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The Incident Object Description Exchange Format v2
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Abstract

The Incident Object Description Exchange Format (IODEF) defines a data representation for sharing information commonly exchanged by Computer Security Incident Response Teams (CSIRTs) about computer security incidents. This document describes the information model for the IODEF and provides an associated data model specified with XML Schema.

Status of This Memo

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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 bot-network, or sharing watch-lists of known malicious IP addresses 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). It provides an XML representation for conveying:

- cyber intelligence to characterize threats;
- cyber incident reports to document particular cyber security events or relationships between events;
- cyber event mitigation to request proactive and reactive mitigation approaches to cyber intelligence or incidents; and
- cyber information sharing meta-data so that these various classes of information can be exchanged among parties.

The data model encodes information about hosts, networks, and the services running on these systems; attack methodology and associated forensic evidence; impact of the activity; and limited approaches for documenting workflow.

The overriding purpose of the IODEF is to enhance the operational capabilities of CSIRTs. Community adoption of the IODEF provides an improved ability to resolve incidents and convey situational awareness by simplifying collaboration and data sharing. This structured format provided by the IODEF allows for:

- increased automation in processing of incident data, since the resources of security analysts to parse free-form textual documents will be reduced;
- decreased effort in normalizing similar data (even when highly structured) from different sources; and
- a common format on which to build interoperable tools for incident handling and subsequent analysis, specifically when data comes from multiple constituencies.

Coordinating with other CSIRTs is not strictly a technical problem. There are numerous procedural, trust, and legal considerations that might prevent an organization from sharing information. The IODEF does not attempt to address them. However, operational implementations of the IODEF will need to consider this broader context.

Sections 3 and 8 specify the IODEF data model with text and an XML schema. The types used by the data model are covered in Section 2. Processing considerations, the handling of extensions, and internationalization issues related to the data model are covered in Sections 4, 5, and 6, respectively. Examples are listed in Section 7. Section 1 provides the background for the IODEF, and Section 9 documents the security considerations.

1.1. Changes from 5070

This document contains changes with respect to its predecessor RFC5070.

- All of the RFC5070 Errata was implemented.
- Imported the xmlns:ds namespace to include digital signature hash classes.
- The following classes were added to IODEF-Document: AdditionalData.
- The following class was added to Incident: IndicatorData.
- The following classes were added to Incident and EventData: Discovery.
- The following classes and attributes were added to the Service class: EmailData, DomainData, AssetID, ApplicationHeader @virtual, and @ownership. Service@ip_protocol was renamed to @ip-protocol.
- The following classes were added to the Record class: HashData and WindowsRegistryKeysModified.
- The following classes were added to the RelatedActivity class: ThreatActor, Campaign, Confidence, Description, and AdditionalData.
- The following classes were added to Assessment: IncidentCategory, SystemImpact, BusinessImpact, IntendedImpact and MitigatingFactor.
- The following classes were added to Node: PostalAddress and DomainData. The following classes were removed from Node: Removed NodeName and DateTime.
- The following classes were added to the Contact class: ContactTitle.

- The following classes were added to Expectation and HistoryItem: DefinedCOA.

- Additional enumerated values were added to the following attributes: @restriction, {Expectation, HistoryItem}@action, NodeRole@category, Incident@purpose, Contact@role, AdditionalData@dtype, System@spoofed.

- Removed all "ext-" attributes in favor of using an IANA registry for extending attributes.

- Removed Impact class in favor of using SystemImpact and IncidentCategory.

1.2. 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 [refs.requirements].

1.3. Notations

The normative IODEF data model is specified with the text in Section 3 and the XML schema in Section 8. To help 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 specific elements and attributes of the IODEF schema. The terms "class" and "element" will be used interchangeably to reference either the corresponding data element in the information or data models, respectively.

1.4. About the IODEF Data Model

The IODEF data model is a data representation that provides a framework for sharing information commonly exchanged by CSIRTs about computer security incidents. A number of considerations were made in the design of the data model.

- The data model serves as a transport format. Therefore, its specific representation is not the optimal representation for on-disk storage, long-term archiving, or in-memory processing.

- As there is no precise widely agreed upon definition for an incident, the data model does not attempt to dictate one through its implementation. Rather, a broad understanding is assumed in the IODEF that is flexible enough to encompass most operators.

- Describing an incident for all definitions would require an extremely complex data model. Therefore, the IODEF only intends to be a framework to convey commonly exchanged incident information. It ensures that there are ample mechanisms for extensibility to support organization-specific information, and techniques to reference information kept outside of the explicit data model.

- The domain of security analysis is not fully standardized and must rely on free-form textual descriptions. The IODEF attempts to strike a balance between supporting this free-form content, while still allowing automated processing of incident information.

- The IODEF is only one of several security relevant data representations being standardized. Attempts were made to ensure they were complementary. The data model of the Intrusion Detection Message Exchange Format [RFC4765] influenced the design of the IODEF.

Further discussion of the desirable properties for the IODEF can be found in the Requirements for the Format for Incident Information Exchange (FINE) [refs.requirements].

