type="iodef:TimezoneType"/>
    <!--
     ============================================================
     ==  History class                                         ==
     ============================================================
    -->
    <xs:element name="History">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:HistoryItem" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="restriction"
                      type="iodef:restriction-type" use="optional"/>
        <xs:attribute name="ext-restriction"
                      type="xs:string" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="HistoryItem">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:DateTime"/>
          <xs:element ref="iodef:IncidentID" minOccurs="0"/>
          <xs:element ref="iodef:Contact" minOccurs="0"/>
          <xs:element ref="iodef:Description"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:DefinedCOA"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:AdditionalData"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="action"
                      type="iodef:action-type" use="required"/>
        <xs:attribute name="ext-action"
                      type="xs:string" use="optional"/>
        <xs:attribute name="restriction"
                      type="iodef:restriction-type" use="optional"/>
        <xs:attribute name="ext-restriction"
```

```
                    type="xs:string" use="optional"/>
        <xs:attribute name="observable-id" type="xs:ID" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="DefinedCOA" type="xs:string"/>
    <!--
     ========================================================================
     ==  Expectation class                                                 ==
     ========================================================================
    -->
    <xs:element name="Expectation">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:Description"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:DefinedCOA"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:StartTime" minOccurs="0"/>
          <xs:element ref="iodef:EndTime" minOccurs="0"/>
          <xs:element ref="iodef:Contact" minOccurs="0"/>
        </xs:sequence>
        <xs:attribute name="action"
                      type="iodef:action-type" default="other"/>
        <xs:attribute name="ext-action"
                      type="xs:string" use="optional"/>
        <xs:attribute name="severity" type="iodef:severity-type"/>
        <xs:attribute name="restriction"
                      type="iodef:restriction-type" use="optional"/>
        <xs:attribute name="ext-restriction"
                      type="xs:string" use="optional"/>
        <xs:attribute name="observable-id" type="xs:ID" use="optional"/>
      </xs:complexType>
    </xs:element>
    <!--
     ========================================================================
     ==  Discovery class                                                   ==
     ========================================================================
    -->
    <xs:element name="Discovery">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:Description"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Contact"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:DetectionPattern"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
```

```
        <xs:attribute name="source"
                      type="discovery-source-type" use="optional"
                      default="unknown"/>
        <xs:attribute name="ext-source"
                      type="xs:string" use="optional"/>
        <xs:attribute name="restriction"
                      type="iodef:restriction-type" use="optional"/>
        <xs:attribute name="ext-restriction"
                      type="xs:string" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:simpleType name="discovery-source-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="nidps"/>
        <xs:enumeration value="hips"/>
        <xs:enumeration value="siem"/>
        <xs:enumeration value="av"/>
        <xs:enumeration value="third-party-monitoring"/>
        <xs:enumeration value="incident"/>
        <xs:enumeration value="os-log"/>
        <xs:enumeration value="application-log"/>
        <xs:enumeration value="device-log"/>
        <xs:enumeration value="network-flow"/>
        <xs:enumeration value="passive-dns"/>
        <xs:enumeration value="investigation"/>
        <xs:enumeration value="audit"/>
        <xs:enumeration value="internal-notification"/>
        <xs:enumeration value="external-notification"/>
        <xs:enumeration value="leo"/>
        <xs:enumeration value="partner"/>
        <xs:enumeration value="actor"/>
        <xs:enumeration value="unknown"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:element name="DetectionPattern">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:Application"/>
          <xs:element ref="iodef:Description"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element name="DetectionConfiguration"
                      type="xs:string"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="restriction"
                      type="iodef:restriction-type" use="optional"/>
        <xs:attribute name="ext-restriction"
```

```
                    type="xs:string" use="optional"/>
        <xs:attribute name="observable-id" type="xs:ID" use="optional"/>
      </xs:complexType>
    </xs:element>
    <!--
     ================================================================
     ==  Method class                                               ==
     ================================================================
    -->
    <xs:element name="Method">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:Reference"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Description"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="sci:AttackPattern"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="sci:Vulnerability"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="sci:Weakness"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:AdditionalData"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="restriction"
                      type="iodef:restriction-type" use="optional"/>
        <xs:attribute name="ext-restriction"
                      type="xs:string" use="optional"/>
      </xs:complexType>
    </xs:element>
    <!--
     ================================================================
     ==  Reference class                                            ==
     ================================================================
    -->
    <xs:element name="Reference">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="enum:ReferenceName" minOccurs="0"/>
          <xs:element ref="iodef:URL"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Description"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="observable-id" type="xs:ID" use="optional"/>
      </xs:complexType>
    </xs:element>
```

```
    <!--
     ========================================================================
     ==  Assessment class                                                  ==
     ========================================================================
    -->
    <xs:element name="Assessment">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:IncidentCategory"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:choice maxOccurs="unbounded">
            <xs:element ref="iodef:SystemImpact"/>
            <xs:element ref="iodef:BusinessImpact"/>
            <xs:element ref="iodef:TimeImpact"/>
            <xs:element ref="iodef:MonetaryImpact"/>
            <xs:element ref="iodef:IntendedImpact"/>
          </xs:choice>
          <xs:element ref="iodef:Counter"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:MitigatingFactor"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Cause"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Confidence" minOccurs="0"/>
          <xs:element ref="iodef:AdditionalData"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="occurrence">
          <xs:simpleType>
            <xs:restriction base="xs:NMTOKEN">
              <xs:enumeration value="actual"/>
              <xs:enumeration value="potential"/>
            </xs:restriction>
          </xs:simpleType>
        </xs:attribute>
        <xs:attribute name="restriction"
                      type="iodef:restriction-type" use="optional"/>
        <xs:attribute name="ext-restriction"
                      type="xs:string" use="optional"/>
        <xs:attribute name="observable-id" type="xs:ID" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="IncidentCategory" type="iodef:MLStringType"/>
    <xs:element name="BusinessImpact" type="iodef:BusinessImpactType"/>
    <xs:element name="IntendedImpact" type="iodef:BusinessImpactType"/>
    <xs:element name="MitigatingFactor" type="iodef:MLStringType"/>
    <xs:element name="Cause" type="iodef:MLStringType"/>
    <xs:element name="SystemImpact">
```

```
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:Description"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="severity"
                      type="iodef:severity-type" use="optional"/>
        <xs:attribute name="completion"
                      type="iodef:systemimpact-completion-type"
                      use="optional"/>
        <xs:attribute name="type"
                      type="systemimpact-type-type"
                      use="optional" default="unknown"/>
        <xs:attribute name="ext-type" type="xs:string" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:simpleType name="systemimpact-completion-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="failed"/>
        <xs:enumeration value="succeeded"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:simpleType name="systemimpact-type-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="takeover-account"/>
        <xs:enumeration value="takeover-service"/>
        <xs:enumeration value="takeover-system"/>
        <xs:enumeration value="cps-manipulation"/>
        <xs:enumeration value="cps-damage"/>
        <xs:enumeration value="availability-data"/>
        <xs:enumeration value="availability-account"/>
        <xs:enumeration value="availability-service"/>
        <xs:enumeration value="availability-system"/>
        <xs:enumeration value="damaged-system"/>
        <xs:enumeration value="damaged-data"/>
        <xs:enumeration value="breach-proprietary"/>
        <xs:enumeration value="breach-privacy"/>
        <xs:enumeration value="breach-credential"/>
        <xs:enumeration value="breach-configuration"/>
        <xs:enumeration value="integrity-data"/>
        <xs:enumeration value="integrity-configuration"/>
        <xs:enumeration value="integrity-hardware"/>
        <xs:enumeration value="traffic-redirection"/>
        <xs:enumeration value="monitoring-traffic"/>
        <xs:enumeration value="monitoring-host"/>
        <xs:enumeration value="policy"/>
        <xs:enumeration value="unknown"/>
        <xs:enumeration value="ext-value"/>
```

```
      </xs:restriction>
    </xs:simpleType>
    <xs:complexType name="BusinessImpactType">
      <xs:sequence>
        <xs:element ref="iodef:Description"
                    minOccurs="0" maxOccurs="unbounded"/>
      </xs:sequence>
      <xs:attribute name="severity"
                    type="businessimpact-severity-type" use="optional"/>
      <xs:attribute name="ext-severity"
                    type="xs:string" use="optional"/>
      <xs:attribute name="type"
                    type="businessimpact-type-type"
                    use="optional" default="unknown"/>
      <xs:attribute name="ext-type" type="xs:string" use="optional"/>
    </xs:complexType>
    <xs:simpleType name="businessimpact-severity-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="none"/>
        <xs:enumeration value="low"/>
        <xs:enumeration value="medium"/>
        <xs:enumeration value="high"/>
        <xs:enumeration value="unknown"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:simpleType name="businessimpact-type-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="breach-proprietary"/>
        <xs:enumeration value="breach-privacy"/>
        <xs:enumeration value="breach-credential"/>
        <xs:enumeration value="loss-of-integrity"/>
        <xs:enumeration value="loss-of-service"/>
        <xs:enumeration value="theft-financial"/>
        <xs:enumeration value="theft-service"/>
        <xs:enumeration value="degraded-reputation"/>
        <xs:enumeration value="asset-damage"/>
        <xs:enumeration value="asset-manipulation"/>
        <xs:enumeration value="legal"/>
        <xs:enumeration value="extortion"/>
        <xs:enumeration value="unknown"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:element name="TimeImpact">
      <xs:complexType>
        <xs:simpleContent>
          <xs:extension base="iodef:PositiveFloatType">
```

```
            <xs:attribute name="severity" type="iodef:severity-type"/>
            <xs:attribute name="metric"
                          type="timeimpact-metric-type" use="required"/>
            <xs:attribute name="ext-metric"
                          type="xs:string" use="optional"/>
            <xs:attribute name="duration" type="iodef:duration-type"/>
            <xs:attribute name="ext-duration"
                          type="xs:string" use="optional"/>
          </xs:extension>
        </xs:simpleContent>
      </xs:complexType>
    </xs:element>
    <xs:simpleType name="timeimpact-metric-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="labor"/>
        <xs:enumeration value="elapsed"/>
        <xs:enumeration value="downtime"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:element name="MonetaryImpact">
      <xs:complexType>
        <xs:simpleContent>
          <xs:extension base="iodef:PositiveFloatType">
            <xs:attribute name="severity" type="iodef:severity-type"/>
            <xs:attribute name="currency" type="xs:string"/>
          </xs:extension>
        </xs:simpleContent>
      </xs:complexType>
    </xs:element>
    <xs:element name="Confidence">
      <xs:complexType>
        <xs:attribute name="rating"
                      type="confidence-rating-type" use="required"/>
        <xs:attribute name="ext-rating"
                      type="xs:string" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:simpleType name="confidence-rating-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="low"/>
        <xs:enumeration value="medium"/>
        <xs:enumeration value="high"/>
        <xs:enumeration value="numeric"/>
        <xs:enumeration value="unknown"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
```

```
    <!--
     ========================================================================
     == EventData class                                                    ==
     ========================================================================
    -->
    <xs:element name="EventData">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:Description"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:DetectTime" minOccurs="0"/>
          <xs:element ref="iodef:StartTime" minOccurs="0"/>
          <xs:element ref="iodef:EndTime" minOccurs="0"/>
          <xs:element ref="iodef:RecoveryTime" minOccurs="0"/>
          <xs:element ref="iodef:ReportTime" minOccurs="0"/>
          <xs:element ref="iodef:Contact"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Discovery"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Assessment" minOccurs="0"/>
          <xs:element ref="iodef:Method"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Flow"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Expectation"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Record" minOccurs="0"/>
          <xs:element ref="iodef:EventData"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:AdditionalData"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="restriction"
                      type="iodef:restriction-type" use="optional"/>
        <xs:attribute name="ext-restriction"
                      type="xs:string" use="optional"/>
        <xs:attribute name="observable-id" type="xs:ID" use="optional"/>
      </xs:complexType>
    </xs:element>
    <!--
     ========================================================================
     ==  Flow class                                                        ==
     ========================================================================
    -->
    <xs:element name="Flow">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:System" maxOccurs="unbounded"/>
```

```
      </xs:sequence>
    </xs:complexType>
  </xs:element>
  <!--
   ================================================================
   ==  System class                                               ==
   ================================================================
  -->
  <xs:element name="System">
    <xs:complexType>
      <xs:sequence>
        <xs:element ref="iodef:Node"/>
        <xs:element ref="iodef:NodeRole"
                    minOccurs="0" maxOccurs="unbounded"/>
        <xs:element ref="iodef:Service"
                    minOccurs="0" maxOccurs="unbounded"/>
        <xs:element ref="iodef:OperatingSystem"
                    minOccurs="0" maxOccurs="unbounded"/>
        <xs:element ref="iodef:Counter"
                    minOccurs="0" maxOccurs="unbounded"/>
        <xs:element name="AssetID"
                    type="xs:string"
                    minOccurs="0" maxOccurs="unbounded"/>
        <xs:element ref="iodef:Description"
                    minOccurs="0" maxOccurs="unbounded"/>
        <xs:element ref="iodef:AdditionalData"
                    minOccurs="0" maxOccurs="unbounded"/>
      </xs:sequence>
      <xs:attribute name="category" type="system-category-type"/>
      <xs:attribute name="ext-category"
                    type="xs:string" use="optional"/>
      <xs:attribute name="interface" type="xs:string"/>
      <xs:attribute name="spoofed"
                    type="yes-no-unknown-type" default="unknown"/>
      <xs:attribute name="virtual"
                    type="yes-no-unknown-type" use="optional"
                    default="unknown"/>
      <xs:attribute name="ownership" type="system-ownership-type"
                    use="optional"/>
      <xs:attribute name="ext-ownership"
                    type="xs:string" use="optional"/>
      <xs:attribute name="restriction"
                    type="iodef:restriction-type" use="optional"/>
      <xs:attribute name="ext-restriction"
                    type="xs:string" use="optional"/>
      <xs:attribute name="observable-id" type="xs:ID" use="optional"/>
    </xs:complexType>
  </xs:element>
```

```
    <xs:element name="OperatingSystem" type="iodef:SoftwareType"/>
    <xs:simpleType name="system-category-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="source"/>
        <xs:enumeration value="target"/>
        <xs:enumeration value="intermediate"/>
        <xs:enumeration value="sensor"/>
        <xs:enumeration value="infrastructure"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:simpleType name="system-ownership-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="organization"/>
        <xs:enumeration value="personal"/>
        <xs:enumeration value="partner"/>
        <xs:enumeration value="customer"/>
        <xs:enumeration value="no-relationship"/>
        <xs:enumeration value="unknown"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <!--
     ================================================================
     == Node class                                                 ==
     ================================================================
    -->
    <xs:element name="Node">
      <xs:complexType>
        <xs:sequence>
          <xs:choice maxOccurs="unbounded">
            <xs:element ref="iodef:DomainData"
                        minOccurs="0" maxOccurs="unbounded"/>
            <xs:element ref="iodef:Address"
                        minOccurs="0" maxOccurs="unbounded"/>
          </xs:choice>
          <xs:element ref="iodef:PostalAddress" minOccurs="0"/>
          <xs:element ref="iodef:Location"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Counter"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
      </xs:complexType>
    </xs:element>
    <xs:element name="Address">
      <xs:complexType>
        <xs:simpleContent>
          <xs:extension base="xs:string">
```

```
            <xs:attribute name="category"
                          type="address-category-type"
                          default="ipv6-addr"/>
            <xs:attribute name="ext-category"
                          type="xs:string" use="optional"/>
            <xs:attribute name="vlan-name" type="xs:string"/>
            <xs:attribute name="vlan-num" type="xs:integer"/>
            <xs:attribute name="observable-id"
                          type="xs:ID" use="optional"/>
          </xs:extension>
        </xs:simpleContent>
      </xs:complexType>
    </xs:element>
    <xs:simpleType name="address-category-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="asn"/>
        <xs:enumeration value="atm"/>
        <xs:enumeration value="e-mail"/>
        <xs:enumeration value="mac"/>
        <xs:enumeration value="ipv4-addr"/>
        <xs:enumeration value="ipv4-net"/>
        <xs:enumeration value="ipv4-net-masked"/>
        <xs:enumeration value="ipv4-net-mask"/>
        <xs:enumeration value="ipv6-addr"/>
        <xs:enumeration value="ipv6-net"/>
        <xs:enumeration value="ipv6-net-masked"/>
        <xs:enumeration value="site-uri"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:element name="Location" type="iodef:MLStringType"/>
    <xs:element name="NodeRole">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:Description"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="category"
                      type="noderole-category-type" use="required"/>
        <xs:attribute name="ext-category"
                      type="xs:string" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:simpleType name="noderole-category-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="client"/>
        <xs:enumeration value="client-enterprise"/>
        <xs:enumeration value="client-partner"/>
```

```
        <xs:enumeration value="client-remote"/>
        <xs:enumeration value="client-kiosk"/>
        <xs:enumeration value="client-mobile"/>
        <xs:enumeration value="server-internal"/>
        <xs:enumeration value="server-public"/>
        <xs:enumeration value="www"/>
        <xs:enumeration value="mail"/>
        <xs:enumeration value="webmail"/>
        <xs:enumeration value="messaging"/>
        <xs:enumeration value="streaming"/>
        <xs:enumeration value="voice"/>
        <xs:enumeration value="file"/>
        <xs:enumeration value="ftp"/>
        <xs:enumeration value="p2p"/>
        <xs:enumeration value="name"/>
        <xs:enumeration value="directory"/>
        <xs:enumeration value="credential"/>
        <xs:enumeration value="print"/>
        <xs:enumeration value="application"/>
        <xs:enumeration value="database"/>
        <xs:enumeration value="backup"/>
        <xs:enumeration value="dhcp"/>
        <xs:enumeration value="assessment"/>
        <xs:enumeration value="source-control"/>
        <xs:enumeration value="config-management"/>
        <xs:enumeration value="monitoring"/>
        <xs:enumeration value="infra"/>
        <xs:enumeration value="infra-firewall"/>
        <xs:enumeration value="infra-router"/>
        <xs:enumeration value="infra-switch"/>
        <xs:enumeration value="camera"/>
        <xs:enumeration value="proxy"/>
        <xs:enumeration value="remote-access"/>
        <xs:enumeration value="log"/>
        <xs:enumeration value="virtualization"/>
        <xs:enumeration value="pos"/>
        <xs:enumeration value="scada"/>
        <xs:enumeration value="scada-supervisory"/>
        <xs:enumeration value="sinkhole"/>
        <xs:enumeration value="honeypot"/>
        <xs:enumeration value="anonymization"/>
        <xs:enumeration value="c2-server"/>
        <xs:enumeration value="malware-distribution"/>
        <xs:enumeration value="drop-server"/>
        <xs:enumeration value="hop-point"/>
        <xs:enumeration value="reflector"/>
        <xs:enumeration value="phishing-site"/>
        <xs:enumeration value="spear-phishing-site"/>
```

```
        <xs:enumeration value="recruiting-site"/>
        <xs:enumeration value="fraudulent-site"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <!--
     ========================================================================
     ==  Service Class                                                     ==
     ========================================================================
    -->
    <xs:element name="Service">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:ServiceName" minOccurs="0"/>
          <xs:element ref="iodef:Port" minOccurs="0"/>
          <xs:element ref="iodef:Portlist" minOccurs="0"/>
          <xs:element ref="iodef:ProtoType" minOccurs="0"/>
          <xs:element ref="iodef:ProtoCode" minOccurs="0"/>
          <xs:element ref="iodef:ProtoField" minOccurs="0"/>
          <xs:element ref="iodef:ApplicationHeader" minOccurs="0"/>
          <xs:element ref="iodef:EmailData" minOccurs="0"/>
          <xs:element ref="iodef:Application" minOccurs="0"/>
        </xs:sequence>
        <xs:attribute name="ip-protocol"
                      type="xs:integer" use="optional"/>
        <xs:attribute name="observable-id" type="xs:ID" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="Port" type="xs:integer"/>
    <xs:element name="Portlist" type="iodef:PortlistType"/>
    <xs:element name="ProtoType" type="xs:integer"/>
    <xs:element name="ProtoCode" type="xs:integer"/>
    <xs:element name="ProtoField" type="xs:integer"/>
    <xs:element name="ApplicationHeader">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:ApplicationHeaderField"
                      maxOccurs="unbounded"/>
        </xs:sequence>
      </xs:complexType>
    </xs:element>
    <xs:element name="ApplicationHeaderField"
                type="iodef:ExtensionType"/>
    <xs:element name="ServiceName">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:IANAService"
                      minOccurs="0"/>
```

```
          <xs:element ref="iodef:URL"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Description"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
      </xs:complexType>
    </xs:element>
    <xs:element name="IANAService" type="xs:string"/>
    <xs:element name="Application" type="iodef:SoftwareType"/>
    <!--
     ========================================================================
     ==  Counter class                                                     ==
     ========================================================================
    -->
    <xs:element name="Counter">
      <xs:complexType>
        <xs:simpleContent>
          <xs:extension base="xs:float">
            <xs:attribute name="type"
                          type="counter-type-type" use="required"/>
            <xs:attribute name="ext-type"
                          type="xs:string" use="optional"/>
            <xs:attribute name="unit"
                          type="counter-unit-type" use="required"/>
            <xs:attribute name="ext-unit"
                          type="xs:string" use="optional"/>
            <xs:attribute name="meaning"
                          type="xs:string" use="optional"/>
            <xs:attribute name="duration" type="iodef:duration-type"/>
            <xs:attribute name="ext-duration"
                          type="xs:string" use="optional"/>
          </xs:extension>
        </xs:simpleContent>
      </xs:complexType>
    </xs:element>
    <xs:simpleType name="counter-type-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="counter"/>
        <xs:enumeration value="rate"/>
        <xs:enumeration value="average"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:simpleType name="counter-unit-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="byte"/>
        <xs:enumeration value="mbit"/>
        <xs:enumeration value="packet"/>
```

```
        <xs:enumeration value="flow"/>
        <xs:enumeration value="session"/>
        <xs:enumeration value="event"/>
        <xs:enumeration value="alert"/>
        <xs:enumeration value="message"/>
        <xs:enumeration value="host"/>
        <xs:enumeration value="site"/>
        <xs:enumeration value="organization"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <!--
     ================================================================
     ==  EmailData class                                           ==
     ================================================================
    -->
    <xs:element name="EmailData">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:EmailTo"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:EmailFrom" minOccurs="0"/>
          <xs:element ref="iodef:EmailSubject" minOccurs="0"/>
          <xs:element ref="iodef:EmailX-Mailer" minOccurs="0"/>
          <xs:element ref="iodef:EmailHeaderField"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:EmailHeaders" minOccurs="0"/>
          <xs:element ref="iodef:EmailBody" minOccurs="0"/>
          <xs:element ref="iodef:EmailMessage" minOccurs="0"/>
          <xs:element ref="iodef:HashData"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="SignatureData"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="observable-id" type="xs:ID" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="EmailTo" type="xs:string"/>
    <xs:element name="EmailFrom" type="xs:string"/>
    <xs:element name="EmailSubject" type="xs:string"/>
    <xs:element name="EmailX-Mailer" type="xs:string"/>
    <xs:element name="EmailHeaderField" type="iodef:ExtensionType"/>
    <xs:element name="EmailHeaders" type="xs:string"/>
    <xs:element name="EmailBody" type="xs:string"/>
    <xs:element name="EmailMessage" type="xs:string"/>
    <!--
     ================================================================
     ==   DomainData class                                         ==
```

```
     ============================================================================
    -->
    <xs:element name="DomainData">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:Name"/>
          <xs:element ref="iodef:DateDomainWasChecked"
                      minOccurs="0"/>
          <xs:element ref="iodef:RegistrationDate"
                      minOccurs="0"/>
          <xs:element ref="iodef:ExpirationDate"
                      minOccurs="0"/>
          <xs:element ref="iodef:RelatedDNS"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Nameservers"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:DomainContacts"
                      minOccurs="0"/>
        </xs:sequence>
        <xs:attribute name="system-status"
                      type="domaindata-system-status-type"/>
        <xs:attribute name="ext-system-status"
                      type="xs:string" use="optional"/>
        <xs:attribute name="domain-status"
                      type="domaindata-domain-status-type"/>
        <xs:attribute name="ext-domain-status"
                      type="xs:string" use="optional"/>
        <xs:attribute name="observable-id" type="xs:ID" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="Name" type="xs:string"/>
    <xs:element name="DateDomainWasChecked" type="xs:dateTime"/>
    <xs:element name="RegistrationDate" type="xs:dateTime"/>
    <xs:element name="ExpirationDate" type="xs:dateTime"/>
    <xs:simpleType name="domaindata-system-status-type">
      <xs:restriction base="xs:string">
        <xs:enumeration value="spoofed"/>
        <xs:enumeration value="fraudulent"/>
        <xs:enumeration value="innocent-hacked"/>
        <xs:enumeration value="innocent-hijacked"/>
        <xs:enumeration value="unknown"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:simpleType name="domaindata-domain-status-type">
      <xs:restriction base="xs:string">
        <xs:enumeration value="reservedDelegation"/>
        <xs:enumeration value="assignedAndActive"/>
```

```
        <xs:enumeration value="assignedAndInactive"/>
        <xs:enumeration value="assignedAndOnHold"/>
        <xs:enumeration value="revoked"/>
        <xs:enumeration value="transferPending"/>
        <xs:enumeration value="registryLock"/>
        <xs:enumeration value="registrarLock"/>
        <xs:enumeration value="other"/>
        <xs:enumeration value="unknown"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:element name="RelatedDNS" type="iodef:ExtensionType"/>
    <xs:element name="Nameservers">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:Server"/>
          <xs:element ref="iodef:Address" maxOccurs="unbounded"/>
        </xs:sequence>
      </xs:complexType>
    </xs:element>
    <xs:element name="Server" type="xs:string"/>
    <xs:element name="DomainContacts">
      <xs:complexType>
        <xs:choice>
          <xs:element ref="iodef:SameDomainContact"/>
          <xs:element ref="iodef:Contact"
                      minOccurs="1" maxOccurs="unbounded"/>
        </xs:choice>
      </xs:complexType>
    </xs:element>
    <xs:element name="SameDomainContact" type="xs:string"/>
    <!--
     ========================================================================
     ==  Record class                                                      ==
     ========================================================================
    -->
    <xs:element name="Record">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:RecordData" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="restriction"
                      type="iodef:restriction-type" use="optional"/>
        <xs:attribute name="ext-restriction"
                      type="xs:string" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="RecordData">
```

```
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:DateTime" minOccurs="0"/>
          <xs:element ref="iodef:Description"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Application" minOccurs="0"/>
          <xs:element ref="iodef:RecordPattern"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:RecordItem"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:URL"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:FileData"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:WindowsRegistryKeysModified"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:CertificateData"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:AdditionalData"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="restriction"
                      type="iodef:restriction-type" use="optional"/>
        <xs:attribute name="ext-restriction"
                      type="xs:string" use="optional"/>
        <xs:attribute name="observable-id" type="xs:ID" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="RecordPattern">
      <xs:complexType>
        <xs:simpleContent>
          <xs:extension base="xs:string">
            <xs:attribute name="type"
                          type="recordpattern-type-type"
                          use="required"/>
            <xs:attribute name="ext-type"
                          type="xs:string" use="optional"/>
            <xs:attribute name="offset"
                          type="xs:integer" use="optional"/>
            <xs:attribute name="offsetunit"
                          type="recordpattern-offsetunit-type"
                          use="optional" default="line"/>
            <xs:attribute name="ext-offsetunit"
                          type="xs:string" use="optional"/>
            <xs:attribute name="instance"
                          type="xs:integer" use="optional"/>
          </xs:extension>
        </xs:simpleContent>
```

```
      </xs:complexType>
    </xs:element>
    <xs:simpleType name="recordpattern-type-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="regex"/>
        <xs:enumeration value="binary"/>
        <xs:enumeration value="xpath"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:simpleType name="recordpattern-offsetunit-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="line"/>
        <xs:enumeration value="byte"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:element name="RecordItem" type="iodef:ExtensionType"/>
    <!--
     ========================================================================
     ==  WindowsRegistryKeysModified Class                                 ==
     ========================================================================
    -->
    <xs:element name="WindowsRegistryKeysModified">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:Key" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="observable-id" type="xs:ID" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="Key">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:KeyName"/>
          <xs:element ref="iodef:Value" minOccurs="0"/>
        </xs:sequence>
        <xs:attribute name="registryaction"
                      type="key-registryaction-type"/>
        <xs:attribute name="ext-registryaction"
                      type="xs:string" use="optional"/>
        <xs:attribute name="observable-id" type="xs:ID" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="KeyName" type="xs:string"/>
    <xs:element name="Value" type="xs:string"/>
    <xs:simpleType name="key-registryaction-type">
      <xs:restriction base="xs:NMTOKEN">
```

```
        <xs:enumeration value="add-key"/>
        <xs:enumeration value="add-value"/>
        <xs:enumeration value="delete-key"/>
        <xs:enumeration value="delete-value"/>
        <xs:enumeration value="modify-key"/>
        <xs:enumeration value="modify-value"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <!--
    ========================================================================
    ==  FileData Class                                                    ==
    ========================================================================
    -->
    <xs:element name="FileData">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:File"
                      minOccurs="1" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="restriction"
                      type="iodef:restriction-type" use="optional"/>
        <xs:attribute name="ext-restriction"
                      type="xs:string" use="optional"/>
        <xs:attribute name="observable-id" type="xs:ID" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="File">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:FileName" minOccurs="0"/>
          <xs:element ref="iodef:FileSize" minOccurs="0"/>
          <xs:element ref="FileType" minOccurs="0"/>
          <xs:element ref="iodef:URL"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:HashData" minOccurs="0"/>
          <xs:element ref="iodef:SignatureData" minOccurs="0"/>
          <xs:element ref="iodef:AssociatedSoftware" minOccurs="0"/>
          <xs:element ref="iodef:FileProperties"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="observable-id" type="xs:ID" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="FileName" type="xs:string"/>
    <xs:element name="FileSize" type="xs:integer"/>
    <xs:element name="FileType" type="xs:string"/>
    <xs:element name="AssociatedSoftware" type="iodef:SoftwareType"/>
```

```
    <xs:element name="FileProperties" type="iodef:ExtensionType"/>
    <!--
    ========================================================================
    ==  HashData Class                                                    ==
    ========================================================================
    -->
    <xs:element name="HashData">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:HashTargetID" minOccurs="0"/>
          <xs:element ref="iodef:Hash"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:FuzzyHash"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="scope"
                      type="hashdata-scope-type" use="required"/>
        <xs:attribute name="ext-scope" type="xs:string" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="HashTargetID" type="xs:string"/>
    <xs:simpleType name="hashdata-scope-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="file-contents"/>
        <xs:enumeration value="file-pe-section"/>
        <xs:enumeration value="file-pe-iat"/>
        <xs:enumeration value="file-pe-resource"/>
        <xs:enumeration value="file-pdf-object"/>
        <xs:enumeration value="email-hash"/>
        <xs:enumeration value="email-headers-hash"/>
        <xs:enumeration value="email-body-hash"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:element name="Hash">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="ds:DigestMethod"/>
          <xs:element ref="ds:DigestValue"/>
          <xs:element ref="ds:CanonicalizationMethod"
                      minOccurs="0"/>
          <xs:element ref="iodef:Application" minOccurs="0"/>
        </xs:sequence>
      </xs:complexType>
    </xs:element>
    <xs:element name="FuzzyHash">
      <xs:complexType>
        <xs:sequence>
```

```
          <xs:element ref="iodef:FuzzyHashValue"
                      maxOccurs="unbounded"/>
          <xs:element ref="iodef:Application" minOccurs="0"/>
          <xs:element ref="iodef:AdditionalData"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
      </xs:complexType>
    </xs:element>
    <xs:element name="FuzzyHashValue" type="iodef:ExtensionType"/>
    <!--
     ========================================================================
     ==  SignatureData Class                                               ==
     ========================================================================
    -->
    <xs:element name="SignatureData">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="ds:Signature" maxOccurs="unbounded"/>
        </xs:sequence>
      </xs:complexType>
    </xs:element>
    <!--
     ========================================================================
     ==  CertificateData                                                   ==
     ========================================================================
    -->
    <xs:element name="CertificateData">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:Certificate" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="restriction"
                      type="iodef:restriction-type" use="optional"/>
        <xs:attribute name="ext-restriction"
                      type="xs:string" use="optional"/>
        <xs:attribute name="observable-id" type="xs:ID" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="Certificate">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="ds:X509Data"/>
          <xs:element ref="iodef:Description"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="observable-id" type="xs:ID" use="optional"/>
      </xs:complexType>
    </xs:element>
```

```
    <!--
     ========================================================================
     == IndicatorData Class                                                ==
     ========================================================================
    -->
    <xs:element name="IndicatorData">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:Indicator"
                      minOccurs="1" maxOccurs="unbounded"/>
        </xs:sequence>
      </xs:complexType>
    </xs:element>
    <xs:element name="Indicator">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:IndicatorID"/>
          <xs:element ref="iodef:AlternativeIndicatorID"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Description"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:StartTime" minOccurs="0"/>
          <xs:element ref="iodef:EndTime" minOccurs="0"/>
          <xs:element ref="iodef:Confidence" minOccurs="0"/>
          <xs:element ref="iodef:Contact"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:choice>
            <xs:element ref="iodef:Observable"/>
            <xs:element ref="iodef:ObservableReference"/>
            <xs:element ref="iodef:IndicatorExpression"/>
            <xs:element ref="iodef:IndicatorReference"/>
          </xs:choice>
          <xs:element ref="iodef:NodeRole"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:AttackPhase"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Reference"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:AdditionalData"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="restriction"
                      type="iodef:restriction-type" use="optional"/>
        <xs:attribute name="ext-restriction"
                      type="xs:string" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="IndicatorID">
```

```
      <xs:complexType>
        <xs:simpleContent>
          <xs:extension base="xs:ID">
            <xs:attribute name="name" type="xs:string" use="required"/>
            <xs:attribute name="version"
                          type="xs:string" use="required"/>
          </xs:extension>
        </xs:simpleContent>
      </xs:complexType>
    </xs:element>
    <xs:element name="AlternativeIndicatorID">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:IndicatorID" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="restriction"
                      type="iodef:restriction-type" use="optional"/>
        <xs:attribute name="ext-restriction"
                      type="xs:string" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="Observable">
      <xs:complexType>
        <xs:choice>
          <xs:element ref="iodef:System" minOccurs="0"/>
          <xs:element ref="iodef:Address" minOccurs="0"/>
          <xs:element ref="iodef:DomainData" minOccurs="0"/>
          <xs:element ref="iodef:Service" minOccurs="0"/>
          <xs:element ref="iodef:EmailData" minOccurs="0"/>
          <xs:element ref="iodef:WindowsRegistryKeysModified"
                           minOccurs="0"/>
          <xs:element ref="iodef:FileData" minOccurs="0"/>
          <xs:element ref="iodef:CertificateData" minOccurs="0"/>
          <xs:element ref="iodef:RegistryHandle" minOccurs="0"/>
          <xs:element ref="iodef:RecordData" minOccurs="0"/>
          <xs:element ref="iodef:EventData" minOccurs="0"/>
          <xs:element ref="iodef:Incident" minOccurs="0"/>
          <xs:element ref="iodef:Expectation" minOccurs="0"/>
          <xs:element ref="iodef:Reference" minOccurs="0"/>
          <xs:element ref="iodef:Assessment" minOccurs="0"/>
          <xs:element ref="iodef:DetectionPattern" minOccurs="0"/>
          <xs:element ref="iodef:HistoryItem" minOccurs="0"/>
          <xs:element ref="iodef:BulkObservable" minOccurs="0"/>
          <xs:element ref="iodef:AdditionalData"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:choice>
        <xs:attribute name="restriction"
                      type="iodef:restriction-type" use="optional"/>
```

```
        <xs:attribute name="ext-restriction"
                      type="xs:string" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="BulkObservable">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:BulkObservableFormat" minOccurs="0"/>
          <xs:element name="BulkObservableList"/>
          <xs:element ref="iodef:AdditionalData"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="type"
                      type="bulkobservable-type-type" use="required"/>
        <xs:attribute name="ext-type" type="xs:string" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:simpleType name="bulkobservable-type-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="asn"/>
        <xs:enumeration value="atm"/>
        <xs:enumeration value="e-mail"/>
        <xs:enumeration value="ipv4-addr"/>
        <xs:enumeration value="ipv4-net"/>
        <xs:enumeration value="ipv4-net-mask"/>
        <xs:enumeration value="ipv6-addr"/>
        <xs:enumeration value="ipv6-net"/>
        <xs:enumeration value="ipv6-net-mask"/>
        <xs:enumeration value="mac"/>
        <xs:enumeration value="site-uri"/>
        <xs:enumeration value="domain-name"/>
        <xs:enumeration value="domain-to-ipv4"/>
        <xs:enumeration value="domain-to-ipv6"/>
        <xs:enumeration value="domain-to-ipv4-timestamp"/>
        <xs:enumeration value="domain-to-ipv6-timestamp"/>
        <xs:enumeration value="ipv4-port"/>
        <xs:enumeration value="ipv6-port"/>
        <xs:enumeration value="windows-reg-key"/>
        <xs:enumeration value="file-hash"/>
        <xs:enumeration value="email-x-mailer"/>
        <xs:enumeration value="email-subject"/>
        <xs:enumeration value="http-user-agent"/>
        <xs:enumeration value="http-request-uri"/>
        <xs:enumeration value="mutex"/>
        <xs:enumeration value="file-path"/>
        <xs:enumeration value="user-name"/>
      </xs:restriction>
    </xs:simpleType>
```

```
    <xs:element name="BulkObservableFormat">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:Hash" minOccurs="0"/>
          <xs:element ref="iodef:AdditionalData"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
      </xs:complexType>
    </xs:element>
    <xs:element name="BulkObservableList" type="xs:string"/>
    <xs:element name="IndicatorExpression">
      <xs:complexType>
        <xs:sequence maxOccurs="unbounded">
          <xs:choice>
            <xs:element ref="iodef:IndicatorExpression"/>
            <xs:element ref="iodef:Observable"/>
            <xs:element ref="iodef:ObservableReference"/>
            <xs:element ref="iodef:IndicatorReference"/>
          </xs:choice>
          <xs:element ref="iodef:Confidence" minOccurs="0"/>
          <xs:element ref="iodef:AdditionalData"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="operator"
                      type="indicatorexpression-operator-type"
                      use="optional" default="and"/>
        <xs:attribute name="ext-operator"
                      type="xs:string" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:simpleType name="indicatorexpression-operator-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="not"/>
        <xs:enumeration value="and"/>
        <xs:enumeration value="or"/>
        <xs:enumeration value="xor"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:element name="ObservableReference">
      <xs:complexType>
        <xs:attribute name="uid-ref" type="xs:IDREF" use="required"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="IndicatorReference">
      <xs:complexType>
        <xs:attribute name="uid-ref" type="xs:IDREF" use="optional"/>
        <xs:attribute name="euid-ref" type="xs:string" use="optional"/>
        <xs:attribute name="version" type="xs:string" use="optional"/>
```

```
    </xs:complexType>
  </xs:element>
  <xs:element name="AttackPhase">
    <xs:complexType>
      <xs:sequence>
        <xs:element ref="iodef:AttackPhaseID"
                    minOccurs="0" maxOccurs="unbounded"/>
        <xs:element ref="iodef:URL" maxOccurs="unbounded"/>
        <xs:element ref="iodef:Description"
                    minOccurs="0" maxOccurs="unbounded"/>
        <xs:element ref="iodef:AdditionalData"
                    minOccurs="0" maxOccurs="unbounded"/>
      </xs:sequence>
    </xs:complexType>
  </xs:element>
  <xs:element name="AttackPhaseID" type="xs:string"/>
  <!--
   ========================================================================
   == Miscellaneous Classes                                              ==
   ========================================================================
  -->
  <xs:element name="AdditionalData" type="iodef:ExtensionType"/>
  <xs:element name="Description" type="iodef:MLStringType"/>
  <xs:element name="URL" type="xs:anyURI"/>
  <!--
   ========================================================================
   == IODEF Data Types                                                   ==
   ========================================================================
  -->
  <xs:simpleType name="PositiveFloatType">
    <xs:restriction base="xs:float">
      <xs:minExclusive value="0"/>
    </xs:restriction>
  </xs:simpleType>
  <xs:complexType name="MLStringType">
    <xs:simpleContent>
      <xs:extension base="xs:string">
        <xs:attribute name="translation-id"
                      type="xs:string" use="optional"/>
        <xs:attribute ref="xml:lang"/>
      </xs:extension>
    </xs:simpleContent>
  </xs:complexType>
  <xs:simpleType name="PortlistType">
    <xs:restriction base="xs:string">
      <xs:pattern value="\d+(\-\d+)?(,\d+(\-\d+)?)*"/>
    </xs:restriction>
  </xs:simpleType>
```

```
    <xs:simpleType name="TimezoneType">
      <xs:restriction base="xs:string">
        <xs:pattern
         value="Z|[\+\-](0[0-9]|1[0-4]):[0-5][0-9]"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:complexType name="ExtensionType" mixed="true">
      <xs:sequence>
        <xs:any namespace="##any" processContents="lax"
                minOccurs="0" maxOccurs="unbounded"/>
      </xs:sequence>

      <xs:attribute name="name" type="xs:string" use="optional"/>
      <xs:attribute name="dtype"
                    type="iodef:dtype-type" use="required"/>
      <xs:attribute name="ext-dtype" type="xs:string" use="optional"/>
      <xs:attribute name="meaning" type="xs:string" use="optional"/>
      <xs:attribute name="formatid" type="xs:string" use="optional"/>
      <xs:attribute name="restriction"
                    type="iodef:restriction-type" use="optional"/>
      <xs:attribute name="ext-restriction"
                    type="xs:string" use="optional"/>
      <xs:attribute name="observable-id" type="xs:ID" use="optional"/>
    </xs:complexType>
    <xs:complexType name="SoftwareType">
      <xs:sequence>
        <xs:element ref="iodef:SoftwareReference" minOccurs="0"/>
        <xs:element ref="iodef:URL"
                    minOccurs="0" maxOccurs="unbounded"/>
        <xs:element ref="iodef:Description"
                    minOccurs="0" maxOccurs="unbounded"/>
      </xs:sequence>
    </xs:complexType>
    <xs:element name="SoftwareReference">
      <xs:complexType>
        <xs:sequence>
          <xs:any namespace="##any" processContents="lax"
                  minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="spec-name"
                      type="softwarereference-spec-name-type"
                      use="required"/>
        <xs:attribute name="ext-spec-name"
                      type="xs:string" use="optional"/>
        <xs:attribute name="dtype"
                      type="softwarereference-dtype-type"
                      use="optional"/>
        <xs:attribute name="ext-dtype" type="xs:string" use="optional"/>
```

```
      </xs:complexType>
    </xs:element>
    <xs:simpleType name="softwarereference-spec-name-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="custom"/>
        <xs:enumeration value="cpe"/>
        <xs:enumeration value="swid"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:simpleType name="softwarereference-dtype-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="bytes"/>
        <xs:enumeration value="integer"/>
        <xs:enumeration value="real"/>
        <xs:enumeration value="string"/>
        <xs:enumeration value="xml"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <!--
     ========================================================================
     == Global attribute type declarations                                 ==
     ========================================================================
    -->
    <xs:simpleType name="yes-no-unknown-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="yes"/>
        <xs:enumeration value="no"/>
        <xs:enumeration value="unknown"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:simpleType name="restriction-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="default"/>
        <xs:enumeration value="public"/>
        <xs:enumeration value="partner"/>
        <xs:enumeration value="need-to-know"/>
        <xs:enumeration value="private"/>
        <xs:enumeration value="white"/>
        <xs:enumeration value="green"/>
        <xs:enumeration value="amber"/>
        <xs:enumeration value="red"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:simpleType name="severity-type">
      <xs:restriction base="xs:NMTOKEN">
```

```
        <xs:enumeration value="low"/>
        <xs:enumeration value="medium"/>
        <xs:enumeration value="high"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:simpleType name="duration-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="second"/>
        <xs:enumeration value="minute"/>
        <xs:enumeration value="hour"/>
        <xs:enumeration value="day"/>
        <xs:enumeration value="month"/>
        <xs:enumeration value="quarter"/>
        <xs:enumeration value="year"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:simpleType name="action-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="nothing"/>
        <xs:enumeration value="contact-source-site"/>
        <xs:enumeration value="contact-target-site"/>
        <xs:enumeration value="contact-sender"/>
        <xs:enumeration value="investigate"/>
        <xs:enumeration value="block-host"/>
        <xs:enumeration value="block-network"/>
        <xs:enumeration value="block-port"/>
        <xs:enumeration value="rate-limit-host"/>
        <xs:enumeration value="rate-limit-network"/>
        <xs:enumeration value="rate-limit-port"/>
        <xs:enumeration value="redirect-traffic"/>
        <xs:enumeration value="honeypot"/>
        <xs:enumeration value="upgrade-software"/>
        <xs:enumeration value="rebuild-asset"/>
        <xs:enumeration value="harden-asset"/>
        <xs:enumeration value="remediate-other"/>
        <xs:enumeration value="status-triage"/>
        <xs:enumeration value="status-new-info"/>
        <xs:enumeration value="watch-and-report"/>
        <xs:enumeration value="defined-coa"/>
        <xs:enumeration value="other"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:simpleType name="dtype-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="boolean"/>
        <xs:enumeration value="byte"/>
```

```
        <xs:enumeration value="bytes"/>
        <xs:enumeration value="character"/>
        <xs:enumeration value="date-time"/>
        <xs:enumeration value="integer"/>
        <xs:enumeration value="ntpstamp"/>
        <xs:enumeration value="portlist"/>
        <xs:enumeration value="real"/>
        <xs:enumeration value="string"/>
        <xs:enumeration value="file"/>
        <xs:enumeration value="path"/>
        <xs:enumeration value="frame"/>
        <xs:enumeration value="packet"/>
        <xs:enumeration value="ipv4-packet"/>
        <xs:enumeration value="ipv6-packet"/>
        <xs:enumeration value="url"/>
        <xs:enumeration value="csv"/>
        <xs:enumeration value="winreg"/>
        <xs:enumeration value="xml"/>
        <xs:enumeration value="ext-value"/>
      </xs:restriction>
    </xs:simpleType>
  </xs:schema>
```

9. Security Considerations

The IODEF data model does not directly introduce security or privacy issues. However, as the data encoded by the IODEF might be considered sensitive by the parties exchanging it or by those described by it, care needs to be taken to ensure appropriate handling during the document construction, exchange, processing, archiving, subsequent retrieval and analysis.

9.1. Security

The underlying messaging format and protocol used to exchange instances of the IODEF MUST provide appropriate guarantees of confidentiality, integrity, and authenticity. The use of a standardized security protocol is encouraged. The Real-time Inter-network Defense (RID) protocol [RFC6545] and its associated transport binding IODEF/RID over HTTP/TLS [RFC6546] provide such security.

An IODEF implementation may act on the data in the document. These actions might be explicitly requested in the document or the result of analytical logic that triggered on data in the document. For this reason, care must be taken by IODEF implementations to properly authenticate the sender and receiver of the document. The sender needs confidence that sensitive information and timely requests for action are sent to the correct recipient. The recipient may

interpret the contents of the document differently based on who sent it; or vary actions based on the sender. While the sender of the document may explicitly convey confidence in the data in a granular way using the Confidence class, the recipient is free to ignore or refine this information to make its own assessment. Ambiguous Confidence elements (where it is unclear to which of a set of other elements the Confidence element relates) in a document MUST be ignored by the recipient.

Certain classes may require out-of-band coordination to agree upon their semantics (e.g., Confidence@rating="low" or DefinedCOA). This coordination MUST occur prior to operational data exchange to prevent the incorrect interpretation of these select data elements. When parsing these data elements, implementations should validate, when possible, that they conform to the agreed upon semantics. These semantics may need to be periodically reevaluated.

Executable content of various forms could be embedded into the IODEF document directly or through an extension. Implementation MUST handle this content with care to prevent unintentional automated execution. The following classes are explicitly intended to represent content that might be executable:

- All classes of type iodef:ExtensionType and the RecordPattern class can represent arbitrary binary strings such as legitimate software programs or malware.

- The EmailMessage and EmailBody classes can represent email attachments that can contain arbitrary content.

- The DetectionPattern class could specify a machine-readable configuration that directs the execution of the corresponding tool.

Per Section 4.3, IODEF implementations will need to periodically consult the IANA registries specified in Section 10.2 to discover newly registered enumerated attribute values. These implementations MUST communicate with IANA in a way that ensures the integrity of the values and the authenticity of the source. HTTPS over TLS [RFC2818][RFC5246] provides such security.

9.2. Privacy

The IODEF contains numerous fields that are identifiers which could be linked to an individual or organization. IODEF documents may contain sensitive information about these identified parties; and repeated document exchanges about the same and related parties may

enable the correlation of data about them. Likewise, a party may report on another to a third party without their knowledge.

When creating an IODEF document, careful consideration must be given to what information is shared. Personal identifiers and attributable sensitive information should only be shared when necessary.

When exchanging documents, transport security MUST provide document-level confidentiality. XML element-level confidentiality can also be provided by using [W3C.XMLENC].

In order to suggest data processing and handling guidelines of the encoded information, the IODEF allows a document sender to convey a privacy policy using the restriction attribute. The various instances of this attribute allow different data elements of the document to be covered by dissimilar policies. While flexible, it must be stressed that this approach only serves as a guideline from the sender, as the recipient is free to ignore it.

Although outside of the scope of an IODEF implementation, the contents of IODEF documents and any derived analysis should be archived with at appropriate confidentiality controls. Likewise, access to retrieve and analyze this data should be restricted to authorized users.

10. IANA Considerations

This document registers a namespace, an XML schema, and a number of registries that map to enumerated values defined in the data model. It also defines an expert review process for IODEF-related XML registry entries.

10.1. Namespace and Schema

This document uses URNs to describe an XML namespace and schema conforming to a registry mechanism described in [RFC3688]

Registration for the IODEF namespace:

- URI: urn:ietf:params:xml:ns:iodef-2.0
- Registrant Contact: See the first author of the "Author’s Address" section of this document.
- XML: None. Namespace URIs do not represent an XML specification.

Registration for the IODEF XML schema:

- URI: urn:ietf:params:xml:schema:iodef-2.0
- Registrant Contact: See the first author of the "Author's Address" section of this document.
- XML: See Section 8 of this document.

10.2. Enumerated Value Registries

This document creates 34 identically structured registries to be managed by IANA:

- Name of the parent registry: "Incident Object Description Exchange Format v2 (IODEF)"
- URL of the registry: http://www.iana.org/assignments/iodef2
- Namespace format: A registry entry consists of:
  - Value. A value for a given IODEF attribute. It MUST conform to the formatting specified by the IODEF ENUM data type which is implemented as an "xs:NMTOKEN" type per Section 3.3.4 of [W3C.SCHEMA.DTYPES]. The value SHOULD conform to the convention specified in Section 5.2.
  - Description. A short description of the enumerated value.
  - Reference. An optional list of URIs to further describe the value.
- Allocation policy: Expert Review per [RFC5226]. This reviewer will ensure that the requested registry entry conforms to the prescribed formatting. The reviewer will also ensure that the entry is an appropriate value for the attribute per the information model (Section 3).

The registries to be created are named in the "Registry Name" column of Table 1. Each registry is initially populated with values and descriptions that come from an attribute specified in the IODEF schema (Section 8) whose description is found in a sub-section of the information model (Section 3). The initial values for the Value and Description fields of a given registry are listed in the "IV (Value)" and "IV (Description)" columns respectively. The "IV (Value)" points to a given schema type per Section 8. Each enumerated value in the schema gets a corresponding entry in a given registry. The "IV (Description)" points to a section in the text of this document that describes each enumerated value. The initial value of the Reference

field of every registry entry described below should be this document.

Registry Name	IV (Value)	IV (Description)
Restriction	iodef-restriction-type	Section 3.3.1
Incident-purpose	incident-purpose-type	Section 3.2
Incident-status	incident-status-type	Section 3.2
Contact-role	contact-role-type	Section 3.9
Contact-type	contact-type-type	Section 3.9
RegistryHandle-registry	registryhandle-registry-type	Section 3.9.1
PostalAddress-type	postaladdress-type-type	Section 3.9.2
Telephone-type	telephone-type-type	Section 3.9.4
Email-type	email-type-type	Section 3.9.3
Expectation-action	action-type	Section 3.15
Discovery-source	discovery-source-type	Section 3.10
SystemImpact-type	systemimpact-type-type	Section 3.12.1
BusinessImpact-severity	businessimpact-severity-type	Section 3.12.2
BusinessImpact-type	businessimpact-type-type	Section 3.12.2
TimeImpact-metric	timeimpact-metric-type	Section 3.12.3
TimeImpact-duration	duration-type	Section 3.12.3
Confidence-rating	confidence-rating-type	Section 3.12.5

NodeRole-category	noderole-category-type	Section 3.18.2
System-category	system-category-type	Section 3.17
System-ownership	system-ownership-type	Section 3.17
Address-category	address-category-type	Section 3.18.1
Counter-type	counter-type-type	Section 3.18.3
Counter-unit	counter-unit-type	Section 3.18.3
DomainData-system-status	domaindata-system-status-type	Section 3.19
DomainData-domain-status	domaindata-domain-status-type	Section 3.19
RecordPattern-type	recordpattern-type-type	Section 3.22.2
RecordPattern-offsetunit	recordpattern-offsetunit-type	Section 3.22.2
Key-registryaction	key-registryaction-type	Section 3.23.1
HashData-scope	hashdata-scope-type	Section 3.26
BulkObservable-type	bulkobservable-type-type	Section 3.29.3.1
IndicatorExpression-operator	indicatorexpression-operator-type	Section 3.29.4
ExtensionType-dtype	dtype-type	Section 2.16
SoftwareReference-spec-id	softwarereference-spec-id-type	Section 2.15.1
SoftwareReference-dtype	softwarereference-dtype-type	Section 2.15.1

Table 1: IANA Enumerated Value Registries

10.3. Expert Review of IODEF-Related XML Registry Entries

IODEF class extensions, per Section 5.2, could register their namespaces and schemas with the IANA XML Namespace ("ns", http://www.iana.org/assignments/xml-registry/xml-registry.xhtml#ns) and Schema registries ("schema", http://www.iana.org/assignments/xml-registry/xml-registry.xhtml#schema) described in [RFC3688]. In addition to any reviews required by IANA, changes to the XML Schema registry for schema names beginning with "urn:ietf:params:xml:schema:iodef" are subject to an additional IODEF Expert Review [RFC5226] to ensure compatibility with IODEF and other existing IODEF extensions.

The IODEF expert(s) for these reviews will be designated by the IETF Security Area Directors.

This document obsoletes [RFC6685].

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Resource-Oriented Lightweight Indicator Exchange
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Abstract

This document defines a resource-oriented approach to cyber security information sharing. Using this approach, a CSIRT or other stakeholder may share and exchange representations of cyber security incidents, indicators, and other related information as Web-addressable resources. The transport protocol binding is specified as HTTP(S) with a MIME media type of Atom+XML. An appropriate set of link relation types specific to cyber security information sharing is defined. The resource representations leverage the existing IODEF [RFC5070] and RID [RFC6545] specifications as appropriate. Coexistence with deployments that conform to existing specifications including RID [RFC6545] and Transport of Real-time Inter-network Defense (RID) Messages over HTTP/TLS [RFC6546] is supported via appropriate use of HTTP status codes.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

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Table of Contents

1. Introduction

This document defines a resource-oriented approach to cyber security information sharing that follows the REST (Architectural Styles and t he Design of Network-based Software Architectures) architectural style. The resource representations leverage the existing IODEF [RFC5070] and RID [RFC6545] specifications as appropriate. The transport protocol binding is specified as HTTP(S) with a media type of Atom+XML. An appropriate set of link relation types specific to cyber security information sharing is defined. Using this approach, a CSIRT or other stakeholder may exchange cyber security incident and/or indicator information as Web-addressable resources.

The goal of this specification is to define a loosely-coupled, agile approach to cyber security situational awareness. This approach has architectural advantages for some use case scenarios, such as when a CSIRT or other stakeholder is required to share cyber security information broadly (e.g., at internet scale), or when an information sharing consortium requires support for asymmetric interactions amongst their stakeholders.

Coexistence with deployments that conform to existing specifications including RID [RFC6545] and Transport of Real-time Inter-network Defense (RID) Messages over HTTP/TLS [RFC6546] is supported via appropriate use of HTTP status codes.

2. Terminology

The key words "MUST," "MUST NOT," "REQUIRED," "SHALL," "SHALL NOT," "SHOULD," "SHOULD NOT," "RECOMMENDED," "MAY," and "OPTIONAL" in this document are to be interpreted as described in [RFC2119]. Definitions for some of the common computer security-related

terminology used in this document can be found in Section 2 of [RFC5070].

3. Background and Motivation

It is well known that Internet security threats are evolving ever more rapidly, and are becoming ever more sophisticated than before. The threat actors are frequently distributed and are not constrained to operating within a fixed, closed consortium. The technical skills needed to perform effective analysis of a security incident, or to even recognize an indicator of compromise are already specialized and relatively scarce. As threats continue to evolve, even an established network of CSIRT may find that it does not always have all of the skills and knowledge required to immediately identify and respond to every new incident. Effective identification of and response to a sophisticated, multi-stage attack frequently depends upon cooperation and collaboration, not only amongst the defending CSIRTs, but also amongst other stakeholders, including, potentially, individual end users.

Existing approaches to cyber security information sharing are based upon message exchange patterns that are point-to-point, and event-driven. Sometimes, information that may be useful to, and sharable with multiple peers is only made available to peers after they have specifically requested it. Unfortunately, a sharing peer may not know, a priori, what information to request from another peer. Sending unsolicited RID reports does provide a mechanism for alerting, however these reports are again sent point-to-point, and must be reviewed for relevance and then prioritized for action by the recipient. Thus, distribution of some relevant incident and indicator information may exhibit significant latency.

In order to appropriately combat the evolving threats, the defending CSIRTs should be enabled to operate in a more agile manner, sharing selected cyber security information proactively, if and as appropriate.

For example, a CSIRT analyst would benefit by having the ability to search a comprehensive collection of indicators that has been published by a government agency, or by another member of a sharing consortium. The representation of each indicator may include links to the related resources, enabling an appropriately authenticated and authorized analyst to freely navigate the information space of indicators, incidents, and other cyber security domain concepts, as needed. In general, a more Web-centric sharing approach will enable a more dynamic and agile collaboration amongst a broader, and varying constituency.

The following sections discuss additional specific technical issues that motivate the development of an alternative approach.

3.1. Message-oriented versus Resource-oriented Architecture

The existing approaches to cyber security information sharing are based upon message-oriented interactions. The following paragraphs explore some of the architectural constraints associated with message-oriented interactions and consider the relative merits of an alternative model based on a Resource-oriented architecture for use in some use case scenarios.

3.1.1. Message-oriented Architecture

In general, message-based integration architectures may be based upon either an RPC-style or a document-style binding. The message types defined by RID represent an example of an RPC-style request. This approach imposes implied requirements for conversational state management on both of the communicating RID endpoint(s). Experience has shown that this state management frequently becomes the limiting factor with respect to the runtime scalability of an RPC-style architecture.

In addition, the practical scalability of a peer-to-peer message-based approach will be limited by the administrative procedures required to manage O(N^2) trust relationships and at least O(N) policy groups.

As long as the number of CSIRTs participating in an information sharing consortium is limited to a relatively smaller number of nodes (i.e., O(2^N), where N < 5), these scalability constraints may not represent a critical concern. However, when there is a requirement to support a significantly larger number of participating peers, a different architectural approach will be required. One alternative to the message-based approach that has demonstrated scalability is the REST [REST] architectural style.

3.1.2. Resource-Oriented Architecture

Applying the REST architectural style to the problem domain of cyber security information sharing would take the approach of exposing incidents, indicators, and any other relevant types as simple Web-addressable resources. By using this approach, a CSIRT or other organization can more quickly and easily share relevant incident and indicator information with a much larger and potentially more diverse constituency. A client may leverage virtually any available HTTP user agent in order to make requests of the service provider. This

improved ease of use could enable more rapid adoption and broader participation, thereby improving security for everyone.

A key interoperability aspect of any RESTful Web service will be the choices regarding the available resource representations. For example, clients may request that a given resource representation be returned as either XML or JSON. In order to enable back-compatibility and interoperability with existing CSIRT implementations, IODEF [RFC5070] is specified for this transport binding as a mandatory to implement (MTI) data representation for incident and indicator resources. In addition to the REQUIRED representation, an implementation MAY support additional representations if and as needed such as IODEF extensions, the RID schema, or other schemas. For example, an implementation may choose to provide support for returning a JSON representation of an incident resource.

Finally, an important principle of the REST architectural style is the use of hypertext links as the embodiment of application state (HATEOAS). Rather than the server maintaining conversational state for each client context, the server will instead include a suitable set of hyperlinks in the resource representation that is returned to the client. In this way, the server remains stateless with respect to a series of client requests. The included hyperlinks provide the client with a specific set of permitted state transitions. Using these links the client may perform an operation, such as updating or deleting the resource representation. The client may also be provided with hypertext links that can be used to navigate to any related resource. For example, the resource representation for an incident object may contain links to the related indicator resource(s).

This document specifies the use of Atom Syndication Format [RFC4287] and Atom Publishing Protocol [RFC5023] as the mechanism for representing the required hypertext links.

3.1.2.1. A Resource-Oriented Use Case: "Mashup"

In this section we consider a non-normative example use case scenario for creating a cyber security "mashup".

Any CSIRT can enable any authenticated and authorized client that is a member of the sharing community to quickly and easily navigate through any of the cyber security information that that provider is willing to share. An authenticated and authorized analyst may then make HTTP(S) requests to collect incident and indicator information known at one CSIRT with threat actor data being made available from another CSIRT. The resulting correlations may yield new insights

that enable a more timely and effective defensive response. Of course, this report may, in turn, be made available to others as a new Web-addressable resource, reachable via another URL. By employing the RESTful Web service approach the effectiveness of the collaboration amongst a consortium of CSIRTs and their stakeholders can be greatly improved.

3.2. Authentication of Users

In the store-and-forward, message-based model for information sharing client authentication is provided via a Public Key Infrastructure (PKI) -based trust and mutually authenticated TLS between the messaging system endpoints. There is no provision to support authentication of a client by another means. As a result, participation in the sharing community is limited to those organizations that have sufficient resources and capabilities to manage a PKI.

A CSIRT may apply XML Security to the content of a message, however the contact information provided within the message body represents a self-asserted identity, and there is no guarantee that the contact information will be recognized by the peer. As a result, the audit trail and the granularity of any authorization policies is limited to the identity of the peer CSIRT organization.

A CSIRT implementing this specification MUST implement server-authenticated TLS. The CSIRT may choose to authenticate its client users via any suitable authentication scheme that can be implemented via HTTP(S). A participating CSIRT MAY choose to support more than one authentication method. Support for use of a Federated Identity approach is RECOMMENDED. Establishing a specific end user identity prior to processing a request is RECOMMENDED. Doing so will enable the source system to maintain a more complete audit trail of exactly what cyber security incident and indicator information has been shared, when, and with whom.

3.3. Authorization Policy Enforcement

A key aspect of any cyber security information sharing arrangement is assigning the responsibility for authorization policy enforcement. The authorization policy must be enforced either at the destination system, or the source system, or both. The following sections discuss these alternatives in greater detail.

3.3.1. Enforcement at Destination System

The store-and-forward, message-based approach to cyber security information sharing requires that the origin system delegate authorization policy enforcement to the destination system. The origin system may leverage XML Encryption and DigitalSignature to protect the message content. In addition, the origin system assigns a number of policy-related attribute values, including a "restriction" attribute, before the message is sent. These labels indicate the sender's expectation for confidentiality enforcement and appropriate handling at the destination. Section 9.1 of RFC6545 provides specific guidance to implementers on use of the XML security standards in order to achieve the required levels of security for the exchange of incident information.

Once the message has been received at the destination system, the XML encryption and digital signature protections on the message will be processed, and based upon the pre-established PKI-based trust relationships, the message content is validated and decrypted. Typical implementations will then pass the cleartext data to an internal Incident Handling System (IHS) for further review and/or action by a human operator or analyst. Regardless of where in the deployment architecture the XML message-level security is being handled, eventually the message content will be made available as cleartext for handling by human systems analysts and other operational staff.

The authorization policy enforcement of the message contents must then be provided by the destination IHS. It is the responsibility of the destination system to honor the intent of the policy restriction labels assigned by the origin system. Ideally, these policy labels would serve as part of a distributed Mandatory Access Control scheme. However, in practice a typical IHS will employ a Discretionary Access Control (DAC) model rather than a MAC model and so the policy related attributes are defined to represent handling "hints" and provide no guarantee of enforcement at the destination.

As a result, ensuring that the destination system or counterparty will in fact correctly enforce the intended authorization policies becomes a key issue when entering into any information sharing agreements. The origin CSIRT must accept a non-zero risk of information leakage, and therefore must rely upon legal recourse as a compensating control. Establishing such legal sharing agreements can be a slow and difficult process, as it assumes a high level of trust in the peer, with respect to both intent and also technical capabilities.

3.3.2. Enforcement at Source System

In this model, the required authorization policy enforcements are implemented entirely within the source system. Enforcing the required authorization policy controls at the source system eliminates the risk of subsequent information leakage at the destination system due to inadequate or incomplete implementation of the expected controls. The destination system is not expected to perform any additional authorization enforcements. Authorization enforcement at the source system may be based on, e.g. Role-based Access Controls applied in the context of an established user identity. The source system may use any appropriate authentication mechanism in order to determine the user identity of the requestor, including, e.g. federated identity. An analyst or operator at a CSIRT may request specific information on a given incident or indicator from a peer CSIRT, and the source system will return a suitable representation of that resource based upon the specific role of the requestor. A different authenticated user (perhaps from the same destination CSIRT) may receive a different representation of the same resource, based upon the source system applying suitable Role-based Access Control policy enforcements for the second user identity.

Consistent with HTTP [RFC2616] a user’s request MAY be denied with a resulting HTTP status code value of 4xx such as 401 Unauthorized, 403 Forbidden, or 404 Not Found, or 405 Method Not Allowed, if and as appropriate.

4. RESTful Usage Model

This section describes the basic use of Atom Syndication Format [RFC4287] and Atom Publishing Protocol [RFC5023] as a RESTful transport binding and dynamic discovery protocol, respectively, for cyber security information sharing.

As described in Atom Publishing Protocol [RFC5023], an Atom Service Document is an XML-based document format that allows a client to dynamically discover the collections provided by a publisher.

As described in Atom Syndication Format [RFC4287], Atom is an XML-based document format that describes lists of related information items known as collections, or "feeds". Each feed document contains a collection of zero or more related information items called "member entries" or "entries".

When applied to the problem domain of cyber security information sharing, an Atom feed may be used to represent any meaningful collection of information resources such as a set of incidents, or

indicators. Each entry in a feed could then represent an individual incident, or indicator, or some other resource, as appropriate. Additional feeds could be used to represent other meaningful and useful collections of cyber security resources. A feed may be categorized, and any feed may contain information from zero or more categories. The naming scheme and the semantic meaning of the terms used to identify an Atom category are application-defined.

4.1. Dynamic Service Discovery versus Static URL Template

In order to specify a protocol for cyber security information sharing using the REST architectural style it is necessary to define the set of resources to be modeled, and how these resources are related. Based on this interface contract, clients will then interact with the REST service by navigating the modeled entities, and their relationships. The interface contract between the client and the server may either be statically bound or dynamically bound.

In the statically bound case, the clients have a priori knowledge of the resources that are supported. In the REST architectural style this static interface contract takes the form of a URL template. This approach is not appropriate for the cyber security information sharing domain for at least two reasons.

First, there is no standard for a cyber security domain model. While information security practitioners can generally agree on some of the basic concepts that are important to modeling the cyber security domain -- such as "indicator," "incident," or "attacker," -- there is no single domain model that can been referenced as the basis for specifying a standardized RESTful URI Template. Second, the use of static URL templates creates a tighter coupling between the client implementation and the server implementation. Security threats on the internet are evolving ever more rapidly, and it will never be possible to establish a statically defined resource model and URL Template. Even if there were an initial agreement on an appropriate URL template, it would eventually need to change. If and when a CSIRT finds that it needs to change the URL template, then any existing deployed clients would need to be upgraded.

Thus, rather than attempting to define a fixed set of resources via a URI Template, this document has instead specified an approach based on dynamic discovery of resources via an Atom Publishing Protocol Service Document. By using this approach, it is possible to standardize the RESTful usage model, without needing to standardize on the definitions of specific, strongly-typed resources. A client can dynamically discover what resources are provided by a given CSIRT, and then navigate that domain model accordingly A specific server implementation may still embody a particular URL template,

however the client does not need a priori knowledge of the format of the links, and the URL itself is effectively opaque to the client. Clients are not bound to any particular server's interface.

The following paragraphs provide a number of non-normative examples to illustrate the use of Atom Publishing Protocol for basic cyber security information sharing service discovery, as well as the use of Atom Syndication Format as a mechanism to publish cyber security information feeds.

Normative requirements are defined below, in Section 5.

4.2. Non-Normative Examples

4.2.1. Service Discovery

This section provides a non-normative example of a client doing service discovery.

An Atom service document enables a client to dynamically discover what feeds a particular publisher makes available. Thus, a CSIRT may use an Atom service document to enable clients of the CSIRT to determine what specific cyber security information the CSIRT makes available to the community. The service document could be made available at any well known location, such as via a link from the CSIRT's home page. One common technique is to include a link in the <HEAD> section of the organization's home page, as shown below:

Example of bootstrapping Service Document discovery:

```
   <link rel="introspection"  type="application/atomsvc+xml" title="Atom Publ
ishing Protocol Service Document" href="/csirt/svcdoc.xml" />
```

A client may then format an HTTP GET request to retrieve the service document:

```
GET /csirt/svcdoc.xml
Host: www.example.org
Accept: application/atomsvc+xml
```

Notice the use of the HTTP Accept: request header, indicating the MIME type for Atom service discovery. The response to this GET request will be an XML document that contains information on the specific feed collections that are provided by the CSIRT.

Example HTTP GET response:

```
HTTP/1.1 200 OK
Date: Fri, 24 Aug 2012 17:09:11 GMT
Content-Length: 570
Content-Type: application/atomsvc+xml;charset="utf-8"

<?xml version="1.0" encoding="UTF-8"?>
<service xmlns="http://www.w3.org/2007/app"
         xmlns:atom="http://www.w3.org/2005/Atom">
    <workspace xml:lang="en-US" xmlns:xml="http://www.w3.org/XML/1998/name
space">
      <atom:title type="text">Incidents</atom:title>
      <collection  href="http://example.org/csirt/incidents">
         <atom:title type="text">Incidents Feed</atom:title>
         <accept>application/atom+xml; type=entry</accept>
      </collection>
    </workspace>
</service>
```

This simple Service Document example shows that this CSIRT provides one workspace, named "Incidents." Within that workspace, the CSIRT makes one feed collection available. When attempting to GET or POST entries to that feed collection, the client must indicate a content type of application/atom+xml.

A CSIRT may also offer a number of different feeds, each containing different types of cyber security information. In the following example, the feeds have been categorized. This categorization will help the clients to decide which feeds will meet their needs.

```
      HTTP/1.1 200 OK
      Date: Fri, 24 Aug 2012 17:10:11 GMT
      Content-Length: 1912
      Content-Type: application/atomsvc+xml;charset="utf-8"

       <?xml version="1.0" encoding='utf-8'?>
          <service xmlns="http://www.w3.org/2007/app"
            xmlns:atom="http://www.w3.org/2005/Atom">
            <workspace>
              <atom:title>Cyber Security Information Sharing</atom:title>
              <collection href="http://example.org/csirt/public/indicators" >
                <atom:title>Public Indicators</atom:title>
                <categories fixed="yes">
                  <atom:category scheme="http://example.org/csirt/restriction" t
erm="public" />
                  <atom:category scheme="http://example.org/csirt/purpose" term=
"reporting" />
                </categoies>
                <accept>application/atom+xml; type=entry</accept>
              </collection>
              <collection href="http://example.org/csirt/public/incidents" >
                <atom:title>Public Incidents</atom:title>
                <categories fixed="yes">
                  <atom:category scheme="http://example.org/csirt/restriction" t
erm="public" />
                  <atom:category scheme="http://example.org/csirt/purpose" term=
"reporting" />
                </categoies>
                <accept>application/atom+xml; type=entry</accept>
            </collection>
            </workspace>
            <workspace>
              <atom:title>Private Consortium Sharing</atom:title>
              <collection href="http://example.org/csirt/private/incidents" >
                <atom:title>Incidents</atom:title>
                <accept>application/atom+xml;type=entry</accept>
                <categories fixed="yes">
                  <atom:category scheme="http://example.org/csirt/purpose" term=
"traceback, mitigation, reporting" />
                    <atom:category scheme="http://example.org/csirt/restriction" t
erm="private, need-to-know" />
                </categories>
              </collection>
            </workspace>
          </service>
```

In this example, the CSIRT is providing a total of three feed collections, organized into two different workspaces. The first workspace contains two feeds, consisting of publicly available indicators and publicly available incidents, respectively. The second workspace provides one additional feed, for use by a sharing consortium. The feed contains incident information containing entries related to three purposes: traceback, mitigation, and

reporting. The entries in this feed are categorized with a restriction of either "Need-to-Know" or "private". An appropriately authenticated and authorized client may then proceed to make GET requests for one or more of these feeds. The publicly provided incident information may be accessible with or without authentication. However, users accessing the feed targeted to the private sharing consortium would be expected to authenticate, and appropriate authorization policies would subsequently be enforced by the feed provider.

4.2.2. Feed Retrieval

This section provides a non-normative example of a client retrieving an incident feed.

Having discovered the available cyber security information sharing feeds, an authenticated and authorized client who is a member of the private sharing consortium may be interested in receiving the feed of known incidents. The client may retrieve this feed by performing an HTTP GET operation on the indicated URL.

Example HTTP GET request for a Feed:

```
GET /csirt/private/incidents
Host: www.example.org
Accept: application/atom+xml
```

The corresponding HTTP response would be an XML document containing the incidents feed:

Example HTTP GET response for a Feed:

```
      HTTP/1.1 200 OK
      Date: Fri, 24 Aug 2012 17:20:11 GMT
      Content-Length: 2882
      Content-Type: application/atom+xml;type=feed;charset="utf-8"

      <?xml version="1.0" encoding="UTF-8"?>
      <feed xmlns="http://www.w3.org/2005/Atom"
          xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
          xsi:schemaLocation="http://www.w3.org/2005/Atom file:/C:/schemas/atom.
xsd
                              urn:ietf:params:xml:ns:iodef-1.0 file:/C:/schemas/
iodef-1.0.xsd"
          xml:lang="en-US">

          <generator version="1.0" xml:lang="en-US">emc-csirt-iodef-feed-service
</generator>
          <id xml:lang="en-US">http://www.example.org/csirt/private/incidents</i
d>
          <title type="text" xml:lang="en-US">Atom formatted representation of a
 feed of IODEF documents</title>
          <updated xml:lang="en-US">2012-05-04T18:13:51.0Z</updated>
          <author>
              <email>csirt@example.org</email>
              <name>EMC CSIRT</name>
          </author>

          <!-- By convention there is usually a self link for the feed -->
          <link href="http://www.example.org/csirt/private/incidents" rel="self"
/>

          <entry>
              <id>http://www.example.org/csirt/private/incidents/123456</id>
              <title>Sample Incident</title>
              <link href="http://www.example.org/csirt/private/incidents/123456"
 rel="self"/>       <!-- by convention -->
              <link href="http://www.example.org/csirt/private/incidents/123456"
 rel="alternate"/>  <!-- required by Atom spec -->
              <published>2012-08-04T18:13:51.0Z</published>
              <updated>2012-08-05T18:13:51.0Z</updated>
              <!-- The category is based upon IODEF purpose and restriction attr
ibutes -->
              <category term="traceback" scheme="purpose" label="trace back" />
              <category term="need-to-know" scheme="restriction" label="need to
know" />
              <summary>A short description of this incident, extracted from the
IODEF Incident class, <description> element. </summary>
          </entry>

          <entry>
              <!-- ...another entry... -->
          </entry>

      </feed>
```

This feed document has two atom entries, one of which has been elided. The completed entry illustrates an Atom <entry> element that provides a summary of essential details about one particular

incident. Based upon this summary information and the provided category information, a client may choose to do an HTTP GET operation to retrieve the full details of the incident. This example provides a RESTful alterntive to the RID investigation request messaage, as described in sections 6.1 and 7.2 of RFC6545.

4.2.3. Entry Retrieval

This section provides a non-normative example of a client retrieving an incident as an Atom entry.

Having retrieved the feed of interest, the client may then decide based on the description and/or category information that one of the entries in the feed is of further interest. The client may retrieve this incident Entry by performing an HTTP GET operation on the indicated URL.

Example HTTP GET request for an Entry:

```
GET /csirt/private/incidents/123456
Host: www.example.org
Accept: application/atom+xml
```

The corresponding HTTP response would be an XML document containing the incident:

Example HTTP GET response for an Entry:

```
   HTTP/1.1 200 OK
   Date: Fri, 24 Aug 2012 17:30:11 GMT
   Content-Length: 4965
   Content-Type: application/atom+xml;type=entry;charset="utf-8"

   <?xml version="1.0" encoding="UTF-8"?>
   <entry>
     <id>http://www.example.org/csirt/private/incidents/123456</id>
     <title>Sample Incident</title>
     <link href="http://www.example.org/csirt/private/incidents/123456" rel="
self"/>       <!-- by convention -->
     <link href="http://www.example.org/csirt/private/incidents/123456" rel="
alternate"/>  <!-- required by Atom spec -->
     <published>2012-08-04T18:13:51.0Z</published>
     <updated>2012-08-05T18:13:51.0Z</updated>
     <!-- The category is based upon IODEF purpose and restriction attributes
 -->
     <category term="traceback" scheme="purpose" label="trace back" />
     <category term="need-to-know" scheme="restriction" label="need to know"
/>
     <summary>A short description of this incident, extracted from the IODEF
Incident class, <description> element. </summary>
```

```
        <!-- Refer to section 5.9 for the list of supported (cyber information-s
pecific) link relationships -->
        <!-- Typical operations that can be performed on this IODEF message incl
ude edit -->
        <link href="http://www.example.org/csirt/private/incidents/123456" rel="
edit"/>

        <!-- the next and previous are just sequential access, may not map to an
ything related to this IODEF Incident ID -->
        <link href="http://www.example.org/csirt/private/incidents/123457" rel="
next"/>
        <link href="http://www.example.org/csirt/private/incidents/123455" rel="
previous"/>

        <!-- navigate up to the full collection.  Might also be rel="collection"
 as per IANA registry -->
        <link href="http://www.example.org/csirt/private/incidents" rel="up"/>

        <content type="application/xml">
          <iodef:IODEF-Document lang="en" xmlns:iodef="urn:ietf:params:xml:ns:io
def-1.0">
            <iodef:Incident purpose="traceback" restriction="need-to-know">

              <!-- Note that the ID is assigned using a namespace that is our ba
se URL, so that it can also be leveraged as an Atom link -->
              <iodef:IncidentID name="http://www.example.org/csirt/private/incid
ents">123456</iodef:IncidentID>

              <iodef:DetectTime>2004-02-02T22:49:24+00:00</iodef:DetectTime>
              <iodef:StartTime>2004-02-02T22:19:24+00:00</iodef:StartTime>
              <iodef:ReportTime>2004-02-02T23:20:24+00:00</iodef:ReportTime>
              <iodef:Description>
                Host involved in DoS attack
              </iodef:Description>
              <iodef:Assessment>
                <iodef:Impact completion="failed" severity="low" type="dos"/>
              </iodef:Assessment>
              <iodef:Contact role="creator" type="organization">
                <iodef:ContactName>Constituency-contact for 192.0.2.35
                </iodef:ContactName>
                <iodef:Email>Constituency-contact@192.0.2.35</iodef:Email>
              </iodef:Contact>
              <iodef:EventData>
                <iodef:Flow>
                  <iodef:System category="source">
                    <iodef:Node>
                      <iodef:Address category="ipv4-addr">192.0.2.35
                      </iodef:Address>
                    </iodef:Node>
                    <iodef:Service ip_protocol="6">
                      <iodef:Port>38765</iodef:Port>
                    </iodef:Service>
                  </iodef:System>
                  <iodef:System category="target">
                    <iodef:Node>
                      <iodef:Address category="ipv4-addr">192.0.2.67
                      </iodef:Address>
                    </iodef:Node>
```

```
                    <iodef:Service ip_protocol="6">
                      <iodef:Port>80</iodef:Port>
                    </iodef:Service>
                  </iodef:System>
                </iodef:Flow>
                <iodef:Expectation action="rate-limit-host" severity="high">
                  <iodef:Description>
                    Rate-limit traffic close to source
                  </iodef:Description>
                </iodef:Expectation>
                <iodef:Record>
                  <iodef:RecordData>
                    <iodef:Description>
                      The IPv4 packet included was used in the described attack
                    </iodef:Description>
                    <iodef:RecordItem dtype="ipv4-packet">450000522ad9
                      0000ff06c41fc0a801020a010102976d0050103e020810d9
                      4a1350021000ad6700005468616e6b20796f7520666f7220
                      6361726566756c6c792072656164696e6720746869732052
                      46432e0a
                    </iodef:RecordItem>
                  </iodef:RecordData>
                </iodef:Record>
              </iodef:EventData>
            </iodef:Incident>
          </iodef:IODEF-Document>
        </content>
      </entry>
```

As can be seen in the example response, above, an IODEF document is contained within the Atom <content> element. The client may now process the IODEF document as needed.

Note also that, as described previously, the content of the Atom <category> element is application-defined. In the present context, the Atom categories have been assigned based on a mapping of the <restriction> and <purpose> attributes, as defined in the IODEF schema. In addition, the IODEF <incidentID> element has been judiciously chosen so that the associated name attribute, as well as the corresponding incidentID value, can be concatenated in order to easily create the corresponding <id> element for the Atom entry. These and other mappings are normatively defined in Section 5, below.

Finally, it should be noted that in order to optimize the client experience, and avoid an additional round trip, a feed provider may choose to include the entry content inline, as part of the feed document. That is, an Atom <entry> element within a Feed document

may contain an Atom <content> element as a child. In this case, the client will receive the full content of the entries within the feed. The decision of whether to include the entry content inline or to include it as a link is a design choice left to the feed provider (e.g. based upon local environmental factors such as the number of entries contained in a feed, the available network bandwidth, the available server compute cycles, the expected client usage patterns, etc.).

4.2.4. Use of Link Relations

As noted previously, a key benefit of using the RESTful architectural style is the ability to enable the client to navigate to related resources through the use of hypermedia links. In the Atom Syndication Format, the type of the related resource identified in a <link> element is indicated via the "rel" attribute, where the value of this attribute identifies the kind of related resource available at the corresponding "href" attribute. Thus, in lieu of a well-known URI template the URI itself is effectively opaque to the client, and therefore the client must understand the semantic meaning of the "rel" attribute in order to successfully navigate. Broad interoperability may be based upon a sharing consortium defining a well-known set of Atom Link Relation types. These Link Relation types may either be registered with IANA, or held in a private registry.

Individual CSIRTs may always define their own link relation types in order to support specific use cases, however support for a core set of well-known link relation types is encouraged as this will maximize interoperability.

In addition, it may be beneficial to define use case profiles that correspond to specific groupings of supported link relationship types. In this way, a CSIRT may unambiguously specify the classes of use cases for which a client can expect to find support.

The following sections provide NON-NORMATIVE examples of link relation usage. Four distinct cyber security information sharing use case scenarios are described. In each use case, the unique benefits of adopting a resource-oriented approach to information sharing are illustrated. It is important to note that these use cases are intended to be a small representative set and is by no means meant to be an exhaustive list. The intent is to illustrate how the use of link relationship types will enable this resource-oriented approach to cyber security information sharing to successfully support the complete range of existing use cases, and also to motivate an initial list of well-defined link relationship types.

4.2.4.1. Use Case: Incident Sharing

This section provides a non-normative example of an incident sharing use case.

In this use case, a member CSIRT shares incident information with another member CSIRT in the same consortium. The client CSIRT retreives a feed of incidents, and is able to identify one particular entry of interest. The client then does an HTTP GET on that entry, and the representation of that resource contains link relationships for both the associated "indicators" and the incident "history", and so on. The client CSIRT recognizes that some of the indicator and history may be relevant within her local environment, and can respond proactively.

Example HTTP GET response for an incident entry:

```
      <?xml version="1.0" encoding="UTF-8"?>
      <entry>
        <id>http://www.example.org/csirt/private/incidents/123456</id>
        <title>Sample Incident</title>
        <link href="http://www.example.org/csirt/private/incidents/123456" rel="
self"/>       <!-- by convention -->
        <link href="http://www.example.org/csirt/private/incidents/123456" rel="
alternate"/>  <!-- required by Atom spec -->
        <published>2012-08-04T18:13:51.0Z</published>
        <updated>2012-08-05T18:13:51.0Z</updated>

        <link href="http://www.example.org/csirt/private/incidents/123456" rel="
edit"/>

        <!-- The links to indicators related to this incident, and the history o
f this incident, and so on.... -->
        <link href="http://www.example.org/csirt/private/incidents/123456/relati
onships/indicators" rel="indicators"/>
        <link href="http://www.example.org/csirt/private/incidents/1234456/relat
ionships/history" rel="history"/>
        <link href="http://www.example.org/csirt/private/incidents/1234456/relat
ionships/campaign" rel="campaign"/>

        <!-- navigate up to the full collection.  Might also be rel="collection"
 as per IANA registry -->
        <link href="http://www.example.org/csirt/private/incidents" rel="up"/>

        <content type="application/xml">
          <iodef:IODEF-Document lang="en" xmlns:iodef="urn:ietf:params:xml:ns:io
def-1.0">
            <iodef:Incident purpose="traceback" restriction="need-to-know">
              <iodef:IncidentID name="http://www.example.org/csirt/private/incid
ents">123456</iodef:IncidentID>
              <!-- ...additional incident data.... -->
              </iodef:Incident>
          </iodef:IODEF-Document>
        </content>
      </entry>
```

As can be seen in the example response, the Atom <link> elements enable the client to navigate to the related indicator resources, and/or the history entries associated with this incident.

4.2.4.2. Use Case: Collaborative Investigation

This section provides a non-normative example of a collaborative investigation use case.

In this use case, two member CSIRTs that belong to a closed sharing consortium are collaborating on an incident investigation. The initiating CSIRT performs an HTTP GET to retrieve the service document of the peer CSIRT, and determines the collection name to be used for creating a new investigation request. The initiating CSIRT then POSTs a new incident entry to the appropriate collection URL.

The target CSIRT acknowledges the request by responding with an HTTP status code 201 Created.

Example HTTP GET response for the service document:

```
HTTP/1.1 200 OK
Date: Fri, 24 Aug 2012 17:09:11 GMT
Content-Length: 934
Content-Type: application/atomsvc+xml;charset="utf-8"

<?xml version="1.0" encoding="UTF-8"?>
<service xmlns="http://www.w3.org/2007/app"
         xmlns:atom="http://www.w3.org/2005/Atom">
    <workspace xml:lang="en-US" xmlns:xml="http://www.w3.org/XML/1998/name
space">
      <atom:title type="text">RID Use Case Requests</atom:title>
      <collection  href="http://www.example.org/csirt/RID/InvestigationReq
uests">
         <atom:title type="text">Investigation Requests</atom:title>
         <accept>application/atom+xml; type=entry</accept>  <!-- perhaps w
e should have a more specific media type -->
      </collection>
      <collection  href="http://www.example.org/csirt/RID/TraceRequests">
         <atom:title type="text">Trace Requests</atom:title>
         <accept>application/atom+xml; type=entry</accept>
      </collection>
      <!-- ...and so on.... -->
    </workspace>
</service>
```

As can be seen in the example response, the Atom <collection> elements enable the client to determine the appropriate collection URL to request an investigation or a trace.

The client CSIRT then POSTs a new entry to the appropriate feed collection. Note that the <content> element of the new entry may contain a RID message of type "InvestigationRequest" if desired, however this would NOT be required. The entry content itself need only be an IODEF document, with the choice of the target collection resource URL indicating the callers intent. A CSIRT would be free to use any URI template to accept investigationRequests.

```
POST /csirt/RID/InvestigationRequests HTTP/1.1
Host: www.example.org
Content-Type: application/atom+xml;type=entry
Content-Length: 852

<?xml version="1.0" encoding="UTF-8"?>
<entry xmlns="http://www.w3.org/2005/Atom">
  <title>New Investigation Request</title>
  <id>http://www.example2.org/csirt/private/incidents/123456</id>  <!-- id and u
pdated not guranteed to be preserved -->
  <updated>2012-08-12T11:08:22Z</updated>                          <!-- may want
to profile that behavior in this document -->
  <author><name>Name of peer CSIRT</name></author>
  <content type="application/xml">
    <iodef:IODEF-Document lang="en" xmlns:iodef="urn:ietf:params:xml:ns:iodef-1.
0">
      <iodef:Incident purpose="traceback" restriction="need-to-know">
      <iodef:IncidentID name="http://www.example2.org/csirt/private/incidents">1
23</iodef:IncidentID>
        <!-- ...additional incident data.... -->
      </iodef:Incident>
    </iodef:IODEF-Document>
  </content>
</entry>
```

The receiving CSIRT acknowledges the request with HTTP return code 201 Created.