1.5. About the IODEF Implementation

The IODEF implementation is specified as an Extensible Markup Language (XML) [W3C.XML] Schema [W3C.SCHEMA].

Implementing the IODEF in XML provides numerous advantages. Its extensibility makes it ideal for specifying a data encoding framework that supports various character encodings. Likewise, the abundance of related technologies (e.g., XSL, XPath, XML-Signature) makes for simplified manipulation. However, XML is fundamentally a text representation, which makes it inherently inefficient when binary data must be embedded or large volumes of data must be exchanged.

2. IODEF Data Types

The various data elements of the IODEF data model are typed. This section discusses these data types. When possible, native Schema data types were adopted, but for more complicated formats, regular expressions (see Appendix F of [W3C.SCHEMA.DTYPES]) or external standards were used.

2.1. Integers

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

The INTEGER data type is implemented as an "xs:integer" in [W3C.SCHEMA.DTYPES].

2.2. Real Numbers

Real (floating-point) attributes are represented by the REAL data type. Real data MUST be encoded in Base 10.

The REAL data type is implemented as an "xs:float" in [W3C.SCHEMA.DTYPES].

2.3. Characters and Strings

A single character is represented by the CHARACTER data type. A character 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 implement as an "xs:string" in [W3C.SCHEMA.DTYPES].

2.4. Multilingual Strings

STRING data that represents multi-character attributes in a language different than the default encoding of the document is of the ML_STRING data type.

The ML_STRING data type is implemented as an "iodef:MLStringType" in the schema.

2.5. Bytes

A binary octet is represented by the BYTE data type. A sequence of binary octets is represented by the BYTE[] data type. These octets are encoded using base64.

The BYTE data type is implemented as an "xs:base64Binary" in [W3C.SCHEMA.DTYPES].

2.6. Hexadecimal Bytes

A binary octet is represented by the HEXBIN (and HEXBIN[]) data type. This octet is encoded as a character tuple consisting of two hexadecimal digits.

The HEXBIN data type is implemented as an "xs:hexBinary" in [W3C.SCHEMA.DTYPES].

2.7. Enumerated Types

Enumerated types are represented by the ENUM data type, and consist of an ordered list of acceptable values. Each value has a representative keyword. Within the IODEF schema, the enumerated type keywords are used as attribute values.

The ENUM data type is implemented as a series of "xs:NMTOKEN" in the schema.

2.8. Date-Time Strings

Date-time strings are represented by the DATETIME data type. Each date-time string identifies a particular instant in time. Ranges are not supported.

Date-time strings are formatted according to a subset of [ISO8601] documented in [RFC3339].

The DATETIME data type is implemented as an "xs:dateTime" in the schema.

2.9. Timezone String

A timezone offset from UTC is represented 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 as an "xs:string" with a regular expression constraint in [W3C.SCHEMA.DTYPES]. This regular expression is identical to the timezone representation implemented in an "xs:dateTime".

2.10. Port Lists

A list of network ports are represented 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 as an "xs:string" with a regular expression constraint in the schema.

2.11. Postal Address

A postal address is represented by the POSTAL data type. This data type is an ML_STRING whose format is documented in Section 2.23 of [RFC4519]. It defines a postal address as a free-form multi-line string separated by the "$" character.

The POSTAL data type is implemented as an "xs:string" in the schema.

2.12. Person or Organization

The name of an individual or organization is represented by the NAME data type. This data type is an ML_STRING whose format is documented in Section 2.3 of [RFC4519].

The NAME data type is implemented as an "xs:string" in the schema.

2.13. Telephone and Fax Numbers

A telephone or fax number is represented by the PHONE data type. The format of the PHONE data type is documented in Section 2.35 of [RFC4519].

The PHONE data type is implemented as an "xs:string" in the schema.

2.14. Email String

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

The EMAIL data type is implemented as an "xs:string" in the schema.

2.15. Uniform Resource Locator strings

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

The URL data type is implemented as an "xs:anyURI" in the schema.

2.16. Identifiers and Identifier References

An identifier unique to the Document is represented by the ID data type. A reference to this identifier is represented by the IDREF data type. The acceptable format of ID and IDREF is documented in Section 3.3.8 and 3.3.9 of [W3C.SCHEMA.DTYPES].

The ID and IDREF data types are implemented as "xs:ID" and "xs:IDREF" in the schema.

3. The IODEF Data Model

In this section, the individual components of the IODEF data model will be discussed in detail. For each class, the semantics will be described and the relationship with other classes will be depicted with UML. When necessary, specific comments will be made about corresponding definition in 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.