```
HTTP/1.1 201 Created
Date: Fri, 24 Aug 2012 19:17:11 GMT
Content-Length: 906
Content-Type: application/atom+xml;type=entry
Location: http://www.example.org/csirt/RID/InvestigationRequests/823
ETag: "8a9h9he4qphqh"

<?xml version="1.0" encoding="UTF-8"?>
<entry xmlns="http://www.w3.org/2005/Atom">
  <title>New Investigation Request</title>
  <id>http://www.example.org/csirt/RID/InvestigationRequests/823</id>  <!-- id a
nd updated not guranteed to be preserved -->
  <updated>2012-08-12T11:08:30Z</updated>                              <!-- may
want to profile that behavior in this document -->
  <published>2012-08-12T11:08:30Z</published>
  <author><name>Name of peer CSIRT</name></author>
  <content type="application/xml">
    <iodef:IODEF-Document lang="en" xmlns:iodef="urn:ietf:params:xml:ns:iodef-1.
0">
      <iodef:Incident purpose="traceback" restriction="need-to-know">
      <iodef:IncidentID name="http://www.example.org/csirt/private/incidents">12
3</iodef:IncidentID>
        <!-- ...additional incident data.... -->
      </iodef:Incident>
    </iodef:IODEF-Document>
  </content>
</entry>
```

Consistent with HTTP/1.1 RFC, the location header indicates the URL of the newly created InvestigationRequest. If for some reason the request were not authorized, the client would receive an HTTP status code 403 Unauthorized. In this case the HTTP response body may contain additional details, if an as appropriate.

4.2.4.3. Use Case: Search (Query)

This section provides a non-normative example of a search use case.

The following example provides a RESTful alternative to the RID Query messaage, as described in sections 6.5 and 7.4 of RFC6545. Note that in the RESTful approach described herein there is no requirement to define a query language specific to RID queries. Instead, CSIRTs may provide support for search operations via existing search facilities, and advertise these capabilities via an appropriate URL template. Clients dynamically retrieve the search description document, and invoke specific searches via an instantiated URL template.

An HTTP response body may include a link relationship of type "search." This link provides a reference to an OpenSearch description document.

Example HTTP response that includes a "search" link:

```
HTTP/1.1 200 OK
Date: Fri, 24 Aug 2012 17:20:11 GMT
Content-Length: nnnn
Content-Type: application/atom+xml;type=feed;charset="utf-8"

<?xml version="1.0" encoding="UTF-8"?>
<feed xmlns="http://www.w3.org/2005/Atom"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="http://www.w3.org/2005/Atom file:/C:/schemas/atom.
xsd
                        urn:ietf:params:xml:ns:iodef-1.0 file:/C:/schemas/
iodef-1.0.xsd"
      xml:lang="en-US">

      <link href="http://www.example.org/opensearchdescription.xml" rel="sea
rch"
            type="application/opensearchdescription+xml"
            title="CSIRT search facility" />

      <!-- ...other links... -->

      <entry>
          <!-- ...zero or more entries... -->
      </entry>

</feed>
```

The OpenSearch Description document contains the information needed by a client to request a search. An example of an Open Search description document is shown below:

Example HTTP response that includes a "search" link:

```
<?xml version="1.0" encoding="UTF-8"?>
<OpenSearchDescription xmlns="http://a9.com/-/spec/opensearch/1.1/
">
  <ShortName>CSIRT search example</ShortName>
  <Description>Cyber security information sharing consortium searc
h interface</Description>
  <Tags>example csirt indicator search</Tags>
  <Contact>admin@example.org</Contact>
  <!-- ...optionally, other elements, as per OpenSearch specificat
ion... -->
  <Url type="application/opensearchdescription+xml" rel="self" tem
plate="http://www.example.com/csirt/opensearchdescription.xml"/>
  <Url type="application/atom+xml" rel="results" template="http://
www.example.org/csirt?q={searchTerms}&amp;format=Atom+xml"/>
  <LongName>www.example.org CSIRT search</LongName>
  <Query role="example" searchTerms="incident" />
  <Language>en-us</Language>
  <OutputEncoding>UTF-8</OutputEncoding>
  <InputEncoding>UTF-8</InputEncoding>
</OpenSearchDescription>
```

The OpenSearch Description document shown above contains two <Url> elements that contain parameterized URL templates. These templates provide a representation of how the client should make search requests. The exact format of the query string, including the parameterization is specified by the feed provider.

This OpenSearch Description Document also contains an example of a <Query> element. Each <Query> element describes a specific search request that can be made by the client. Note that the parameters of the <Query> element correspond to the URL template parameters. In this way, a provider may fully describe the search interface available to the clients. Section 5.12, below, provides specific NORMATIVE requirements for the use of Open Search.

4.2.4.4. Use Case: Cyber Data Repository

This section provides a non-normative example of a cyber security data repository use case.

In this use case a client accesses a persistent repository of cyber security data via a RESTful usage model. Retrieving a feed collection is analogous to an SQL SELECT statement producing a result set. Retrieving an individual Atom Entry is analogous to a SQL SELECT statement based upon a primary key producing a unique record. The cyber security data contained in the repository may include different data types, including indicators, incidents, becnmarks, or

any other related resources. In this use case, the repository is queried via HTTP GET, and the results that are returned to the client may optionally contain URL references to other cyber security resources that are known to be related. These related resources may also be persisted locally, or they may exist at another (remote) cyber data respository.

Example HTTP GET request to a persistent repository for any resources representing Distributed Denial of Service (DDOS) attacks:

```
GET /csirt/repository/ddos
Host: www.example.org
Accept: application/atom+xml
```

The corresponding HTTP response would be an XML document containing the DDOS feed.

Example HTTP GET response for a DDOS feed:

```
      HTTP/1.1 200 OK
      Date: Fri, 24 Aug 2012 17:20:11 GMT
      Content-Length: nnnn
      Content-Type: application/atom+xml;type=feed;charset="utf-8"

      <?xml version="1.0" encoding="UTF-8"?>
      <feed xmlns="http://www.w3.org/2005/Atom"
          xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
          xsi:schemaLocation="http://www.w3.org/2005/Atom file:/C:/schemas/atom.
xsd
                              urn:ietf:params:xml:ns:iodef-1.0 file:/C:/schemas/
iodef-1.0.xsd"
          xml:lang="en-US">

          <generator version="1.0" xml:lang="en-US">emc-csirt-iodef-feed-service
</generator>
          <id xml:lang="en-US">http://www.example.org/csirt/repository/ddos</id>
          <title type="text" xml:lang="en-US">Atom formatted representation of a
 feed of known ddos resources.</title>
          <updated xml:lang="en-US">2012-05-04T18:13:51.0Z</updated>
          <author>
              <email>csirt@example.org</email>
              <name>EMC CSIRT</name>
          </author>

          <!-- By convention there is usually a self link for the feed -->
          <link href="http://www.example.org/csirt/repository/ddos" rel="self"/>

          <entry>
              <id>http://www.example.org/csirt/repository/ddos/123456</id>
              <title>Sample DDOS Incident</title>
              <link href="http://www.example.org/csirt/repository/ddos/123456" r
el="self"/>          <!-- by convention -->
              <link href="http://www.example.org/csirt/repository/ddos/123456" r
el="alternate"/>     <!-- required by Atom spec -->
              <link href="http://www.example.org/csirt/repository/ddos/987654" r
el="related"/>       <!-- link to a related DDOS resource in this repository -->
              <link href="http://www.cyber-agency.gov/repository/indicators/1a2b
3c" rel="related"/>  <!-- link to a related DDOS resource in another repository
-->
              <published>2012-08-04T18:13:51.0Z</published>
              <updated>2012-08-05T18:13:51.0Z</updated>
              <!-- The category is based upon IODEF purpose and restriction attr
ibutes -->
              <category term="traceback" scheme="purpose" label="trace back" />
              <category term="need-to-know" scheme="restriction" label="need to
know" />
              <category term="ddos" scheme="ttp" label="tactics, techniques, and
 procedures"/>
              <summary>A short description of this DDOS attack, extracted from t
he IODEF Incident class, <description> element. </summary>
          </entry>

          <entry>
              <!-- ...another entry... -->
          </entry>

      </feed>
```

This feed document has two atom entries, one of which has been elided. The completed entry illustrates an Atom <entry> element that provides a summary of essential details about one particular DDOS incident. Based upon this summary information and the provided category information, a client may choose to do an HTTP GET operation to retrieve the full details of the DDOS incident. This example shows how a persistent repository may provide links to additional resources, both local and remote.

Note that the provider of a persistent repostory is not obligated to follow any particular URL template scheme. The repository available at the hypothetical provider "www.example.com" uses a different URL pattern than the hypothetical repository available at "www.cyber-agency.gov". When a client de-references a link to resource that is located in a remote repository the client may be challenged for authentication credentials acceptable to that provider. If the two repository providers choose to support a federated identity scheme or some other form of single-sign-on technology, then the user experience can be improved for interactive clients (e.g., a human user at a browser). However, this is not required and is an implementation choice that is out of scope for this specification.

5. Requirements for RESTful (Atom+xml) Binding

This section provides the NORMATIVE requirements for using Atom format and Atom Pub as a RESTful binding for cyber security information sharing.

5.1. Transport Layer Security

Servers implementing this specification MUST support server-authenticated TLS.

Servers MAY support mutually authenticated TLS.

5.2. Archiving and Paging

A feed may contain an arbitrary number of entries. In some cases, the complete response to a given query may consist of a logical result set that contains a large number of entries. As a practical matter, the full result set may need to be divided into more managable portions. For example, a query may produce a full result set that may need to be grouped into logical pages, for purposes of rendering on a user interface.

An historical feed may need to be stable, and/or divided into some defined epochs.

Use cases that require capabilities for paging and archiving of feeds SHOULD support the mechanisms described in Feed Paging and Archiving [RFC5005].

5.3. Expectation and Impact Classes

It is frequently the case that a CSIRT organization will need to triage their investigation and response activities based upon, e.g., the state of the current threat environment, or simply as a result of having limited resources.

In order to enable CSIRTs to effectively prioritize their response activity, it is RECOMMENDED that feed implementors provide Atom categories that correspond to the IODEF Expectation and Impact classes. The availability of these feed categories will enable clients to more easily retrieve and prioritize cyber security information that has already been identified as having a specific potential impact, or having a specific expectation.

Support for these catagories may also enable efficiencies for organizations that already have established (or plan to establish) operational processes and workflows that are based on these IODEF classes.

5.4. User Authentication

Servers MUST require user authentication.

Servers MAY support more than one client authentication method.

Servers participating in an information sharing consotium and supporting interactive user logins by members of the consortium SHOULD support client authentication via a federated identity scheme as per SAML 2.0.

Servers MAY support client authenticated TLS.

5.5. User Authorization

This document does not mandate the use of any specific user authorization mechanisms. However, service implementers SHOULD provide appropriate authorization checking for all resource accesses, including individual Atom Entries, Atom Feeds, and Atom Service Documents.

Authorization for a resource MAY be adjudicated based on the value(s) of the associated Atom <category> element(s).

When the content model for the Atom <content> element of an Atom Entry contains an <IODEF-Document>, then authorization MUST be adjudicated based upon the Atom <category> element(s), whose values have been mapped as per Section 5.9.

Any use of the <category> element(s) as an input to an authorization policy decision MUST include both the "scheme" and "term" attributes contained therein. As described in Section 5.9 below, the namespace of the "term" attribute is scoped by the associated "scheme" attribute.

5.6. Content Model

Member entry resources providing a representation of an incident resource (e.g., as specified in the link relation type) MUST use the IODEF schema as the content model for the Atom Entry <content> element.

Member Entry resources providing a representation of an indicator resource (e.g., as specified in the link relation type) MUST use the IODEF schema as the content model for the Atom Entry <content> element.

The resource representation MAY include an appropriate indicator schema type within the <AdditionalData> element of the IODEF Incident class. Supported indicator schema types SHALL be registered via an IANA table (todo: IANA registration/review).

Member Entry resources providing a representation of a RID report resource (e.g., as specified in the link relation type) MUST use the RID schema as the content model for the Atom Entry <content> element.

Member Entry resources providing representation of other types, SHOULD use the IODEF schema as the content model for the Atom Entry <content> element.

If the member entry content model is not IODEF, then the <content> element of the Atom entry MUST contain an appropriate XML namespace declaration.

5.7. HTTP methods

The following table defines the HTTP [RFC2616] uniform interface methods supported by this specification:

HTTP method	Description
GET	Returns a representation of an individual member entry resource, or a feed collection.
PUT	Replaces the current representation of the specified member entry resource with the representation provided in the HTTP request body.
POST	Creates a new instance of a member entry resource. The representation of the new resource is provided in the HTTP request body.
DELETE	Removes the indicated member entry resource, or feed collection.
HEAD	Returns metadata about the member entry resource, or feed collection, contained in HTTP response headers.
PATCH	Support TBD.

Table 1: Uniform Interface for Resource-Oriented Lightweight Indicator Exchange

Clients MUST be capable of recognizing and prepared to process any standard HTTP status code, as defined in [RFC2616]

5.8. Service Discovery

This specification requires that a CSIRT MUST publish an Atom Service Document that describes the set of cyber security information sharing feeds that are provided.

The service document SHOULD be discoverable via the CSIRT organization’s Web home page or another well-known public resource.

5.8.1. Workspaces

The service document MAY include multiple workspaces. Any CSIRT providing both public feeds and private consortium feeds MUST place these different classes of feeds into different workspaces, and provide appropriate descriptions and naming conventions to indicate the intended audience of each workspace.

5.8.2. Collections

A CSIRT MAY provide any number of collections within a given Workspace. It is RECOMMENDED that each collection appear in only a single Workspace. It is RECOMMENDED that at least one collection be provided that accepts new incident reports from users. At least one

collection MUST provide a feed of incident information for which the content model for the entries uses the IODEF schema. The title of this collection SHOULD be "Incidents".

5.8.3. Service Document Security

Access to the service document MUST be protected via server-authenticated TLS and a server-side certificate.

When deploying a service document for use by a closed consortium, the service document MAY also be digitally signed and/or encrypted, using XML DigSig and/or XML Encryption, respectively.

5.9. Category Mapping

This section defines normative requirements for mapping IODEF metadata to corresponding Atom category elements. (todo: decide between IANA registration of scheme, or use a full URI).

5.9.1. Collection Category

An Atom collection MAY hold entries from one or more categories. The collection category set MUST contain at least the union of all the member entry categories. A collection MAY have additional category metadata that are unique to the collection, and not applicable to any individual member entry. A collection containing IODEF incident content MUST contain at least two <category> elements. One category MUST be specified with the value of the "scheme" attribute as "restriction". One category MUST be specified with the value of the "scheme" attribute as "purpose". The value of the "fixed" attribute for both of these category elements MUST be "yes". When the category scheme="restriction", the allowable values for the "term" attribute are constrained as per section 3.2 of IODEF, e.g. public, need-to-know, private, default. When the category scheme="purpose", the allowable values for the "term" attribute are constrained as per section 3.2 of IODEF, e.g. traceback, mitigation, reporting, other.

5.9.2. Entry Category

An Atom entry containing IODEF content MUST contain at least two <category> elements. One category MUST be specified with the value of the "scheme" attribute as "restriction". One category MUST be specified with the value of the "scheme" attribute as "purpose". When the category scheme="restriction", the value of the "term" attribute must be exactly one of (public, need-to-know, private, default). When the category scheme="purpose", the value of the "term" attribute must be exactly one of (traceback, mitigation, reporting, other). When the purpose is "other"....

Any member entry MAY have any number of additional categories.

5.10. Entry ID

The ID element for an Atom entry SHOULD be established via the concatenation of the value of the name attribute from the IODEF <IncidentID> element and the corresponding value of the <IncidentID> element. This requirement ensures a simple and direct one-to-one relationship between an IODEF incident ID and a corresponding Feed entry ID and avoids the need for any system to maintain a persistent store of these identity mappings.

(todo: Note that this implies a constraint on the IODEF document that is more restrictive than the current IODEF schema. IODEF section 3.3 requires only that the name be a STRING type. Here we are stating that name must be an IRI. Possible request to update IODEF to constrain, or to support a new element or attribute).

5.11. Entry Content

The <content> element of an Atom <entry> SHOULD include an IODEF document. The <entry> element SHOULD include an appropriate XML namespace declaration for the IODEF schema. If the content model of the <entry> element does not follow the IODEF schema, then the <entry> element MUST include an appropriate XML namespace declaration.

A client MAY ignore content that is not using the IODEF schema.

5.12. Link Relations

In addition to the standard Link Relations defined by the Atom specification, this specification defines the following additional Link Relation terms, which are introduced specifically in support of the Resource-Oriented Lightweight Indicator Exchange protocol.

Name	Description	Conformance
service	Provides a link to an atom service document associated with the collection feed.	MUST
search	Provides a link to an associated Open Search document that describes a URL template for search queries.	MUST
history	Provides a link to a	MUST

		collection of zero or more historical entries that are associated with the resource.	
	incidents	Provides a link to a collection of zero or more instances of actual cyber security event(s) that are associated with the resource.	MUST
	indicators	Provides a link to a collection of zero or more instances of cyber security indicators that are associated with the resource.	MUST
	evidence	Provides a link to a collection of zero or more resources that provides some proof of attribution for an incident. The evidence may or may not have any identified chain of custody.	SHOULD
	campaign	Provides a link to a collection of zero or more resources that provides a representation of the associated cyber attack campaign.	SHOULD
	attacker	Provides a link to a collection of zero or more resources that provides a representation of the attacker.	SHOULD
	vector	Provides a link to a collection of zero or more resources that provides a representation of the method used by the attacker.	SHOULD
	assessments	Provides a link to a collection of zero or more resources that represent the results of executing a benchmark.	SHOULD
	reports	Provides a link to a collection of zero or more	SHOULD

	resources that represent RID reports.	
traceRequests	Provides a link to a collection of zero or more resources that represent RID traceRequests.	SHOULD
investigationRequests	Provides a link to a collection of zero or more resources that represent RID investigationRequests.	SHOULD

Table 2: Link Relations for Resource-Oriented Lightweight Indicator Exchange

Unless specifically registered with IANA these short names MUST be fully qualified via concatenation with a base-uri. An appropriate base-uri could be established via agreement amongst the members of an information sharing consortium. For example, the rel="indicators" relationship would become rel="http://www.example.org/csirt/incidents/relationships/indicators."

5.12.1. Additional Link Relation Requirements

An IODEF document that is carried in an Atom Entry SHOULD NOT contain a <relatedActivity> element. Instead, the related activity SHOULD be available via a link rel=related.

An IODEF document that is carried in an Atom Entry SHOULD NOT contain a <history> element. Instead, the related history SHOULD be available via a link rel="history" (todo: or a fully qualified link rek name). The associated href MAY leverage OpenSearch to specify the required query.

An Atom Entry MAY include additional link relationships not specified here. If a client encounters a link relationship of an unkown type the client MUST ignore the offending link and continue processing the remaining resource representation as if the offending link element did not appear.

5.13. Member Entry Forward Security

As described in Authorization Policy Enforcement (Authorization Policy Enforcement) a RESTful model for cyber security information sharing requires that all of the required security enforcement for feeds and entries MUST be enforced at the source system, at the point the representation of the given resource(s) is

created. A CSIRT provider SHALL NOT return any feed content or member entry content for which the client identity has not been specifically authenticated, authorized, and audited.

Sharing communities that have a requirement for forward message security (such that client systems are required to participate in providing message level security and/or distributed authorization policy enforcement), MUST use the RID schema as the content model for the member entry <content> element.

5.14. Date Mapping

The Atom feed <updated> element MUST be populated with the current time at the instant the feed representation was generated. The Atom entry <published> element MUST be populated with the same time value as the <reportTime> element from the IODEF document.

5.15. Search

Implementers MUST support OpenSearch 1.1 [opensearch] as the mechanism for describing how clients may form search requests.

Implementers MUST provide a link with a relationship type of "search". This link SHALL return an Open Search Description Document as defined in OpenSearch 1.1.

Implementers MUST support an OpenSearch 1.1 compliant search URL template that enables a search query via Atom Category, including the scheme attribute and terms attribute as search parameters.

Implementers SHOULD support search based upon the IODEF AlternativeID class as a search parameter.

Implementers SHOULD support search based upon the four timestamp elements of the IODEF Incident class: <startTime>, <EndTime>, <DetectTime>, and <ReportTime>.

Implementers MAY support additional search capabilities based upon any of the remaining elements of the IODEF Incident class, including the <Description> element.

Collections that support use of the RID schema as a content model in the Atom member entry <content> element (e.g. in a report resource representation reachable via the "report" link relationship) MUST support search operations that include the RID MessageType as a search parameter, in addition to the aforementioned IODEF schema elements, as contained within the <ReportSchema> element.

Implementers MUST fully qualify all OpenSearch URL template parameter names using the defined IODEF or RID XML namespaces, as appropriate.

5.16. / (forward slash) Resource URL

The "/" resource MAY be provided for compatibility with existing deployments that are using Transport of Real-time Inter-network Defense (RID) Messages over HTTP/TLS [RFC6546]. Consistent with RFC6546 errata, a client requesting a GET on "/" MUST receive an HTTP status code 405 Method Not Allowed. An implementation MAY provide full support for RFC6546 such that a POST to "/" containing a recognized RID message type just works. Alternatively, a client requesting a POST to "/" MAY receive an HTTP status code 307 Temporary Redirect. In this case, the location header in the HTTP response will provide the URL of the appropriate RID endpoint, and the client may repeat the POST method at the indicated location. This resource could also leverage the new draft by reschke that proposes HTTP status code 308 (cf: draft-reschke-http-status-308-07.txt).

6. Security Considerations

This document defines a resource-oriented approach to lightweight indicator exchange using HTTP, TLS, Atom Syndicate Format, and Atom Publishing Protocol. As such, implementers must understand the security considerations described in those specifications.

In addition, there are a number of additional security considerations that are unique to this specification.

As described above in the section Authentication of Users (Section 3.2), the approach described herein is based upon all policy enforcements being implemented at the point when a resource representation is created. As such, CSIRTS sharing cyber security information using this specification must take care to authenticate their HTTP clients using a suitably strong user authentication mechanism. Sharing communities that are exchanging information on well-known indicators and incidents for purposes of public education may choose to rely upon, e.g. HTTP Authentication, or similar. However, sharing communities that are engaged in sensitive collaborative analysis and/or operational response for indicators and incidents targeting high value information systems should adopt a suitably stronger user authentication solution, such as TLS client certificates, or a risk-based or multi-factor approach. In general, trust in the sharing consortium will depend upon the members maintaining adequate user authentication mechanisms.

Collaborating consortiums may benefit from the adoption of a federated identity solution, such as those based upon SAML-core [SAML-core] and SAML-bind [SAML-bind] and SAML-prof [SAML-prof] for Web-based authentication and cross-organizational single sign-on. Dependency on a trusted third party identity provider implies that appropriate care must be exercised to sufficiently secure the Identity provider. Any attacks on the federated identity system would present a risk to the CISRT, as a relying party. Potential mitigations include deployment of a federation-aware identity provider that is under the control of the information sharing consortium, with suitably stringent technical and management controls.

As discussed above in the section Authorization Policy Enforcement (Section 3.3), authorization of resource representations is the responsibility of the source system, i.e. based on the authenticated user identity associated with an HTTP(S) request. The required authorization policies that are to be enforced must therefore be managed by the security administrators of the source system. Various authorization architectures would be suitable for this purpose, such as RBAC [1] and/or ABAC, as embodied in XACML [XACML]. In particular, implementers adopting XACML may benefit from the capability to represent their authorization policies in a standardized, interoperable format.

Additional security requirements such as enforcing message-level security at the destination system could supplement the security enforcements performed at the source system, however these destination-provided policy enforcements are out of scope for this specification. Implementers requiring this capability should consider leveraging, e.g. the <RIDPolicy> element in the RID schema. Refer to RFC6545 section 9 for more information.

When security policies relevant to the source system are to be enforced at both the source and destination systems, implementers must take care to avoid unintended interactions of the separately enforced policies. Potential risks will include unintended denial of service and/or unintended information leakage. These problems may be mitigated by avoiding any dependence upon enforcements performed at the destination system. When distributed enforcement is unavoidable, the usage of a standard language (e.g. XACML) for the expression of authorization policies will enable the source and destination systems to better coordinate and align their respective policy expressions.

Adoption of the information sharing approach described in this document will enable users to more easily perform correlations across separate, and potentially unrelated, cyber security information providers. A client may succeed in assembling a data set that would

not have been permitted within the context of the authorization policies of either provider when considered individually. Thus, providers may face a risk of an attacker obtaining an access that constitutes an undetected separation of duties (SOD) violation. It is important to note that this risk is not unique to this specification, and a similar potential for abuse exists with any other cyber security information sharing protocol. However, the wide availability of tools for HTTP clients and Atom feed handling implies that the resources and technical skills required for a successful exploit may be less than it was previously. This risk can be best mitigated through appropriate vetting of the client at account provisioning time. In addition, any increase in the risk of this type of abuse should be offset by the corresponding increase in effectiveness that that this specification affords to the defenders.

While it is a goal of this specification to enable more agile cyber security information sharing across a broader and varying constituency, there is nothing in this specification that necessarily requires this type of deployment. A cyber security information sharing consortium may chose to adopt this specification while continuing to operate as a gated community with strictly limited membership.

7. IANA Considerations

This document does not require any actions from IANA.

8. Acknowledgements

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9.3. URIs

[1] http://csrc.nist.gov/groups/SNS/rbac/

Appendix A. Change Tracking

Changes since -02 version, August 15, 2013 to December 2, 2015:

- Added section specifying the use of RFC5005 for Archive and Paging of feeds. See: Section 5.2
- Added section describing use of atom categories that correspond to IODEF expectation class and impact classes. See: Section 5.3
- Dropped references to adoption of a MILE-specific HTTP media type parameter.
- Updated IANA Considerations section to clarify that no IANA actions are required.

Appendix B. Resource Authorization Model

As described in Section 3.3.2 above, ROLIE assumes that all authorization policy enforcement is provided at the source server. The implementation details of the authorization scheme chosen by a ROLIE-compliant provider are out of scope for this specification. Implementers are free to choose any suitable authorization mechanism that is capable of fulfilling the policy enforcement requirements relevant to their consortium and/or organization.

It is well known that one of the major barriers to information sharing is ensuring acceptable use of the information shared. In the case of ROLIE, one way to lower that barrier may be to develop a XACML profile. Use of XACML would allow a ROLIE-compliant provider to express their information sharing authorization policies in a standards-compliant, and machine-readable format.

This improved interoperability may, in turn, enable more agile interactions in the cyber security sharing community. For example, a peer CSIRT, or another interested stakeholder such as an auditor, would be able to review and compare CSIRT sharing policies using appropriate tooling.

The XACML 3.0 standard is based upon the notion that authorization policies are defined in terms of predicate logic expressions written against the attributes associated with one or more of the following four entities:

- SUBJECT
- ACTION
- RESOURCE
- ENVIRONMENT

Thus, a suitable approach to a XACML 3.0 profile for ROLIE authorization policies could begin by using the 3-tuple of [SUBJECT, ACTION, RESOURCE] where:

- SUBJECT is the suitably authenticated identity of the requestor.
- ACTION is the associated HTTP method, GET, PUT, POST, DELETE, HEAD, (PATCH).
- RESOURCE is an XPath expression that uniquely identifies the instance or type of the ROLIE resource being requested.

Implementers who have a need may also choose to evaluate based upon the additional ENVIRONMENT factors, such as current threat level, and so on. One could also write policy to consider the CVSS score associated with the resource, or the lifecycle phase of the resource (vulnerability unverified, confirmed, patch available, etc.), and so on.

Having these policies expressed in a standards-compliant and machine-readable format could improve the agility and effectiveness of a cyber security information sharing group or consortium, and enable better cyber defenses.

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Resource-Oriented Lightweight Information Exchange
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Abstract

This document defines a resource-oriented approach for security automation information publication, discovery, and sharing. Using this approach, producers may publish, share, and exchange representations of software descriptors, security incidents, attack indicators, software vulnerabilities, configuration checklists, and other security automation information as web-addressable resources. Furthermore, consumers and other stakeholders may access and search this security information as needed, establishing a rapid and on-demand information exchange network for restricted internal use or public access repositories. This specification extends the Atom Publishing Protocol and Atom Syndication Format to transport and share security automation resource representations.

Contributing to this document

The source for this draft is being maintained on GitHub. Suggested changes should be submitted as pull requests at <https://github.com/CISecurity/ROLIE>. Instructions are on that page as well. Editorial changes can be managed in GitHub, but any substantial issues need to be discussed on the MILE mailing list.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

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Table of Contents

1. Introduction

This document defines a resource-oriented approach to security automation information sharing that follows the Representational State Transfer (REST) architectural style [REST]. In this approach, computer security resources are maintained in web-accessible repositories structured as Atom Syndication Format [RFC4287] Feeds. Within a given Feed, which may be requested by the consumer, representations of specific types of security automation information are organized, categorized, and described. Furthermore, all collections available to a given user are discoverable, allowing the consumer to search all available content they are authorized to view, and to locate and request the desired information resources. Through use of granular authentication and access controls, only authorized consumers may be permitted the ability to read or write to a given Feed.

The goal of this approach is to increase the communication and sharing of security information between providers and consumers that can be used to automate security processes (e.g., incident reports, vulnerability assessments, configuration checklists, and other security automation information). Such sharing allows human

operators and computer systems to leverage this standardized communication system to gather information that supports the automation of security processes.

To support new types of security automation information being used as time goes on, this specification defines a number of extension points that can be used either privately or globally. These global extensions are IANA registered by ROLIE extension specifications, and provide enhanced interoperability for new use cases and domains. Sections 5 and 6 of this document define the core requirements of all implementations of this specification, and is resource representation agnostic. An overview of the extension system is provided in Section 7. Implementers seeking to provide support for specific security automation information types should refer to the specification for that domain described by the IANA registry found in Section 8.4.

2. Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

The previous key words are used in this document to define the requirements for implementations of this specification. As a result, the key words in this document are not used for recommendations or requirements for the use of ROLIE.

Definitions for some of the common computer security-related terminology used in this document can be found in Section 2 of [RFC7970].

The following terms are unique to this specification:

Information Type A class of security automation information having one or more associated data models. Often such security automation information is used in the automation of a security process. See Section 7.1.2 for more information.

3. XML-related Conventions

3.1. XML Namespaces

This specification uses XML Namespaces [W3C.REC-xml-names-20091208] to uniquely identify XML element names. It uses the following namespace prefix mappings for the indicated namespace URI:

"app" is used for the "http://www.w3.org/2007/app" namespace defined in [RFC5023].

"atom" is used for the "http://www.w3.org/2005/Atom" namespace defined in [RFC4287].

"rolie" is used for the "urn:ietf:params:xml:ns:rolie:1.0" namespace defined in Section 8.1 of this specification.

3.2. RELAX NG Compact Schema

Some sections of this specification are illustrated with fragments of a non-normative RELAX NG Compact schema [relax-NG]. The text of this specification provides the definition of conformance. Schema for the "http://www.w3.org/2007/app" and "http://www.w3.org/2005/Atom" namespaces appear in RFC5023 appendix B [RFC5023] and RFC4287 appendix B [RFC4287] respectively.

A complete informative RELAX NG Compact Schema for the new elements introduced by ROLIE is provided in Appendix A.

4. Background and Motivation

In order to automate security process, tools need access to sufficient sources of structured security information that can be used to drive security processes. Thus, security information sharing is one of the core components of automating security processes. Vulnerabilities, configurations, software identification, security incidents, and patch data are just a few of the classes of information that are shared today to enable effective security on a wide scale. However, as the scale of defense broadens as networks become larger and more complex, and the volume of information to process makes humans-in-the-loop difficult to scale, the need for automation and machine-to-machine communication becomes increasingly critical.

ROLIE seeks to address this need by providing four major information sharing benefits:

Extensible information type categories and format agnosticism: ROLIE is not bound to any given data format or category of information. Instead, information categories are extensible, and entries declare the format of the referenced data. In cases where several formats or serializations are available, ROLIE can use link relations to communicate how a consumer can access these formats. For example, clients may request that a given resource representation be returned as XML, JSON, or in some other format or serialization. This approach allows the provider to support

multiple isomorphic formats allowing the consumer to select the most suitable version.

Open and distributed information sharing: Using the Atom Publishing Protocol, ROLIE feeds can easily aggregate feeds and accept information POSTed to them from other sources. Webs of communicating ROLIE servers form ad-hoc sharing communities, increasing data availability and the ability to correlate linked data across sources for participating consumers. ROLIE servers needn't be distributed however, as large ROLIE repositories can function as a central or federated collections.

Stateless communication model: ROLIE, as a RESTful system, is stateless. That is, the server doesn't keep track of client sessions, but rather uses link relations for state transitions. In practice, this means that any consumer can find and share information at any organizational level and at any time without needing to execute a long series of requests.

Information discovery and navigation: ROLIE provides a number of mechanisms to allow clients to programmatically discover and navigate collections of information in order to dynamically discover new or revised content. Extensible information types and other categories provide one way of determining content that is desirable. Link elements, each with a target URI and an established relationship type, provide a means for ROLIE providers to link other information that is relevant to the current entry or feed.

These benefits result in an information sharing protocol that is lightweight, interactive, open, and most importantly, machine readable.

The requirements in this specification are broken into two major sections, extensions to the Atom Publishing Protocol (AtomPub) [RFC5023], and extensions to the Atom Syndication Format [RFC4287]. All normative requirements in AtomPub and Atom Syndication are inherited from their respective specifications, and apply here unless the requirement is explicitly overridden in this document. In this way, this document may upgrade the requirement (e.g., make a SHOULD a MUST), but will never downgrade a given requirement (e.g., make a MUST a SHOULD).

5. ROLIE Requirements for the Atom Publishing Protocol

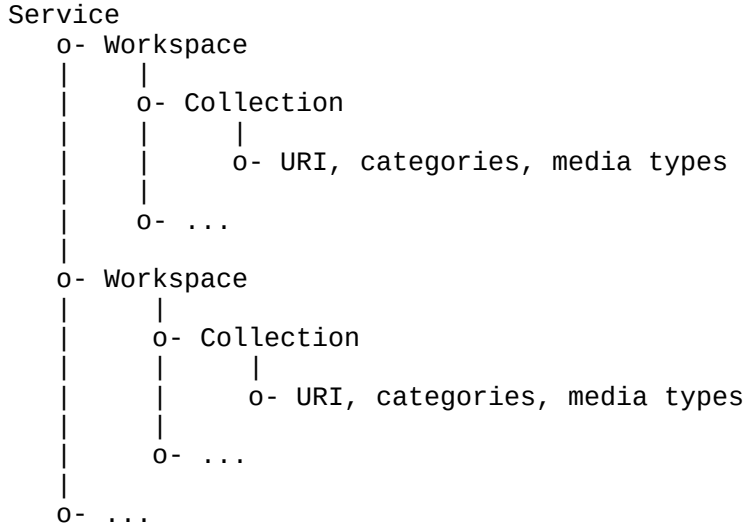
This section describes a number of restrictions of and extensions to the Atom Publishing Protocol (AtomPub) [RFC5023] that define the use of that protocol in the context of a ROLIE-based solution. The

normative requirements in this section are generally oriented towards client and server implementations. An understanding of the Atom Publishing Protocol specification [RFC5023] is helpful to understand the requirements in this section.

5.1. AtomPub Service Documents

As described in RFC5023 section 8 [RFC5023], a Service Document is an XML-based document format that allows a client to dynamically discover the Collections provided by a publisher. A Service Document consists of one or more app:workspace elements that may each contain a number of app:collection elements.

The general structure of a service document is as follows (from RFC5023 section 4.2 [RFC5023]):



Note that the IRIs in the original diagram have been replaced with URIs.

5.1.1. Use of the "app:workspace" Element

In AtomPub, a Workspace, represented by the "app:workspace" element, describes a group of one or more Collections. Building on the AtomPub concept of a Workspace, in ROLIE a Workspace represents an aggregation of Collections pertaining to security automation information resources. This specification does not restrict the number of Workspaces that may be in a Service Document or the specific Collections to be provided within a given Workspace.

A ROLIE implementation can host Collections containing both public and private information entries. It is suggested that implementations segregate Collections into different app:workspace elements by their client access requirements. With proper naming of workspaces, this reduces the amount of trial and error a human user would need to utilize to discover accessible Collections.

5.1.2. Use of the "app:collection" Element

In AtomPub, a Collection in a Service Document, represented by the "app:collection" element, provides metadata that can be used to point to a specific Atom Feed that contains information Entries that may be of interest to a client. The association between a Collection and a Feed is provided by the "href" attribute of the app:collection element. Building on the AtomPub concept of a Collection, in ROLIE a Collection represents a pointer to a group of security automation information resources pertaining to a given type of security automation information. Collections are represented as Atom Feeds as per RFC 5023. Atom Feed specific requirements are defined in Section 6.1.

ROLIE defines specialized data requirements for Collections, Feeds, and Entries containing security automation related data. The difference between a ROLIE and a non-ROLIE Collection defined in a Service Document can be determined as follows:

ROLIE Collection: An app:collection is considered a ROLIE Collection when it contains an app:categories element that contains only one atom:category element with the "scheme" attribute value of "urn:ietf:params:rolie:category:information-type". Further, this category has an appropriate "term" attribute value as defined in Section 7.1.1. This ensures that a given Collection corresponds to a specific type of security automation information.

Non-ROLIE Collection: An app:collection is considered a non-ROLIE Collection when it does not contain an atom:category element with a "scheme" attribute value of "urn:ietf:params:rolie:category:information-type".

By distinguishing between ROLIE and non-ROLIE Collections in this way, implementations supporting ROLIE can host Collections pertaining to security automation information alongside Collections of other non-ROLIE information within the same AtomPub instance.

The following are additional requirements on the use of the app:collection element for a ROLIE Collection:

- The child atom:category elements contained in the app:categories element MUST be the same set of atom:category elements used in the Atom Feed resource referenced by the app:collection "href" attribute value. This ensures that the category metadata associated with the Collection and the associated Feed is discoverable in both of these resources.

- The app:categories element in an app:collection MAY include additional atom:category elements using a scheme other than "urn:ietf:params:rolie:category:information-type". This allows other category metadata to be included.

5.1.3. Service Document Discovery

The Service Document serves as the "head" of a given ROLIE repository: from the Service Document all other repository content can be discovered. A client will need to determine the URL of this Service Document to discover the Collections provided by the repository. The client might determine the URL from a web page, based on out-of-band communication, or through a "service" link relation in a Feed or Entry document that the client has already retrieved. The latter is a typical scenario if the client learns of a specific feed or entry through an out-of-band mechanism, and wishes to discover additional information provided by the repository.

This document does not provide a fully automated discovery mechanism. A mechanism may be defined in the future that allows automated clients to discover the URL to use to retrieve a ROLIE Service Document representing the head of the ROLIE repository.

5.2. Category Documents

As described in RFC5023 section 7 [RFC5023], a Category Document is an XML-based document format that allows a client to dynamically discover the Categories used within AtomPub Service Documents, Atom Syndication Feeds, and Entry documents provided by a publisher. A Category Document consists of one app:categories element that contains a number of inline atom:category elements, or a URI referencing a Category Document.

5.3. Transport Layer Security

ROLIE is intended to be handled with TLS. TLS version 1.2 MUST be supported. TLS 1.2 SHOULD be implemented according to all recommendations and best practices present in [RFC7525].

It is RECOMMENDED that the most recent published version of TLS is supported. If this version is TLS 1.3 [I-D.ietf-tls-tls13] it is

suggested that 0-RTT (Zero Round Trip Time Resumption) is not used in order to prevent replay attacks. Replay attacks on PUT, POST, or DELETE requests can disrupt repository operation by modifying data unexpectedly.

For example, an automated ROLIE repository that updates very frequently may receive a PUT request against a given resource a few times an hour (or more). An attacker may store an early PUT request, and at the end of the resumption window replay the PUT request, reverting the resource to an old version. Not only could an attacker be doing this replay continuously to cause havoc on the server, but the client is completely unaware of the attack taking place.

Given the potentially sensitive nature of data handled by ROLIE, all appropriate precautions should be taken at the transport layer to protect forward secrecy and user privacy.

The server MUST implement certificate-based client authentication. This MAY be enabled on a workspace by workspace basis.

5.4. User Authentication and Authorization

Implementations MUST support user authentication. However, a given implementation MAY allow user authentication to be disabled on a Feed by Feed, or Workspace by Workspace basis.

It is recommended that servers participating in an information sharing consortium and supporting interactive user logins by members of the consortium support client authentication via a federated identity scheme.

This document does not mandate the use of any specific user authorization mechanisms. However, service implementers SHOULD support appropriate authorization checking for all resource accesses, including individual Atom Entries, Atom Feeds, and Atom Service Documents.

5.5. / (forward slash) Resource URL

The "/" resource MAY be supported for compatibility with existing deployments that are using Transport of Real-time Inter-network Defense (RID) Messages over HTTP/TLS [RFC6546]. The following requirements apply only to implementations supporting RFC 6546.

The following additional requirements only apply if a implementation is supporting the "/" resource as described above:

- Consistent with RFC6546 errata, a client requesting a GET on the "/" resource SHOULD receive an HTTP status code 405 Method Not Allowed.

- An implementation MAY provide full support for [RFC6546] such that a POST to the "/" resource containing a recognized RID message is handled correctly as a RID request. Alternatively, a client requesting a POST to "/" MAY receive an HTTP status code 307 Temporary Redirect. In this case, the location header in the HTTP response will provide the URL of the appropriate RID endpoint, and the client may repeat the POST method at the indicated location.

If RFC 6546 is unsupported, then a request for the "/" resource may be handled as deemed appropriate by the server.

5.6. HTTP methods

Servers MAY accept request methods beyond those specified in this document.

Clients MUST be capable of recognizing and processing any standard HTTP status code, as defined in [RFC5023] Section 5.

6. ROLIE Requirements for the Atom Syndication Format

This section describes a number of restrictions of and extensions to the Atom Syndication Format [RFC4287] that define valid use of the format in the context of a ROLIE implementation. An understanding of the Atom Syndication Format specification [RFC4287] is helpful to understand the requirements in this section.

6.1. Use of the "atom:feed" element

As described in RFC4287 section 4.1.1 [RFC4287], an Atom Feed is an XML-based document format that describes a list of related information items. The list of Atom Feeds provided by a ROLIE service are listed in the service’s Service Document through one or more app:collection elements. Each Feed document, represented using the atom:feed element, contains a listing of zero or more Entries.

When applied to the problem domain of security automation information sharing, an Atom Feed may be used to represent any meaningful collection of security automation information resources. Each Entry in an atom:feed represents an individual resource (e.g., a specific checklist, a software vulnerability record). Additional Feeds can be used to represent other collections of security automation resources.

As discussed in Section 5.1.2, ROLIE defines specialized data requirements for Feeds containing security automation related data. The difference between a ROLIE and a non-ROLIE Feed can be determined as follows:

ROLIE Feed: For an atom:feed to be considered a ROLIE Feed, the atom:feed MUST contain only one child atom:category element with the "scheme" attribute value of "urn:ietf:params:rolie:category:information-type". This category MUST have an appropriate "term" attribute value as defined in Section 7.1.1. This ensures that a given Feed corresponds to a specific type of security automation information.

Non-ROLIE Feed: For an atom:feed to be considered a non-ROLIE Feed, the atom:feed MUST NOT contain an atom:category element with a "scheme" attribute value of "urn:ietf:params:rolie:category:information-type".

By distinguishing between ROLIE and non-ROLIE Feeds in this way, implementations supporting ROLIE can host Feeds pertaining to security automation information alongside Feeds of other non-ROLIE information within the same AtomPub instance. This is parallel to the handling of collections ealier in this specification in Section 5.1.2.

The following Atom Feed definition represents a stricter definition of the atom:feed element defined in RFC 4287 when used as a ROLIE Feed. Any element not specified here inherits its definition and requirements from [RFC4287].

```
atomFeed =
   element atom:feed {
      atomCommonAttributes,
      (atomAuthor*
       & atomCategory+
       & atomContributor*
       & atomGenerator?
       & atomIcon?
       & atomId
       & atomLink+
       & atomLogo?
       & atomRights?
       & atomSubtitle?
       & atomTitle
       & atomUpdated
       & extensionElement*),
      atomEntry*
   }
```

The following subsections contain requirements for a ROLIE Feed.

6.1.1. Use of the "atom:category" Element

An atom:feed can contain one or more atom:category elements. In Atom the naming scheme and the semantic meaning of the terms used to identify an Atom category are application-defined.

The following are additional requirements on the use of the atom:category element when used in a ROLIE Feed:

- All member Entries in the Feed MUST represent security automation information records of the provided information type category.
- An atom:feed MAY include additional atom:category elements using a scheme other than "urn:ietf:params:rolie:category:information-type". This allows other category metadata to be included.

6.1.2. Use of the "atom:link" Element

Link relations defined by the atom:link element are used to represent state transitions using a stateless approach. In Atom a type of link relationship can be defined using the "rel" attribute.

A ROLIE atom:feed MUST contain one or more atom:link elements with rel="service" and href attribute whose value is a URI that points to an Atom Service Document associated with the atom:feed. If a client accesses a Feed without first accessing the service's service document, a link with the "service" relationship provides a means to discover additional security automation information. The "service" link relationship is defined in the IANA Link Relations Registry [1].

An atom:feed can contain an arbitrary number of Entries. In some cases, a complete Feed may consist of a large number of Entries. Additionally, as new and updated Entries are ordered at the beginning of a Feed, a client may only be interested in retrieving the first N entries in a Feed to process only the Entries that have changed since the last retrieval of the Feed. As a practical matter, a large set of Entries will likely need to be divided into more manageable portions, or pages. Based on RFC5005 section 3 [RFC5005], link elements SHOULD be included in all Feeds to support paging using the following link relation types:

- "first" - Indicates that the href attribute value of the link identifies a resource URI for the furthest preceding page of the Feed.

- "last" - Indicates that the href attribute value of the link identifies a resource URI for the furthest following page of the Feed.

- "previous" - Indicates that the href attribute value of the link identifies a resource URI for the immediately preceding page of the Feed.

- "next" - Indicates that the href attribute value of the link identifies a resource URI for the immediately following page of the Feed.

For example:

```
<?xml version="1.0" encoding="UTF-8"?>
<feed xmlns="http://www.w3.org/2005/Atom">
    <id>b7f65304-b63b-4246-88e2-c104049c5fd7</id>
    <title>Paged Feed</title>
    <link rel="self" href="https://example.org/feedA?page=5"/>
    <link rel="first" href="https://example.org/feedA?page=1"/>
    <link rel="prev" href="https://example.org/feedA?page=4"/>
    <link rel="next" href="https://example.org/feedA?page=6"/>
    <link rel="last" href="https://example.org/feedA?page=10"/>
    <updated>2012-05-04T18:13:51.0Z</updated>

    <!-- remainder of feed elements -->
</feed>
```

Example Paged Feed

A reference to a historical Feed may need to be stable, and/or a Feed may need to be divided into a series of defined epochs. Implementations SHOULD support the mechanisms described in RFC5005 section 4 [RFC5005] to provide link-based state transitions for maintaining archiving of Feeds.

An atom:feed MAY include additional link relationships not specified in this document. If a client encounters an unknown link relationship type, the client MUST ignore the unrecognized link and continue processing as if the unrecognized link element did not appear. The definition of new Link relations that provide additional state transition extensions is discussed in Section 7.3.

6.1.3. Use of the "atom:updated" Element

The atom:updated element identifies the date and time that a Feed was last updated.

The atom:updated element MUST be populated with the current time at the instant the Feed was last updated by adding, updating, or deleting an Entry; or changing any metadata for the Feed.

6.2. Use of the "atom:entry" Element

Each Entry in an Atom Feed, represented by the atom:entry element, describes a single referenced information record, along with descriptive information about its format, media type, and other publication metadata. The following atom:entry schema definition represents a stricter representation of the atom:entry element defined in [RFC4287] for use in a ROLIE-based Atom Feed as defined in Section 6.1.1.

```
atomEntry =
  element atom:entry {
    atomCommonAttributes,
    (atomAuthor*
    & atomCategory*
    & atomContent
    & atomContributor*
    & atomId
    & atomLink*
    & atomPublished?
    & atomRights?
    & atomSource?
    & atomSummary?
    & atomTitle
    & atomUpdated
    & rolieFormat?
    & rolieProperty*
    & extensionElement*)
  }
```

The notable changes from [RFC4287] are the addition of rolieFormat and rolieProperty elements. Also the atomContent element is restricted to the atomOutOfLineContent formulation and is now REQUIRED.

The following subsections contain requirements for Entries in a ROLIE Feed.

6.2.1. Use of the "atom:content" Element

An atom:content element associates its containing Entry with a content resource identified by the src attribute.

There MUST be exactly one atom:content element in the Entry. The content element MUST adhere to this definition, which is a stricter representation of the atom:content element defined in [RFC4287]:

```
atomContent =
  element atom:content {
    atomCommonAttributes,
    attribute type { atomMediaType },
    attribute src { atomUri },
    empty
}
```

This restricts atomContent in ROLIE to the atomOutofLine formulation presented in[RFC4287].

The type attribute MUST identify the serialization type of the content, for example, application/xml or application/json. A prefixed media type MAY be used to reflect a specific model used with a given serialization approach (e.g., application/rdf+xml). The src attribute MUST be an URI that can be dereferenced to retrieve the related content data.

6.2.2. Use of the "atom:link" Element

Link relations can be included in an atom:entry to represent state transitions for the Entry.

If there is a need to provide the same information in different data models and/or serialization formats, separate Entry instances can be included in the same or a different Feed. Such an alternate content representation can be indicated using an atom:link having a rel attribute with the value "alternate".

An atom:feed MAY include additional link relationships not specified in this document. If a client encounters an unknown link relationship type, the client MUST ignore the unrecognized link and continue processing as if the unrecognized link element did not appear. The definition of new Link relations that provide additional state transition extensions is discussed in Section 7.3.

6.2.3. Use of the "rolie:format" Element

As mentioned earlier, a key goal of this specification is to allow a consumer to review a set of published security automation information resources, and then identify and retrieve any resources of interest. The format of the data is a key criteria to consider when deciding what information to retrieve. For a given type of security automation information, it is expected that a number of different

formats may be used to represent this information. To support this use case, both the serialization format and the specific data model expressed in that format must be known by the consumer.

In the Atom Syndication format, a media type can be defined using the "type" attribute on the "atom:content" element of an atom:entry. The media type can be fully descriptive of the format of the linked document, such as "application/atom+xml". In some cases, however, a format specific media type may not be defined. An example might be when "application/xml" is used because there is no defined specific media type for the content. In such a case the exact data model of the content cannot be known without first retrieving the content.

In cases where a specific media type does not exist, the rolie:format element is used to describe the data model used to express the information referenced in the atom:content element. The rolie:format element also allows a schema to be identified that can be used when parsing the content to verify or better understand the structure of the content.

When it appears, the "rolie:format" element MUST adhere to this definition:

```
rolieFormat =
  element rolie:format {
    appCommonAttributes,
    attribute ns { atomURI },
    attribute version { text } ?,
    attribute schema-location { atomURI } ?,
    attribute schema-type { atomMediaType } ?,
    empty
}
```

The rolie:format element MUST provide a "ns" attribute that identifies the data model of the resource referenced by the atom:content element. For example, the namespace used may be an XML namespace URI, or an identifier that represents a serialized JSON model. The URI used for the "ns" attribute MUST be absolute. The resource identified by the URI need not be resolvable.

The rolie:format element MAY provide a "version" attribute that identifies the version of the format used for the related atom:content.

The rolie:format element MAY provide a "schema-location" attribute that is a URI that identifies a schema resource that can be used to validate the related atom:content.

The rolie:format element MAY provide a "schema-type" attribute, which is a media type (as described in [RFC2045] identifying the format of the schema resource identified by the "schema-location" attribute.

The following nominal example shows how these attributes describe the format of the content:

```
<rolie:format ns="urn:ietf:params:xml:ns:iodef-2.0"
  version="2.0"
  schema-location=
    "https://www.iana.org/assignments/xml-registry/schema/iodef-2.0.xsd"
  schema-type="text/xml"/>
```

The previous element provides an indication that the content of the given entry is using the IODEF v2 format.

6.2.4. Use of the rolie:property Element

An atom:category element provides a way to associate a name/value pair of categorical information using the scheme and term attributes to represent the name, and the label attribute to represent the value. When used in this way an atom:category allows a specific label to be selected from a finite set of possible label values that can be used to further classify a given atom:entry or atom:feed. Within ROLIE, there may be a need to associate additional metadata with an atom:entry. In such a case, use of an atom:category is not practical to represent name/value data for which the allowed values are unbounded. Instead, ROLIE has introduced a new rolie:property element that can represent non-categorical metadata as name/value pairs. Examples include content-specific identifiers, naming data, and other properties that allow for unbounded values.

There MAY be zero or more rolie:property elements in an atom:entry.

The element MUST adhere to this definition:

```
  rolieProperty =
    element rolie:property {
      app:appCommonAttributes,
      attribute name { atom:atomURI },
      attribute value { text }
      empty
  }
```

The name attribute provides a URI that identifies the namespace and name of the property as a URI.

The value attribute is text that provides a value for the property identified by the name attribute.

For example, the nominal element <rolie:property name="urn:ietf:params:rolie:property:content-id" value="12345"/> would expose an IODEF ID value contained in a given entry's content. The name used in the example also demonstrates the use of a registered ROLIE property extension, which is described in Section 7.4.

Implementations MAY use locally defined and namespaced elements in an Entry in order to provide additional information. Clients that do not recognize a property with an unregistered name attribute MUST ignore the rolie:property, that is, the client MUST NOT fail parsing content that contains an unrecognized property.

6.2.5. Requirements for a Standalone Entry

If an Entry is ever shared as a standalone resource, separate from its containing Feed, then the following additional requirements apply:

- The Entry MUST have an atom:link element with rel="collection" and href="[URI of the containing Collection]". This allows the Feed or Feeds for which the Entry is a member to be discovered, along with the related information the Feed may contain. In the case of the Entry have multiple containing Feeds, the Entry MUST have one atom:link for each related Feed.

- The Entry MUST declare the information type of the content resource referenced by the Entry (see Section 7.1.2).

7. Available Extension Points Provided by ROLIE

This specification does not require particular information types or data formats; rather, ROLIE is intended to be extended by additional specifications that define the use of new categories and link relations. The primary point of extension is through the definition of new information type category terms. Additional specifications can register new information type category terms with IANA that serve as the main characterizing feature of a ROLIE Collection/Feed or Resource/Entry. These additional specifications defining new information type terms, can describe additional requirements for including specific categories, link relations, as well as, use of specific data formats supporting a given information type term.

7.1. The Category Extension Point

The atom:category element, defined in RFC 4287 section 4.2.2 [RFC4287], provides a mechanism to provide additional categorization information for a content resource in ROLIE. The ability to define new categories is one of the core extension points provided by Atom. A Category Document, defined in RFC 5023 section 7 [RFC5023], provides a mechanism for an Atom implementation to make discoverable the atom:category terms and associated allowed values.

ROLIE further defines the use of the existing Atom extension category mechanism by allowing ROLIE specific category extensions to be registered with IANA, and additionally has assigned the "urn:ietf:params:rolie:category:information-type" category scheme that has special meaning for implementations of ROLIE. This allows category scheme namespaces to be managed in a more consistent way, allowing for greater interoperability between content producers and consumers.

Any category whose "scheme" attribute uses an unregistered scheme MUST be considered private use. Implementations encountering such a category MUST parse the content without error, but MAY otherwise ignore the element.

Use of the "atom:category" element is discussed in the following subsections.

7.1.1. General Use of the "atom:category" Element

The atom:category element can be used for characterizing a ROLIE Resource. As discussed earlier in this document, an atom:category element has a "term" attribute that indicates the assigned category value, and a "scheme" attribute that provides an identifier for the category type. The "scheme" provides a means to describe how a set of category terms should be used and provides a namespace that can be used to differentiate terms provided by multiple organizations with different semantic meaning.

To further differentiate category types used in ROLIE, an IANA sub-registry has been established for ROLIE protocol parameters to support the registration of new category "scheme" attribute values by ROLIE extension specifications. Use of this extension point is discussed in Section 8.3 using the name field with a type parameter of "category" to indicate a category extension.

7.1.2. Identification of Security Automation Information Types

A ROLIE specific extension point is provided through the atom:category "scheme" value "urn:ietf:params:rolie:category:information-type". This value is a Uniform Resource Name (URN) [RFC8141] that is registered with IANA as described in Section 8.3. When used as the "scheme" attribute in this way, the "term" attribute is expected to be a registered value as defined in Section 8.4. Through this mechanism a given security automation information type can be used to:

1. identify that an "app:collection" element in a Service Document points to an Atom Feed that contains Entries pertaining to a specific type of security automation information (see Section 5.1.2), or

2. identify that an "atom:feed" element in an Atom Feed contains Entries pertaining to a specific type of security automation information (see Section 6.1.1).

3. identify the information type of a standalone Resource (see Section 6.2.5).

For example, the notional security automation information type "incident" would be identified as follows:

```
<atom:category
    scheme="urn:ietf:params:rolie:category:information-type"
    term="incident"/>
```

A security automation information type represents a class of information that represents the same or similar information model [RFC3444]. Note that this document does not register any information types, but offers the following as examples of potential information types:

indicator: Computing device- or network-related "observable features and phenomenon that aid in the forensic or proactive detection of malicious activity; and associated meta-data" (from [RFC7970]).

incident: Information pertaining to and "derived analysis from security incidents" (from [RFC7970]).

vulnerability reports: Information identifying and describing a vulnerability in hardware or software.

configuration checklists: Content that can be used to assess the configuration settings related to installed software.

software tags: Metadata used to identify and characterize installable software.

This is a short list to inspire new engineering of information type extensions that support the automation of security processes.

This document does not specify any information types. Instead, information types in ROLIE are expected to be registered in extension documents that describe one or more new information types. This allows the information types used by ROLIE implementations to grow over time to support new security automation use cases. These extension documents may also enhance ROLIE Service, Category, Feed, and Entry documents by defining link relations, other categories, and Format data model extensions to address the representational needs of these specific information types. New information types are added to ROLIE through registrations to the IANA ROLIE Security Resource Information Type registry defined in Section 8.4.

7.2. The "rolie:format" Extension Point

Security automation data pertaining to a given information type may be expressed using a number of supported formats. As described in Section 6.2.3, the rolie:format element is used to describe the specific data model used to represent the resource referenced by a given "atom:entry". The structure provided by the rolie:format element, provides a mechanism for extension within the atom:entry model. ROLIE extensions MAY further restrict which data models are allowed to be used for a given information type.

By declaring the data model used for a given Resource, a consumer can choose to download or ignore the Resource, or look for alternate formats. This saves the consumer from downloading and parsing resources that the consumer is not interested in or resources expressed in formats that are not supported by the consumer.

7.3. The Link Relation Extension Point

This document uses several link relations defined in the IANA Link Relation Types registry [2]. Additional link relations can be registered in this registry to allow new relationships to be represented in ROLIE according to RFC 4287 section 4.2.7.2 [RFC4287]. Based on the preceding reference, if the link relation is too specific or limited in the intended use, an absolute URI can be used in lieu of registering a new simple name with IANA.

7.4. The "rolie:property" Extension Point

As discussed previously in Section 6.2.4, many formats contain unique identifying and characterizing properties that are vital for sharing information. In order to provide a global reference for these properties, this document establishes an IANA registry in Section 8.3 that allows ROLIE extensions to register named properties using the name field with a type parameter of "property" to indicate a property extension. Implementations SHOULD prefer the use of registered properties over implementation specific properties when possible.

ROLIE extensions are expected to register new and use existing properties to provide valuable identifying and characterizing information for a given information type and/or format.

The namespace "urn:ietf:params:rolie:property:local" has been reserved in the IANA ROLIE Parameters table for private use as defined in [RFC8126]. Any property whose "name" attribute uses this as a prefix MUST be considered private use. Implementations encountering such a property MUST parse the content without error, but MAY otherwise ignore the element.

This document also registers a number of general use properties that can be used to expose content information in any ROLIE use case. The following are descriptions of how to use these registered properties:

urn:ietf:params:rolie:property:content-author-name The "value" attribute of this property is a text representation indicating the individual or organization that authored the content referenced by the "src" attribute of the entry’s atom:content element. This author may differ from the atom:author when the author of the content and the entry are different people or entities.

urn:ietf:params:rolie:property:content-id The "value" attribute of this property is a text representation of an identifier pertaining to or extracted from the content referenced by the "src" attribute of the entry’s atom:content element. For example, if the atom:entry’s atom:content element links to an IODEF document, the "content-id" value would be an identifier of that IODEF document.

urn:ietf:params:rolie:property:content-published-date The "value" attribute of this property is a text representation indicating the original publication date of the content referenced by the "src" attribute of the entry’s atom:content element. This date may differ from the published date of the ROLIE Entry because publication of the content and the ROLIE Entry represent different events. The date MUST be formatted as specified in [RFC3339].

urn:ietf:params:rolie:property:content-updated-date The "value" attribute of this property is a text representation indicating the date that the content, referenced by the "src" attribute of the entry's atom:content element, was last updated. This date may differ from the updated date of the ROLIE Entry because updates made to the content and to the ROLIE Entry are different events. The date MUST be formatted as specified in [RFC3339].

8. IANA Considerations

This document has a number of IANA considerations described in the following subsections.

8.1. XML Namespaces and Schema URNs

This document uses URNs to describe XML namespaces and XML schemas conforming to a registry mechanism described in [RFC3688].

ROLIE XML Namespace The ROLIE namespace (rolie-1.0) has been registered in the "ns" registry.

URI: urn:ietf:params:xml:ns:rolie-1.0

Registrant Contact: IESG

XML: None. Namespace URIs do not represent an XML specification.

ROLIE XML Schema The ROLIE schema (rolie-1.0) has been registered in the "schema" registry.

URI: urn:ietf:params:xml:schema:rolie-1.0

Registrant Contact: IESG

XML: See Appendix A of this document.

8.2. ROLIE URN Sub-namespace

IANA has added an entry to the "IETF URN Sub-namespace for Registered Protocol Parameter Identifiers" registry located at <http://www.iana.org/assignments/params/params.xml#params-1> as per RFC3553 [RFC3553].

The entry is as follows:

Registry name: rolie

Specification: This document

Repository: ROLIE URN Parameters. See Section 8.3 [TO BE REMOVED: This registration should take place at the following location: https://www.iana.org/assignments/rolie]

Index value: See Section 8.3

8.3. ROLIE URN Parameters

A new top-level registry has been created, entitled "Resource Oriented Lightweight Information Exchange (ROLIE) URN Parameters". [TO BE REMOVED: This registration should take place at the following location: https://www.iana.org/assignments/rolie]

Registration in the ROLIE URN Parameters registry is via the Specification Required policy [RFC8126]. Registration requests must be sent to both the MILE WG mailing list (mile@ietf.org) and IANA. IANA will forward registration requests to the Designated Expert.

Each entry in this sub-registry must record the following fields:

Name: A URN segment that adheres to the pattern {type}:{label}. The keywords are defined as follows:

{type}: The parameter type. The allowed values are "category" or "property". "category" denotes a category extension as discussed in Section 7.1. "property" denotes a property extension as discussed in Section 7.4.

{label}: A required US-ASCII string that conforms to the URN syntax requirements (see [RFC8141]). This string must be unique within the namespace defined by the {type} keyword. The "local" label for both the "category" and "property" types has been reserved for private use.

Extension URI: The identifier to use within ROLIE, which is the full URN using the form: urn:ietf:params:rolie:{name}, where {name} is the "name" field of this registration.

Reference: A static link to the specification and section that the definition of the parameter can be found.

Sub-registry: An optional field that links to an IANA sub-registry for this parameter. If the {type} is "category", the sub-registry must contain a "name" field whose registered values MUST be US-ASCII. The list of names are the allowed values of the "term" attribute in the atom:category element. (See Section 7.1.2).

This repository has the following initial values:

Name	Extension URI	Reference	Sub-Registry
category:information-type	urn:ietf:params:rolie:category:information-type	This document, Section 8.4	[TO BE REMOVED: This registration should take place at the following location: https://www.iana.org/assignments/rolie/category/information-type]
property:content-author-name	urn:ietf:params:rolie:property:content-author-name	This document, Section 7.4	None
property:content-id	urn:ietf:params:rolie:property:content-id	This document, Section 7.4	None
property:content-published-date	urn:ietf:params:rolie:property:content-published-date	This document, Section 7.4	None
property:content-updated-date	urn:ietf:params:rolie:property:content-updated-date	This document, Section 7.4	None

8.4. ROLIE Security Resource Information Type Sub-Registry

A new sub-registry has been created to store ROLIE information type values.

Name of Registry: "ROLIE Information Types"

Location of Registry: https://www.iana.org/assignments/rolie/category/information-type

Fields to record in the registry:

name: The full name of the security resource information type as a string from the printable ASCII character set [RFC0020] with individual embedded spaces allowed. This value must be unique in the context of this table. The ABNF [RFC5234] syntax for this field is:

```
1*VCHAR *(SP 1*VCHAR)
```

index: This is an IANA-assigned positive integer that identifies the registration. The first entry added to this registry uses the value 1, and this value is incremented for each subsequent entry added to the registry.

reference: A list of one or more URIs [RFC3986] from which the registered specification can be obtained. The registered specification MUST be readily and publicly available from that URI. The URI SHOULD be a stable reference.

Allocation Policy: Specification required as per [RFC8126]

9. Security Considerations

This document defines a resource-oriented approach for lightweight information exchange using HTTP over TLS, the Atom Syndication Format, and the Atom Publishing Protocol. As such, implementers must understand the security considerations described in those specifications. All that follows is guidance, more specific instruction is out of scope for this document.

To protect the confidentiality of a given resource provided by a ROLIE implementation, requests for retrieval of the resource need to be authenticated to prevent unauthorized users from accessing the resource (see Section 5.4). It can also be useful to log and audit access to sensitive resources to verify that proper access controls remain in place over time.

Access control to information published using ROLIE should use mechanisms that are appropriate to the sensitivity of the information. Primitive authentication mechanisms like HTTP Basic Authentication [RFC7617] are rarely appropriate for sensitive information. A number of authentication schemes are defined in the HTTP Authentication Schemes Registry [3]. Of these, HOBA [RFC7486] and SCRAM-SHA-256 [RFC7804] provide improved security properties over HTTP Basic [RFC7617]and Digest [RFC7616] Authentication Schemes. However, sharing communities that are engaged in sensitive collaborative analysis and/or operational response for indicators and incidents targeting high value information systems should adopt a

suitably stronger user authentication solution, such as a risk-based or multi-factor approach.

Collaborating consortiums may benefit from the adoption of a federated identity solution, such as those based upon OAuth [RFC6749] with JWT [RFC7797], or SAML-core [SAML-core], SAML-bind [SAML-bind], and SAML-prof [SAML-prof] for Web-based authentication and cross-organizational single sign-on. Dependency on a trusted third party identity provider implies that appropriate care must be exercised to sufficiently secure the Identity provider. Any attacks on the federated identity system would present a risk to the consortium, as a relying party. Potential mitigations include deployment of a federation-aware identity provider that is under the control of the information sharing consortium, with suitably stringent technical and management controls.

Authorization of resource representations is the responsibility of the source system, i.e. based on the authenticated user identity associated with an HTTP(S) request. The required authorization policies that are to be enforced must therefore be managed by the security administrators of the source system. Various authorization architectures would be suitable for this purpose, such as RBAC [4] and/or ABAC, as embodied in XACML [XACML]. In particular, implementers adopting XACML may benefit from the capability to represent their authorization policies in a standardized, interoperable format. Note that implementers are free to choose any suitable authorization mechanism that is capable of fulfilling the policy enforcement requirements relevant to their consortium and/or organization.

Additional security requirements such as enforcing message-level security at the destination system could supplement the security enforcements performed at the source system, however these destination-provided policy enforcements are out of scope for this specification. Implementers requiring this capability should consider leveraging, e.g. the <RIDPolicy> element in the RID schema. Refer to RFC6545 section 9 for more information. Additionally, the underlying serialization approach used in the representation (e.g., XML, JSON) can offer encryption and message authentication capabilities. For example, XMLDSig [RFC3275] for XML, and JSON Web Encryption [RFC7516] and JSON Web Signature[RFC7515] for JSON can provide such mechanisms.

When security policies relevant to the source system are to be enforced at both the source and destination systems, implementers must take care to avoid unintended interactions of the separately enforced policies. Potential risks will include unintended denial of service and/or unintended information leakage. These problems may be

mitigated by avoiding any dependence upon enforcements performed at the destination system. When distributed enforcement is unavoidable, the usage of a standard language (e.g. XACML) for the expression of authorization policies will enable the source and destination systems to better coordinate and align their respective policy expressions.

A service discovery mechanism is not explicitly specified in this document, and there are several approaches available for implementers. When selecting this mechanism, implementations need to ensure that their choice provides a means for authenticating the server. As described in the discovery section, DNS SRV Records are a possible solution to discovery.

10. Privacy Considerations

The optional author field may provide an identification privacy issue if populated without the author's consent. This information may become public if posted to a public feed. Special care should be taken when aggregating or sharing entries from other feeds, or when programmatically generating ROLIE entries from some data source that the author's personal info is not shared without their consent.

When using the Atom Publishing Protocol to POST entries to a feed, attackers may use correlating techniques to profile the user. The request time can be compared to the generated "updated" field of the entry in order to build out information about a given user. This correlation attempt can be mitigated by not using HTTP requests to POST entries when profiling is a risk, and rather use backend control of the Feeds.

Adoption of the information sharing approach described in this document will enable users to more easily perform correlations across separate, and potentially unrelated, cyber security information providers. A client may succeed in assembling a data set that would not have been permitted within the context of the authorization policies of either provider when considered individually. Thus, providers may face a risk of an attacker obtaining an access that constitutes an undetected separation of duties (SOD) violation. It is important to note that this risk is not unique to this specification, and a similar potential for abuse exists with any other cyber security information sharing protocol. However, the wide availability of tools for HTTP clients and Atom Feed handling implies that the resources and technical skills required for a successful exploit may be less than it was previously. This risk can be best mitigated through appropriate vetting of the client at account provisioning time. In addition, any increase in the risk of this type of abuse should be offset by the corresponding increase in effectiveness that this specification affords to the defenders.

Overall, privacy concerns in ROLIE can be mitigated by following security considerations and careful use of the optional personally identifying elements (e.g., author) provided by Atom Syndication and ROLIE.

11. Acknowledgements

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12.3. URIs

[1] https://www.iana.org/assignments/link-relations/link-relations.xhtml

[2] https://www.iana.org/assignments/link-relations/link-relations.xhtml

[3] https://www.iana.org/assignments/http-authschemes/http-authschemes.xhtml

[4] http://csrc.nist.gov/groups/SNS/rbac/

Appendix A. Relax NG Compact Schema for ROLIE

This appendix is informative.

The Relax NG schema below defines the rolie:format element.

```
   # -*- rnc -*-
   # RELAX NG Compact Syntax Grammar for the rolie ns

   namespace rolie = "urn:ietf:params:xml:ns:rolie-1.0"

   # import the ATOM Syndication RELAX NG Compact Syntax Grammar
   include "atomsynd.rnc"

   # rolie:format
   rolieFormat =
      element rolie:format {
         atomCommonAttributes,
         attribute ns { atomUri },
         attribute version { text } ?,
         attribute schema-location { atomUri } ?,
         attribute schema-type { atomMediaType } ?,
         empty
      }

   # rolie:property

   rolieProperty =
      element rolie:property {
        atomCommonAttributes,
        attribute name { atomUri },
        attribute value { text },
        empty
    }

     }
```

Appendix B. Examples of Use

B.1. Service Discovery

This section provides a non-normative example of a client doing service discovery.

An Atom Service Document enables a client to dynamically discover what Feeds a particular publisher makes available. Thus, a provider uses an Atom Service Document to enable authorized clients to determine what specific information the provider makes available to the community. The Service Document should be made accessible from a easily found location, such as a link from the producer’s home page.

A client may format an HTTP GET request to retrieve the service document from the specified location:

```
GET /rolie/servicedocument
Host: www.example.org
Accept: application/atomsvc+xml
```

Notice the use of the HTTP Accept: request header, indicating the MIME type for Atom service discovery. The response to this GET request will be an XML document that contains information on the specific Collections that are provided.

Example HTTP GET response:

```
HTTP/1.1 200 OK
Date: Fri, 24 Aug 2016 17:09:11 GMT
Content-Length: 570
Content-Type: application/atomsvc+xml;charset="utf-8"

<?xml version="1.0" encoding="UTF-8"?>
<service xmlns="http://www.w3.org/2007/app"
    xmlns:atom="http://www.w3.org/2005/Atom">
  <workspace>
    <atom:title type="text">Vulnerabilities</atom:title>
    <collection href="https://example.org/provider/vulns">
      <atom:title type="text">Vulnerabilities Feed</atom:title>
      <categories fixed="yes">
        <atom:category
            scheme="urn:ietf:params:rolie:category:information-type"
            term="vulnerability"/>
      </categories>
    </collection>
  </workspace>
</service>
```

This simple Service Document example shows that the server provides one workspace, named "Vunerabilities". Within that workspace, the server makes one Collection available.

A server may also offer a number of different Collections, each containing different types of security automation information. In the following example, a number of different Collections are provided, each with its own category and authorization scope. This categorization will help the clients to decide which Collections will meet their needs.

```
HTTP/1.1 200 OK
Date: Fri, 24 Aug 2016 17:10:11 GMT
Content-Length: 1912
Content-Type: application/atomsvc+xml;charset="utf-8"

<?xml version="1.0" encoding='utf-8'?>
<service xmlns="http://www.w3.org/2007/app"
    xmlns:atom="http://www.w3.org/2005/Atom">
  <workspace>
    <atom:title>Public Security Information Sharing</atom:title>
    <collection
        href="https://example.org/provider/public/vulns">
      <atom:title>Public Vulnerabilities</atom:title>
      <atom:link rel="service"
        href="https://example.org/rolie/servicedocument"/>
      <categories fixed="yes">
        <atom:category
            scheme="urn:ietf:params:rolie:category:information-type"
            term="vulnerability"/>
      </categories>
    </collection>
  </workspace>
  <workspace>
    <atom:title>Private Consortium Sharing</atom:title>
    <collection
        href="https://example.org/provider/private/incidents">
      <atom:title>Incidents</atom:title>
      <atom:link rel="service"
        href="https://example.org/rolie/servicedocument"/>
      <categories fixed="yes">
        <atom:category
            scheme="urn:ietf:params:rolie:category:information-type"
            term="incident"/>
      </categories>
    </collection>
  </workspace>
</service>
```

In this example, the provider is making available a total of two Collections, organized into two different workspaces. The first workspace contains a Collection consisting of publicly available software vulnerabilities. The second workspace provides an incident Collection for use by a private sharing consortium. An appropriately authenticated and authorized client may then proceed to make HTTP requests for these Collections. The publicly provided vulnerability information may be accessible with or without authentication. However, users accessing the Collection restricted to authorized

members of a private sharing consortium are expected to authenticate before access is allowed.

B.2. Feed Retrieval

This section provides a non-normative example of a client retrieving an vulnerability Feed.

Having discovered the available security information sharing Collections, a client who is a member of the general public may be interested in receiving the Collection of public vulnerabilities. The client may retrieve the Feed for this Collection by performing an HTTP GET operation on the URL indicated by the Collection's "href" attribute.

Example HTTP GET request for a Feed:

```
GET /provider/public/vulns
Host: www.example.org
Accept: application/atom+xml
```

The corresponding HTTP response would be an XML document containing the vulnerability Feed:

Example HTTP GET response for a Feed:

```
HTTP/1.1 200 OK
Date: Fri, 24 Aug 2016 17:20:11 GMT
Content-Length: 2882
Content-Type: application/atom+xml;charset="utf-8"

<?xml version="1.0" encoding="UTF-8"?>
<feed xmlns="http://www.w3.org/2005/Atom"
    xmlns:rolie="urn:ietf:params:xml:ns:rolie-1.0"
    xml:lang="en-US">
  <id>2a7e265a-39bc-43f2-b711-b8fd9264b5c9</id>
  <title type="text">
      Atom formatted representation of
      a feed of XML vulnerability documents
  </title>
  <category
      scheme="urn:ietf:params:rolie:category:information-type"
      term="vulnerability"/>
  <updated>2016-05-04T18:13:51.0Z</updated>
  <link rel="self"
      href="https://example.org/provider/public/vulns" />
  <link rel="service"
      href="https://example.org/rolie/servicedocument"/>
  <entry>
    <rolie:format ns="urn:ietf:params:xml:ns:exampleformat"/>
    <id>dd786dba-88e6-440b-9158-b8fae67ef67c</id>
    <title>Sample Vulnerability</title>
    <published>2015-08-04T18:13:51.0Z</published>
    <updated>2015-08-05T18:13:51.0Z</updated>
    <summary>A vulnerability issue identified by CVE-...</summary>
    <content type="application/xml"
        src="https://example.org/provider/vulns/123456/data"/>
  </entry>

  <entry>
      <!-- ...another entry... -->
  </entry>

</feed>
```

This Feed document has two Atom Entries, one of which has been elided. The first Entry illustrates an atom:entry element that provides a summary of essential details about one particular vulnerability. Based upon this summary information and the provided category information, a client may choose to do an HTTP GET request, on the content "src" attribute, to retrieve the full details of the vulnerability.

B.3. Entry Retrieval

This section provides a non-normative example of a client retrieving an vulnerability as an Atom Entry.

Having retrieved the Feed of interest, the client may then decide, based on the description and/or category information, that one of the entries in the Feed is of further interest. The client may retrieve this vulnerability Entry by performing an HTTP GET operation on the URL indicated by the "src" attribute of the atom:content element.

Example HTTP GET request for an Entry:

```
GET /provider/public/vulns/123456
Host: www.example.org
Accept: application/atom+xml;type=entry
```

The corresponding HTTP response would be an XML document containing the Atom Entry for the vulnerability record:

Example HTTP GET response for an Entry:

```
HTTP/1.1 200 OK
Date: Fri, 24 Aug 2016 17:30:11 GMT
Content-Length: 713
Content-Type: application/atom+xml;type=entry;charset="utf-8"

<?xml version="1.0" encoding="UTF-8"?>
<entry xmlns="http://www.w3.org/2005/Atom"
    xmlns:rolie="urn:ietf:params:xml:ns:rolie-1.0"
    xml:lang="en-US">
  <id>f63aafa9-4082-48a3-9ce6-97a2d69d4a9b</id>
  <title>Sample Vulnerability</title>
  <published>2015-08-04T18:13:51.0Z</published>
  <updated>2015-08-05T18:13:51.0Z</updated>
  <category
      scheme="urn:ietf:params:rolie:category:information-type"
      term="vulnerability"/>
  <summary>A vulnerability issue identified by CVE-...</summary>
  <rolie:format ns="urn:ietf:params:xml:ns:exampleformat"/>
  <content type="application/xml"
      src="https://example.org/provider/vulns/123456/data">
  </content>
</entry>
```

The example response above shows an XML document referenced by the "src" attribute of the atom:content element. The client may retrieve the document using this URL.

Appendix C. Change History

Changes in draft-ietf-mile-rolie-14 since draft-ietf-mile-rolie-13 revision:

Removed /.well-known registration and updated Discovery text.

Fixed small namespacing error in RNC schema.

Changes in draft-ietf-mile-rolie-13 since draft-ietf-mile-rolie-12 revision:

Adjusted .well-known registration.

Updated IANA Consideration text.

Changes in draft-ietf-mile-rolie-11 since draft-ietf-mile-rolie-09 revision:

Incorporated ART last call review and AD review changes.

Changes in draft-ietf-mile-rolie-09 since draft-ietf-mile-rolie-08 revision:

TLS requirements changed to clarify TLS versioning and recommendations

Informative references and textual discussion added to Security Considerations around HTTP Authentication and content Signing/ Encryption.

IANA Expert review clarified.

Editorial changes from AD review/WGLC.

Changes in draft-ietf-mile-rolie-08 since draft-ietf-mile-rolie-07 revision:

Reworked "usage of app:collection" and "usage of atom:feed" sections to clarify ROLIE vs non-ROLIE collections/feeds

Removed requirement from Security Considerations that was a duplicate of text earlier in the document

TLS requirement clarifications around mutal authentication

Clarified requirements around support for the "/" resource

Added IANA property registrations for content-id, content-published-date, and content-updated-date that can be used across all ROLIE extensions to increase consistency/interop

Assorted editorial changes

Changes in draft-ietf-mile-rolie-07 since draft-ietf-mile-rolie-06 revision:

Condensed and re-focused Sections 1 and 4 to be more concise.

Added /.well-known/ registration and requirement for service discovery.

Added local category, property namespace, and additional property registrations

Added privacy considerations section.

Made a number of editorial changes as per WGLC review.

Changes in draft-ietf-mile-rolie-06 since draft-ietf-mile-rolie-05 revision:

Changed to standards track

Added the rolie:property element

Fixed references (Normative vs Informative)

Set Service and Category document URL template requirements

Fixed XML snippets in examples

Changes in draft-ietf-mile-rolie-05 since draft-ietf-mile-rolie-04 revision:

Added ROLIE specific terminology to section 2

Added AtomPub Category Document in section 5.2

Edited document, improving consistency in terminology usage and capitalization of key terms, as well as enhancing clarity.

Removed unused format parameter type in section 8.3

Schema removed, the normative schema consists of the snippets in the requirements sections.

Changes in draft-ietf-mile-rolie-04 since draft-ietf-mile-rolie-03 revision:

- Further specification and clarification of requirements
- IANA Considerations and extension system fleshed out and described.
- Examples and References updated.
- Schema created.
- Fixed both internal section and external document referencing.
- Removed XACML Guidance Appendix. This will be added to a future draft on ROLIE Authentication and Access Control.

Changes made in draft-ietf-mile-rolie-03 since draft-ietf-mile-rolie-02 revision:

- Atom Syndication and Atom Pub requirements split and greatly expanded for increased justification and technical specification.
- Reintroduction and reformatting of some use case examples in order to provide some guidance on use.
- Established rough version of IANA table extension system along with explanations of said system.
- Re-organized document to put non-vital information in appendices.

Changes made in draft-ietf-mile-rolie-02 since draft-field-mile-rolie-01 revision:

- All CSIRT and IODEF/RID material moved to companion CSIRT document
- Recast document into a more general use perspective. The implication of CSIRTs as the defacto end-user has been removed where ever possible. All of the original CSIRT based use cases remain completely supported by this document, it has been opened up to support many other use cases.
- Changed the content model to broaden support of representation
- Edited and rewrote much of sections 1,2 and 3 in order to accomplish a broader scope and greater readability

- Removed any requirements from the Background section and, if not already stated, placed them in the requirements section
- Re-formatted the requirements section to make it clearer that it contains the lions-share of the requirements of the specification

Changes made in draft-ietf-mile-rolie-01 since draft-field-mile-rolie-02 revision:

- Added section specifying the use of RFC5005 for Archive and Paging of Feeds.
- Added section describing use of atom categories that correspond to IODEF expectation class and impact classes. See: normative-expectation-impact
- Dropped references to adoption of a MILE-specific HTTP media type parameter.
- Updated IANA Considerations section to clarify that no IANA actions are required.

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XMPP Protocol Extensions for Use with IODEF
draft-ietf-mile-xmpp-grid-00

Abstract

This document describes the extensions made to Extensible Messaging and Presence Protocol (XMPP) [RFC6120]that enables the use of XMPP as a transport protocol for collecting and distributing any security telemetry information between and among network platforms, endpoints, and most any network connected device. Specifically, this document will focus on how these extensions can be used to transport the Incident Object Description Exchange Format (IODEF) information.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

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This Internet-Draft will expire on October 8, 2016.

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Table of Contents

1. Introduction

XMPP-Grid is a set of standards-based XMPP [RFC6120] messages with extensions. It is intended for use as a secure transport and communications protocol ecosystem for devices and organizations to interconnect, forming an information grid for the exchange of formatted data (e.g. XML, JSON, etc). This document describes the extensions made to XMPP [RFC6120]that enables use of XMPP as a transport protocol for securely collecting and distributing security telemetry information between and among network platforms, endpoints, and most any network connected device.

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119].

1.1. Glossary of Terms

AAA

Authentication, Authorization and Accounting.

CA

Certification Authority.

Capability Provider

Providers who are capable of sharing information on XMPP-Grid.

CMDB

Configuration Management Database.

IDS

Intrusion Detection System.

IPS

Intrusion Prevention System.

JID

Jabber Identifier, native address of an XMPP entity.

MDM

Mobile Device Management.

NAC

Network Admission Control.

PDP

Policy Decision Point.

PEP

Policy Enforcement Point.

Presence

XMPP-Grid node availability and online status on XMPP-Grid.

Publisher

A capability provider sharing contet information to other devices participating on XMPP-Grid.

SIEM

Security Information and Event Management.

Subscriber

A device participating in XMPP-Grid and subscribing or consuming information published by Publishers on XMPP-Grid.

Sub-Topics

Topic created by XMPP-Grid Controller under a capability provider’s topic based on message filter criteria expressed by subscribers.

Topics

Contextual information channel created on XMPP-Grid where a published message by the Publisher will be propagated by XMPP in real-time to a set a subscribed devices.

VoIP

Voice over IP.

XMPP-Grid

Set of standards-based XMPP messages with extensions, intended for use as a transport and communications protocol framework between devices forming an information grid for sharing information.

XMPP-Grid Controller

Centralized component of XMPP-Grid responsible for managing all control plane operations.

XMPP-Grid Connection Agent

XMPP-Grid client library that a XMPP-Grid node implements to connect and exchange information with other vendor devices on XMPP-Grid.

XMPP-Grid Node

Platform or device that implements XMPP-Grid Connection Agent to connect to XMPP-Grid and share or consume security data.

1.2. What is XMPP-Grid?

XMPP-Grid is a set of standards-based XMPP messages with extensions. It is intended for use as a transport and communications protocol framework for devices that interconnect with each other, forming a secure information grid.

XMPP-Grid enables secure, bi-directional multi-vendor exchange of contextual information between IT infrastructure platforms such as security monitoring and detection systems, network policy platforms, asset and configuration management, identity and access management platforms. XMPP-Grid can serve to securely exchange any contextual information. XMPP-Grid is built on top of XMPP [RFC6120], [RFC6121] which is an open IETF standard messaging routing protocol used in commercial platforms such as Google Voice, Jabber IM, Microsoft Messenger, AOL IM and a variety of IoT and XML message routing services. XMPP is also being considered as a means to transport IODEF [RFC5070]. XMPP-Grid is designed for orchestration of data

sharing between security platforms on a many-to-many basis for millions of end systems.

XMPP-Grid provides a security data sharing framework that enables multiple vendors to integrate to XMPP-Grid once, then both share and consume data bi-directionally with many IT infrastructure platforms and applications from a single consistent framework akin to a network-wide information bus. This reduces the need to develop to explicit, multiple platform-specific interfaces, thereby increasing the breadth of platforms that can interface and share security data. XMPP-Grid is also configurable thereby enabling partners to share only security data they want to share and consume only information relevant to their platform or use-case and to customize information shared without revising the interfaces. XMPP-Grid is data-agnostic enabling it to operate with virtually any data type such as IODEF [RFC5070].

1.3. Overview of XMPP-Grid

XMPP-Grid employs publish/subscribe/query operations brokered by a controller, which enforces access control in the system. This architecture controls what platforms can connect to the "grid" to share ("publish") and/or consume ("subscribe" or "query") contextual information ("Topics") (described in Section 3.3 and 3.5) such as security data needed to support MILE. The control of publish/subscribe/query operations is architecturally distinct from the actual sharing of the contextual information. Control functions are split into a logical control plane, whereas information exchange is considered a logical data plane. This separation enables scalability and customizability.

XMPP-Grid defines an infrastructure protocol that hides the nuances of the XMPP data plane protocol and makes the information sharing models extensible with simple intuitive interfaces. XMPP-Grid Nodes connect to the Grid using the XMPP-Grid Protocol. The XMPP-Grid Protocol makes use of the XMPP transport protocol and introduces an application layer protocol leveraging XML and XMPP extensions to define the protocol.

The components of XMPP-Grid are:

- XMPP-Grid Controller (Controller): The Controller manages the control plane of XMPP-Grid operations. As such it authenticates and authorizes platforms connecting to the data exchange grid and controls whether or not they can publish, subscribe or query Topics of security data.

- XMPP-Grid Connection Agent (Connection Agent): The Connection Agent enables the adopting Node to communicate with the Controller and other vendor platforms that have adopted XMPP-Grid. Through this communication privileges of the connecting platform--authorization to connect, publish, subscribe, query--are established. The Connection Agent is typically implemented as a client library.

- XMPP-Grid Node (Node): A Node is a platform that has implemented the Connection Agent so that it can connect to an XMPP-Grid deployment to share and/or consume security data.

- Data Repository: This is the source of security data available on the Grid and may be a network security platform, management console, endpoint, etc. XMPP-Grid does not mandate a specific information model, but instead remains open to transport structured or unstructured data. Data may be supplied by the security platform itself or by an external information repository.

- Topic: An XMPP-Grid Topic defines a type of security data that a platform wants to share with other platform(s).

The operations carried out by XMPP-Grid to exchange security data are:

- Grid Connect: This is a Controller operation that authenticates a Node that has implemented the Connection Agent to establish a connection with the XMPP-Grid. Once authenticated, authorization policies on the Controller establish a Node’s privileges on the XMPP-Grid such as the right to undertake publish, subscribe or query operations explained below.

- Publish Topic: Security information is made available when a XMPP-Grid enabled platform "publishes" a "Topic". This operation is authorized by the Controller and communicated to the connecting platform via the Connection Agent.

- Topic Discovery: Nodes on a XMPP-Grid discover Topics of security data relevant to them by searching the Topic directory available within the XMPP-Grid deployment. The Controller maintains such a Topic directory for every instance of XMPP-Grid.

- Subscribe to Topic: A Node seeking to consume security information "subscribes" to a Topic that provides the security information it seeks to serve its use-case. This operation has its authorization checked by the Controller and communicated with the connecting platform via the Connection Agent.

- Query: This operation enables a Node to request a specific set of security data regarding a specific asset (such as a specific user endpoint) or bulk output history from a Topic over a specific span of time. Such queries can be carried out node-to-node or by querying a central data repository. Query structure is adaptable to match the information model in use.

XMPP-Grid is used to exchange security context data between systems on a 1-to-1, 1-to-many, or many-to-many basis. Security data shared between these systems may use pre-negotiated non-standard/native data formats or may utilize an optional common information repository with a standardized data format, such as IODEF. XMPP-Grid is data format agnostic and accommodates transport of whatever format the end systems agree upon.

XMPP-Grid can operate in the following deployment architectures:

- Broker-Flow: An XMPP-Grid control plane brokers the authorization and redirects the Topic subscriber to Topic publisher directly. In this architecture, the Controller only manages the connection; the security data flow is directly between Nodes using data formats negotiated out-of-band.

- Centralized Data-Flow: An XMPP-Grid maintains the data within its optional centralized database. In this architecture, the Controller provides a common information structure for use in formatting and storing security context data, such as IODEF, and directly responds to Node publish and Subscribe requests.

- Proxy-Flow: An XMPP-Grid is acting as proxy, collecting the data from the publisher(s) and presenting it to the subscriber directly. This is used for ad-hoc queries.

Within the deployment architecture, XMPP-Grid may be used in any combination of the following data exchange modes. The flexibility afforded by the different modes enables security information to be exchanged between systems in the method most suitable for serving a given use-case.

- Continuous Topic update stream: This mode delivers in real-time any data published to a Topic to the Nodes that are subscribed to that Topic.

- Directed query: This mode enables Nodes to request a specific set of security information regarding a specific asset, such as a specific user endpoint.

- Bulk historic data query: This mode enables Nodes to request transfer of past output from a Topic over a specific span of time.

1.4. Benefits of XMPP-Grid

Benefits of XMPP-Grid can be summarized on two fronts: 1) end-user benefits, 2) benefits for adopting vendors.

Benefits for end-users deploying security services based on XMPP-Grid security context information sharing capabilities are derived from the results that come with standardization including:

- Consolidating relevant security event data from multiple systems to the "right console at the right time".
- Cross-vendor interoperability out-of-the-box, when using a standard data format.
- Coordinated security response across multiple products from multiple vendors, ranging from endpoint security to AAA, NAC, IDS/IPS, Data Loss Prevention, firewalls to infrastructure such as SIEM, CMDB, physical access control systems.
- Customer product choice and flexibility. No need to buy all security products from one vendor.

Adopting XMPP-Grid security data sharing capabilities provides a number of benefits for adopting vendors, especially when compared to proprietary interfaces, such as:

- Integrate the XMPP-Grid Connection Agent once to interface with many platforms, simultaneously by subscribing or publishing relevant security data
- Security information shared is configurable (via Topics) based on relevance to specific use-cases and platforms
- Only sharing relevant data enables both publishing and subscribing platforms to scale their security data sharing by eliminating excess, irrelevant data
- Integrated authorization and security ensures only appropriate XMPP-Grid operations are executed by permitted platforms
- Ability to share security data in native or structured formats enables data model flexibility for adopting vendors

   o Flexibility, adaptability to evolve to address new use cases over time. Utilize data-agnostic transport protocol or the extensible schema that allows for easy support for vendor-specific data.

1.5. Example Workflow

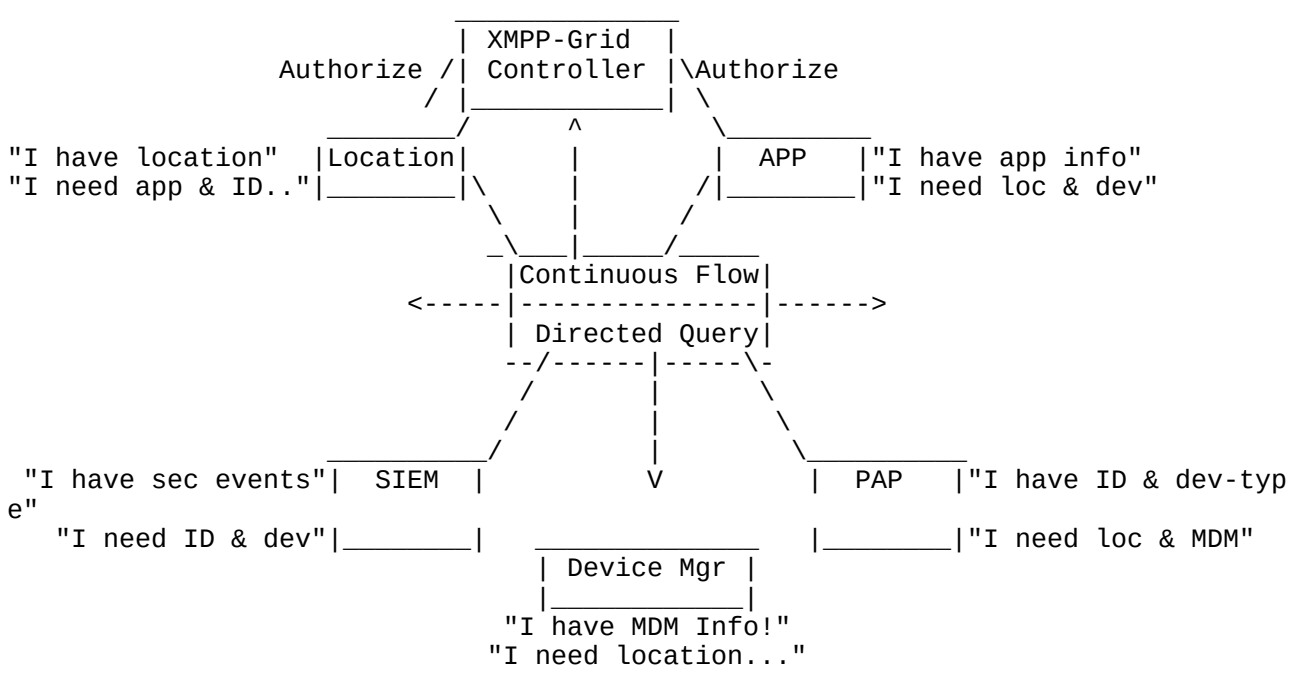


Figure 1: Typical XMPP-Grid Workflow

a. XMPP-Grid Controller establishes a grid for platforms wanting to exchange security data.

b. A platform (Node) with a source of security data requests connection to the Grid.

c. Controller authenticates and establishes authorized privileges (e.g. privilege to publish and/or subscribe to security data Topics) for the requesting Node.

d. Node may either publish a security data Topic, subscribe to a security data Topic, query a Node or Topic, or any combination of these operations.

e. Publishing Nodes unicast Topic updates to the Grid in real-time. The Grid handles replication and distribution of the Topic to

subscribing Nodes. A Node may publish multiple Topics, thereby allowing for customized relevance of the security data shared.

f. Subscribing Nodes receive continuous real-time stream of updates to the Topic to which they are subscribed.

g. Any Node on the Grid may subscribe to any Topics published to the Grid (as permitted by authorization policy), thereby allowing for one-to-one, one-to-many and many-to-many meshed security data sharing between Nodes.

2. XMPP-Grid Architecture

XMPP-Grid is a communication fabric that facilitates secure sharing of information between network elements and networked applications connected to the fabric both in real time and on demand.

XMPP-Grid uses XMPP servers that operate as a cluster with message routing between them, for data plane communication. XMPP-Grid uses a control plane element, the XMPP-Grid Controller, that is an external component of XMPP for centralized policy-based control plane.

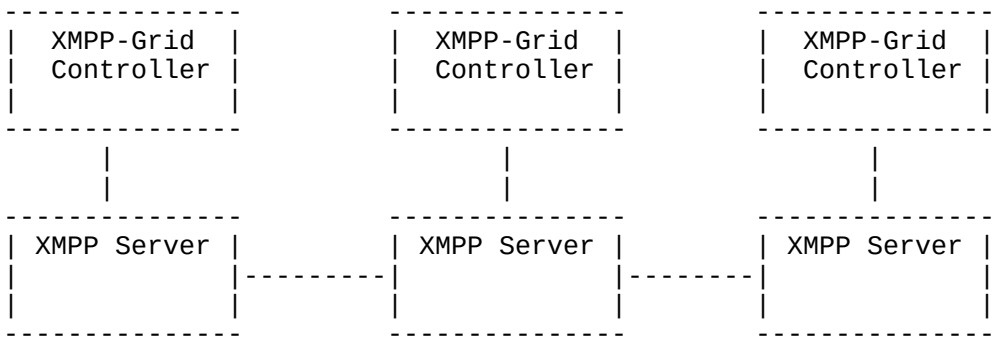


Figure 2: XMPP Server and XMPP-Grid Cluster Architecture

The connected Nodes, with appropriate authorization privileges, can:

- Receive real-time events of the published messages from the publisher through Topic subscriptions
- Make directed queries to other Nodes in the XMPP-Grid with appropriate authorization from the Controller
- Negotiate out-of-band secure file transfer channel with the peer

This model enables flexible API usage depending on the Nodes' contextual and time-sensitivity needs of security information.

2.1. XMPP Overview

XMPP is used as the foundation message routing protocol for exchanging security data between systems across XMPP-Grid. XMPP is a communications protocol for message-oriented middleware based on XML. Designed to be extensible, the protocol uses de-centralized client-server architecture where the clients connect to the servers securely and the messages between the clients are routed through the XMPP servers deployed within the cluster. XMPP has been used extensively for publish-subscribe systems, file transfer, video, VoIP, Internet of Things, Smart Grid Software Defined Networks (SDN) and other collaboration and social networking applications. The following are the 4 IETF specifications produced by XMPP working group:

- [RFC6120] Extensible Messaging and Presence Protocol (XMPP): Core
- [RFC6121] Extensible Messaging and Presence Protocol (XMPP): Instant Messaging and Presence
- [RFC3922] Mapping the Extensible Messaging and Presence Protocol (XMPP) to Common Presence and Instant Messaging (CPIM)
- [RFC3923] End-to-End Signing and Object Encryption for the Extensible Messaging and Presence Protocol (XMPP)

XMPP offers several of the following salient features for building a security data interexchange protocol:

- Open - standards-based, decentralized and federated architecture, with no single point of failure
- Security - Supports domain segregations and federation. Offers strong security via Simple Authentication and Security Layer (SASL) [RFC4422] and Transport Layer Security (TLS) [RFC5246].
- Real-time event management/exchange - using publish, subscribe notifications
- Flexibility and Extensibility - XMPP is XML based and is easily extensible to adapt to new use-cases. Custom functionality can be built on top of it.
- Multiple information exchanges - XMPP offers multiple information exchange mechanisms between the participating clients -

- o
  - * Real-time event notifications through publish and subscribe.
  - * On-demand or directed queries between the clients communicated through the XMPP server
  - * Facilitates out-of-band, direct communication between participating clients
- o Bi-directional - avoids firewall tunneling and avoids opening up a new connection in each direction between client and server.
- o Scalable - supports cluster mode deployment with fan-out and message routing
- o Peer-to-peer communications also enables scale - directed queries and out-of-band file transfer support
- o XMPP offers Node availability, Node service capability discovery, and Node presence within the XMPP network. Nodes ability to detect the availability, presence and capabilities of other participating nodes eases turnkey deployment.

The XMPP extensions used in XMPP-Grid are now part (e.g. publish/ subscribe) of the main XMPP specification [RFC6120] and the presence in [RFC6121]. A full list of XMPP Extension Protocols (XEPs) [RFC6120] can be found in http://xmpp.org/extensions/xep-0001.html .

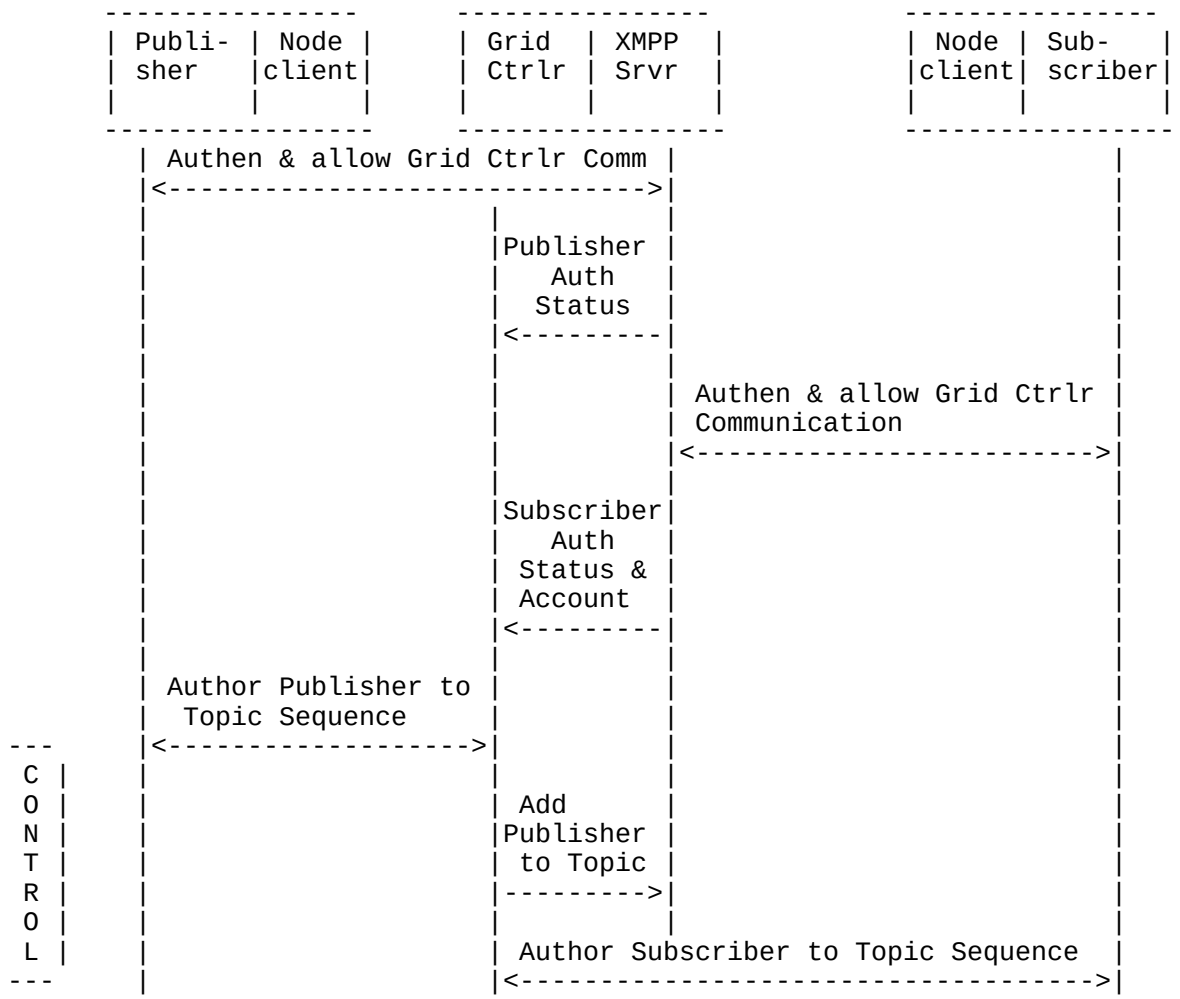
2.2. XMPP-Grid Protocol Extensions to XMPP

XMPP-Grid defines an infrastructure protocol that hides the nuances of the XMPP data plane protocol and makes the information sharing models extensible with simple intuitive APIs. XMPP-Grid Nodes connect to the Grid using the XMPP-Grid Protocol. The XMPP-Grid Protocol makes use of the XMPP transport protocol and introduces an application layer protocol leveraging XML and XMPP extensions to define the protocol. The capability providers on the Grid extend the XMPP-Grid Protocol infrastructure model and define capability specific models and schemas, allowing a cleaner separation of infrastructure and capabilities that can run on the infrastructure.

2.3. XMPP-Grid Controller Protocol Flow

At the heart of the XMPP-Grid network, the XMPP-Grid Controller serves as the centralized policy-based control plane element managing all Node authentications, authorizations, capabilities/Topics and their subscription list. XMPP-Grid Controller manages all control

aspects of the Node communication (including management) with the XMPP-Grid and other participating Nodes with mutual trust and authorizations' enforcement. XMPP-Grid Controller is a component of XMPP server and programs the data plane XMPP server with Node accounts, account status, XMPP Topics that are dynamically created and Topic subscriptions. This is analogous to File Transfer Protocol (FTP) that has control and data plane communication phases. Once the Node requests are authenticated and authorized in the control plane phase by the Controller, the Controller removes itself from the data flow. All data plane communication then occurs between the Nodes, publishers and subscribers of XMPP Topics happen at the XMPP data plane layer.



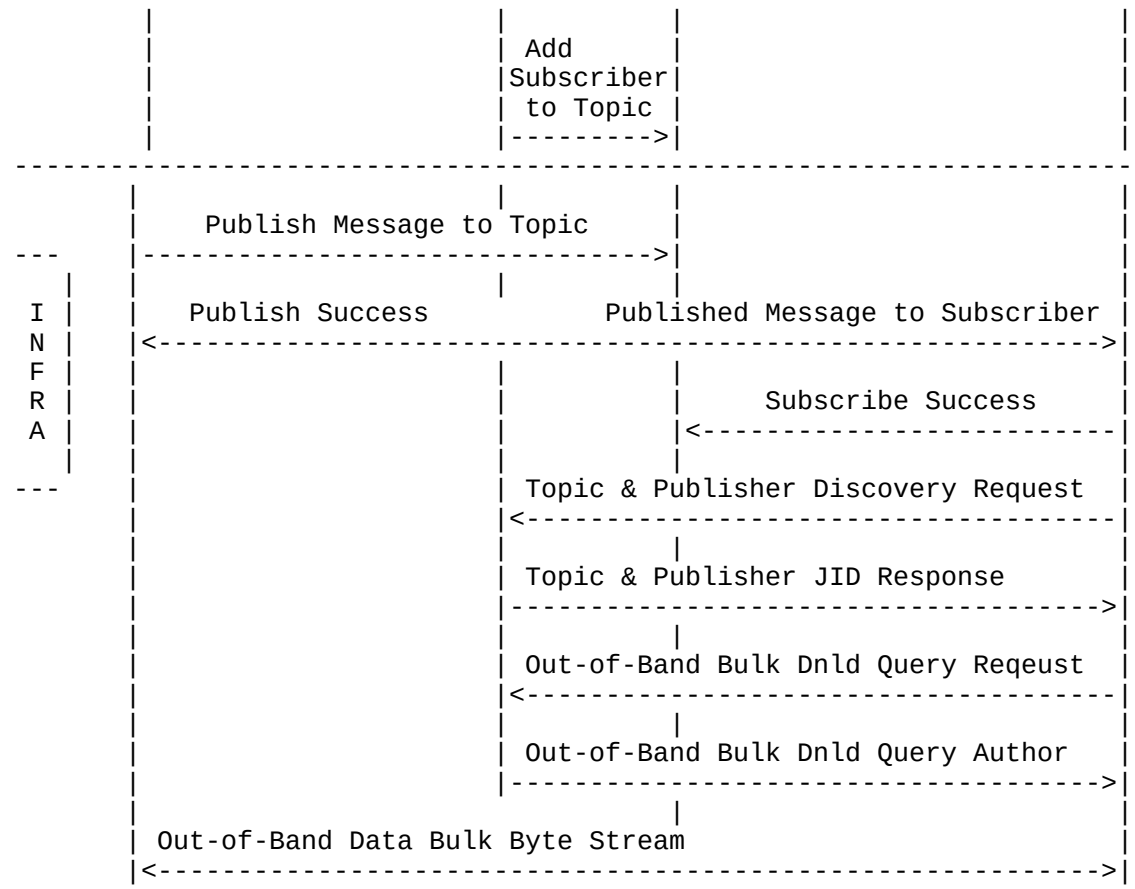


Figure 3: XMPP Controller Message Flow

Through a centralized authorization model, XMPP-Grid Controller provides -

- Visibility into "who is connecting", "who is accessing what"
- Node account management with provisions to add, delete or disable accounts, and with provisions to auto or manual approve Node account approval requests during the Node registration phase
- Centralized, policy-based authorization, providing "who can do what" for publish-subscribe, directed peer-to-peer queries or for bulk out-of-band transfers between participating Nodes

- Topics and subscription list management with provision to enable or disable Topics

- Dynamic creation of sub-Topics within the main Topic depending on attributes of interest from the requesting Node

- Ability to perform message filters on the published messages

2.4. XMPP-Grid Node Connection Protocol Flow

Nodes connecting to XMPP-Grid go through the phases of authentication, registration and authorization before they can participate in information exchange on XMPP-Grid.

2.4.1. Authentication

The communication between the Node and the XMPP-Grid Controller is cryptographically encrypted using TLS. XMPP-Grid uses X.509 certificate-based mutual authentication between the Nodes and Controller. Internally, XMPP uses Simple Authentication and Security Layer (SASL)[RFC4422] External mechanism to authenticate and establish secure tunnel with the Nodes, allowing the XMPP-Grid Controller to rely on this capability offered by XMPP. If the Node certificate does not pass the validation process, the connection establishment is terminated with the error messages defined by the XMPP standard. On successful authentication, XMPP SASL component extracts the Node certificate and Node username to the Controller for registration.

2.4.2. Registration

Once a Node has been authenticated and a secure tunnel has been successfully established, the Nodes will register their accounts with the Controller and Nodes provide their username to the Controller as part of the registration request. XMPP-Grid supports manual registration (requires explicit approval of the Node account) and mutual authentication trust-based auto-approval registration in order to provide additional trust and usability options to the administrator. The administrator may map the Nodes to the Node groups to add additional level of validation and trust, and enforce Node group based authorization. This allows the certificate-username-group trust to get uniquely establishment for each Node and duplicate registration requests using the same username will be rejected.

During the registration process, the Controller restricts all Node communication with the XMPP-Grid and only Node to Controller communication is allowed. Once the Node is successfully registered,

the Controller lifts the restriction and allows the Nodes to communicate on XMPP-Grid after it passes the authorization phase. It should be noted that the registered and authorized Nodes could publish, subscribe or query to multiple XMPP Topics between login and logout to XMPP-Grid. Multiple Node applications running on a Node could use one XMPP-Grid Node to connect to XMPP-Grid. The XMPP-Grid Node should support Node applications' subscription to Topics and should multiplex messages on its connection to XMPP-Grid. If a Node application wants to be identified explicitly on XMPP-Grid, a new XMPP-Grid Node connection to XMPP-Grid is required.

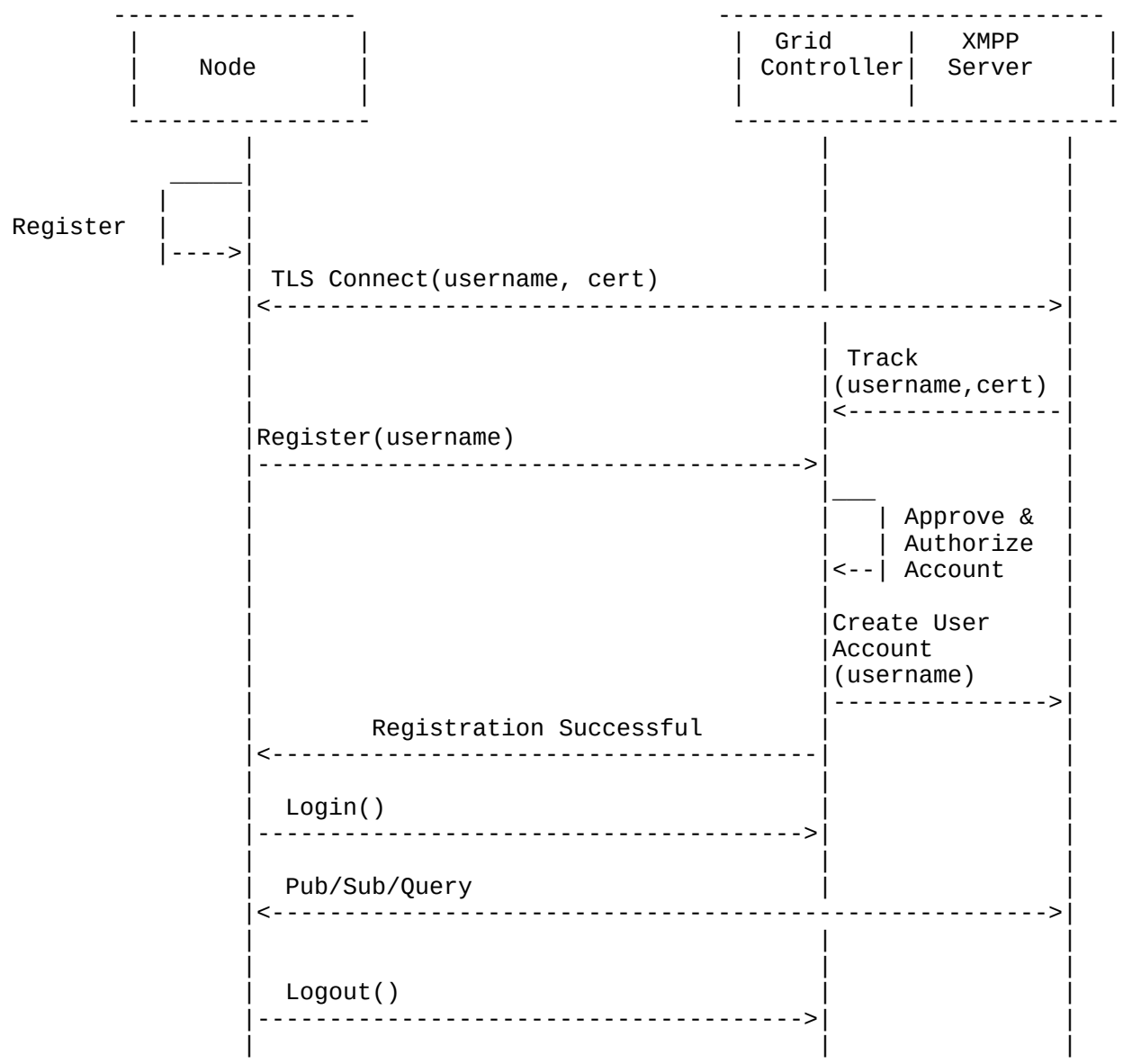


Figure 4: XMPP-Grid Node Registration

2.4.3. Authorization

The registered Nodes send subscription requests to the Controller. The Controller, depending on the defined authorization privileges, grants permissions to subscribe and/or publish to a Topic at the registration time. The Controller updates the XMPP data plane server with the new subscriber information and its capability. Node identity extracted from the request, group to which the Node is assigned during account approval and Topic/capability to which the permission is sought could be some of the ways to authorize Nodes and their requests in XMPP-Grid. Similarly, the Controller authorizes directed peer-to-peer or out-of-band requests from a requesting peer. The destination peer has options to query back the Controller to retrieve and enforce granular authorizations such as read-only, write-only, read/write.

In a Query Authorization flow, the capability provider responding to the query is responsible for enforcing the authorization decision. It retrieves "is authorized" from the XMPP-Grid Controller. Based on the result, the service either allows or disallows the flow from continuing.

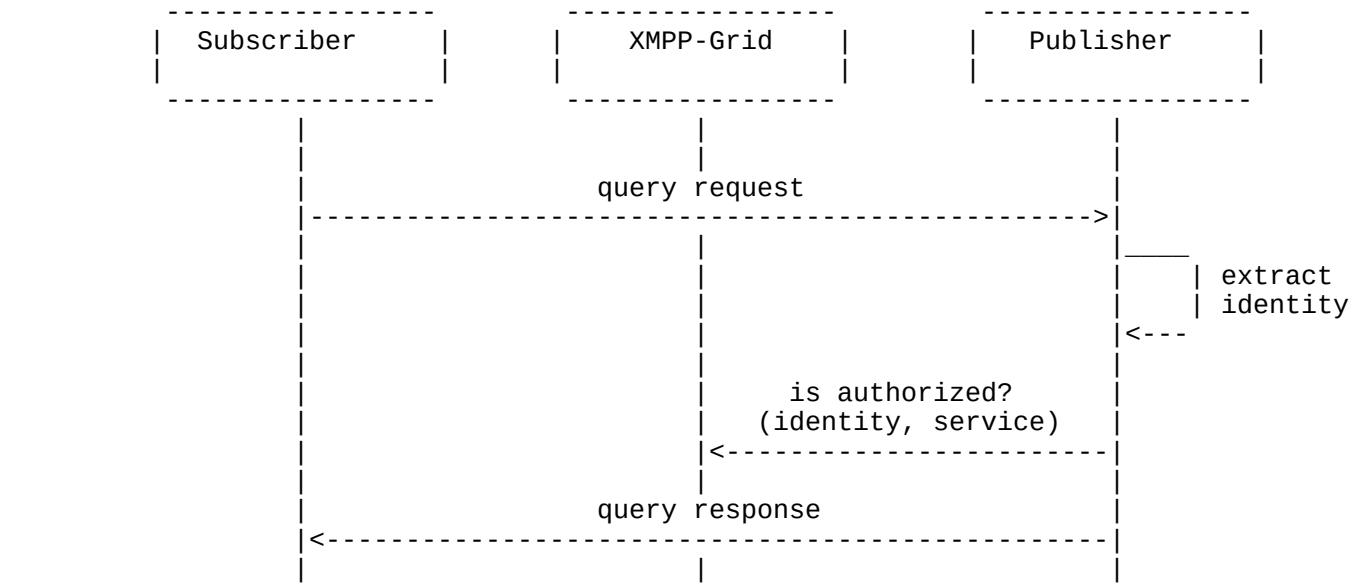


Figure 5: Node Query Authorization Flow

For Publish Authorization, prior to allowing a publish request by a user, the XMPP-Grid Controller calls the rule evaluation engine directly for "is authorized". Based this result, the Controller either allows or disallowed the flow from continuing.

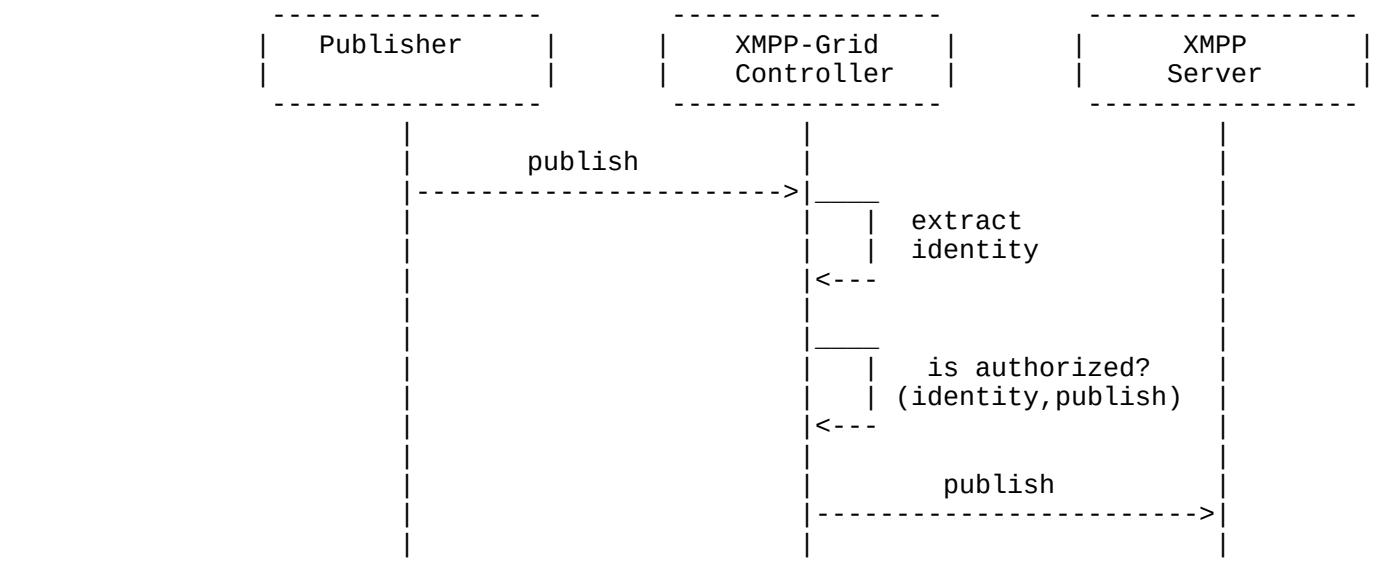


Figure 6: Node Publish Authorization Flow

For Subscribe Authorization, prior to allowing a subscribe request by a user, the XMPP-Grid Controller calls the rule evaluation engine directly for "is authorized". Based this result, the Controller either allows or disallowed the flow from continuing.

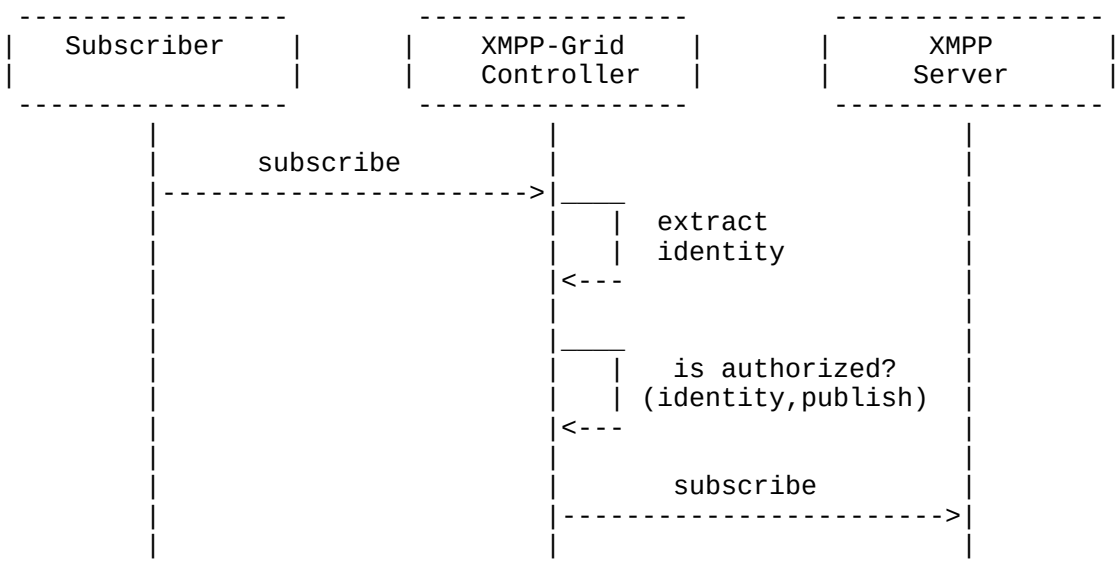


Figure 7: Node Subscribe Authorization Flow

Bulk Data Query differs from other data transfer modes. Unlike with other modes of communication that operate in-band with the XMPP-Grid, bulk downloads occur out-of-band (over a different protocol, outside of the connection that was established with the XMPP-Grid Controller). Previously discussed authorization mechanisms are therefore not appropriate in this context.

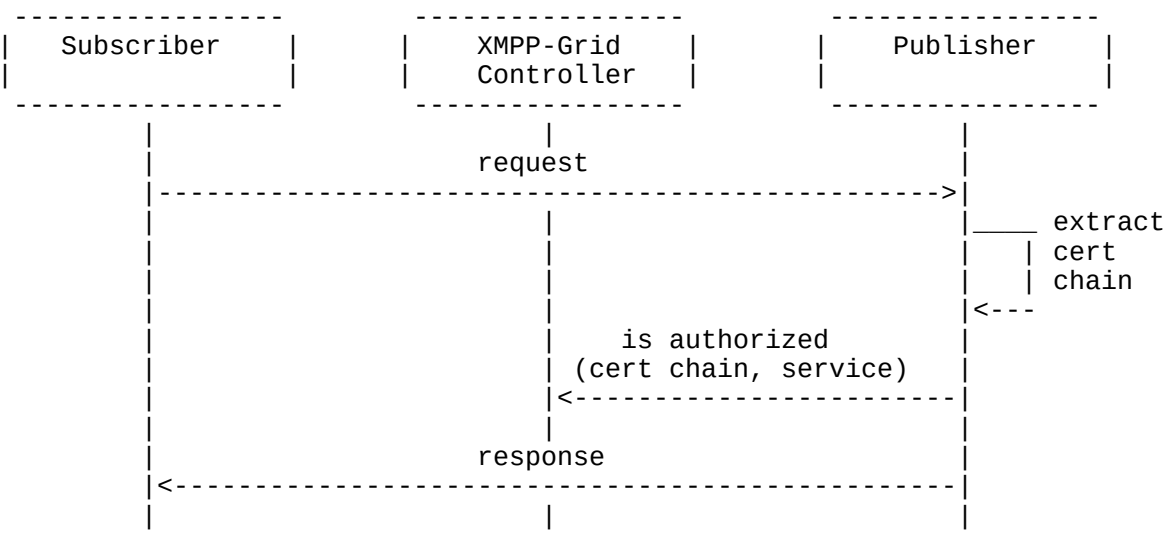


Figure 8: Node Bulk Data Query Flow

Instead the bulk download service sends the certificate chain used by a Node in the TLS connection to the XMPP-Grid Controller for purposes of authenticating and authorizing the Node. Upon receiving a request with a certificate chain, the Controller checks the issuing certificate against the trust store, looks up the identity associated with the certificate, evaluates the rules, and returns "is authorized" to the service. Then the service can either allow or disallow the flow from continuing.

2.5. XMPP-Grid Topics Protocol Flow

For each capability, XMPP-Grid supports extensibility through XML schemas where the providers (publishers) of the capabilities define the schemas for the data exchanged. The capability provider shall also define the version, the available queries and notifications that it can support. The capability provider publishes the messages to one or more XMPP Topics, that it requests XMPP-Grid to create dynamically, depending on:

a. If the capability provider has mutually exclusive schemas, different Topics will be created where the capability provider will be a publisher to each Topic with a separate schema.

b. For a given Topic, if the subscribers wants to receive filtered attributes or attribute values in capability provider’s published data, XMPP-Grid Controller creates sub Topics to the main Topic

based on the message filters expressed. XMPP-Grid Controller enrolls the capability provider as the publisher and the requesting subscribers based on the message filter criteria they express. The capability provider will be the publisher to both the main Topic and the sub-Topics.

c. In the case mentioned in (b) above, it is possible for the capability provider to just publish on the main Topic and have the XMPP-Grid Controller filter the published messages on the Controller-side and deliver attributes and attribute values of interest to the subscribers. Controller-side message filter application and the specify mechanisms such as XPATH that can be used for parsing the messages is beyond the scope of this specification.

2.5.1. Topic Versioning

XMPP-Grid supports versioning to support forward and backward compatible information models. The providers of capability include the version number in the messages they publish and the receiving Nodes can interpret the Topic version and process the attributes accordingly. The expectation is any new version of a capability must be of additive updates only. In other words, existing elements and attributes cannot be changed, only new elements or attributes can be added. This will enable nodes with older capability be able to process newer version. The extra new elements or attributes will be ignored. Instead of using the same Topic for all versions, it is possible in XMPP-Grid to programmatically create separate Topics for each version and allow them to be discovered and subscribed by the Nodes.

In XMPP-Grid, versioning support applies equally to both publish/subscribe, directed and out-of-band queries.

2.5.2. Topic Discovery

The Nodes connected to XMPP-Grid can query the Controller and get the list of all capabilities/Topics running on XMPP-Grid. The XML samples provided in XMPP-Grid Protocol section above provide illustrations of Capability Query and Capability Provider Query.

2.5.3. Subtopics and Message Filters

XMPP-Grid supports semantic message filtering for Topics. The content being published by a provider can be semantically grouped into categories based on domain, location of endpoints for example. The provider of a capability specifies whether it supports semantic

filtering or not to the Controller at the subscribe time to the Topic under consideration.

XMPP-Grid subscribers query the Controller and obtain the filtering options available for each capability, and express their message filtering criteria at subscription time. The Controller, for each unique filter criteria specified by the subscribers, creates a new sub Topic under the main capability Topic. All the subscribers with the same filtering criteria will be subscribed to the Subtopic. The set of filter criteria for a capability will be predefined by the capability provider and could be based on the well-defined attributes of the message.

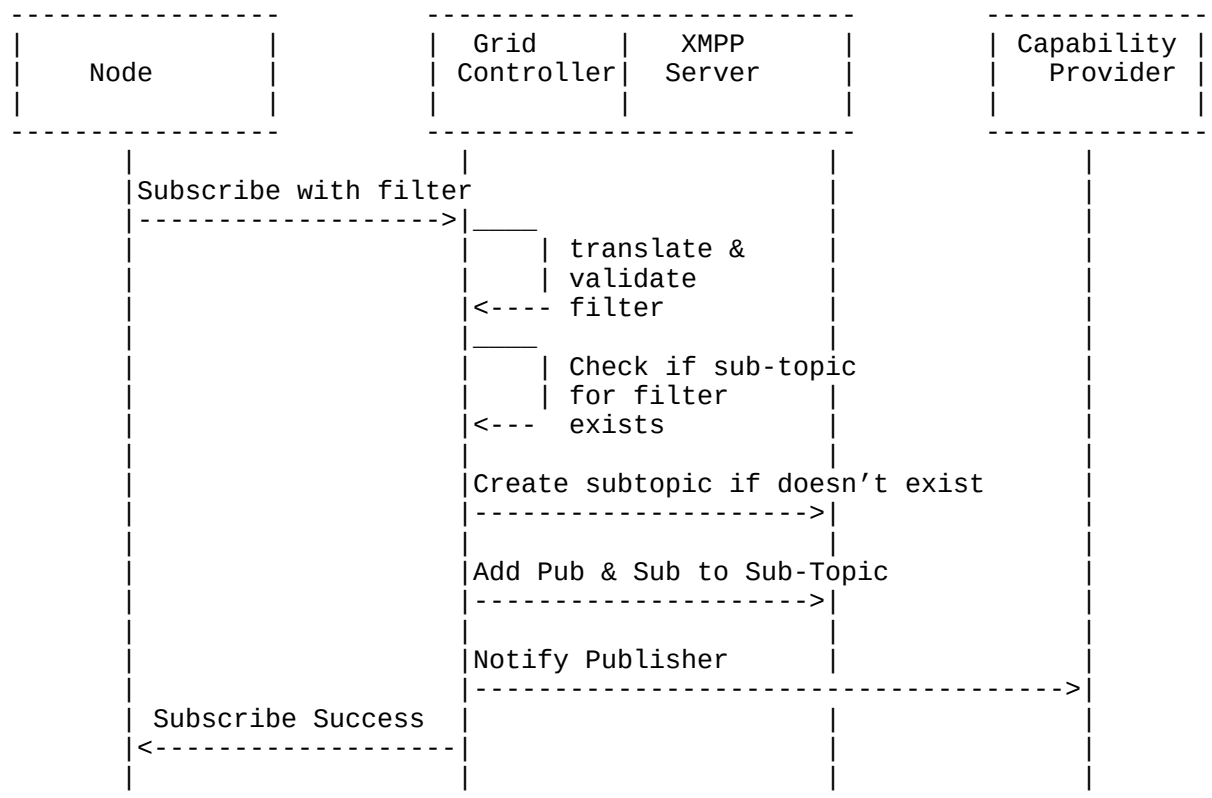


Figure 9: Subtopics and Information Filter Subscribe Operations Flow

The publisher will be responsible for applying the filter on the message and publishing the message on the Topic and the Subtopic based on the filter criteria. Filtering logic will be on the

publisher, as the publisher understands the message content. XMPP-Grid fabric is oblivious to the message content.

To avoid proliferation of new Subtopics, the capability provider could express the configurable limit on the number of Subtopics that can be created for its capability at registration time. The XMPP-Grid Controller will perform periodic cleanup of Subtopics whenever their subscription list reduces to 0.

In XMPP-Grid, message filters are provided to all APIs i.e. publish/subscribe and directed query.

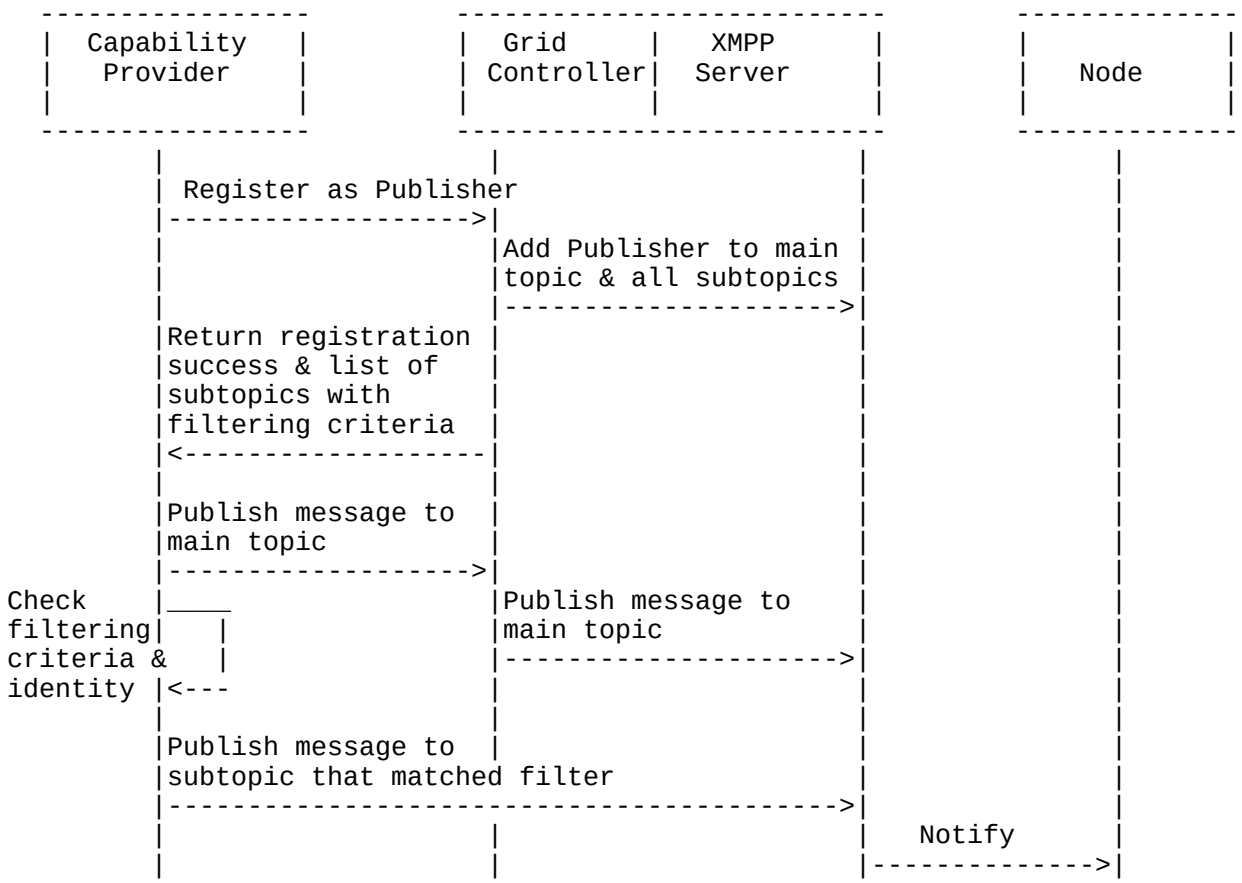


Figure 10: Subtopic Publish Operations Flow

2.6. XMPP-Grid Protocol Details

The XMPP-Grid Protocol provides an abstraction layer over and above XMPP messages with the intent to provide intuitive interfaces to the Nodes connecting to XMPP-Grid. Nodes connecting to XMPP-Grid use the following interfaces (provided as XML samples) offered by XMPP-Grid protocol to connect and participate in information exchange on XMPP-Grid:

o Register the Node to XMPP-Grid: Node identified as "Node2@domain.com/mac" sends the following Registration request to XMPP-Grid controller.

```
<iq id="ay0tK-4" to="grid_Controller.jabber"
    from="Node2@domain.com/syam-mac" type="get">
<grid xmlns='gi' type='request'>
<AccountQuery xmlns='com.domain.gi.gcl.Controller'>
<register></register></AccountQuery>
</grid>
</iq>
```

o Node login to XMPP-Grid: The following XML sample shows the Login request from Node "Node2@domain.com/mac" to XMPP-Grid controller and Login response returned by the XMPP-Grid controller to the Node.

```
// Request
<iq id="ay0tK-5" to="grid_Controller.jabber"
    from="Node2@domain.com/mac" type="get">
  <grid xmlns='gi' type='request'>
    <AccountQuery xmlns='com.domain.gi.gcl.Controller'>
      <login></login>
    </AccountQuery>
  </grid>
</iq>

// Response
<iq xmlns="jabber:client" to=" Node2@domain.com/mac"
    from="grid_Controller.jabber" type="result" id="ay0tK-5">
  <grid xmlns="gi" type="response">
    <AccountQuery xmlns="com.domain.gi.gcl.Controller">
      <login xmlns="">
        <value xmlns:ns2="gi" xmlns:xsi=" xsi:nil="true" />
      </login>
    </AccountQuery>
  </grid>
</iq>
```

o Node logout from XMPP-Grid: The following XML sample shows the Logout request sent by Node "Node2@domain.com/mac" to XMPP-Grid controller.

```
<iq id="o47m2-8" to="grid_Controller.jabber"
    from="Node2@domain.com/mac" type="get">
<grid xmlns='gi' type='request'>
<AccountQuery xmlns='com.domain.gi.gcl.Controller'>
<logout></logout>
</AccountQuery>
</grid>
</iq>
```

o Capability Discovery Query: The following XML sample shows the Capability Discovery query request from Node "Node2@domain.com/mac" to XMPP-Grid controller. The XMPP-Grid controller returns the list of capabilities supported by XMPP-Grid and their versions as a response to the Node's request.

```
// Request
<iq id="tVKqm-6" to="grid_Controller.jabber"
    from="Node2@domain.com/mac" type="get">
    <grid xmlns="xgrid" type="request">
        <ns2:getCapabilityListRequest xmlns:ns2=" xmlns:ns4="
                xmlns:ns3=" xmlns:ns5=" xmlns:ns6=" xmlns:ns7=" />
    </grid>
</iq>

// Response
<iq from="grid_Controller.jabber" id="tVKqm-6"
    to="Node2@domain.com/mac" type="result" xmlns="jabber:client">
    <grid type="response" xmlns="xgrid">
        <ns2:getCapabilityListResponse xmlns:ns2=" xmlns:ns3="
                xmlns:ns4=" xmlns:ns5=" xmlns:ns6=" xmlns:ns7=">
            <ns2:capability xmlns:xsi=
                        " xsi:type="ns5:TrustSecMetaDataCapability">
                <ns2:id>0</ns2:id>
                <ns2:name>TrustSecMetaDataCapability-1.0</ns2:name>
                <ns2:version>1.0</ns2:version>
            </ns2:capability>
            <ns2:capability
                xmlns:xsi=" xsi:type="ns5:EndpointProfileMetaDataCapability">
                <ns2:id>0</ns2:id>
                <ns2:name>
                     EndpointProfileMetaDataCapability-1.0</ns2:name>
                <ns2:version>1.0</ns2:version>
            </ns2:capability>
```

```
            <ns2:capability xmlns:xsi=
                            " xsi:type="ns5:IdentityGroupCapability">
                <ns2:id>0</ns2:id>
                <ns2:name>IdentityGroupCapability-1.0</ns2:name>
                <ns2:version>1.0</ns2:version>
            </ns2:capability>
            <ns2:capability xmlns:ns9=" xmlns:xsi="
                            xsi:type="ns9:TDAnalysisServiceCapability">
                <ns2:id>0</ns2:id>
                <ns2:name>TDAnalysisServiceCapability-1.0</ns2:name>
                <ns2:version>1.0</ns2:version>
            </ns2:capability>
            <ns2:capability xmlns:xsi=" xsi:type="
                            ns7:NetworkCaptureCapability">
                <ns2:id>0</ns2:id>
                <ns2:name>NetworkCaptureCapability-1.0</ns2:name>
                <ns2:version>1.0</ns2:version>
            </ns2:capability>
            <ns2:capability xmlns:xsi=
                            " xsi:type="ns6:EndpointProtectionServiceCapability"
>
                <ns2:id>0</ns2:id>
                <ns2:name>
                            EndpointProtectionServiceCapability-1.0</ns2:name>
                <ns2:version>1.0</ns2:version>
            </ns2:capability>
            <ns2:capability xmlns:xsi=
                           " xsi:type="ns4:GridControllerAdminServiceCapability">
                <ns2:id>0</ns2:id>
                <ns2:name>
                     GridControllerAdminServiceCapability-1.0</ns2:name>
                <ns2:version>1.0</ns2:version>
            </ns2:capability>
            <ns2:capability xmlns:xsi=
                            " xsi:type="ns5:SessionDirectoryCapability">
                <ns2:id>0</ns2:id>
                <ns2:name>SessionDirectoryCapability-1.0</ns2:name>
                <ns2:version>1.0</ns2:version>
            </ns2:capability>
        </ns2:getCapabilityListResponse>
    </grid>
</iq>
```

o Specific Capability Provider Query: The following XML sample shows the Capability Provider hostname query request from Node "Node2@domain.com/mac" to XMPP-Grid controller. XMPP-Grid controller returns the hostname of the specific Capability Provider as a response to the Node's request.

```
// Request
<iq id="996IL-8" to="grid_Controller.jabber"
    from="Node2@domain.com/mac" type="get">
  <grid xmlns='gi' type='request'>
    <DiscoveryQuery xmlns='com.domain.gi.gcl.Controller'>
      <find><param xsi:type="xs:string" xmlns:ns2="gi" xmlns:xs
                  =" xmlns:xsi=">com.domain.ise.session.SessionQuery
      </param></find>
    </DiscoveryQuery>
  </grid>
</iq>

// Response
<iq from='grid_Controller.jabber' id='996IL-8'
    to='Node2@domain.com/mac' type='result'
    xmlns='jabber:client'>
  <grid type='response' xmlns='gi'>
    <DiscoveryQuery xmlns='com.domain.gi.gcl.Controller'>
      <find xmlns=''><value xmlns:ns3='http://jaxb.dev.java.net/array'
                            xmlns:xsi='http://www.w3.org/2001/XMLSchema-instance
'
                            xsi:type='ns3:stringArray'>
      <item>ise@syam-06.domain.com/syam-mac</item></value></find>
    </DiscoveryQuery>
  </grid>
</iq>
```

o Register as a publisher to the Topic: The following XML sample shows the Register as a Publisher request from a Node "Node2@domain.com/mac" to XMPP-Grid controller.

```
 <iq id="fD65a-6" to="grid_Controller.jabber"
     from="Node2@domain.com/mac" type="get">
     <grid xmlns="xgrid" type="request">
         <ns2:initPublishRequest xmlns:ns2=" xmlns:ns4=
                  " xmlns:ns3=" xmlns:ns5=" xmlns:ns6=" xmlns:ns7=">
             <ns2:capability xsi:type="ns5:SessionCapability"
                             xmlns:xsi=">
                 <ns2:id>0</ns2:id>
                 <ns2:version>1.0</ns2:version>
             </ns2:capability>
         </ns2:initPublishRequest>
     </grid>
 </iq>
```

o Register as a subscriber to the Topic: The following XML sample shows a subscription request made by Node "Node2@domain.com/mac" for "SessionCapability" Topic to XMPP-Grid controller. On success, determined by the Node's authorization privilege, XMPP-Grid controller returns the Topic name, version and the Publishers' hostname as a response to the Node's request.

```
// Subscribe Request
<iq id="lQJIT-6" to="grid_Controller.jabber"
    from="Node2@domain.com/mac" type="get">
    <grid xmlns="xgrid" type="request">
        <ns2:subscribeRequest xmlns:ns2=" xmlns:ns4=" xmlns:ns3
             =" xmlns:ns5=" xmlns:ns6=" xmlns:ns7=">
            <ns2:capability xsi:type="ns5:SessionCapability"
                        xmlns:xsi=">
                <ns2:id>0</ns2:id>
                <ns2:version>1.0</ns2:version>
            </ns2:capability>
        </ns2:subscribeRequest>
    </grid>
</iq>

// Subscribe Response
<iq from="grid_Controller.jabber" id=" lQJIT-6"
    to="Node2@domain.com/mac" type="result" xmlns="jabber:client">
    <grid type="response" xmlns="xgrid">
        <ns2:subscribeResponse xmlns:ns2=
                               " xmlns:ns3=" xmlns:ns4=" xmlns:ns5="
                               xmlns:ns6=" xmlns:ns7=">
            <ns2:topicName>SessionCapability-1.0</ns2:topicName>
            <ns2:xmppDetails>
                <ns2:jid>ise-mnt-XMPP-Grid-004@xgrid.domain.com/gcl
                </ns2:jid>
                <ns2:jid>ise-mnt-XMPP-Grid-005@xgrid.domain.com/gcl
                </ns2:jid>
            </ns2:xmppDetails>
        </ns2:subscribeResponse>
    </grid>
</iq>
```

o Peer-to-Peer Directed Query: The following XML sample shows a peer-to-peer directed query request made by Node "Node2@domain.com/mac" to other XMPP-Grid participating Node "grid_Controller.jabber", seeking identity group information for a specific user "user1". "grid_Controller.jabber" returns the list of identity groups "user1" belongs as a response to the request.

```
// Query Request
<iq id="kR0YY-8" to="grid_Controller.jabber"
      from="Node2@domain.com/mac" type="get">
    <grid xmlns="xgrid" type="request">
        <ns5:getIdentityGroupRequest xmlns:ns2=" xmlns:ns4="
                xmlns:ns3=" xmlns:ns5=" xmlns:ns6=" xmlns:ns7=">
            <ns5:user>
                <ns2:name>user1</ns2:name>
            </ns5:user>
        </ns5:getIdentityGroupRequest>
    </grid>
</iq>

// Query Response
<iq from="grid_Controller.jabber"
    id=" kR0YY-8" to="Node2@domain.com/mac" type="result">
    <grid type="response" xmlns="xgrid">
        <ns5:getIdentityGroupResponse xmlns:ns2=" xmlns:ns3=
            " xmlns:ns4=" xmlns:ns5=" xmlns:ns6=" xmlns:ns7=">
            <ns5:user>
                <ns2:name>user1</ns2:name>
                <ns3:groupList>
                    <ns3:object>
                        <ns2:name>User Identity Groups:Employee
                        </ns2:name>
                        <ns3:type>Identity</ns3:type>
                    </ns3:object>
                </ns3:groupList>
            </ns5:user>
        </ns5:getIdentityGroupResponse>
    </grid>
</iq>
```

3. XMPP-Grid Compatibility with IODEF

The Incident Object Description and Exchange Format (IODEF) [RFC5070] defines a common data format and common exchange procedures for sharing incidents and related data between CSIRTs. RFC5070 provides the information and data model for IODEF specified with XML schema.

XEP-0268 (http://xmpp.org/extensions/xep-0268.html), Incident Handling, defines ways for XMPP server deployments to share incident reports with each other using the IODEF format and handle attacks on the servers in real-time.

Providers of incident reports, across administrative domains, could participate as publishers to an XMPP topic (for example: IODEF). Trust is achieved through authentication, authorization and account approval as defined in Section 2.4. The providers could expose IODEF incident attributes such as Authority as message filter criteria for the topic in order for subscribing systems to subscribe to incident reports from administrative domains of interest. The providers could further expose other IODEF attributes such as Assessment, Method, Attacker etc as message filter criteria for subscribers to selectively choose events of interest that are published from administrative domain(s). Privacy and regulatory requirements of information shared across administrative domains is beyond the scope of this document.

4. IANA Considerations

IANA Considerations to be determined

5. Security Considerations

A XMPP-Grid Controller serves as an controlling broker for XMPP-Grid Nodes such as Enforcement Points, Policy Servers, CMDBs, and Sensors, using a publish-subscribe-search model of information exchange and lookup. By increasing the ability of XMPP-Grid Nodes to learn about and respond to security-relevant events and data, XMPP-Grid can improve the timeliness and utility of the security system. However, this integrated security system can also be exploited by attackers if they can compromise it. Therefore, strong security protections for XMPP-Grid are essential.

This section provides a security analysis of the XMPP-Grid transport protocol and the architectural elements that employ it, specifically with respect to their use of this protocol. Three subsections define the trust model (which elements are trusted to do what), the threat model (attacks that may be mounted on the system), and the countermeasures (ways to address or mitigate the threats previously identified).

5.1. Trust Model

The first step in analyzing the security of the XMPP-Grid transport protocol is to describe the trust model, listing what each architectural element is trusted to do. The items listed here are

assumptions, but provisions are made in the Threat Model and Countermeasures sections for elements that fail to perform as they were trusted to do.

5.1.1. Network

The network used to carry XMPP-Grid messages is trusted to:

- Perform best effort delivery of network traffic

The network used to carry XMPP-Grid messages is not expected (trusted) to:

- Provide confidentiality or integrity protection for messages sent over it
- Provide timely or reliable service

5.1.2. XMPP-Grid Nodes

Authorized XMPP-Grid Nodes are trusted to:

- Preserve the confidentiality of sensitive data retrieved via the XMPP-Grid Controller

5.1.3. XMPP-Grid Controller

The XMPP-Grid Controller is trusted to:

- Broker requests for data and enforce authorization of access to this data throughout its lifecycle
- Perform service requests in a timely and accurate manner
- Create and maintain accurate operational attributes
- Only reveal data to and accept service requests from authorized parties

The XMPP-Grid Controller is not expected (trusted) to:

- Verify the truth (correctness) of data

5.1.4. Certification Authority

The Certification Authority (CA) that issues certificates for the XMPP-Grid Controller and/or XMPP-Grid Nodes (or each CA, if there are several) is trusted to:

- Protect the confidentiality of the CA's private key
- Ensure that only proper certificates are issued and that all certificates are issued in accordance with the CA's policies
- Revoke certificates previously issued when necessary
- Regularly and securely distribute certificate revocation information
- Promptly detect and report any violations of this trust so that they can be handled

The CA is not expected (trusted) to:

- Issue certificates that go beyond name constraints or other constraints imposed by a relying party or a cross-certificate

5.2. Threat Model

To secure the XMPP-Grid transport protocol and the architectural elements that implement it, this section identifies the attacks that can be mounted against the protocol and elements.

5.2.1. Network Attacks

A variety of attacks can be mounted using the network. For the purposes of this subsection the phrase "network traffic" should be taken to mean messages and/or parts of messages. Any of these attacks may be mounted by network elements, by parties who control network elements, and (in many cases) by parties who control network-attached devices.

- Network traffic may be passively monitored to glean information from any unencrypted traffic
- Even if all traffic is encrypted, valuable information can be gained by traffic analysis (volume, timing, source and destination addresses, etc.)
- Network traffic may be modified in transit
- Previously transmitted network traffic may be replayed
- New network traffic may be added
- Network traffic may be blocked, perhaps selectively

- A "Man In The Middle" (MITM) attack may be mounted where an attacker interposes itself between two communicating parties and poses as the other end to either party or impersonates the other end to either or both parties

- Resist attacks (including denial of service and other attacks from XMPP-Grid Nodes)

- Undesired network traffic may be sent in an effort to overload an architectural component, thus mounting a denial of service attack

5.2.2. XMPP-Grid Nodes

An unauthorized XMPP-Grid Nodes (one which is not recognized by the XMPP-Grid Controller or is recognized but not authorized to perform any actions) cannot mount any attacks other than those listed in the Network Attacks section above.

An authorized XMPP-Grid Node, on the other hand, can mount many attacks. These attacks might occur because the XMPP-Grid Node is controlled by a malicious, careless, or incompetent party (whether because its owner is malicious, careless, or incompetent or because the XMPP-Grid Node has been compromised and is now controlled by a party other than its owner). They might also occur because the XMPP-Grid Node is running malicious software; because the XMPP-Grid Node is running buggy software (which may fail in a state that floods the network with traffic); or because the XMPP-Grid Node has been configured improperly. From a security standpoint, it generally makes no difference why an attack is initiated. The same countermeasures can be employed in any case.

Here is a list of attacks that may be mounted by an authorized XMPP-Grid Node:

- Cause many false alarms or otherwise overload the XMPP-Grid Controller or other elements in the network security system (including human administrators) leading to a denial of service or disabling parts of the network security system

- Omit important actions (such as posting incriminating data), resulting in incorrect access

- Use confidential information obtained from the XMPP-Grid Controller to enable further attacks (such as using endpoint health check results to exploit vulnerable endpoints)

- Advertise data crafted to exploit vulnerabilities in the XMPP-Grid Controller or in other XMPP-Grid Nodes, with a goal of compromising those systems

- Issue a search request or set up a subscription that matches an enormous result, leading to resource exhaustion on the XMPP-Grid Controller, the publishing XMPP-Grid Node, and/or the network

- Establish a communication channel using another XMPP-Grid Node's session-id

Dependencies of or vulnerabilities of authorized XMPP-Grid Nodes may be exploited to effect these attacks. Another way to effect these attacks is to gain the ability to impersonate a XMPP-Grid Node (through theft of the XMPP-Grid Node's identity credentials or through other means). Even a clock skew between the XMPP-Grid Node and XMPP-Grid Controller can cause problems if the XMPP-Grid Node assumes that old XMPP-Grid Node data should be ignored.

5.2.3. XMPP-Grid Controllers

An unauthorized XMPP-Grid Controller (one which is not trusted by XMPP-Grid Nodes) cannot mount any attacks other than those listed in the Network Attacks section above.

An authorized XMPP-Grid Controller can mount many attacks. Similar to the XMPP-Grid Node case described above, these attacks might occur because the XMPP-Grid Controller is controlled by a malicious, careless, or incompetent party (either a XMPP-Grid Controller administrator or an attacker who has seized control of the XMPP-Grid Controller). They might also occur because the XMPP-Grid Controller is running malicious software, because the XMPP-Grid Controller is running buggy software (which may fail in a state that corrupts data or floods the network with traffic), or because the XMPP-Grid Controller has been configured improperly.

All of the attacks listed for XMPP-Grid Node above can be mounted by the XMPP-Grid Controller. Detection of these attacks will be more difficult since the XMPP-Grid Controller can create false operational attributes and/or logs that imply some other party created any bad data.

Additional XMPP-Grid Controller attacks may include:

- Expose different data to different XMPP-Grid Nodes to mislead investigators or cause inconsistent behavior

- Mount an even more effective denial of service attack than a single XMPP-Grid Node could

- Obtain and cache XMPP-Grid Node credentials so they can be used to impersonate XMPP-Grid Nodes even after a breach of the XMPP-Grid Controller is repaired

- Obtain and cache XMPP-Grid Controller administrator credentials so they can be used to regain control of the XMPP-Grid Controller after the breach of the XMPP-Grid Controller is repaired

Dependencies of or vulnerabilities of the XMPP-Grid Controller may be exploited to obtain control of the XMPP-Grid Controller and effect these attacks.

5.2.4. Certification Authority

A Certification Authority trusted to issue certificates for the XMPP-Grid Controller and/or XMPP-Grid Nodes can mount several attacks:

- Issue certificates for unauthorized parties, enabling them to impersonate authorized parties such as the XMPP-Grid Controller or a XMPP-Grid Node. This can lead to all the threats that can be mounted by the certificate’s subject.

- Issue certificates without following all of the CA’s policies. Because this can result in issuing certificates that may be used to impersonate authorized parties, this can lead to all the threats that can be mounted by the certificate’s subject.

- Fail to revoke previously issued certificates that need to be revoked. This can lead to undetected impersonation of the certificate’s subject or failure to revoke authorization of the subject, and therefore can lead to all of the threats that can be mounted by that subject.

- Fail to regularly and securely distribute certificate revocation information. This may cause a relying party to accept a revoked certificate, leading to undetected impersonation of the certificate’s subject or failure to revoke authorization of the subject, and therefore can lead to all of the threats that can be mounted by that subject. It can also cause a relying party to refuse to proceed with a transaction because timely revocation information is not available, even though the transaction should be permitted to proceed.

- o Allow the CA's private key to be revealed to an unauthorized party. This can lead to all the threats above. Even worse, the actions taken with the private key will not be known to the CA.

- o Fail to promptly detect and report errors and violations of trust so that relying parties can be promptly notified. This can cause the threats listed earlier in this section to persist longer than necessary, leading to many knock-on effects.

5.3. Countermeasures

Below are countermeasures for specific attack scenarios to the XMPP-Grid infrastructure.

5.3.1. Securing the XMPP-Grid Transport Protocol

To address network attacks, the XMPP-Grid transport protocol described in this document requires that the XMPP-Grid messages MUST be carried over TLS (minimally TLS 1.2 [RFC5246]) as described in [RFC2818]. The XMPP-Grid Node MUST verify the XMPP-Grid Controller's certificate and determine whether the XMPP-Grid Controller is trusted by this XMPP-Grid Node before completing the TLS handshake. The XMPP-Grid Controller MUST authenticate the XMPP-Grid Node either using mutual certificate-based authentication in the TLS handshake or using Basic Authentication as described in IETF RFC 2617. XMPP-Grid Controller MUST use Simple Authentication and Security Layer (SASL), described in [RFC4422], to support the aforesaid authentication mechanisms. SASL offers authentication mechanism negotiations between the XMPP-Grid Controller and XMPP-Grid node during the connection establishment phase. XMPP-Grid Nodes and XMPP-Grid Controllers using mutual certificate-based authentication SHOULD each verify the revocation status of the other party. All XMPP-Grid Controllers and XMPP-Grid Nodes MUST implement both mutual certificate-based authentication and Basic Authentication. The selection of which XMPP-Grid Node authentication technique to use in any particular deployment is left to the administrator.

An XMPP-Grid Controller MAY also support a local, configurable set of Basic Authentication userid-password pairs. If so, it is implementation dependent whether a XMPP-Grid Controller ends a session when an administrator changes the configured password. Since Basic Authentication has many security disadvantages (especially the transmission of reusable XMPP-Grid Node passwords to the XMPP-Grid Controller), it SHOULD only be used when absolutely necessary. Per the HTTP specification, when basic authentication is in use, a XMPP-Grid Controller MAY respond to any request that lacks credentials with an error code similar to HTTP code 401. A XMPP-Grid Node SHOULD avoid this code by submitting basic auth credentials with every

request when basic authentication is in use. If it does not do so, a XMPP-Grid Node MUST respond to this code by resubmitting the same request with credentials (unless the XMPP-Grid Node is shutting down).

As XMPP uses TLS as the transport and security mechanisms, it is understood that best practices such as those in [I-D.ietf-uta-tls-bcp] are followed.

These protocol security measures provide protection against all the network attacks listed in the above document section except denial of service attacks. If protection against these denial of service attacks is desired, ingress filtering, rate limiting per source IP address, and other denial of service mitigation measures may be employed. In addition, a XMPP-Grid Controller MAY automatically disable a misbehaving XMPP-Grid Node.

5.3.2. Securing XMPP-Grid Nodes

XMPP-Grid Nodes may be deployed in locations that are susceptible to physical attacks. Physical security measures may be taken to avoid compromise of XMPP-Grid Nodes, but these may not always be practical or completely effective. An alternative measure is to configure the XMPP-Grid Controller to provide read-only access for such systems. The XMPP-Grid Controller SHOULD also include a full authorization model so that individual XMPP-Grid Nodes may be configured to have only the privileges that they need. The XMPP-Grid Controller MAY provide functional templates so that the administrator can configure a specific XMPP-Grid Node as a DHCP server and authorize only the operations and metadata types needed by a DHCP server to be permitted for that XMPP-Grid Node. These techniques can reduce the negative impacts of a compromised XMPP-Grid Node without diminishing the utility of the overall system.

To handle attacks within the bounds of this authorization model, the XMPP-Grid Controller MAY also include rate limits and alerts for unusual XMPP-Grid Node behavior. XMPP-Grid Controllers SHOULD make it easy to revoke a XMPP-Grid Node’s authorization when necessary. Another way to detect attacks from XMPP-Grid Nodes is to create fake entries in the available data (honeytokens) which normal XMPP-Grid Nodes will not attempt to access. The XMPP-Grid Controller SHOULD include auditable logs of XMPP-Grid Node activities.

To avoid compromise of XMPP-Grid Node, XMPP-Grid Node SHOULD be hardened against attack and minimized to reduce their attack surface. They SHOULD go through a TNC handshake to verify the integrity of the XMPP-Grid Node, and SHOULD, if feasible, utilize a Trusted Platform Module (TPM) for identity and/or integrity measurements of the XMPP-

Grid Node within a TNC handshake. They should be well managed to minimize vulnerabilities in the underlying platform and in systems upon which the XMPP-Grid Node depends. Personnel with administrative access should be carefully screened and monitored to detect problems as soon as possible.

5.3.3. Securing XMPP-Grid Controllers

Because of the serious consequences of XMPP-Grid Controller compromise, XMPP-Grid Controllers SHOULD be especially well hardened against attack and minimized to reduce their attack surface. They SHOULD go through a regular TNC handshake to verify the integrity of the XMPP-Grid Controller, and SHOULD utilize a Trusted Platform Module (TPM) for identity and/or integrity measurements of the XMPP-Grid Node within a TNC handshake. They should be well managed to minimize vulnerabilities in the underlying platform and in systems upon which the XMPP-Grid Controller depends. Network security measures such as firewalls or intrusion detection systems may be used to monitor and limit traffic to and from the XMPP-Grid Controller. Personnel with administrative access should be carefully screened and monitored to detect problems as soon as possible. Administrators should not use password-based authentication but should instead use non-reusable credentials and multi-factor authentication (where available). Physical security measures SHOULD be employed to prevent physical attacks on XMPP-Grid Controllers.

To ease detection of XMPP-Grid Controller compromise should it occur, XMPP-Grid Controller behavior should be monitored to detect unusual behavior (such as a reboot, a large increase in traffic, or different views of an information repository for similar XMPP-Grid Nodes). XMPP-Grid Nodes should log and/or notify administrators when peculiar XMPP-Grid Controller behavior is detected. To aid forensic investigation, permanent read-only audit logs of security-relevant information (especially administrative actions) should be maintained. If XMPP-Grid Controller compromise is detected, a careful analysis should be performed of the impact of this compromise. Any reusable credentials that may have been compromised should be reissued.

5.3.4. Limit on search result size

While XMPP-Grid is designed for high scalability to 100,000s of Nodes, an XMPP-Grid Controller MAY establish a limit to the amount of data it is willing to return in search or subscription results. This mitigates the threat of a XMPP-Grid Node causing resource exhaustion by issuing a search or subscription that leads to an enormous result.

5.3.5. Cryptographically random session-id and authentication checks for ARC

A XMPP-Grid Controller SHOULD ensure that the XMPP-Grid Node establishing an ARC is the same XMPP-Grid Node as the XMPP-Grid Node that established the corresponding SSRC. The XMPP-Grid Controller SHOULD employ both of the following strategies:

- session-ids SHOULD be cryptographically random
- The HTTPS transport for the SSRC and the ARC SHOULD be authenticated using the same credentials. SSL session resumption MAY be used to establish the ARC based on the SSRC SSL session.

5.3.6. Securing the Certification Authority

As noted above, compromise of a Certification Authority (CA) trusted to issue certificates for the XMPP-Grid Controller and/or XMPP-Grid Nodes is a major security breach. Many guidelines for proper CA security have been developed: the CA/Browser Forum's Baseline Requirements, the AICPA/CICA Trust Service Principles, etc. The CA operator and relying parties should agree on an appropriately rigorous security practices to be used.

Even with the most rigorous security practices, a CA may be compromised. If this compromise is detected quickly, relying parties can remove the CA from their list of trusted CAs, and other CAs can revoke any certificates issued to the CA. However, CA compromise may go undetected for some time, and there's always the possibility that a CA is being operated improperly or in a manner that is not in the interests of the relying parties. For this reason, relying parties may wish to "pin" a small number of particularly critical certificates (such as the certificate for the XMPP-Grid Controller). Once a certificate has been pinned, the relying party will not accept another certificate in its place unless the Administrator explicitly commands it to do so. This does not mean that the relying party will not check the revocation status of pinned certificates. However, the Administrator may still be consulted if a pinned certificate is revoked, since the CA and revocation process are not completely trusted.

5.4. Summary

XMPP-Grid's considerable value as a broker for security-sensitive data exchange distribution also makes the protocol and the network security elements that implement it a target for attack. Therefore, strong security has been included as a basic design principle within the XMPP-Grid design process.

The XMPP-Grid transport protocol provides strong protection against a variety of different attacks. In the event that a XMPP-Grid Node or XMPP-Grid Controller is compromised, the effects of this compromise have been reduced and limited with the recommended role-based authorization model and other provisions, and best practices for managing and protecting XMPP-Grid systems have been described. Taken together, these measures should provide protection commensurate with the threat to XMPP-Grid systems, thus ensuring that they fulfill their promise as a network security clearing-house.

6. Privacy Considerations

XMPP-Grid Nodes may publish information about endpoint health, network access, events (which may include information about what services an endpoint is accessing), roles and capabilities, and the identity of the end user operating the endpoint. Any of this published information may be queried by other XMPP-Grid Nodes and could potentially be used to correlate network activity to a particular end user.

Dynamic and static information brokered by a XMPP-Grid Controller, ostensibly for purposes of correlation by XMPP-Grid Nodes for intrusion detection, could be misused by a broader set of XMPP-Grid Nodes which hitherto have been performing specific roles with strict well-defined separation of duties.

Care should be taken by deployers of XMPP-Grid to ensure that the information published by XMPP-Grid Nodes does not violate agreements with end users or local and regional laws and regulations. This can be accomplished either by configuring XMPP-Grid Nodes to not publish certain information or by restricting access to sensitive data to trusted XMPP-Grid Nodes. That is, the easiest means to ensure privacy or protect sensitive data, is to omit or not share it at all.

Another consideration for deployers is to enable end-to-end encryption to ensure the data is protected from the data layer to data layer and thus protect it from the transport layer.

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Using XMPP for Security Information Exchange
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Abstract

This document describes how to use the Extensible Messaging and Presence Protocol (XMPP) to collect and distribute security incident reports and other security-relevant information between network-connected devices, primarily for the purpose of communication among Computer Security Incident Response Teams and associated entities. To illustrate the principles involved, this document describes such a usage for the Incident Object Description Exchange Format (IODEF).

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

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This Internet-Draft will expire on September 28, 2019.

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Table of Contents

1. Introduction

This document defines an architecture, i.e., "XMPP-Grid", as a method for using the Extensible Messaging and Presence Protocol (XMPP) [RFC6120] to collect and distribute security incident reports and other security-relevant information among network platforms, endpoints, and any other network-connected device, primarily for the purpose of communication among Computer Security Incident Response Teams and associated entities. In effect, this document specifies an Applicability Statement ([RFC2026], Section 3.2) that defines how to use XMPP for the exchange of security notifications on a controlled-access network among authorized entities.

Among other things, XMPP provides a publish-subscribe service [XEP-0060] that acts as a broker, enabling control-plane functions by which entities can discover available information to be published or consumed. Although such information can take the form of any structured data (XML, JSON, etc.), this document illustrates the principles of XMPP-Grid with examples that use the Incident Object Description Exchange Format (IODEF) [RFC7970]. That is, while other

security information formats can be shared using XMPP, this document uses IODEF as one such example format that can be published and consumed using XMPP.

2. Terminology

This document uses XMPP terminology defined in [RFC6120] and [XEP-0060]. Because the intended audience for this document is those who implement and deploy security reporting systems, mappings are provided for the benefit of XMPP developers and operators.

Broker: A specific type of controller containing control plane functions; as used here, the term refers to an XMPP publish-subscribe service.

Broker Flow: A method by which security incident reports and other security-relevant information is published and consumed in a mediated fashion through a Broker. In this flow, the Broker handles authorization of Consumers and Providers to Topics, receives messages from Providers, and delivers published messages to Consumers.

Consumer: An entity that contains functions to receive information from other components; as used here, the term refers to an XMPP publish-subscribe Subscriber.

Controller: A "component containing control plane functions that manage and facilitate information sharing or execute on security functions"; as used here, the term refers to an XMPP server, which provides core message delivery [RFC6120] used by publish-subscribe entities.

Node: The XMPP term for a Topic.

Platform: Any entity that connects to the XMPP-Grid in order to publish or consume security-relevant information.

Provider: An entity that contains functions to provide information to other components; as used here, the term refers to an XMPP publish-subscribe Publisher.

Topic: A contextual information channel created on a Broker at which messages generated by a Provider are propagated in real time to one or more Consumers. Each Topic is limited to a specific type and format of security data (e.g. IODEF namespace) and provides an XMPP interface by which the data can be obtained.

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

3. Architecture

The following figure illustrates the architecture of XMPP-Grid.

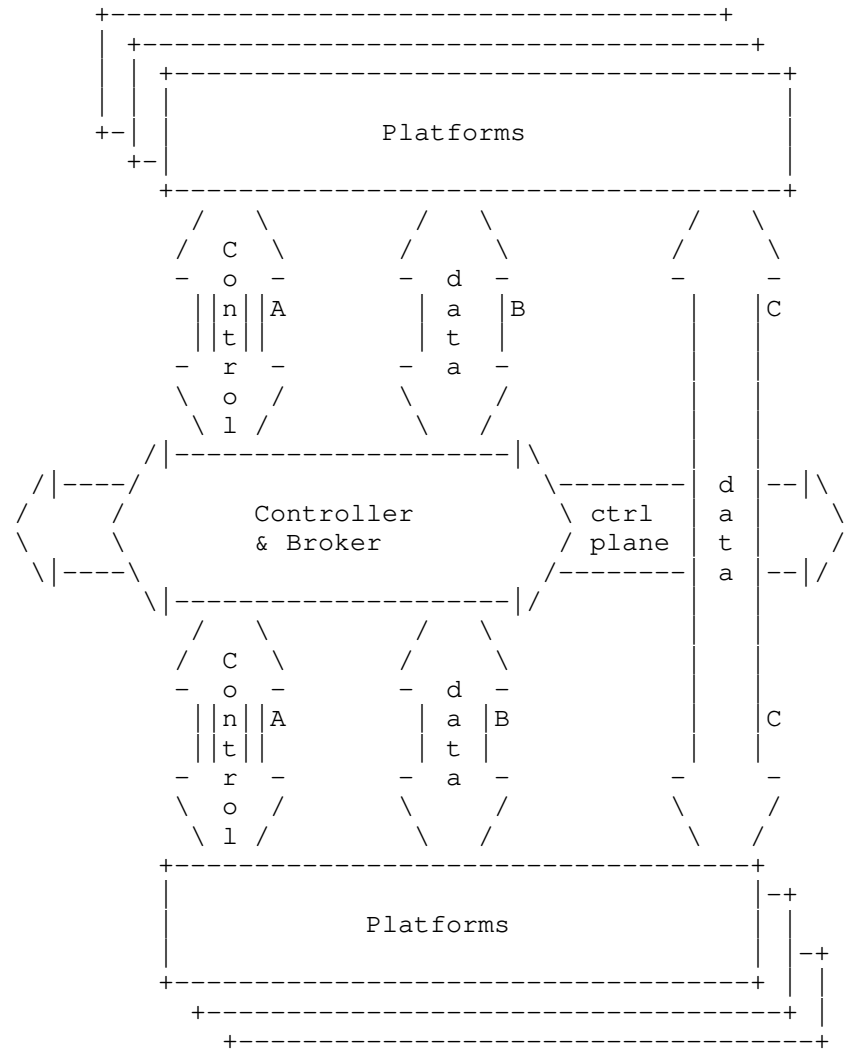

Figure 1: XMPP-Grid Architecture

Platforms connect to the Controller (XMPP server) to authenticate and then establish appropriate authorizations to be a Provider or Consumer of topics of interest at the Broker. The control plane messaging is established through XMPP and shown as "A" (control plane interface) in Figure 1. Authorized Platforms can then share data either through the Broker (shown as "B" in Figure 1) or in some cases directly (shown as "C" in Figure 1). This document focuses primarily on the Broker Flow for information sharing ("direct flow" interactions can be used for specialized purposes such as bulk data transfer, but methods for doing so are outside the scope of this document).

4. Workflow

Implementations of XMPP-Grid workflow adhere to the following workflow:

a. A Platform with a source of security data requests connection to the XMPP-Grid via a Controller.

b. The Controller authenticates the Platform.

c. The Platform establishes authorized privileges (e.g. privilege to publish and/or subscribe to one or more Topics) with a Broker.

d. The Platform can publish security incident reports and other security-relevant information to a Topic, subscribe to a Topic, query a Topic, or any combination of these operations.

e. A Provider unicasts its Topic updates to the Grid in real time through a Broker. The Broker handles replication and distribution of the Topic to Consumers. A Provider can publish the same or different data to multiple Topics.

f. Any Platform on the Grid can subscribe to any Topics published to the Grid (as permitted by authorization policy), and (as Consumers) will then receive a continual, real-time stream of updates from the Topics to which it is subscribed.

The general workflow is summarized in the figure below:

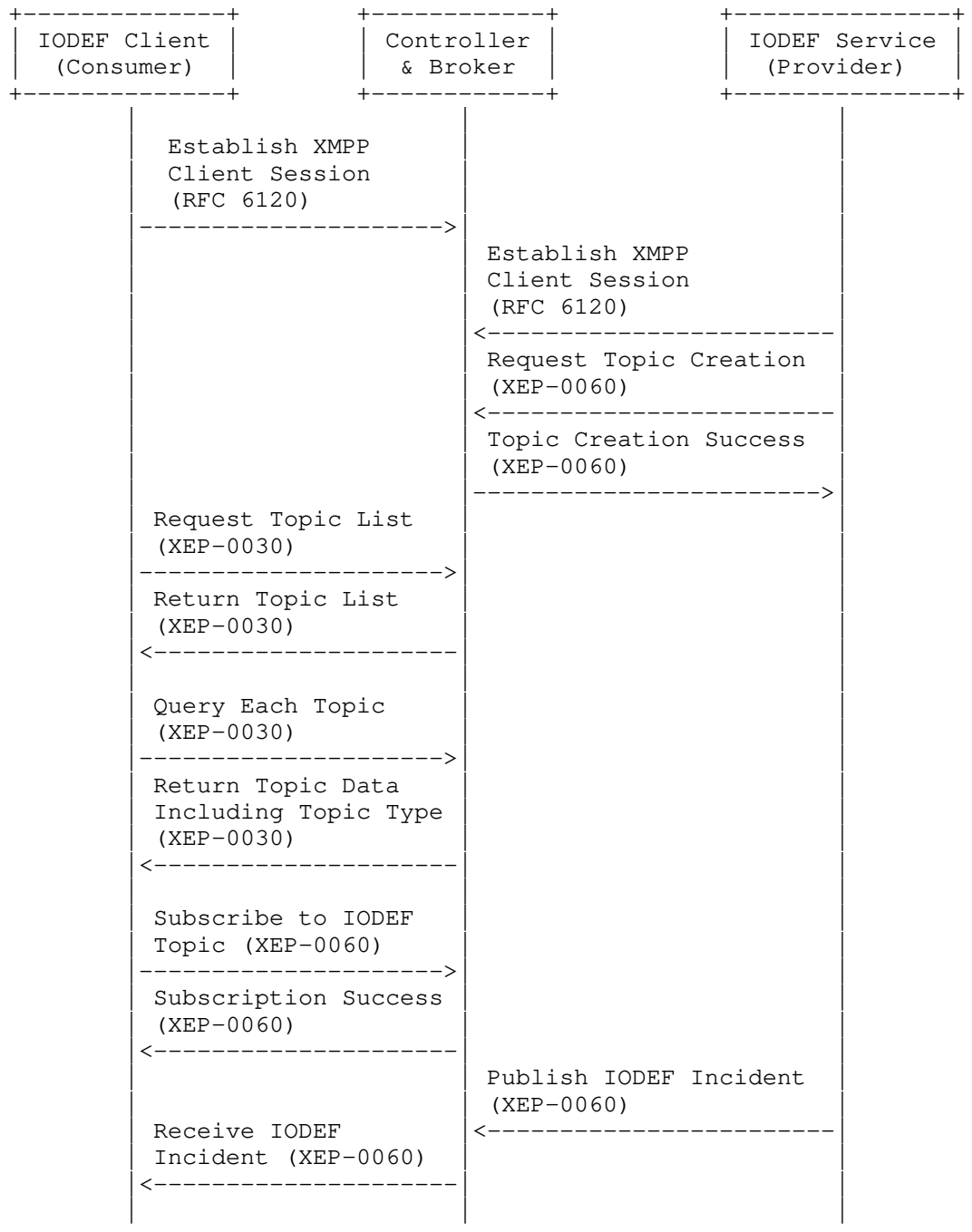

Figure 2: IODEF Example Workflow

XMPP-Grid implementations MUST adhere to the mandatory-to-implement and mandatory-to-negotiate features as defined in [RFC6120]. Similarly, implementations MUST implement [XEP-0060] to facilitate the asynchronous sharing for information. Implementations SHOULD implement Service Discovery as defined in [XEP-0030] to facilitate the means to dynamically discover the available information and namespaces (Topics) to be published or consumed. Implementations should take caution if their deployments allow for a large number of topics. The Result Set Management as defined in [XEP-0059], SHOULD be used to allow the requesting entity to explicitly request Service Discovery result sets to be returned in pages or limited size, if the discovery results are larger in size. Note that the control plane may optionally also implement [XEP-0203] to facilitate delayed delivery of messages to the connected consumer as described in [XEP-0060]. Since information may be timely and sensitive, capability providers should communicate to the controller whether its messages can be cached for delayed delivery during configuration; such function is out of scope for this document.

The following sections provide protocol examples for the service discovery and publish-subscribe parts of the workflow.

5. Service Discovery

Using the XMPP service discovery extension [XEP-0030], a Controller enables Platforms to discover what information can be consumed through the Broker, and at which Topics. Platforms could use [XEP-0059] to restrict the size of the result sets the Controller returns in Service Discovery response. As an example, the Controller at 'security-grid.example' might provide a Broker at 'broker.security-grid.example' hosting a number of Topics. A Platform at 'xmpp-grid-client@mile-host.example' would query the Broker about its available Topics by sending an XMPP "disco#items" request to the Broker:

```
<iq type='get'
    from='xmpp-grid-client@mile-host.example/2EBE702A97D6'
    to='broker.security-grid.example'
    id='B3C17F7B-B9EF-4ABA-B08D-805DA9F34626'>
  <query xmlns='http://jabber.org/protocol/disco#items'/>
</iq>
```

The Broker responds with the Topics it hosts:

```
<iq type='result'
    from='broker.security-grid.example'
    to='xmpp-grid-client@mile-host.example/2EBE702A97D6'
    id='B3C17F7B-B9EF-4ABA-B08D-805DA9F34626'>
  <query xmlns='http://jabber.org/protocol/disco#items'>
    <item node='NEA1'
          name='Endpoint Posture Information'
          jid='broker.security-grid.example'/>
    <item node='MILEHost'
          name='MILE Host Data'
          jid='broker.security-grid.example'/>
  </query>
</iq>
```

In order to determine the exact nature of each Topic (i.e., in order to find topics that publish incidents in the IODEF format), a Platform would send an XMPP "disco#info" request to each Topic:

```
<iq type='get'
    from='xmpp-grid-client@mile-host.example/2EBE702A97D6'
    to='broker.security-grid.example'
    id='D367D4ED-2795-489C-A83E-EAAFA07A0356'
  <query xmlns='http://jabber.org/protocol/disco#info'
         node='MILEHost'/>
</iq>
```

The Broker responds with the "disco#info" description, which MUST include an XMPP Data Form [XEP-0004] including a 'pubsub#type' field that specifies the supported namespace (in this example, the IODEF namespace defined in [RFC7970]):

```
<iq type='result'
    from='broker.security-grid.example'
    to='xmpp-grid-client@mile-host.example/2EBE702A97D6'
    id='D367D4ED-2795-489C-A83E-EAAFA07A0356'/>
  <query xmlns='http://jabber.org/protocol/disco#info'
       node='MILEHost'>
    <identity category='pubsub' type='leaf'/>
    <feature var='http://jabber.org/protocol/pubsub'/>
    <x xmlns='jabber:x:data' type='result'>
     <field var='FORM_TYPE' type='hidden'>
      <value>http://jabber.org/protocol/pubsub#meta-data</value>
     </field>
     <field var='pubsub#type' label='Payload type' type='text-single'>
      <value>urn:ietf:params:xml:ns:iodef-2.0</value>
     </field>
    </x>
  </query>
</iq>
```

The Platform discovers the topics by obtaining the Broker's response and obtaining the namespaces returned in the "pubsub#type" field (in the foregoing example, IODEF 2.0).

6. Publish-Subscribe

Using the XMPP publish-subscribe extension [XEP-0060], a Consumer subscribes to a Topic and a Provider publishes information to that Topic, which the Broker then distributes to all subscribed Consumers.

First, a Provider would create a Topic as follows:

```
<iq type='set'
    from='datasource@provider.example/F12C2EFC9BB0'
    to='broker.security-grid.example'
    id='A67507DF-2F22-4937-8D30-88D2F7DBA279'>
  <pubsub xmlns='http://jabber.org/protocol/pubsub'>
    <create node='MILEHost'/>
  </pubsub>
</iq>
```

Note: The foregoing example is the minimal protocol needed to create a Topic with the default node configuration on the XMPP publish-subscribe service specified in the 'to' address of the creation request stanza. Depending on security requirements, the Provider might need to request a non-default configuration for the node; see [XEP-0060] for detailed examples. To also help with the Topic configuration, the Provider may also optionally include configurations parameters such as:

```
<configure>
  <x xmlns='jabber:x:data' type='submit'>
    <field var='FORM_TYPE' type='hidden'>
      <value>http://jabber.org/protocol/pubsub#node_config</value>
    </field>
    <field var='pubsub#access_model'><value>authorize</value></field>
    <field var='pubsub#persist_items'><value>1</value></field>
    <field var='pubsub#send_last_published_item'><value>never</value></field>
  </x>
</configure>
```

The above configuration indicates the Topic is configured to enable the XMPP-Controller to manage the subscriptions, be in persistent mode and disables the Broker from cacheing the last item published. Please refer to [XEP-0060] a more detailed description of these configuration and other available configuration options.

Unless an error occurs (see [XEP-0060] for various error flows), the Broker responds with success:

```
<iq type='result'
    from='broker.security-grid.example'
    to='datasource@provider.example/F12C2EFC9BB0'
    id='A67507DF-2F22-4937-8D30-88D2F7DBA279'/>
```

Second, a Consumer would subscribe as follows:

```
<iq type='set'
    from='xmpp-grid-client@mile-host.example/2EBE702A97D6'
    to='broker.security-grid.example'
    id='9C6EEE9E-F09A-4418-8D68-3BA6AF852522'>
  <pubsub xmlns='http://jabber.org/protocol/pubsub'>
    <subscribe node='MILEHost'
               jid='xmpp-grid-client@mile-host.example'/>
  </pubsub>
</iq>
```

Unless an error occurs (see [XEP-0060] for various error flows), the Broker responds with success:

```
<iq type='result'
    from='broker.security-grid.example'
    to='xmpp-grid-client@mile-host.example/2EBE702A97D6'
    id='9C6EEE9E-F09A-4418-8D68-3BA6AF852522'>
  <pubsub xmlns='http://jabber.org/protocol/pubsub'>
    <subscription
        node='MILEHost'
        jid='xmpp-grid-client@mile-host.example'
        subscription='subscribed'/>
  </pubsub>
</iq>
```

Third, a Provider would publish an incident to the broker using the MILEHost topic as follows:

```
<iq type='set'
    from='datasource@provider.example/F12C2EFC9BB0'
    to='broker.security-grid.example'
    id='2A17D283-0DAE-4A6C-85A9-C10B1B40928C'>
  <pubsub xmlns='http://jabber.org/protocol/pubsub'>
    <publish node='MILEHost'>
      <item id='8bh1g27skbga47fh9wk7'>
        <IODEF-Document version="2.00" xml:lang="en"
          xmlns="urn:ietf:params:xml:ns:iodef-2.0"
          xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
          xsi:schemaLocation=
            "http://www.iana.org/assignments/xml-registry/
             schema/iodef-2.0.xsd">
          <Incident purpose="reporting" restriction="private">
            <IncidentID name="csirt.example.com">492382</IncidentID>
            <GenerationTime>2015-07-18T09:00:00-05:00</GenerationTime>
            <Contact type="organization" role="creator">
              <Email>
                <EmailTo>contact@csirt.example.com</EmailTo>
              </Email>
            </Contact>
          </Incident>
        </IODEF-Document>
      </item>
    </publish>
  </pubsub>
</iq>
```

(The payload in the foregoing example is from [RFC7970]; payloads for additional use cases can be found in [RFC8274].)

The Broker would then deliver that incident report to all Consumers who are subscribed to the Topic:

```
<message
    from='broker.security-grid.example'
    to='xmpp-grid-client@mile-host.example/2EBE702A97D6'
    id='37B3921D-4F7F-450F-A589-56119A88BC2E'>
  <event xmlns='http://jabber.org/protocol/pubsub#event'>
    <items node='MILEHost'>
      <item id='iah37s61s964gquqy47aksbx9453ks77'>
        <IODEF-Document version="2.00" xml:lang="en"
          xmlns="urn:ietf:params:xml:ns:iodef-2.0"
          xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
          xsi:schemaLocation=
            "http://www.iana.org/assignments/xml-registry/
             schema/iodef-2.0.xsd">
          <Incident purpose="reporting" restriction="private">
            <IncidentID name="csirt.example.com">492382</IncidentID>
            <GenerationTime>2015-07-18T09:00:00-05:00</GenerationTime>
            <Contact type="organization" role="creator">
              <Email>
                <EmailTo>contact@csirt.example.com</EmailTo>
              </Email>
            </Contact>
          </Incident>
        </IODEF-Document>
      </item>
    </items>
  </event>
</message>
```

Note that [XEP-0060] uses the XMPP "<message />" stanza for delivery of content. To ensure that messages are delivered to the Consumer even if the Consumer is not online at the same time that the Publisher generates the message, an XMPP-Grid Controller MUST support "offline messaging" delivery semantics as specified in [RFC6121], best practices for which are further explained in [XEP-0160].

7. IANA Considerations

This document has no actions for IANA.

8. Security Considerations

An XMPP-Grid Controller serves as an controlling broker for XMPP-Grid Platforms such as Enforcement Points, Policy Servers, CMDBs, and Sensors, using a publish-subscribe-search model of information exchange and lookup. By increasing the ability of XMPP-Grid Platforms to learn about and respond to security incident reports and other security-relevant information, XMPP-Grid can improve the timeliness and utility of the security system. However, this

integrated security system can also be exploited by attackers if they can compromise it. Therefore, strong security protections for XMPP-Grid are essential.

As XMPP is the core of this document, the security considerations of [RFC6120] applies. In addition, as XMPP-Grid defines a specific instance, this section provides a security analysis of the XMPP-Grid data transfer protocol and the architectural elements that employ it, specifically with respect to their use of this protocol. Three subsections define the trust model (which elements are trusted to do what), the threat model (attacks that can be mounted on the system), and the countermeasures (ways to address or mitigate the threats previously identified).

8.1. Trust Model

The first step in analyzing the security of the XMPP-Grid transport protocol is to describe the trust model, listing what each architectural element is trusted to do. The items listed here are assumptions, but provisions are made in the Threat Model and Countermeasures sections for elements that fail to perform as they were trusted to do.

8.1.1. Network

The network used to carry XMPP-Grid messages (i.e., the underlying network transport layer over which XMPP runs) is trusted to:

- Perform best effort delivery of network traffic

The network used to carry XMPP-Grid messages is not expected (trusted) to:

- Provide confidentiality or integrity protection for messages sent over it
- Provide timely or reliable service

8.1.2. XMPP-Grid Platforms

Authorized XMPP-Grid Platforms are trusted to:

- Preserve the confidentiality of sensitive data retrieved via the XMPP-Grid Controller

8.1.3. XMPP-Grid Controller

The XMPP-Grid Controller (including its associated Broker) is trusted to:

- Broker requests for data and enforce authorization of access to this data throughout its lifecycle
- Perform service requests in a timely and accurate manner
- Create and maintain accurate operational attributes
- Only reveal data to and accept service requests from authorized parties
- Preserve the integrity (and confidentiality against unauthorized parties) of the data flowing through it.

The XMPP-Grid Controller is not expected (trusted) to:

- Verify the truth (correctness) of data

8.1.4. Certification Authority

To allow XMPP-Grid Platforms to mutually authenticate with XMPP-Grid Controllers, it is expected that a Certification Authority (CA) is employed to issue certificates. Such a CA (or each CA, if there are several) is trusted to:

- Ensure that only proper certificates are issued and that all certificates are issued in accordance with the CA's policies
- Revoke certificates previously issued when necessary
- Regularly and securely distribute certificate revocation information
- Promptly detect and report any violations of this trust so that they can be handled

The CA is not expected (trusted) to:

- Issue certificates that go beyond the XMPP-Grid needs or other constraints imposed by a relying party.

8.2. Threat Model

To secure the XMPP-Grid data transfer protocol and the architectural elements that implement it, this section identifies the attacks that can be mounted against the protocol and elements.

8.2.1. Network Attacks

A variety of attacks can be mounted using the network. For the purposes of this subsection the phrase "network traffic" can be taken to mean messages and/or parts of messages. Any of these attacks can be mounted by network elements, by parties who control network elements, and (in many cases) by parties who control network-attached devices.

- Network traffic can be passively monitored to glean information from any unencrypted traffic
- Even if all traffic is encrypted, valuable information can be gained by traffic analysis (volume, timing, source and destination addresses, etc.)
- Network traffic can be modified in transit
- Previously transmitted network traffic can be replayed
- New network traffic can be added
- Network traffic can be blocked, perhaps selectively
- A "Man In The Middle" (MITM) attack can be mounted where an attacker interposes itself between two communicating parties and poses as the other end to either party or impersonates the other end to either or both parties
- Undesired network traffic can be sent in an effort to overload an architectural component, thus mounting a denial of service attack

8.2.2. XMPP-Grid Platforms

An unauthorized XMPP-Grid Platform (one which is not recognized by the XMPP-Grid Controller or is recognized but not authorized to perform any actions) cannot mount any attacks other than those listed in the Network Attacks section above.

An authorized XMPP-Grid Platform, on the other hand, can mount many attacks. These attacks might occur because the XMPP-Grid Platform is controlled by a malicious, careless, or incompetent party (whether

because its owner is malicious, careless, or incompetent or because the XMPP-Grid Platform has been compromised and is now controlled by a party other than its owner). They might also occur because the XMPP-Grid Platform is running malicious software; because the XMPP-Grid Platform is running buggy software (which can fail in a state that floods the network with traffic); or because the XMPP-Grid Platform has been configured improperly. From a security standpoint, it generally makes no difference why an attack is initiated. The same countermeasures can be employed in any case.

Here is a list of attacks that can be mounted by an authorized XMPP-Grid Platform:

- Cause many false alarms or otherwise overload the XMPP-Grid Controller or other elements in the network security system (including human administrators) leading to a denial of service or disabling parts of the network security system

- Omit important actions (such as posting incriminating data), resulting in incorrect access

- Use confidential information obtained from the XMPP-Grid Controller to enable further attacks (such as using endpoint health check results to exploit vulnerable endpoints)

- Advertise data crafted to exploit vulnerabilities in the XMPP-Grid Controller or in other XMPP-Grid Platforms, with a goal of compromising those systems

- Issue a search request or set up a subscription that matches an enormous result, leading to resource exhaustion on the XMPP-Grid Controller, the publishing XMPP-Grid Platform, and/or the network

- Establish a communication channel using another XMPP-Grid Platform's session-id

- Advertise false data that leads to incorrect (e.g., potentially attacker-controlled or -induced) behavior of XMPP-Grid Platforms, by virtue of applying correct procdeures to the falsified input.

Dependencies of or vulnerabilities of authorized XMPP-Grid Platforms can be exploited to effect these attacks. Another way to effect these attacks is to gain the ability to impersonate an XMPP-Grid Platform (through theft of the XMPP-Grid Platform's identity credentials or through other means). Even a clock skew between the XMPP-Grid Platform and XMPP-Grid Controller can cause problems if the XMPP-Grid Platform assumes that old XMPP-Grid Platform data should be ignored.

8.2.3. XMPP-Grid Controllers

An unauthorized XMPP-Grid Controller (one which is not trusted by XMPP-Grid Platforms) cannot mount any attacks other than those listed in the Network Attacks section above.

An authorized XMPP-Grid Controller can mount many attacks. Similar to the XMPP-Grid Platform case described above, these attacks might occur because the XMPP-Grid Controller is controlled by a malicious, careless, or incompetent party (either an XMPP-Grid Controller administrator or an attacker who has seized control of the XMPP-Grid Controller). They might also occur because the XMPP-Grid Controller is running malicious software, because the XMPP-Grid Controller is running buggy software (which can fail in a state that corrupts data or floods the network with traffic), or because the XMPP-Grid Controller has been configured improperly.

All of the attacks listed for XMPP-Grid Platform above can be mounted by the XMPP-Grid Controller. Detection of these attacks will be more difficult since the XMPP-Grid Controller can create false operational attributes and/or logs that imply some other party created any bad data.

Additional XMPP-Grid Controller attacks can include:

- Expose different data to different XMPP-Grid Platforms to mislead investigators or cause inconsistent behavior
- Mount an even more effective denial of service attack than a single XMPP-Grid Platform could; some mechanisms include inducing the many platforms to perform the same operation in an amplification-style attack, completely refusing to pass any traffic at all, or sending floods of traffic to (certain) platforms or other targets.
- Obtain and cache XMPP-Grid Platform credentials so they can be used to impersonate XMPP-Grid Platforms even after a breach of the XMPP-Grid Controller is repaired. Some SASL mechanisms (including the mandatory-to-implement SCRAM and EXTERNAL with TLS mutual certificate-based authentication) do not admit this class of attack, but others (such as PLAIN) are susceptible.
- Obtain and cache XMPP-Grid Controller administrator credentials so they can be used to regain control of the XMPP-Grid Controller after the breach of the XMPP-Grid Controller is repaired.
- Eavesdrop, inject or modify the data being transferred between provider and consumer

Dependencies of or vulnerabilities of the XMPP-Grid Controller can be exploited to obtain control of the XMPP-Grid Controller and effect these attacks.

8.2.4. Certification Authority

A Certification Authority trusted to issue certificates for the XMPP-Grid Controller and/or XMPP-Grid Platforms can mount several attacks:

- Issue certificates for unauthorized parties, enabling them to impersonate authorized parties such as the XMPP-Grid Controller or an XMPP-Grid Platform. This can lead to all the threats that can be mounted by the certificate's subject.

- Issue certificates without following all of the CA's policies. Because this can result in issuing certificates that can be used to impersonate authorized parties, this can lead to all the threats that can be mounted by the certificate's subject.

- Fail to revoke previously issued certificates that need to be revoked. This can lead to undetected impersonation of the certificate's subject or failure to revoke authorization of the subject, and therefore can lead to all of the threats that can be mounted by that subject.

- Fail to regularly and securely distribute certificate revocation information. This can cause a relying party to accept a revoked certificate, leading to undetected impersonation of the certificate's subject or failure to revoke authorization of the subject, and therefore can lead to all of the threats that can be mounted by that subject. It can also cause a relying party to refuse to proceed with a transaction because timely revocation information is not available, even though the transaction should be permitted to proceed.

- Allow the CA's private key to be revealed to an unauthorized party. This can lead to all the threats above. Even worse, the actions taken with the private key will not be known to the CA.

- Fail to promptly detect and report errors and violations of trust so that relying parties can be promptly notified. This can cause the threats listed earlier in this section to persist longer than necessary, leading to many knock-on effects.

8.3. Countermeasures

Below are countermeasures for specific attack scenarios to the XMPP-Grid infrastructure.

8.3.1. Securing the XMPP-Grid Data Transfer Protocol

To address network attacks, the XMPP-Grid data transfer protocol described in this document requires that the XMPP-Grid messages MUST be carried over TLS (minimally TLS 1.2 and preferrably TLS 1.3 [RFC8446]) as described in [RFC6120] and updated by [RFC7590]. The XMPP-Grid Controller and XMPP-Grid Platforms SHOULD mutually authenticate. The XMPP-Grid Platform MUST verify the XMPP-Grid Controller's certificate and determine whether the XMPP-Grid Controller is trusted by this XMPP-Grid Platform before completing the TLS handshake. To ensure interoperability, implementations MUST implement at least one of either the SASL EXTERNAL mechanism [RFC4422] or the SASL SCRAM mechanism. When using the SASL SCRAM mechanism, the SCRAM-SHA-256-PLUS variant SHOULD be preferred over the SCRAM-SHA-256 variant; and SHA-256 variants [RFC7677] SHOULD be preferred over SHA-1 variants [RFC5802]). XMPP-Grid Platforms and XMPP-Grid Controllers using certificate-based authentication SHOULD each verify the revocation status of the other party's certificate. The selection of which XMPP-Grid Platform authentication technique to use in any particular deployment is left to the administrator.

These protocol security measures provide protection against all the network attacks listed in the above document section except denial of service attacks. If protection against these denial of service attacks is desired, ingress filtering, rate limiting per source IP address, and other denial of service mitigation measures can be employed. In addition, an XMPP-Grid Controller MAY automatically disable a misbehaving XMPP-Grid Platform.

8.3.2. Securing XMPP-Grid Platforms

XMPP-Grid Platforms can be deployed in locations that are susceptible to physical attacks. Physical security measures can be taken to avoid compromise of XMPP-Grid Platforms, but these are not always practical or completely effective. An alternative measure is to configure the XMPP-Grid Controller to provide read-only access for such systems. The XMPP-Grid Controller SHOULD also include a full authorization model so that individual XMPP-Grid Platforms can be configured to have only the privileges that they need. The XMPP-Grid Controller MAY provide functional templates so that the administrator can configure a specific XMPP-Grid Platform as a DHCP [RFC2131] server and authorize only the operations and metadata types needed by a DHCP server to be permitted for that XMPP-Grid Platform. These

techniques can reduce the negative impacts of a compromised XMPP-Grid Platform without diminishing the utility of the overall system.

To handle attacks within the bounds of this authorization model, the XMPP-Grid Controller MAY also include rate limits and alerts for unusual XMPP-Grid Platform behavior. XMPP-Grid Controllers SHOULD make it easy to revoke an XMPP-Grid Platform's authorization when necessary. The XMPP-Grid Controller SHOULD include auditable logs of XMPP-Grid Platform activities.

To avoid compromise of XMPP-Grid Platform, XMPP-Grid Platform SHOULD be hardened against attack and minimized to reduce their attack surface. They should be well managed to minimize vulnerabilities in the underlying platform and in systems upon which the XMPP-Grid Platform depends. Personnel with administrative access should be carefully screened and monitored to detect problems as soon as possible.

8.3.3. Securing XMPP-Grid Controllers

Because of the serious consequences of XMPP-Grid Controller compromise, XMPP-Grid Controllers need to be especially well hardened against attack and minimized to reduce their attack surface. They need to be well managed to minimize vulnerabilities in the underlying platform and in systems upon which the XMPP-Grid Controller depends. Network security measures such as firewalls or intrusion detection systems can be used to monitor and limit traffic to and from the XMPP-Grid Controller. Personnel with administrative access ought to be carefully screened and monitored to detect problems as soon as possible. Administrators SHOULD NOT use password-based authentication but SHOULD instead use non-reusable credentials and multi-factor authentication (where available). Physical security measures ought to be employed to prevent physical attacks on XMPP-Grid Controllers.

To ease detection of XMPP-Grid Controller compromise should it occur, XMPP-Grid Controller behavior should be monitored to detect unusual behavior (such as a reboot, a large increase in traffic, or different views of an information repository for similar XMPP-Grid Platforms). It is a matter of local policy whether XMPP-Grid Platforms log and/or notify administrators when peculiar XMPP-Grid Controller behavior is detected, and whether read-only audit logs of security-relevant information (especially administrative actions) are maintained; however, such behavior is encouraged to aid in forensic analysis. Furthermore, if compromise of an XMPP-Grid Controller is detected, a careful analysis should be performed and any reusable credentials that can have been compromised should be reissued.

To address the potential for the XMPP-Grid controller to eavesdrop, modify or inject data, it would be desirable to deploy end-to-end encryption between the provider and the consumer(s). Unfortunately, because there is no standardized method for encryption of one-to-many messages within XMPP, techniques for enforcing end-to-end encryption are out of scope for this specification.

8.3.4. Broker Access Models for Topics

The XMPP publish-subscribe specification [XEP-0060] defines five access models for subscribing to Topics at a Broker: open, presence, roster, authorize, and whitelist. The first model allows uncontrolled access and the next two models are appropriate only in instant-messaging applications. Therefore, a Broker SHOULD support only the authorize model (under which the Topic owner needs to approve all subscription requests and only subscribers can retrieve data items) and the whitelist model (under which only preconfigured Platforms can subscribe or retrieve data items). In order to ease the deployment burden, subscription approvals and whitelist management can be automated (e.g, the Topic "owner" can be a policy server). The choice between "authorize" and "whitelist" as the default access model is a matter for local service policy.

8.3.5. Limit on Search Result Size

While XMPP-Grid is designed for high scalability to 100,000s of Platforms, an XMPP-Grid Controller MAY establish a limit to the amount of data it is willing to return in search or subscription results. Platforms could use [XEP-0059] to restrict the size of the result sets the Controller returns in search or subscription results or topics' service discovery. This mitigates the threat of an XMPP-Grid Platform causing resource exhaustion by issuing a search or subscription that leads to an enormous result.

8.3.6. Securing the Certification Authority

As noted above, compromise of a Certification Authority (CA) trusted to issue certificates for the XMPP-Grid Controller and/or XMPP-Grid Platforms is a major security breach. Many guidelines for proper CA security have been developed: the CA/Browser Forum's Baseline Requirements, the AICPA/CICA Trust Service Principles, the IETF's Certificate Transparency [RFC6962] etc. The CA operator and relying parties should agree on an appropriately rigorous security practices to be used.

Even with the most rigorous security practices, a CA can be compromised. If this compromise is detected quickly, relying parties can remove the CA from their list of trusted CAs, and other CAs can

revoke any certificates issued to the CA. However, CA compromise may go undetected for some time, and there's always the possibility that a CA is being operated improperly or in a manner that is not in the interests of the relying parties. For this reason, relying parties may wish to "pin" a small number of particularly critical certificates (such as the certificate for the XMPP-Grid Controller). Once a certificate has been pinned, the relying party will not accept another certificate in its place unless the Administrator explicitly commands it to do so. This does not mean that the relying party will not check the revocation status of pinned certificates. However, the Administrator can still be consulted if a pinned certificate is revoked, since the CA and revocation process are not completely trusted. By "pinning" one or a small set of certificates, the relying party has the effective XMPP-Grid Controller(s) authorized to connect to.

8.3.7. End-to-End Encryption of Messages

Because it is expected that there will be a relatively large number of Consumers for every Topic, for purposes of content discovery and scaling this document specifies a "one-to-many" communications pattern using the XMPP Publish-Subscribe extension. Unfortunately, there is no standardized technology for end-to-end encryption of one-to-many messages in XMPP. This implies that messages can be subject to eavesdropping, data injection, and data modification attacks within a Broker or Controller. If it is necessary to mitigate against such attacks, implementers would need to select a messaging pattern other than [XEP-0060], most likely the basic "instant messaging" pattern specified in [RFC6121] with a suitable XMPP extension for end-to-end encryption (such as [RFC3923] or a more modern method such as [XEP-0384]). The description of such an approach is out of scope for this document.

8.4. Summary

XMPP-Grid's considerable value as a broker for security-sensitive data exchange distribution also makes the protocol and the network security elements that implement it a target for attack. Therefore, strong security has been included as a basic design principle within the XMPP-Grid design process.

The XMPP-Grid data transfer protocol provides strong protection against a variety of different attacks. In the event that an XMPP-Grid Platform or XMPP-Grid Controller is compromised, the effects of this compromise have been reduced and limited with the recommended role-based authorization model and other provisions, and best practices for managing and protecting XMPP-Grid systems have been described. Taken together, these measures should provide protection

commensurate with the threat to XMPP-Grid systems, thus ensuring that they fulfill their promise as a network security clearing-house.

9. Privacy Considerations

XMPP-Grid Platforms can publish information about endpoint health, network access, events (which can include information about what services an endpoint is accessing), roles and capabilities, and the identity of the end user operating the endpoint. Any of this published information can be queried by other XMPP-Grid Platforms and could potentially be used to correlate network activity to a particular end user.

Dynamic and static information brokered by an XMPP-Grid Controller, ostensibly for purposes of correlation by XMPP-Grid Platforms for intrusion detection, could be misused by a broader set of XMPP-Grid Platforms which hitherto have been performing specific roles with strict well-defined separation of duties.

Care needs to be taken by deployers of XMPP-Grid to ensure that the information published by XMPP-Grid Platforms does not violate agreements with end users or local and regional laws and regulations. This can be accomplished either by configuring XMPP-Grid Platforms to not publish certain information or by restricting access to sensitive data to trusted XMPP-Grid Platforms. That is, the easiest means to ensure privacy or protect sensitive data, is to omit or not share it at all.

Similarly, care must be taken by deployers and XMPP-Grid Controller implementations as they implement the appropriate auditing tools. In particular, any information, such as logs must be sensitive to the type of information stored to ensure that the information does not violate privacy and agreements with end users or local and regional laws and regulations.

Another consideration for deployers is to enable end-to-end encryption to ensure the data is protected from the data layer to data layer and thus protect it from the transport layer. The means to achieve end-to-end encrpytion is beyond the scope of this document.

10. Operations and Management Considerations

In order to facilitate the management of Providers and the onboarding of Consumers, it is helpful to generate the following ahead of time:

- Agreement between the operators of Provider services and the implementers of Consumer software regarding identifiers for common

Topics (e.g., these could be registered with the XMPP Software Foundation's registry of well-known nodes for service discovery and publish-subscribe located at <https://xmpp.org/registrar/nodes.html>).

- Security certificates (including appropriate certificate chains) for Controllers, including identification of any Providers associated with the Controllers (which might be located at subdomains).

- Consistent and secure access control policies for publishing and subscribing to Topics.

These matters are out of scope for this document but ought to be addressed by the XMPP-Grid community.

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12.1. Normative References

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JSON representation of IODEF
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Abstract

RFC5070-bis provides XML-based data representation on incident information, but the use of the IODEF data model is not limited to XML. JSON representation is sometimes preferred since it is easy to handle from certain programming environments. This draft represents the IODEF data model in JSON. Note that this 00 version draft is prepared for the purpose of encouraging discussion on the need for JSON representation.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

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This Internet-Draft will expire on December 10, 2016.

Table of Contents

1. Introduction

RFC5070-bis defines an data model for sharing incident information. It facilitates automated exchange of information among parties over networks. The data model can be implemented in a form of XML, but it is not always suitable for implementation. JSON-based representation is often useful.

Therefore, in this document, we provide a means to represent IODEF data model in JSON.

1.1. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

2. The IODEF Information Model in JSON

The data model of IODEF is defined in RFC5070-bis, and this section represent the elements of the data model in JSON.

2.1. IODEF-Document Class

The IODEF-Document class is the top level class in the IODEF data model. All IODEF documents are an instance of this class. This class provides seven parameters: version, lang, format-id, private-enum-name, private-enum-id, Incident, and AdditionalData.

The example below represents how to describe this class in JSON.

```
"IODEF-Document": {
  "version": "1.0",
  "lang": "en",
  "format-id": "RFC5070",
  "Incident": [
     <<< omitted >>>
  ]
}
```

Figure 1: IODEF-Document Class in JSON

2.2. Incident Class

The Incident class describes commonly exchanged information when reporting or sharing derived analysis from security incidents.

The example below represents how to describe this class in JSON.

```
"Incident": {
  "purpose": "reporting",
  "lang": "en",
  "restriction": "green",
  "IncidentID": {<<< omitted >>>},
  "RelatedActivity": [<<< omitted >>>],
  "GenerationTime": "2015-10-02T11:18:00-05:00",
  "Description": ["Incident class description field"],
  "Assessment": [<<< omitted >>>],
  "Methods": [<<< omitted >>>],
  "Contact": [<<< omitted >>>]
  "EventData": [<<< omitted >>>],
  "IndicatorList": [<<< omitted >>>] # check whether it can exist once or more
  "History": {<<< omitted >>>},
  "AdditionalData": [<<< omitted >>>],
}
```

Figure 2: Incident Class in JSON

2.3. Common Attributes

There are a number of recurring attributes used in the information model. They are documented in this section.

2.3.1. restriction Attribute

RFC5070-bis defines the restriction Attribute as one of common attributes. It is defined as below:

```
"restriction":{"enum": ["public", "partner", "need-to-know",
"private", "default", "white", "green", "amber", "red", "ext-value"]}
```

2.3.2. observable-id Attribute

RFC5070-bis defines the observable-id attribute as one of common attributes. The value of this attribute is a unique identifier in the scope of the document.It is defined as below:

```
"observable-id": {"type": "string"},
```

Figure 3: observable-id in JSON

2.4. IncidentID Class

The example below represents how to describe this class in JSON.

```
"IncidentID": {
  "id": "nict20150518-0001",
  "name": "NICT_cert",
  "instance": "cyberlab"
}
```

Figure 4: IncidentID Class in JSON

2.5. AlternativeID Class

The example below represents how to describe this class in JSON.

```
"AltervativeID": {
  "restriction": "private",
  "IncidentID": [<<<omitted>>>]
}
```

Figure 5: AlternativeID Class in JSON

2.6. RelatedActivity Class

The example below represents how to describe this class in JSON.

```
"RelatedActivity": {
  "restriction": "private",
  "ThreatActor": [
    {
      "ThreatActorID": "TA-12-AGGRESSIVE-BUTTERFLY",
      "Description": "Aggressive Butterfly"
    }
  ],
  "Campaign": [
    {
      "CampaignID": "C-2015-59405",
      "Description": "Orange Giraffe"
    }
  ]
}
```

Figure 6: RelatedActivity Class in JSON

2.7. ThreatActor Class

The example below represents how to describe this class in JSON.

```
"ThreatActor": {
  "ThreatActorID": "TA-12-AGGRESSIVE-BUTTERFLY",
  "Description": "Aggressive Butterfly"
}
```

Figure 7: ThreatActor Class in JSON

2.8. Campaign Class

The example below represents how to describe this class in JSON.

```
"Campaign": {
  "CampaignID": "C-2015-59405",
  "Description": "Orange Giraffe"
}
```

Figure 8: Campaign Class in JSON

2.9. Contact Class

The example below represents how to describe this class in JSON.

```
"Contact": {
  "type": "organization",
  "role": "creator",
  "ContactName": "CSIRT for example.com",
  "email": {
    "emailTo": "contact@csirt.example.com"
  }
}
```

Figure 9: Contact Class in JSON

2.9.1. RegistryHandle Class

The example below represents how to describe this class in JSON.

```
"RegistryHandle": {
  "RegistryHandleName": "MyAPNIC",
  "registry": "apnic",
}
```

Figure 10: RegistryHandle Class in JSON

2.9.2. PostalAddress Class

The example below represents how to describe this class in JSON.

```
"PostalAddress": {
  "type": "mailing",
  "PAddress": "184-8795",
  "Description": "4-2-1 Nukui-Kitamachi Koganei Tokyo, Japan"
},
```

Figure 11: PostalAddress Class in JSON

2.9.3. Email Class

The example below represents how to describe this class in JSON.

```
"Email": {
  "emailTo": "contact@csirt.example.com"
},
```

Figure 12: Email Class in JSON

2.9.4. Telephone Class

The example below represents how to describe this class in JSON.

```
"Telephone": {
  "TelephoneNumber": "+81423275862"
},
```

Figure 13: Telephone Class in JSON

2.10. Discovery Class

The example below represents how to describe this class in JSON.

```
"Discovery": {
  "DetectionPattern": {
    "Application": {
      "Description": "Microsoft Win"
    }
  }
}
```

Figure 14: Discovery Class in JSON

2.10.1. DetectionPattern Class

The example below represents how to describe this class in JSON.

```
"DetectionPattern": {
  "Application": {
    "Description": "Microsoft Win"
  }
}
```

Figure 15: DetectionPattern Class in JSON

2.11. Method Class

The example below represents how to describe this class in JSON.

```
"Method": {
  "Vulnerability": {}
}
```

Figure 16: Method Class in JSON

2.11.1. Reference Class

The example below represents how to describe this class in JSON.

```
"Reference":{
  "URL":"http://www.nict.go.jp"
}
```

Figure 17: Reference Class in JSON

2.12. Assessment Class

The example below represents how to describe this class in JSON.

```
"Assessment": {
  "BusinessImpact": {
    "type": "breach-proprietary"
  }
}
```

Figure 18: Assessment Class in JSON

2.12.1. SystemImpact Class

The example below represents how to describe this class in JSON.

```
"SystemImpact":{
  "severity":"low",
  "type":"unknown"
},
```

Figure 19: SystemImpact Class in JSON

2.12.2. BusinessImpact Class

The example below represents how to describe this class in JSON.

```
"BusinessImpact": {
  "type": "breach-proprietary"
}
```

Figure 20: BusinessImpact Class in JSON

2.12.3. TimeImpact Class

The example below represents how to describe this class in JSON.

```
"TimeImpact":{
  "value":"5 hours",
  "metric":"elapsed"
}
```

Figure 21: TimeImpact Class in JSON

2.12.4. MonetaryImpact Class

The example below represents how to describe this class in JSON.

```
"MonetaryImpact":{}
```

Figure 22: MonetaryImpact Class in JSON

2.12.5. Confidence Class

The example below represents how to describe this class in JSON.

```
                        "Confidence": {
                          "rating": "medium"
                        }
```

Figure 23: Confidence Class in JSON

2.13. History Class

The example below represents how to describe this class in JSON.

```
              "History": {
                "HistoryItem": {
                  "DateTime": "2015-10-15T11:18:00-05:00",
                  "action": "investigate"
                }
              },
```

Figure 24: History Class in JSON

2.13.1. HistoryItem Class

The example below represents how to describe this class in JSON.

```
               "HistoryItem": {
                 "DateTime": "2015-10-15T11:18:00-05:00",
                 "action": "investigate"
               }
```

Figure 25: HistoryItem Class in JSON

2.14. EventData Class

The example below represents how to describe this class in JSON.

```
"EventData": {
  "ReportTime": "2016-06-01 18:05:33",
  "System": {
    "category": "source",
    "Node": {
      "Address": {
        "category": "ipv4-addr",
        "AddressValue": "192.228.139.118"
      },
      "Location": "OrgID=7"
    },
    "Service": {
      "ip-protocol": 6,
      "Port": 49183
    }
},
```

Figure 26: EventData Class in JSON

2.15. Expectation Class

The example below represents how to describe this class in JSON.

```
"Expectation": {
  "action": "investigate"
},
```

Figure 27: Expectation Class in JSON

2.16. System Class

The example below represents how to describe this class in JSON.

```
"System": {
  "category": "source",
  "Node": {
    "Address": {
      "category": "ipv4-addr",
      "AddressValue": "192.228.139.118"
    },
    "Location": "OrgID=7"
  },
  "Service": {
    "ip-protocol": 6,
    "Port": 49183
  }
```

Figure 28: System Class in JSON

2.17. Node Class

The example below represents how to describe this class in JSON.

```
"Node": {
  "Address": {
    "category": "ipv4-addr",
    "AddressValue": "192.228.139.118"
  },
```

Figure 29: Node Class in JSON

2.17.1. Address Class

The example below represents how to describe this class in JSON.

```
"Address": {
  "category": "ipv4-addr",
  "AddressValue": "192.228.139.118"
},
```

Figure 30: Address Class in JSON

2.17.2. NodeRole Class

The example below represents how to describe this class in JSON.

```
"NodeRole": {
  "category": "client"
},
```

Figure 31: NodeRole Class in JSON

2.17.3. Counter Class

The example below represents how to describe this class in JSON.

```
"Counter": {
  "value": "3",
  "type": "count",
  "unit": "packet"
}
```

Figure 32: Counter Class in JSON

2.18. DomainData Class

The example below represents how to describe this class in JSON.

```
"DomainData": {
  "system-status": "innocent-hacked",
  "domain-status": "assignedAndInactive",
  "Name": "temp1.nict.go.jp"
},
```

Figure 33: DomainData Class in JSON

2.18.1. Nameserver Class

The example below represents how to describe this class in JSON.

```
"NameServers": {
  "Server": "vgw.nict.go.jp",
  "Address": {
    "AddressValue": "133.243.18.5",
    "category": "ipv4-addr"
  }
}
```

Figure 34: Nameserver Class in JSON

2.18.2. DomainContacts Class

The example below represents how to describe this class in JSON.

```
"DomainContacts": {
  "Contact": {
    "role": "user",
    "type": "organization"
  }
}
```

Figure 35: DomainContacts Class in JSON

2.19. Service Class

The example below represents how to describe this class in JSON.

```
"Service": {
  "ServiceName": {
    "Description": "It seems to be a scan from an infected machine."
  },
  "ip-protocol": 6,
  "Port": 49183
}
```

Figure 36: Service Class in JSON

2.19.1. ServiceName Class

The example below represents how to describe this class in JSON.

```
"ServiceName": {
  "Description": "It seems to be a scan from an infected machine."
},
```

Figure 37: ServiceName Class in JSON

2.19.2. ApplicationHeader Class

The example below represents how to describe this class in JSON.

```
"ApplicationHeader": {}
```

Figure 38: ApplicationHeader Class in JSON

2.20. EmailData Class

The example below represents how to describe this class in JSON.

```
"EmailData":{}
```

Figure 39: EmailData Class in JSON

2.21. Record Class

The example below represents how to describe this class in JSON.

```
"Record": {
  "RecordPattern": {
    "type": "regex",
    "value": "[0-9][A-Z]"
  },
  "RecordItem": {}
},
```

Figure 40: Record Class in JSON

2.21.1. RecordPattern Class

The example below represents how to describe this class in JSON.

```
"RecordPattern": {
  "type": "regex",
  "value": "[0-9][A-Z]"
},
```

Figure 41: RecordPattern Class in JSON

2.22. WindowsRegistryKeysModified Class

The example below represents how to describe this class in JSON.

```
"WindowsRegistryKeysModified": {
  "Key": {
    "KeyValue": "xxxxxxxxxxxxxxxxxxxxxxx",
    "KeyName":"HKEY_LOCAL_MACHINExxxxxxx",
  }
}
```

Figure 42: WindowsRegistryKeysModified Class in JSON

2.22.1. Key Class

The example below represents how to describe this class in JSON.

```
"Key": {
  "KeyValue": "xxxxxxxxxxxxxxxxxxxxxxx",
  "KeyName":"HKEY_LOCAL_MACHINExxxxxxx",
}
```

Figure 43: Key Class in JSON

2.23. CertificateData Class

The example below represents how to describe this class in JSON.

```
           "CertificateData": {
             "Certificate": {
               "X509Data": {
                 "X509IssuerSerial": {
                   "X509IssuerName": "CN=TAMURA Kent, OU=TRL, O=IBM, L=Yamato-s
hi, ST=Kanagawa, C=JP",
                   "X509SerialNumber": "12345678"
                 },
                 "X509SKI": "31d97bd7"
               }
             }
           }
```

Figure 44: CertificateData Class in JSON

2.23.1. Certificate Class

The example below represents how to describe this class in JSON.

```
             "Certificate": {
               "X509Data": {
                 "X509IssuerSerial": {
                   "X509IssuerName": "CN=TAMURA Kent, OU=TRL, O=IBM, L=Yamato-s
hi, ST=Kanagawa, C=JP",
                   "X509SerialNumber": "12345678"
                 },
                 "X509SKI": "31d97bd7"
               }
             }
```

Figure 45: Certificate Class in JSON

2.24. FileData Class

The example below represents how to describe this class in JSON.

```
                           "FileData": {
                             "File": {
                               "FileName": "dummy.exe"
                             }
                           },
```

Figure 46: FileData Class in JSON

2.24.1. File Class

The example below represents how to describe this class in JSON.

```
"File": {
  "FileName": "dummy.exe"
}
```

Figure 47: File Class in JSON

2.25. HashData Class

The example below represents how to describe this class in JSON.

```
"HashData": {
  "scope": "file-contents",
  "Hash": {
    "DigestMethod": "http://www.w3.org/2000/09/xmldsig#sha1",
    "DigestValue": "xxxxxxxxxxx"
  }
}
```

Figure 48: HashData Class in JSON

2.25.1. Hash Class

The example below represents how to describe this class in JSON.

```
"Hash": {
  "DigestMethod": "http://www.w3.org/2000/09/xmldsig#sha1",
  "DigestValue": "xxxxxxxxxxx"
}
```

Figure 49: Hash Class in JSON

2.25.2. FuzzyHash Class

The example below represents how to describe this class in JSON.

```
"FuzzyHash": {
  "FuzzyHashValue": {}
}
```

Figure 50: FuzzyHash Class in JSON

2.26. SignatureData Class

The example below represents how to describe this class in JSON.

```
"SignatureData": {
  "Signature": "xxxxxxxx"
}
```

Figure 51: SignatureData Class in JSON

2.27. Indicator Class

The example below represents how to describe this class in JSON.

```
"Indicator": {
  "IndicatorID": {
    "id": "G90823490",
    "name": "csirt.example.com",
    "version": "1"
  },
  "Description": "C2 domains",
  "StartTime": "2014-12-02T11:18:00-05:00",
  "Observable": {
    "BulkObservable": {
      "type": "fqdn"
    },
    "BulkObservableList": [
      "kj290023j09r34.example.com",
      "09ijk23jfj0k8.example.net",
      "klknjwfjiowjefr923.example.org",
      "oimireik79msd.example.org"
    ]
  }
}
```

Figure 52: Indicator Class in JSON

2.27.1. IndicatorID Class

The example below represents how to describe this class in JSON.

```
"IndicatorID": {
  "id": "G90823490",
  "name": "csirt.example.com",
  "version": "1"
},
```

Figure 53: IndicatorID Class in JSON

2.27.2. AlternativeIndicatorID Class

The example below represents how to describe this class in JSON.

```
"AlternativeIndicatorID": {
  "IndicatorReference": {
    "uid-ref": "xxxxx"
  }
},
```

Figure 54: AlternativeIndicatorID Class in JSON

2.27.3. Observable Class

The example below represents how to describe this class in JSON.

```
"Observable": {
  "BulkObservable": {
    "type": "fqdn"
  },
  "BulkObservableList": [
    "kj290023j09r34.example.com",
    "09ijk23jfj0k8.example.net",
    "klknjwfjiowjefr923.example.org",
    "oimireik79msd.example.org"
  ]
}
```

Figure 55: Observable Class in JSON

2.27.4. IndicatorExpression Class

The example below represents how to describe this class in JSON.

```
"IndicatorExpression": {}
```

Figure 56: IndicatorExpression Class in JSON

2.27.5. ObservableReference Class

The example below represents how to describe this class in JSON.

```
"ObservableReference": {
  "uid-ref": "xxxxx"
},
```

Figure 57: ObservableReference Class in JSON

2.27.6. IndicatorReference Class

The example below represents how to describe this class in JSON.

```
"IndicatorReference": {
  "uid-ref": "xxxxx"
}
```

Figure 58: IndicatorReference Class in JSON

2.27.7. AttackPhase Class

The example below represents how to describe this class in JSON.

```
"AttackPhase": {
  "Description": "Currently, the infected host is scanning arbitrary
 hosts to find next targets."
}
```

Figure 59: AttackPhase Class in JSON

3. Notable differences from RFC5070-bis (to be deleted)

- Flow class is deleted, and EventData class now has the instance of System class.
- Record class is deleted, and the link to the Record class are directly connected to RecordData class, which is then renamed to Record class.

4. Examples

This section provides example of IODEF documents. These examples do not represent the full capabilities of the data model or the the only way to encode particular information.

4.1. Minimal Example

A document containing only the mandatory elements and attributes.

```
          {
            "version": "2.0",
            "lang": "en",
            "Incident": [
              {
                "purpose": "reporting",
                "restriction": "private",
                "IncidentID": {
                  "id": 492382,
                  "name": "csirt.example.com"
                },
                "GenerationTime": "2015-07-18T09:00:00-05:00",
                "Contact": [
                  {
                    "type": "organization",
                    "role": "creator",
                    "email": {
                      "emailTo": "contact@csirt.example.com"
                    }
                  }
                ]
              }
            ]
          }
```

Figure 60: JSON representation example 1

4.2. Indicators from a Campaign

An example of C2 domains from a given campaign.

```
{
  "version": "2.0",
  "lang": "en",
  "Incidents": [
    {
      "purpose": "watch",
      "restriction": "green",
      "IncidentID": {
        "id": "897923",
        "name": "csirt.example.com"
      },
      "RelatedActivity": [
        {
          "ThreatActor": [
            {
              "ThreatActorID": "TA-12-AGGRESSIVE-BUTTERFLY",
              "Description": "Aggressive Butterfly"
```

```
            }
          ],
          "Campaign": [
            {
              "CampaignID": "C-2015-59405",
              "Description": "Orange Giraffe"
            }
          ]
        }
      ],
      "GenerationTime": "2015-10-02T11:18:00-05:00",
      "Description": [
        "Summarizes the Indicators of Compromise for the Orange Giraffe campaign
 of the Aggressive Butterfly crime gang."
      ],
      "Assessment": [
        {
          "BusinessImpact": {
            "type": "breach-proprietary"
          }
        }
      ],
      "Contacts": [
        {
          "type": "organization",
          "role": "creator",
          "ContactName": "CSIRT for example.com",
          "Email": {
            "emailTo": "contact@csirt.example.com"
          }
        }
      ],
      "IndicatorList": [
        {
          "IndicatorID": {
            "id": "G90823490",
            "name": "csirt.example.com",
            "version": "1"
          },
          "Description": "C2 domains",
          "StartTime": "2014-12-02T11:18:00-05:00",
          "Observable": {
            "BulkObservable": {
              "type": "fqdn"
            },
            "BulkObservableList": [
              "kj290023j09r34.example.com",
              "09ijk23jfj0k8.example.net",
              "klknjwfjiowjefr923.example.org",
```

```
              "oimireik79msd.example.org"
            ]
          }
        }
      ]
    }
  ]
}
```

Figure 61: JSON representation example 2

5. The IODEF Data Model (JSON Schema)

```
        {
        {
          "$schema": "http://json-schema.org/draft-04/schema#",
          "definitions": {
            "lang": {
              "enum": [
                "en",
                "jp"
              ]
            },
            "restriction": {
              "enum": [
                "public",
                "partner",
                "need-to-know",
                "private",
                "default",
                "white",
                "green",
                "amber",
                "red",
                "ext-value"
              ]
            },
            "URLtype": {
              "type": "string"
            },
            "IDtype": {
              "type": "string"
            },
            "ExtensionType": {
              "type": "object",
              "properties": {
                "name": {
                  "type": "string"
```

```
            },
            "dtype": {
              "enum": [
                "boolean",
                "byte",
                "bytes",
                "character",
                "date-time",
                "ntpstamp",
                "integer",
                "portlist",
                "real",
                "string",
                "file",
                "path",
                "frame",
                "packet",
                "ipv4-packet",
                "ipv6-packet",
                "url",
                "csv",
                "winreg",
                "xml",
                "ext-value"
              ]
            },
            "ext-dtype": {
              "type": "string"
            },
            "meaning": {
              "type": "string"
            },
            "formatid": {
              "type": "string"
            },
            "restriction": {
              "$ref": "#/definitions/restriction"
            },
            "ext-restriction": {
              "type": "string"
            },
            "observable-id": {
              "$ref": "#/definitions/IDtype"
            }
          }
        },
        "SoftwareType": {
          "type": "object",
```

```
                "properties": {
                  "SoftwareReference": {
                    "$ref": "#/definitions/SoftwareReference"
                  },
                  "URL": {
                    "$ref": "#/definitions/URLtype"
                  },
                  "Description": {
                    "type": "string"
                  }
                },
                "required": [],
                "additionalProperties": false
              },
              "SoftwareReference": {
                "type": "object",
                "properties": {
                  "value": {
                    "type": "string"
                  },
                  "spec-name": {
                    "type": "string"
                  },
                  "ext-spec-name": {
                    "type": "string"
                  },
                  "dtype": {
                    "type": "string"
                  },
                  "ext-dtype": {
                    "type": "string"
                  }
                },
                "required": [
                  "spec-name"
                ],
                "additionalProperties": false
              },
              "Incident": {
                "title": "Incident",
                "description": "JSON schema for Incident class",
                "type": "object",
                "properties": {
                  "purpose": {
                    "enum": [
                      "traceback",
                      "mitigation",
                      "reporting",
```

```
        "watch",
        "other",
        "ext-value"
      ]
    },
    "ext-purpose": {
      "type": "string"
    },
    "status": {
      "enum": [
        "blabla"
      ]
    },
    "ext-status": {
      "type": "string"
    },
    "lang": {
      "$ref": "#/definitions/lang"
    },
    "restriction": {
      "$ref": "#/definitions/restriction"
    },
    "ext-restriction": {
      "type": "string"
    },
    "observable-id": {
      "$ref": "#/definitions/IDtype"
    },
    "IncidentID": {
      "$ref": "#/definitions/IncidentID"
    },
    "AlternativeID": {
      "type": "object"
    },
    "RelatedActivity": {
      "type": "array",
      "items": {
        "$ref": "#/definitions/RelatedActivity"
      }
    },
    "DetectTime": {
      "type": "string"
    },
    "StartTime": {
      "type": "string"
    },
    "EndTime": {
      "type": "string"
```

```
    },
    "RecoveryTime": {
      "type": "string"
    },
    "ReportTime": {
      "type": "string"
    },
    "GenerationTime": {
      "type": "string"
    },
    "Description": {
      "type": "array",
      "items": {
        "type": "string"
      }
    },
    "Discovery": {
      "type": "array",
      "items": {
        "$ref": "#/definitions/Discovery"
      }
    },
    "Assessment": {
      "type": "array",
      "items": {
        "$ref": "#/definitions/Assessment"
      }
    },
    "Methods": {
      "type": "array",
      "items": {
        "$ref": "#/definitions/Method"
      }
    },
    "Contacts": {
      "type": "array",
      "items": {
        "$ref": "#/definitions/Contact"
      }
    },
    "EventData": {
      "type": "array",
      "items": {
        "$ref": "#/definitions/EventData"
      }
    },
    "IndicatorList": {
      "type": "array",
```

```
                "items": {
                  "$ref": "#/definitions/Indicator"
                },
              },
              "History": {
                "$ref": "#/definitions/History"
              },
              "AdditionalData": {
                "type": "array",
                "items": {
                  "$ref": "#/definitions/ExtensionType"
                }
              }
            },
            "required": [
              "IncidentID",
              "GenerationTime",
              "Contacts",
              "purpose"
            ],
            "additionalProperties": false
          },
          "IncidentID": {
            "title": "IncidentID",
            "description": "JSON schema for IncidentID class",
            "type": "object",
            "properties": {
              "id": {
                "type": "string"
              },
              "name": {
                "type": "string"
              },
              "instance": {
                "type": "string"
              },
              "restriction": {
                "$ref": "#/definitions/restriction"
              },
              "ext-restriction": {
                "type": "string"
              }
            },
            "required": [
              "name"
            ],
            "additionalProperties": false
          },
```

```
            "RelatedActivity": {
              "properties": {
                "restriction": {
                  "$ref": "#/definitions/restriction"
                },
                "ext-restriction": {
                  "type": "string"
                },
                "IncidentID": {
                  "type": "array",
                  "items": {
                    "$ref": "#/definitions/IncidentID"
                  }
                },
                "URL": {
                  "type": "array",
                  "items": {
                    "$ref": "#/definitions/URLtype"
                  }
                },
                "ThreatActor": {
                  "type": "array",
                  "items": {
                    "$ref": "#/definitions/ThreatActor"
                  }
                },
                "Campaign": {
                  "type": "array",
                  "items": {
                    "$ref": "#/definitions/Campaign"
                  }
                },
                "IndicatorID": {
                  "type": "array",
                  "items": {
                    "$ref": "#/definitions/IndicatorID"
                  }
                },
                "Confidence": {
                  "$ref": "#/definitions/Confidence"
                },
                "Description": {
                  "type": "array",
                  "items": {
                    "type": "string"
                  }
                },
                "AdditionalData": {
```

```
                    "type": "array",
                    "items": {
                      "$ref": "#/definitions/ExtensionType"
                    }
                  }
                },
                "additionalProperties": false
              },
              "ThreatActor": {
                "properties": {
                  "restriction": {
                    "$ref": "#/definitions/restriction"
                  },
                  "ext-restriction": {
                    "type": "string"
                  },
                  "ThreatActorID": {
                    "type": "string"
                  },
                  "Description": {
                    "type": "string"
                  },
                  "URL": {
                    "$ref": "#/definitions/URLtype"
                  },
                  "AdditionalData": {
                    "type": "array",
                    "items": {
                      "$ref": "#/definitions/ExtensionType"
                    }
                  }
                },
                "additionalProperties": false
              },
              "Campaign": {
                "properties": {
                  "restriction": {
                    "$ref": "#/definitions/restriction"
                  },
                  "ext-restriction": {
                    "type": "string"
                  },
                  "CampaignID": {},
                  "URL": {
                    "$ref": "#/definitions/URLtype"
                  },
                  "Description": {
                    "type": "string"
```

```
            },
            "AdditionalData": {
              "type": "array",
              "items": {
                "$ref": "#/definitions/ExtensionType"
              }
            }
          }
        },
        "Contact": {
          "type": "object",
          "properties": {
            "role": {},
            "ext-role": {},
            "type": {},
            "ext-type": {},
            "restriction": {
              "$ref": "#/definitions/restriction"
            },
            "ext-restriction": {
              "type": "string"
            },
            "ContactName": {},
            "ContactTitle": {},
            "Description": {
              "type": "string"
            },
            "RegistryHandle": {},
            "PostalAddress": {},
            "Email": {},
            "Telephone": {
              "$ref": "#/definitions/Telephone"
            },
            "Timezone": {},
            "Contact": {
              "$ref": "#/definitions/Contact"
            },
            "AdditionalData": {
              "type": "array",
              "items": {
                "$ref": "#/definitions/ExtensionType"
              }
            }
          },
          "required": [
            "role",
            "type"
          ],
```

```
      "additionalProperties": false
    },
    "RegistryHandle": {
      "type": "object",
      "properties": {
        "RegistryHandleName": {},
        "registry": {},
        "ext-registry": {}
      },
      "required": [
        "registry"
      ],
      "additionalProperties": false
    },
    "PostalAddress": {
      "type": "object",
      "properties": {
        "type": {
          "type": "string"
        },
        "ext-type": {
          "type": "string"
        },
        "PAddress": {
          "type": "string"
        },
        "Description": {
          "type": "string"
        }
      },
      "required": [
        "PAddress"
      ],
      "additionalProperties": false
    },
    "Email": {
      "type": "object",
      "properties": {
        "type": {},
        "ext-type": {},
        "EmailTo": {},
        "Description": {
          "type": "string"
        }
      },
      "required": [
        "EmailTo"
      ],
```

```
      "additionalProperties": false
    },
    "Telephone": {
      "type": "object",
      "properties": {
        "type": {},
        "ext-type": {},
        "TelephoneNumber": {},
        "Description": {
          "type": "string"
        }
      },
      "required": [
        "TelephoneNumber"
      ],
      "additionalProperties": false
    },
    "Discovery": {
      "type": "object",
      "properties": {
        "source": {},
        "ext-source": {},
        "restriction": {
          "$ref": "#/definitions/restriction"
        },
        "ext-restriction": {
          "type": "string"
        },
        "Description": {
          "type": "string"
        },
        "Contact": {
          "$ref": "#/definitions/Contact"
        },
        "DetectionPattern": {
          "$ref": "#/definitions/DetectionPattern"
        }
      },
      "required": [],
      "additionalProperties": false
    },
    "DetectionPattern": {
      "type": "object",
      "properties": {
        "restriction": {
          "$ref": "#/definitions/restriction"
        },
        "ext-restriction": {
```

```
                  "type": "string"
                },
                "observable-id": {
                  "$ref": "#/definitions/IDtype"
                },
                "Application": {
                  "$ref": "#/definitions/SoftwareType"
                },
                "Description": {
                  "type": "string"
                },
                "DetectionConfiguration": {}
              },
              "required": [
                "Application"
              ],
              "additionalProperties": false
            },
            "Method": {
              "type": "object",
              "properties": {
                "restriction": {
                  "$ref": "#/definitions/restriction"
                },
                "ext-restriction": {
                  "type": "string"
                },
                "References": {
                  "type": "array",
                  "items": {
                    "$ref": "#/definitions/Reference"
                  }
                },
                "Description": {
                  "type": "string"
                },
                "AttackPattern": {},
                "Vulnerability": {},
                "Weakness": {},
                "AdditionalData": {
                  "type": "array",
                  "items": {
                    "$ref": "#/definitions/ExtensionType"
                  }
                }
              },
              "required": [],
              "additionalProperties": false
```

```
            },
            "Reference": {
              "type": "object",
              "properties": {
                "observable-id": {
                  "$ref": "#/definitions/IDtype"
                },
                "ReferenceName": {},
                "URL": {
                  "$ref": "#/definitions/URLtype"
                },
                "Description": {
                  "type": "string"
                }
              },
              "required": [],
              "additionalProperties": false
            },
            "Assessment": {
              "type": "object",
              "properties": {
                "occurrence": {},
                "restriction": {
                  "$ref": "#/definitions/restriction"
                },
                "ext-restriction": {
                  "type": "string"
                },
                "observable-id": {
                  "$ref": "#/definitions/IDtype"
                },
                "IncidentCategory": {},
                "SystemImpact": {
                  "$ref": "#/definitions/SystemImpact"
                },
                "BusinessImpact": {},
                "TimeImpact": {
                  "$ref": "#/definitions/TimeImpact"
                },
                "MonetaryImpact": {
                  "$ref": "#/definitions/MonetaryImpact"
                },
                "IntendedImpact": {},
                "Counter": {
                  "$ref": "#/definitions/Counter"
                },
                "MitigatingFactor": {},
                "Cause": {},
```

```
        "Confidence": {
          "$ref": "#/definitions/Confidence"
        },
        "AdditionalData": {
          "type": "array",
          "items": {
            "$ref": "#/definitions/ExtensionType"
          }
        }
      },
      "required": [],
      "additionalProperties": false
    },
    "SystemImpact": {
      "type": "object",
      "properties": {
        "severity": {},
        "completion": {},
        "type": {},
        "ext-type": {},
        "Description": {
          "type": "string"
        }
      },
      "required": [
        "type"
      ],
      "additionalProperties": false
    },
    "BusinessImpact": {
      "type": "object",
      "properties": {
        "severity": {},
        "ext-severity": {},
        "type": {},
        "ext-type": {},
        "Description": {
          "type": "string"
        }
      },
      "required": [
        "type"
      ],
      "additionalProperties": false
    },
    "TimeImpact": {
      "type": "object",
      "properties": {
```

```
        "value": {},
        "severity": {},
        "metric": {},
        "ext-metric": {},
        "duration": {},
        "ext-duration": {}
      },
      "required": [
        "metric"
      ],
      "additionalProperties": false
    },
    "MonetaryImpact": {
      "type": "object",
      "properties": {
        "MonetaryImpactValue": {},
        "severity": {},
        "currency": {}
      },
      "required": [],
      "additionalProperties": false
    },
    "Confidence": {
      "type": "object",
      "properties": {
        "ConfidenceValue": {},
        "rating": {},
        "ext-rating": {}
      },
      "required": [
        "rating"
      ],
      "additionalProperties": false
    },
    "History": {
      "type": "object",
      "properties": {
        "restriction": {
          "$ref": "#/definitions/restriction"
        },
        "ext-restriction": {
          "type": "string"
        },
        "HistoryItem": {}
      },
      "required": [
        "HistoryItem"
      ],
```

```
      "additionalProperties": false
    },
    "HistoryItem": {
      "type": "object",
      "properties": {
        "action": {},
        "ext-action": {},
        "restriction": {
          "$ref": "#/definitions/restriction"
        },
        "ext-restriction": {
          "type": "string"
        },
        "observable-id": {
          "$ref": "#/definitions/IDtype"
        },
        "DateTime": {},
        "IncidentID": {},
        "Contact": {
          "$ref": "#/definitions/Contact"
        },
        "Description": {
          "type": "string"
        },
        "DefinedCOA": {},
        "AdditionalData": {
          "type": "array",
          "items": {
            "$ref": "#/definitions/ExtensionType"
          }
        }
      },
      "required": [
        "DateTime",
        "action"
      ],
      "additionalProperties": false
    },
    "EventData": {
      "type": "object",
      "properties": {
        "restriction": {
          "$ref": "#/definitions/restriction"
        },
        "ext-restriction": {
          "type": "string"
        },
        "observable-id": {
```

```
                  "$ref": "#/definitions/IDtype"
                },
                "Description": {
                  "type": "string"
                },
                "DetectTime": {},
                "StartTime": {},
                "EndTime": {},
                "RecoveryTime": {},
                "ReportTime": {
                  "type": "string"
                },
                "Contact": {
                  "$ref": "#/definitions/Contact"
                },
                "Discovery": {
                  "$ref": "#/definitions/Discovery"
                },
                "Assessment": {},
                "Method": {
                  "$ref": "#/definitions/Method"
                },
                "System": {
                  "$ref": "#/definitions/System"
                },
                "Expectation": {
                  "$ref": "#/definitions/Expectation"
                },
                "Record": {
                  "$ref": "#/definitions/Record"
                },
                "EventData": {
                  "$ref": "#/definitions/EventData"
                },
                "AdditionalData": {
                  "type": "array",
                  "items": {
                    "$ref": "#/definitions/ExtensionType"
                  }
                }
              },
              "required": [
                "ReportTime"
              ],
              "additionalProperties": false
            },
            "Expectation": {
              "type": "object",
```

```
                "properties": {
                  "action": {},
                  "ext-action": {},
                  "severity": {},
                  "restriction": {
                    "$ref": "#/definitions/restriction"
                  },
                  "ext-restriction": {
                    "type": "string"
                  },
                  "observable-id": {
                    "$ref": "#/definitions/IDtype"
                  },
                  "Description": {
                    "type": "string"
                  },
                  "DefinedCOA": {},
                  "StartTime": {},
                  "EndTime": {},
                  "Contact": {
                    "$ref": "#/definitions/Contact"
                  }
                },
                "required": [],
                "additionalProperties": false
              },
              "System": {
                "type": "object",
                "properties": {
                  "category": {
                    "enum": [
                      "source",
                      "target",
                      "intermediate",
                      "sensor",
                      "infrastructure",
                      "ext-value"
                    ]
                  },
                  "ext-category": {},
                  "interface": {},
                  "spoofed": {},
                  "virtual": {},
                  "ownership": {},
                  "ext-ownership": {},
                  "restriction": {
                    "$ref": "#/definitions/restriction"
                  },
```

```
                "ext-restriction": {
                  "type": "string"
                },
                "observable-id": {
                  "$ref": "#/definitions/IDtype"
                },
                "Node": {
                  "$ref": "#/definitions/Node"
                },
                "NodeRole": {
                  "$ref": "#/definitions/NodeRole"
                },
                "Service": {
                  "$ref": "#/definitions/Service"
                },
                "OperatingSystem": {},
                "Counter": {
                  "$ref": "#/definitions/Counter"
                },
                "AssetID": {},
                "Description": {
                  "type": "string"
                },
                "AdditionalData": {
                  "type": "array",
                  "items": {
                    "$ref": "#/definitions/ExtensionType"
                  }
                }
              },
              "required": [
                "Node"
              ],
              "additionalProperties": false
            },
            "Node": {
              "type": "object",
              "properties": {
                "DomainData": {
                  "$ref": "#/definitions/DomainData"
                },
                "Address": {
                  "$ref": "#/definitions/Address"
                },
                "PostalAddress": {},
                "Location": {
                  "type": "string"
                },
```

```
        "Counter": {
          "$ref": "#/definitions/Counter"
        }
      },
      "required": [],
      "additionalProperties": false
    },
    "Address": {
      "type": "object",
      "properties": {
        "AddressValue": {},
        "category": {},
        "ext-category": {},
        "vlan-name": {},
        "vlan-num": {
          "type": "integer"
        },
        "observable-id": {
          "$ref": "#/definitions/IDtype"
        }
      },
      "required": [
        "category"
      ],
      "additionalProperties": false
    },
    "NodeRole": {
      "type": "object",
      "properties": {
        "category": {},
        "ext-category": {},
        "Description": {
          "type": "string"
        }
      },
      "required": [
        "category"
      ],
      "additionalProperties": false
    },
    "Counter": {
      "type": "object",
      "properties": {
        "value": {
          "type": "string"
        },
        "type": {},
        "ext-type": {},
```

```
        "unit": {},
        "ext-unit": {},
        "meaning": {},
        "duration": {},
        "ext-duration": {}
      },
      "required": [
        "type",
        "unit"
      ],
      "additionalProperties": false
    },
    "DomainData": {
      "type": "object",
      "properties": {
        "system-status": {},
        "ext-system-status": {},
        "domain-status": {},
        "ext-domain-status": {},
        "observable-id": {
          "$ref": "#/definitions/IDtype"
        },
        "Name": {},
        "DateDomainWasChecked": {},
        "RegistrationDate": {},
        "ExpirationDate": {},
        "RelatedDNS": {},
        "NameServers": {
          "$ref": "#/definitions/NameServers"
        },
        "DomainContacts": {
          "$ref": "#/definitions/DomainContacts"
        }
      },
      "required": [
        "Name",
        "system-status",
        "domain-status"
      ],
      "additionalProperties": false
    },
    "NameServers": {
      "type": "object",
      "properties": {
        "Server": {},
        "Address": {
          "$ref": "#/definitions/Address"
        }
```

```
      },
      "required": [
        "Server",
        "Address"
      ],
      "additionalProperties": false
    },
    "DomainContacts": {
      "type": "object",
      "properties": {
        "SameDomainContact": {},
        "Contact": {
          "$ref": "#/definitions/Contact"
        }
      },
      "required": [
        "Contact"
      ],
      "additionalProperties": false
    },
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        "observable-id": {
          "$ref": "#/definitions/IDtype"
        },
        "ServiceName": {},
        "Port": {},
        "Portlist": {},
        "ProtoCode": {},
        "ProtoType": {},
        "ProtoField": {},
        "ApplicationHeader": {},
        "EmailData": {},
        "Application": {}
      },
      "required": [],
      "additionalProperties": false
    },
    "ServiceName": {
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      "properties": {
        "IANAService": {},
        "URL": {
          "$ref": "#/definitions/URLtype"
        },
        "Description": {
```

```
            "type": "string"
          }
        },
        "required": [],
        "additionalProperties": false
      },
      "ApplicationHeader": {
        "type": "object",
        "properties": {
          "ApplicationHeaderField": {}
        },
        "required": [
          "ApplictionHeaderField"
        ],
        "additionalProperties": false
      },
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        "type": "object",
        "properties": {
          "EmailTo": {},
          "EmailFrom": {},
          "EmailSubject": {},
          "EmailX-Mailer": {},
          "EmailHeaderField": {},
          "EmailHeaders": {},
          "EmailBody": {},
          "EmailMessage": {},
          "HashData": {
            "$ref": "#/definitions/HashData"
          },
          "SignatureData": {
            "$ref": "#/definitions/SignatureData"
          }
        },
        "required": [],
        "additionalProperties": false
      },
      "Record": {
        "type": "object",
        "properties": {
          "restriction": {
            "$ref": "#/definitions/restriction"
          },
          "ext-restriction": {
            "type": "string"
          },
          "observable-id": {
            "$ref": "#/definitions/IDtype"
```

```
            },
            "DateTime": {},
            "Description": {
              "type": "string"
            },
            "Applicadtion": {},
            "RecordPattern": {},
            "RecordItem": {},
            "URL": {
              "$ref": "#/definitions/URLtype"
            },
            "FileData": {
              "$ref": "#/definitions/FileData"
            },
            "WindowsRegistryKeysModified": {},
            "CertificateData": {
              "$ref": "#/definitions/CertificateData"
            },
            "AdditionalData": {
              "type": "array",
              "items": {
                "$ref": "#/definitions/ExtensionType"
              }
            }
          },
          "required": [],
          "additionalProperties": false
        },
        "RecordPattern": {
          "type": "object",
          "properties": {
            "RecordPatternValue": {},
            "type": {},
            "ext-type": {},
            "offset": {},
            "offsetunit": {},
            "ext-offsetunit": {},
            "instance": {
              "type": "integer"
            }
          },
          "required": [
            "type"
          ],
          "additionalProperties": false
        },
        "WindowsRegistryKeysModified": {
          "type": "object",
```

```
            "properties": {
              "observabile-id": {},
              "Key": {}
            },
            "required": [
              "Key"
            ],
            "additionalProperties": false
          },
          "Key": {
            "type": "object",
            "properties": {
              "registryaction": {},
              "ext-registryaction": {},
              "observable-id": {
                "$ref": "#/definitions/IDtype"
              },
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              "KeyValue": {}
            },
            "required": [
              "KeyName"
            ],
            "additionalProperties": false
          },
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            "type": "object",
            "properties": {
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                "$ref": "#/definitions/restriction"
              },
              "ext-restriction": {
                "type": "string"
              },
              "observable-id": {
                "$ref": "#/definitions/IDtype"
              },
              "Certificate": {
                "$ref": "#/definitions/Certificate"
              }
            },
            "required": [
              "Certificate"
            ],
            "additionalProperties": false
          },
          "Certificate": {
            "type": "object",
```

```
      "properties": {
        "observable-id": {
          "$ref": "#/definitions/IDtype"
        },
        "X509Data": {},
        "Description": {
          "type": "string"
        }
      },
      "required": [
        "X509Data"
      ],
      "additionalProperties": false
    },
    "FileData": {
      "type": "object",
      "properties": {
        "restriction": {
          "$ref": "#/definitions/restriction"
        },
        "ext-restriction": {
          "type": "string"
        },
        "observable-id": {
          "$ref": "#/definitions/IDtype"
        },
        "File": {
          "$ref": "#/definitions/File"
        }
      },
      "required": [
        "File"
      ],
      "additionalProperties": false
    },
    "File": {
      "type": "object",
      "properties": {
        "FileName": {
          "type": "string"
        },
        "FileSize": {},
        "FileType": {},
        "URL": {
          "$ref": "#/definitions/URLtype"
        },
        "HashData": {
          "$ref": "#/definitions/HashData"
```

```
        },
        "SignatureData": {
          "$ref": "#/definitions/SignatureData"
        },
        "AssociatedSoftware": {},
        "FileProperties": {}
      },
      "required": [],
      "additionalProperties": false
    },
    "HashData": {
      "type": "object",
      "properties": {
        "scope": {},
        "HashTargetID": {},
        "Hash": {
          "$ref": "#/definitions/Hash"
        },
        "FuzzyHash": {
          "$ref": "#/definitions/FuzzyHash"
        }
      },
      "required": [
        "scope"
      ],
      "additionalProperties": false
    },
    "Hash": {
      "type": "object",
      "properties": {
        "DigestMethod": {
          "type": "string"
        },
        "DigestValue": {
          "type": "string"
        },
        "CanonicalizationMethod": {},
        "Application": {}
      },
      "required": [
        "DigestMethod",
        "DigestValue"
      ],
      "additionalProperties": false
    },
    "FuzzyHash": {
      "type": "object",
      "properties": {
```

```
                "FuzzyHashValue": {
                  "$ref": "#/definitions/ExtensionType"
                },
                "Application": {},
                "AdditionalData": {
                  "type": "array",
                  "items": {
                    "$ref": "#/definitions/ExtensionType"
                  }
                }
              },
              "required": [
                "FuzzyHashValue"
              ],
              "additionalProperties": false
            },
            "SignatureData": {
              "type": "object",
              "properties": {
                "Signature": {
                  "SignatureValue": "xxxxxxxx",
                  "id": "xxxxxxxx"
                }
              },
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              ],
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                },
                "AlternativeIndicatorID": {
                  "$ref": "#/definitions/AlternativeIndicatorID"
                },
                "Description": {
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                },
                "StartTime": {},
```

```
                "EndTime": {},
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                },
                "Contact": {
                  "$ref": "#/definitions/Contact"
                },
                "Observable": {},
                "ObservableReference": {
                  "$ref": "#/definitions/ObservableReference"
                },
                "IndicatorExpression": {
                  "$ref": "#/definitions/IndicatorExpression"
                },
                "IndicatorReference": {
                  "$ref": "#/definitions/IndicatorReference"
                },
                "NodeRole": {
                  "$ref": "#/definitions/NodeRole"
                },
                "AttackPhase": {
                  "$ref": "#/definitions/AttackPhase"
                },
                "Reference": {
                  "$ref": "#/definitions/Reference"
                },
                "AdditionalData": {
                  "type": "array",
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                  }
                }
              },
              "required": [
                "IndicatorID"
              ],
              "additionalProperties": false
            },
            "IndicatorID": {
              "type": "object",
              "properties": {
                "id": {},
                "name": {
                  "type": "string"
                },
                "version": {
                  "type": "string"
                }
```

```
      },
      "required": [
        "name",
        "version"
      ],
      "additionalProperties": false
    },
    "AlternativeIndicatorID": {
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      "properties": {
        "restriction": {
          "$ref": "#/definitions/restriction"
        },
        "ext-restriction": {
          "type": "string"
        },
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          "$ref": "#/definitions/IndicatorReference"
        }
      },
      "required": [
        "IndicatorReference"
      ],
      "additionalProperties": false
    },
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      "properties": {
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          "$ref": "#/definitions/restriction"
        },
        "ext-restriction": {
          "type": "string"
        },
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        "DomainData": {
          "$ref": "#/definitions/DomainData"
        },
        "EmailData": {},
        "Service": {
          "$ref": "#/definitions/Service"
        },
        "WindowsRegistryKeysModified": {},
        "FileData": {
          "$ref": "#/definitions/FileData"
        },
        "CertificateData": {
```

```
                "$ref": "#/definitions/CertificateData"
              },
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              "Record": {
                "$ref": "#/definitions/Record"
              },
              "EventData": {},
              "Incident": {},
              "Expectation": {
                "$ref": "#/definitions/Expectation"
              },
              "Reference": {
                "$ref": "#/definitions/Reference"
              },
              "Assessment": {},
              "DetectionPattern": {},
              "HistoryItem": {},
              "BulkObservable": {
                "type": "string"
              },
              "AdditionalData": {
                "type": "array",
                "items": {
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                }
              }
            },
            "required": [],
            "additionalProperties": false
          },
          "BulkObservable": {
            "type": "object",
            "properties": {
              "type": {},
              "ext-type": {},
              "BulkObservableFormant": {},
              "BulkObservableList": {
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              },
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                "type": "array",
                "items": {
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                }
              }
            },
            "required": [],
            "additionalProperties": false
```

```
    },
    "BulkObservableFormat": {
      "type": "object",
      "properties": {
        "Hash": {
          "$ref": "#/definitions/Hash"
        },
        "AdditionalData": {
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          "items": {
            "$ref": "#/definitions/ExtensionType"
          }
        }
      },
      "required": [],
      "additionalProperties": false
    },
    "IndicatorExpression": {
      "type": "object",
      "properties": {
        "operator": {},
        "ext-operator": {
          "type": "string"
        },
        "IndicatorExpression": {
          "$ref": "#/definitions/IndicatorExpression"
        },
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        "ObservableReference": {
          "$ref": "#/definitions/ObservableReference"
        },
        "IndicatorReference": {
          "$ref": "#/definitions/IndicatorReference"
        },
        "AdditionalData": {
          "type": "array",
          "items": {
            "$ref": "#/definitions/ExtensionType"
          }
        }
      },
      "required": [],
      "additionalProperties": false
    },
    "ObservableReference": {
      "type": "object",
      "properties": {
        "uid-ref": {}
```

```
        },
        "required": [
          "uid-ref"
        ],
        "additionalProperties": false
      },
      "IndicatorReference": {
        "type": "object",
        "properties": {
          "uid-ref": {},
          "euid-ref": {
            "type": "string"
          },
          "version": {
            "type": "string"
          }
        },
        "required": [],
        "additionalProperties": false
      },
      "AttackPhase": {
        "type": "object",
        "properties": {
          "AttackPhaseID": {
            "type": "string"
          },
          "URL": {
            "$ref": "#/definitions/URLtype"
          },
          "Description": {
            "type": "string"
          },
          "AdditionalData": {
            "type": "array",
            "items": {
              "$ref": "#/definitions/ExtensionType"
            }
          }
        },
        "required": [],
        "additionalProperties": false
      }
    },
    "title": "IODEF-Document",
    "description": "JSON schema for IODEF-Document class",
    "type": "object",
    "properties": {
      "version": {
```

```
            "type": "string"
          },
          "lang": {
            "$ref": "#/definitions/lang"
          },
          "format-id": {
            "type": "string"
          },
          "private-enum-name": {
            "type": "string"
          },
          "private-enum-id": {
            "type": "string"
          },
          "Incidents": {
            "type": "array",
            "items": {
              "$ref": "#/definitions/Incident"
            }
          },
          "AdditionalData": {
            "type": "array",
            "items": {
              "$ref": "#/definitions/ExtensionType"
            }
          }
        },
        "required": [
          "version",
          "Incidents"
        ],
        "additionalProperties": false
      }
```

Figure 62: JSON schema

6. Acknowledgements

TBD.

7. IANA Considerations

This memo includes no request to IANA.

8. Security Considerations

This memo does not provide any further security considerations than the one described in RFC 5070-bis.

9. References

9.1. Normative References

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Abstract

RFC 7970 [RFC7970] provides XML-based data representation on incident information, but the use of the IODEF data model is not limited to XML. JSON representation is sometimes preferred since it is easy to handle from certain programming environments. This draft represents the IODEF data model in JSON. Note that this 00 version draft is prepared for the purpose of encouraging discussion on the need for JSON representation.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

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This Internet-Draft will expire on March 31, 2018.

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Table of Contents

1. Introduction

RFC 7970 [RFC7970] defines an data model for sharing incident information. It facilitates automated exchange of information among parties over networks. The data model can be implemented in a form of XML, but it is not always suitable for implementation. JSON-based representation is often useful.

Therefore, in this document, we provide a means to represent IODEF data model in JSON.

1.1. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

2. The IODEF Information Model in JSON

The data model of IODEF is defined in RFC 7970 [RFC7970], and this section illustrates their representations in JSON. Note that the complete JSON schema is defined in Section 5.

2.1. IODEF-Document Class

The IODEF-Document class is the top level class in the IODEF data model. This class is defined in Section 3.1 of RFC 7970 [RFC7970] and has the following fields: "version", "lang", "format-id", "private-enum-name", "private-enum-id", "Incident", and "AdditionalData". An example of this class in JSON is as follows. Note that JSON representation in this draft treats attributes and elements of each class defined in RFC 7970 [RFC7970] equally and is agnostic on the order of their appearances.

```
 "IODEF-Document": {
   "version": "2.0",                                    //STRING
   "lang": "en",                                          //ENUM
   "format-id": "RFC7970",                              //STRING
   "Incident": [ ... ]                                 //Incident
 }
```

Figure 1: IODEF-Document Class in JSON

2.2. Incident Class

The Incident class describes commonly exchanged information when reporting or sharing derived analysis from security incidents. This class is defined in Section 3.2 of RFC 7970 [RFC7970]. It has the following fields: "purpose", "lang", "restriction", "ext-restriction", "IncidentID", "RelatedActivity", "GenrationTime", "Description", "Assessment", "Methods", "Contact", "EventData", "IndicatorData", "History", and "AdditionalData". An example of this class in JSON is as follows.

```
    "Incident": {
      "purpose": "reporting",                                    //ENUM
      "lang": "en",                                             //STRING
      "restriction": "green",                                    //ENUM
      "IncidentID": { ... },                          //IncidentID Class
      "RelatedActivity": [ ... ],                  //RelatedActivity Class
      "GenerationTime": "2015-10-02T11:18:00-05:00",         //DateTime
      "Description": ["Incident class description field"], //ML_STRING
      "Assessment": [ ... ],                                  //Assessment
      "Method": [ ... ],                                         //Method
      "Contact": [ ... ]                                        //Contact
      "EventData": [ ... ],                                    //EventData
      "IndicatorData": { ... }                              //IndicatorData
      "History": { ... },                                          //History
      "AdditionalData": [ ... ],                          //AdditionalData
    }
```

Figure 2: Incident Class in JSON

2.3. Common Attributes

There are a number of recurring attributes used in the information model. They are documented in this section.

2.3.1. restriction Attribute

RFC 7970 [RFC7970] defines the restriction Attribute as one of common attributes. It is defined as below:

```
"restriction":{"enum": ["public", "partner", "need-to-know", "private", "default
", "white", "green", "amber", "red", "ext-value"]}
```

Figure 3: restrition in JSON

Note that you must use "ext-restriction" field (STRING type) when the value of "restriction" field is set to "ext-value". The example on the use of the "ext-restriction" field is shown below.

```
   "restriction": "ext-value"                                  // ENUM
   "ext-restriction": "registration required"                 // STRING
```

Figure 4: ext-restrition in JSON

2.3.2. observable-id Attribute

RFC 7970 [RFC7970] defines the observable-id attribute as one of common attributes. The value of this attribute is a unique identifier in the scope of the document.It is defined as below:

```
"observable-id": {"type": "string"},
```

Figure 5: observable-id in JSON

2.4. IncidentID Class

This class is defined in Section 3.4 of RFC 7970 [RFC7970]. It has the following fields: "IncidentID", "id", "name", "instance", "restriction", and "ext-restriction". The example below represents how to describe this class in JSON.

```
 "IncidentID": {
   "id": "nict20150518-0001",                          // STRING
   "name": "NICT_cert",                                // STRING
   "instance": "cyberlab"                              // STRING
   "restriction": "ext-value"                            // ENUM
   "ext-restriction": "registration required"          // STRING
 }
```

Figure 6: IncidentID Class in JSON

2.5. AlternativeID Class

This class is defined in Section 3.5 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
 "AltervativeID": {
   "restriction": "private",                                //ENUM
   "IncidentID": [<<<omitted>>>]                       //IncidentID
 }
```

Figure 7: AlternativeID Class in JSON

2.6. RelatedActivity Class

This class is defined in Section 3.6 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"RelatedActivity": {
  "restriction": "private",                                  //ENUM
  "ThreatActor": [                                       //ThreatActor
    {
      "ThreatActorID": "TA-12-AGGRESSIVE-BUTTERFLY",
      "Description": "Aggressive Butterfly"
    }
  ],
  "Campaign": [                                            //Campaign
    {
      "CampaignID": "C-2015-59405",
      "Description": "Orange Giraffe"
    }
  ]
}
```

Figure 8: RelatedActivity Class in JSON

2.7. ThreatActor Class

This class is defined in Section 3.7 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"ThreatActor": {
  "ThreatActorID": "TA-12-AGGRESSIVE-BUTTERFLY",
  "Description": "Aggressive Butterfly"
}
```

Figure 9: ThreatActor Class in JSON

2.8. Campaign Class

This class is defined in Section 3.8 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"Campaign": {
  "CampaignID": "C-2015-59405",                             //STRING
  "Description": "Orange Giraffe"                        //ML_STRING
}
```

Figure 10: Campaign Class in JSON

2.9. Contact Class

This class is defined in Section 3.9 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"Contact": {
  "type": "organization",
  "role": "creator",
  "ContactName": "CSIRT for example.com",
  "email": {
    "emailTo": "contact@csirt.example.com"
  }
}
```

Figure 11: Contact Class in JSON

2.9.1. RegistryHandle Class

This class is defined in Section 3.9.1 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"RegistryHandle": {
  "RegistryHandleName": "MyAPNIC",
  "registry": "apnic",
}
```

Figure 12: RegistryHandle Class in JSON

2.9.2. PostalAddress Class

This class is defined in Section 3.9.2 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"PostalAddress": {
  "type": "mailing",
  "PAddress": "184-8795",
  "Description": "4-2-1 Nukui-Kitamachi Koganei Tokyo, Japan"
},
```

Figure 13: PostalAddress Class in JSON

2.9.3. Email Class

This class is defined in Section 3.9.3 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"Email": {
  "emailTo": "contact@csirt.example.com"
},
```

Figure 14: Email Class in JSON

2.9.4. Telephone Class

This class is defined in Section 3.9.4 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"Telephone": {
  "TelephoneNumber": "+81423275862"
},
```

Figure 15: Telephone Class in JSON

2.10. Discovery Class

This class is defined in Section 3.10 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"Discovery": {
  "DetectionPattern": {
    "Application": {
      "Description": "Microsoft Win"
    }
  }
}
```

Figure 16: Discovery Class in JSON

2.10.1. DetectionPattern Class

This class is defined in Section 3.10.1 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"DetectionPattern": {
  "Application": {
    "Description": "Microsoft Win"
  }
}
```

Figure 17: DetectionPattern Class in JSON

2.11. Method Class

This class is defined in Section 3.11 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"Method": {
  "Vulnerability": {}
}
```

Figure 18: Method Class in JSON

2.11.1. Reference Class

This class is defined in Section 3.11.1 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"Reference":{
  "URL":"http://www.nict.go.jp"
}
```

Figure 19: Reference Class in JSON

2.12. Assessment Class

This class is defined in Section 3.12 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"Assessment": {
  "BusinessImpact": {
    "type": "breach-proprietary"
  }
}
```

Figure 20: Assessment Class in JSON

2.12.1. SystemImpact Class

This class is defined in Section 3.12.1 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"SystemImpact":{
  "severity":"low",
  "type":"unknown"
},
```

Figure 21: SystemImpact Class in JSON

2.12.2. BusinessImpact Class

This class is defined in Section 3.12.2 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"BusinessImpact": {
  "type": "breach-proprietary"
}
```

Figure 22: BusinessImpact Class in JSON

2.12.3. TimeImpact Class

This class is defined in Section 3.12.3 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"TimeImpact":{
  "value":"5 hours",
  "metric":"elapsed"
}
```

Figure 23: TimeImpact Class in JSON

2.12.4. MonetaryImpact Class

This class is defined in Section 3.12.4 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"MonetaryImpact":{}
```

Figure 24: MonetaryImpact Class in JSON

2.12.5. Confidence Class

This class is defined in Section 3.12.5 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"Confidence": {
  "rating": "medium"
}
```

Figure 25: Confidence Class in JSON

2.13. History Class

This class is defined in Section 3.13 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"History": {
  "HistoryItem": {
    "DateTime": "2015-10-15T11:18:00-05:00",
    "action": "investigate"
  }
},
```

Figure 26: History Class in JSON

2.13.1. HistoryItem Class

This class is defined in Section 3.13.1 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"HistoryItem": {
  "DateTime": "2015-10-15T11:18:00-05:00",
  "action": "investigate"
}
```

Figure 27: HistoryItem Class in JSON

2.14. EventData Class

This class is defined in Section 3.14 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"EventData": {
  "ReportTime": "2016-06-01 18:05:33",
  "System": {
    "category": "source",
    "Node": {
      "Address": {
        "category": "ipv4-addr",
        "AddressValue": "192.228.139.118"
      },
      "Location": "OrgID=7"
    },
    "Service": {
      "ip-protocol": 6,
      "Port": 49183
    }
  },
```

Figure 28: EventData Class in JSON

2.15. Expectation Class

This class is defined in Section 3.15 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"Expectation": {
  "action": "investigate"
},
```

Figure 29: Expectation Class in JSON

2.16. System Class

This class is defined in Section 3.17 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"System": {
  "category": "source",
  "Node": {
    "Address": {
      "category": "ipv4-addr",
      "AddressValue": "192.228.139.118"
    },
    "Location": "OrgID=7"
  },
  "Service": {
    "ip-protocol": 6,
    "Port": 49183
  }
```

Figure 30: System Class in JSON

2.17. Node Class

This class is defined in Section 3.18 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"Node": {
  "Address": {
    "category": "ipv4-addr",
    "AddressValue": "192.228.139.118"
  },
```

Figure 31: Node Class in JSON

2.17.1. Address Class

This class is defined in Section 3.18.1 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"Address": {
  "category": "ipv4-addr",
  "AddressValue": "192.228.139.118"
},
```

Figure 32: Address Class in JSON

2.17.2. NodeRole Class

This class is defined in Section 3.18.2 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"NodeRole": {
  "category": "client"
},
```

Figure 33: NodeRole Class in JSON

2.17.3. Counter Class

This class is defined in Section 3.18.3 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"Counter": {
  "value": "3",
  "type": "count",
  "unit": "packet"
}
```

Figure 34: Counter Class in JSON

2.18. DomainData Class

This class is defined in Section 3.19 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"DomainData": {
  "system-status": "innocent-hacked",
  "domain-status": "assignedAndInactive",
  "Name": "temp1.nict.go.jp"
},
```

Figure 35: DomainData Class in JSON

2.18.1. Nameserver Class

This class is defined in Section 3.19.1 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"NameServers": {
  "Server": "vgw.nict.go.jp",
  "Address": {
    "AddressValue": "133.243.18.5",
    "category": "ipv4-addr"
  }
}
```

Figure 36: Nameserver Class in JSON

2.18.2. DomainContacts Class

This class is defined in Section 3.19.2 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"DomainContacts": {
  "Contact": {
    "role": "user",
    "type": "organization"
  }
}
```

Figure 37: DomainContacts Class in JSON

2.19. Service Class

This class is defined in Section 3.20 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"Service": {
  "ServiceName": {
    "Description": "It seems to be a scan from an infected machine."
  },
  "ip-protocol": 6,
  "Port": 49183
}
```

Figure 38: Service Class in JSON

2.19.1. ServiceName Class

This class is defined in Section 3.20.1 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"ServiceName": {
  "Description": "It seems to be a scan from an infected machine."
},
```

Figure 39: ServiceName Class in JSON

2.19.2. ApplicationHeader Class

This class is defined in Section 3.20.2 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"ApplicationHeader": {}
```

Figure 40: ApplicationHeader Class in JSON

2.20. EmailData Class

This class is defined in Section 3.21 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"EmailData":{}
```

Figure 41: EmailData Class in JSON

2.21. Record Class

This class is defined in Section 3.22.1 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"Record": {
  "RecordPattern": {
    "type": "regex",
    "value": "[0-9][A-Z]"
  },
  "RecordItem": {}
},
```

Figure 42: Record Class in JSON

2.21.1. RecordPattern Class

This class is defined in Section 3.22.2 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"RecordPattern": {
  "type": "regex",
  "value": "[0-9][A-Z]"
},
```

Figure 43: RecordPattern Class in JSON

2.22. WindowsRegistryKeysModified Class

This class is defined in Section 3.23 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"WindowsRegistryKeysModified": {
  "Key": {
    "KeyValue": "xxxxxxxxxxxxxxxxxxxxxx",
    "KeyName":"HKEY_LOCAL_MACHINExxxxxxx",
  }
}
```

Figure 44: WindowsRegistryKeysModified Class in JSON

2.22.1. Key Class

This class is defined in Section 3.23.1 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"Key": {
  "KeyValue": "xxxxxxxxxxxxxxxxxxxxxx",
  "KeyName":"HKEY_LOCAL_MACHINExxxxxxx",
}
```

Figure 45: Key Class in JSON

2.23. CertificateData Class

This class is defined in Section 3.24 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
            "CertificateData": {
              "Certificate": {
                "X509Data": {
                  "X509IssuerSerial": {
                    "X509IssuerName": "CN=TAMURA Kent, OU=TRL, O=IBM, L=Yamato-s
hi, ST=Kanagawa, C=JP",
                    "X509SerialNumber": "12345678"
                  },
                  "X509SKI": "31d97bd7"
                }
              }
            }
```

Figure 46: CertificateData Class in JSON

2.23.1. Certificate Class

This class is defined in Section 3.24.1 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
            "Certificate": {
              "X509Data": {
                "X509IssuerSerial": {
                  "X509IssuerName": "CN=TAMURA Kent, OU=TRL, O=IBM, L=Yamato-s
hi, ST=Kanagawa, C=JP",
                  "X509SerialNumber": "12345678"
                },
                "X509SKI": "31d97bd7"
              }
            }
```

Figure 47: Certificate Class in JSON

2.24. FileData Class

This class is defined in Section 3.25 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
                          "FileData": {
                            "File": {
                              "FileName": "dummy.exe"
                            }
                          },
```

Figure 48: FileData Class in JSON

2.24.1. File Class

This class is defined in Section 3.25.1 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"File": {
  "FileName": "dummy.exe"
}
```

Figure 49: File Class in JSON

2.25. HashData Class

This class is defined in Section 3.26 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"HashData": {
  "scope": "file-contents",
  "Hash": {
    "DigestMethod": "http://www.w3.org/2000/09/xmldsig#sha1",
    "DigestValue": "xxxxxxxxxxx"
  }
}
```

Figure 50: HashData Class in JSON

2.25.1. Hash Class

This class is defined in Section 3.26.1 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"Hash": {
  "DigestMethod": "http://www.w3.org/2000/09/xmldsig#sha1",
  "DigestValue": "xxxxxxxxxxx"
}
```

Figure 51: Hash Class in JSON

2.25.2. FuzzyHash Class

This class is defined in Section 3.26.2 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"FuzzyHash": {
  "FuzzyHashValue": {}
}
```

Figure 52: FuzzyHash Class in JSON

2.26. SignatureData Class

This class is defined in Section 3.27 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"SignatureData": {
  "Signature": "xxxxxxxx"
}
```

Figure 53: SignatureData Class in JSON

2.27. Indicator Class

This class is defined in Section 3.29 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"Indicator": {
  "IndicatorID": {
    "id": "G90823490",
    "name": "csirt.example.com",
    "version": "1"
  },
  "Description": "C2 domains",
  "StartTime": "2014-12-02T11:18:00-05:00",
  "Observable": {
    "BulkObservable": {
      "type": "fqdn"
    },
    "BulkObservableList": [
      "kj290023j09r34.example.com",
      "09ijk23jfj0k8.example.net",
      "klknjwfjiowjefr923.example.org",
      "oimireik79msd.example.org"
    ]
  }
}
```

Figure 54: Indicator Class in JSON

2.27.1. IndicatorID Class

This class is defined in Section 3.29.1 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"IndicatorID": {
  "id": "G90823490",
  "name": "csirt.example.com",
  "version": "1"
},
```

Figure 55: IndicatorID Class in JSON

2.27.2. AlternativeIndicatorID Class

This class is defined in Section 3.29.2 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"AlternativeIndicatorID": {
  "IndicatorReference": {
    "uid-ref": "xxxxx"
  }
},
```

Figure 56: AlternativeIndicatorID Class in JSON

2.27.3. Observable Class

This class is defined in Section 3.29.3 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"Observable": {
  "BulkObservable": {
    "type": "fqdn"
  },
  "BulkObservableList": [
    "kj290023j09r34.example.com",
    "09ijk23jfj0k8.example.net",
    "klknjwfjiowjefr923.example.org",
    "oimireik79msd.example.org"
  ]
}
```

Figure 57: Observable Class in JSON

2.27.4. IndicatorExpression Class

This class is defined in Section 3.29.4 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"IndicatorExpression": {}
```

Figure 58: IndicatorExpression Class in JSON

2.27.5. ObservableReference Class

This class is defined in Section 3.29.6 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"ObservableReference": {
  "uid-ref": "xxxxx"
},
```

Figure 59: ObservableReference Class in JSON

2.27.6. IndicatorReference Class

This class is defined in Section 3.29.7 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"IndicatorReference": {
  "uid-ref": "xxxxx"
}
```

Figure 60: IndicatorReference Class in JSON

2.27.7. AttackPhase Class

This class is defined in Section 3.29.8 of RFC 7970 [RFC7970]. The example below represents how to describe this class in JSON.

```
"AttackPhase": {
  "Description": "Currently, the infected host is scanning arbitrary
 hosts to find next targets."
}
```

Figure 61: AttackPhase Class in JSON

3. Notable differences from RFC 7970 (to be deleted)

- Flow class is deleted, and EventData class now has the instance of System class.
- Record class is deleted, and the link to the Record class are directly connected to RecordData class, which is then renamed to Record class.

4. Examples

This section provides example of IODEF documents. These examples do not represent the full capabilities of the data model or the the only way to encode particular information.

4.1. Minimal Example

A document containing only the mandatory elements and attributes.

```
{
  "version": "2.0",
  "lang": "en",
  "Incident": [
    {
      "purpose": "reporting",
      "restriction": "private",
      "IncidentID": {
        "id": 492382,
        "name": "csirt.example.com"
      },
      "GenerationTime": "2015-07-18T09:00:00-05:00",
      "Contact": [
        {
          "type": "organization",
          "role": "creator",
          "email": {
            "emailTo": "contact@csirt.example.com"
          }
        }
      ]
    }
  ]
}
```

Figure 62: JSON representation example 1

4.2. Indicators from a Campaign

An example of C2 domains from a given campaign.

```
{
  "version": "2.0",
  "lang": "en",
  "Incidents": [
    {
      "purpose": "watch",
      "restriction": "green",
      "IncidentID": {
        "id": "897923",
        "name": "csirt.example.com"
      },
      "RelatedActivity": [
        {
```

```
          "ThreatActor": [
            {
              "ThreatActorID": "TA-12-AGGRESSIVE-BUTTERFLY",
              "Description": "Aggressive Butterfly"
            }
          ],
          "Campaign": [
            {
              "CampaignID": "C-2015-59405",
              "Description": "Orange Giraffe"
            }
          ]
        }
      ],
      "GenerationTime": "2015-10-02T11:18:00-05:00",
      "Description": [
        "Summarizes the Indicators of Compromise for the Orange Giraffe campaign
 of the Aggressive Butterfly crime gang."
      ],
      "Assessment": [
        {
          "BusinessImpact": {
            "type": "breach-proprietary"
          }
        }
      ],
      "Contacts": [
        {
          "type": "organization",
          "role": "creator",
          "ContactName": "CSIRT for example.com",
          "Email": {
            "emailTo": "contact@csirt.example.com"
          }
        }
      ],
      "IndicatorList": [
        {
          "IndicatorID": {
            "id": "G90823490",
            "name": "csirt.example.com",
            "version": "1"
          },
          "Description": "C2 domains",
          "StartTime": "2014-12-02T11:18:00-05:00",
          "Observable": {
            "BulkObservable": {
              "type": "fqdn"
            },
```

```
            "BulkObservableList": [
              "kj290023j09r34.example.com",
              "09ijk23jfj0k8.example.net",
              "klknjwfjiowjefr923.example.org",
              "oimireik79msd.example.org"
            ]
          }
        }
      ]
    }
  ]
}
```

Figure 63: JSON representation example 2

5. The IODEF Data Model (JSON Schema)

```
        {
        {
          "$schema": "http://json-schema.org/draft-04/schema#",
          "definitions": {
            "lang": {
              "enum": [
                "en",
                "jp"
              ]
            },
            "restriction": {
              "enum": [
                "public",
                "partner",
                "need-to-know",
                "private",
                "default",
                "white",
                "green",
                "amber",
                "red",
                "ext-value"
              ]
            },
            "URLtype": {
              "type": "string"
            },
            "IDtype": {
              "type": "string"
            },
            "ExtensionType": {
```

```
                "type": "object",
                "properties": {
                  "name": {
                    "type": "string"
                  },
                  "dtype": {
                    "enum": [
                      "boolean",
                      "byte",
                      "bytes",
                      "character",
                      "date-time",
                      "ntpstamp",
                      "integer",
                      "portlist",
                      "real",
                      "string",
                      "file",
                      "path",
                      "frame",
                      "packet",
                      "ipv4-packet",
                      "ipv6-packet",
                      "url",
                      "csv",
                      "winreg",
                      "xml",
                      "ext-value"
                    ]
                  },
                  "ext-dtype": {
                    "type": "string"
                  },
                  "meaning": {
                    "type": "string"
                  },
                  "formatid": {
                    "type": "string"
                  },
                  "restriction": {
                    "$ref": "#/definitions/restriction"
                  },
                  "ext-restriction": {
                    "type": "string"
                  },
                  "observable-id": {
                    "$ref": "#/definitions/IDtype"
                  }
```

```
      }
    },
    "SoftwareType": {
      "type": "object",
      "properties": {
        "SoftwareReference": {
          "$ref": "#/definitions/SoftwareReference"
        },
        "URL": {
          "$ref": "#/definitions/URLtype"
        },
        "Description": {
          "type": "string"
        }
      },
      "required": [],
      "additionalProperties": false
    },
    "SoftwareReference": {
      "type": "object",
      "properties": {
        "value": {
          "type": "string"
        },
        "spec-name": {
          "type": "string"
        },
        "ext-spec-name": {
          "type": "string"
        },
        "dtype": {
          "type": "string"
        },
        "ext-dtype": {
          "type": "string"
        }
      },
      "required": [
        "spec-name"
      ],
      "additionalProperties": false
    },
    "Incident": {
      "title": "Incident",
      "description": "JSON schema for Incident class",
      "type": "object",
      "properties": {
        "purpose": {
```

```
      "enum": [
        "traceback",
        "mitigation",
        "reporting",
        "watch",
        "other",
        "ext-value"
      ]
    },
    "ext-purpose": {
      "type": "string"
    },
    "status": {
      "enum": [
        "blabla"
      ]
    },
    "ext-status": {
      "type": "string"
    },
    "lang": {
      "$ref": "#/definitions/lang"
    },
    "restriction": {
      "$ref": "#/definitions/restriction"
    },
    "ext-restriction": {
      "type": "string"
    },
    "observable-id": {
      "$ref": "#/definitions/IDtype"
    },
    "IncidentID": {
      "$ref": "#/definitions/IncidentID"
    },
    "AlternativeID": {
      "type": "object"
    },
    "RelatedActivity": {
      "type": "array",
      "items": {
        "$ref": "#/definitions/RelatedActivity"
      }
    },
    "DetectTime": {
      "type": "string"
    },
    "StartTime": {
```

```
      "type": "string"
    },
    "EndTime": {
      "type": "string"
    },
    "RecoveryTime": {
      "type": "string"
    },
    "ReportTime": {
      "type": "string"
    },
    "GenerationTime": {
      "type": "string"
    },
    "Description": {
      "type": "array",
      "items": {
        "type": "string"
      }
    },
    "Discovery": {
      "type": "array",
      "items": {
        "$ref": "#/definitions/Discovery"
      }
    },
    "Assessment": {
      "type": "array",
      "items": {
        "$ref": "#/definitions/Assessment"
      }
    },
    "Methods": {
      "type": "array",
      "items": {
        "$ref": "#/definitions/Method"
      }
    },
    "Contacts": {
      "type": "array",
      "items": {
        "$ref": "#/definitions/Contact"
      }
    },
    "EventData": {
      "type": "array",
      "items": {
        "$ref": "#/definitions/EventData"
```

```
            }
          },
          "IndicatorList": {
            "type": "array",
            "items": {
              "$ref": "#/definitions/Indicator"
            },
          },
          "History": {
            "$ref": "#/definitions/History"
          },
          "AdditionalData": {
            "type": "array",
            "items": {
              "$ref": "#/definitions/ExtensionType"
            }
          }
        },
        "required": [
          "IncidentID",
          "GenerationTime",
          "Contacts",
          "purpose"
        ],
        "additionalProperties": false
      },
      "IncidentID": {
        "title": "IncidentID",
        "description": "JSON schema for IncidentID class",
        "type": "object",
        "properties": {
          "id": {
            "type": "string"
          },
          "name": {
            "type": "string"
          },
          "instance": {
            "type": "string"
          },
          "restriction": {
            "$ref": "#/definitions/restriction"
          },
          "ext-restriction": {
            "type": "string"
          }
        },
        "required": [
```

```
        "name"
      ],
      "additionalProperties": false
    },
    "RelatedActivity": {
      "properties": {
        "restriction": {
          "$ref": "#/definitions/restriction"
        },
        "ext-restriction": {
          "type": "string"
        },
        "IncidentID": {
          "type": "array",
          "items": {
            "$ref": "#/definitions/IncidentID"
          }
        },
        "URL": {
          "type": "array",
          "items": {
            "$ref": "#/definitions/URLtype"
          }
        },
        "ThreatActor": {
          "type": "array",
          "items": {
            "$ref": "#/definitions/ThreatActor"
          }
        },
        "Campaign": {
          "type": "array",
          "items": {
            "$ref": "#/definitions/Campaign"
          }
        },
        "IndicatorID": {
          "type": "array",
          "items": {
            "$ref": "#/definitions/IndicatorID"
          }
        },
        "Confidence": {
          "$ref": "#/definitions/Confidence"
        },
        "Description": {
          "type": "array",
          "items": {
```

```
                    "type": "string"
                  }
                },
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            "ext-value"
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        "EmailHeaderField": {},
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                },
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                "Reference": {
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      "additionalProperties": false
    },
    "AlternativeIndicatorID": {
      "type": "object",
      "properties": {
        "restriction": {
          "$ref": "#/definitions/restriction"
        },
        "ext-restriction": {
          "type": "string"
        },
        "IndicatorReference": {
          "$ref": "#/definitions/IndicatorReference"
        }
      },
      "required": [
        "IndicatorReference"
      ],
      "additionalProperties": false
    },
    "Observable": {
      "type": "object",
      "properties": {
        "restriction": {
          "$ref": "#/definitions/restriction"
        },
        "ext-restriction": {
          "type": "string"
        },
        "System": {},
        "Address": {},
        "DomainData": {
          "$ref": "#/definitions/DomainData"
        },
        "EmailData": {},
        "Service": {
          "$ref": "#/definitions/Service"
        },
        "WindowsRegistryKeysModified": {},
```

```
                "FileData": {
                  "$ref": "#/definitions/FileData"
                },
                "CertificateData": {
                  "$ref": "#/definitions/CertificateData"
                },
                "RegistryHandle": {},
                "Record": {
                  "$ref": "#/definitions/Record"
                },
                "EventData": {},
                "Incident": {},
                "Expectation": {
                  "$ref": "#/definitions/Expectation"
                },
                "Reference": {
                  "$ref": "#/definitions/Reference"
                },
                "Assessment": {},
                "DetectionPattern": {},
                "HistoryItem": {},
                "BulkObservable": {
                  "type": "string"
                },
                "AdditionalData": {
                  "type": "array",
                  "items": {
                    "$ref": "#/definitions/ExtensionType"
                  }
                }
              },
              "required": [],
              "additionalProperties": false
            },
            "BulkObservable": {
              "type": "object",
              "properties": {
                "type": {},
                "ext-type": {},
                "BulkObservableFormant": {},
                "BulkObservableList": {
                  "type": "string"
                },
                "AdditionalData": {
                  "type": "array",
                  "items": {
                    "$ref": "#/definitions/ExtensionType"
                  }
```

```
        }
      },
      "required": [],
      "additionalProperties": false
    },
    "BulkObservableFormat": {
      "type": "object",
      "properties": {
        "Hash": {
          "$ref": "#/definitions/Hash"
        },
        "AdditionalData": {
          "type": "array",
          "items": {
            "$ref": "#/definitions/ExtensionType"
          }
        }
      },
      "required": [],
      "additionalProperties": false
    },
    "IndicatorExpression": {
      "type": "object",
      "properties": {
        "operator": {},
        "ext-operator": {
          "type": "string"
        },
        "IndicatorExpression": {
          "$ref": "#/definitions/IndicatorExpression"
        },
        "Observable": {},
        "ObservableReference": {
          "$ref": "#/definitions/ObservableReference"
        },
        "IndicatorReference": {
          "$ref": "#/definitions/IndicatorReference"
        },
        "AdditionalData": {
          "type": "array",
          "items": {
            "$ref": "#/definitions/ExtensionType"
          }
        }
      },
      "required": [],
      "additionalProperties": false
    },
```

```
            "ObservableReference": {
              "type": "object",
              "properties": {
                "uid-ref": {}
              },
              "required": [
                "uid-ref"
              ],
              "additionalProperties": false
            },
            "IndicatorReference": {
              "type": "object",
              "properties": {
                "uid-ref": {},
                "euid-ref": {
                  "type": "string"
                },
                "version": {
                  "type": "string"
                }
              },
              "required": [],
              "additionalProperties": false
            },
            "AttackPhase": {
              "type": "object",
              "properties": {
                "AttackPhaseID": {
                  "type": "string"
                },
                "URL": {
                  "$ref": "#/definitions/URLtype"
                },
                "Description": {
                  "type": "string"
                },
                "AdditionalData": {
                  "type": "array",
                  "items": {
                    "$ref": "#/definitions/ExtensionType"
                  }
                }
              },
              "required": [],
              "additionalProperties": false
            }
          },
          "title": "IODEF-Document",
```

```
            "description": "JSON schema for IODEF-Document class",
            "type": "object",
            "properties": {
              "version": {
                "type": "string"
              },
              "lang": {
                "$ref": "#/definitions/lang"
              },
              "format-id": {
                "type": "string"
              },
              "private-enum-name": {
                "type": "string"
              },
              "private-enum-id": {
                "type": "string"
              },
              "Incidents": {
                "type": "array",
                "items": {
                  "$ref": "#/definitions/Incident"
                }
              },
              "AdditionalData": {
                "type": "array",
                "items": {
                  "$ref": "#/definitions/ExtensionType"
                }
              }
            },
            "required": [
              "version",
              "Incidents"
            ],
            "additionalProperties": false
          }
```

Figure 64: JSON schema

6. Acknowledgements

TBD.

7. IANA Considerations

This memo includes no request to IANA.

8. Security Considerations

This memo does not provide any further security considerations than the one described in RFC 7970 [RFC7970].

9. References

9.1. Normative References

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