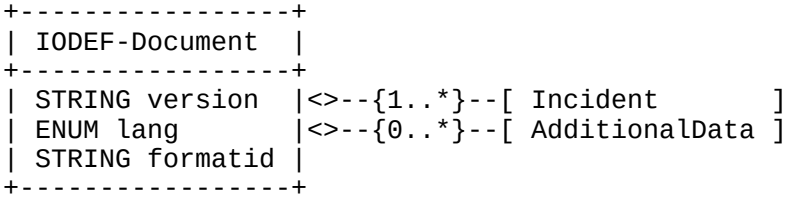

Figure 1: IODEF-Document Class

The aggregate class that constitute IODEF-Document is:

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

AdditionalData
: Zero or more. Mechanism by which to extend the data model. See Section 3.9

The IODEF-Document class has three attributes:

version

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

lang
Required. ENUM. A valid language code per [RFC5646] constrained by the definition of "xs:language". The interpretation of this code is described in Section 6.

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

3.2. Incident Class

Every incident is represented by an instance of the Incident class. This class provides a standardized representation for commonly exchanged incident data.

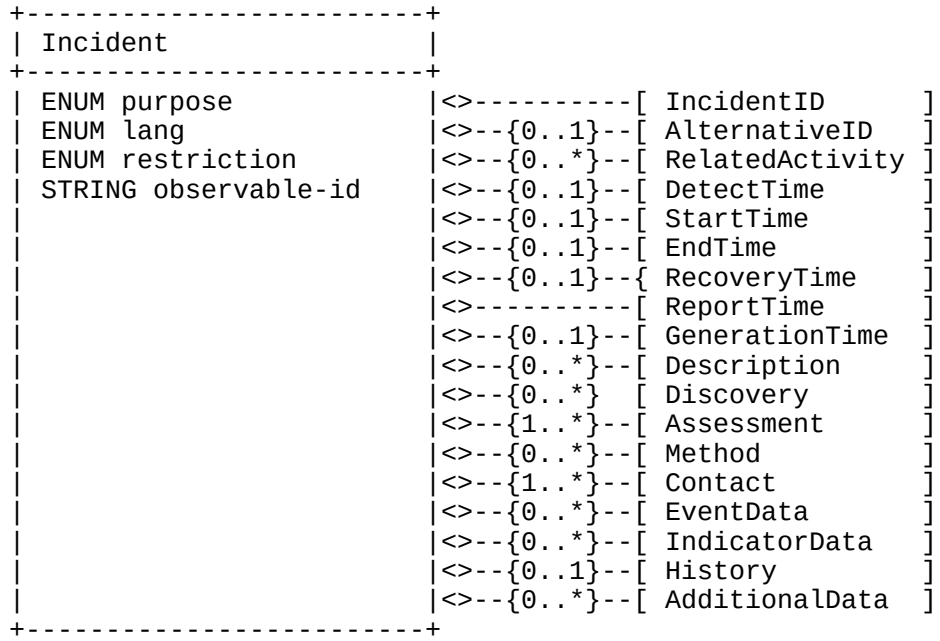

Figure 2: The Incident Class

The aggregate classes that constitute Incident are:

IncidentID

One. An incident tracking number assigned to this incident by the CSIRT that generated the IODEF document.

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

RelatedActivity
Zero or more. Related activity and attribution of this activity.

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

StartTime
Zero or one. The time the incident started.

EndTime
Zero or one. The time the incident ended.

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

ReportTime
One. The time the incident was reported.

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

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

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

Assessment
One or more. A characterization of the impact of the incident.

Method
Zero or more. The techniques used by the intruder in the incident.

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

EventData
Zero or more. Description of the events comprising the incident.

IndicatorData
Zero or more. Description of indicators.

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

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

The Incident class has three attributes:

purpose
Required. ENUM. The purpose attribute represents the reason why the IODEF document was created. It is closely related to the Expectation class (Section 3.17). These values are maintained in the "Incident-purpose" IANA registry per Table 1. This attribute is defined as an enumerated list:

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

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

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

4. watch. The document was sent to convey indicators to watch for particular activity.

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

lang
Optional. ENUM. A valid language code per [RFC5646] constrained by the definition of "xs:language". The interpretation of this code is described in Section 6.

restriction
Optional. ENUM. See Section 3.3.1.

observable-id
Optional. ID. See Section 3.3.2.

3.3. Common Attributes

There are a number of recurring attributes used by the data 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 specified 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 Table 1.

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'.

3.3.2. observable-id Attribute

Information included in an incident report may be an observable relevant to an indicator. The observable-id attribute provides a unique identifier in the scope of the document for this observable. This identifier can then used to reference the observable with an ObservableReference class to define an indicator in the IndicatorData class.

3.4. IncidentID Class

The IncidentID class represents an incident tracking number that is unique in the context of the CSIRT and identifies the activity characterized in an IODEF Document. This identifier would serve as an index into the CSIRT incident handling 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.

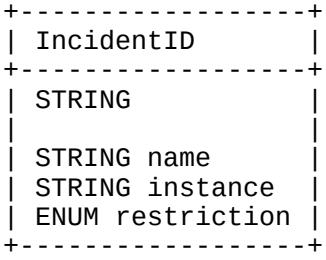

Figure 3: The IncidentID Class

The IncidentID class has three attributes:

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. The default value is "public".

3.5. AlternativeID Class

The AlternativeID class lists the incident 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 incident tracking numbers of the CSIRT that generated the IODEF document must never be considered an AlternativeID.

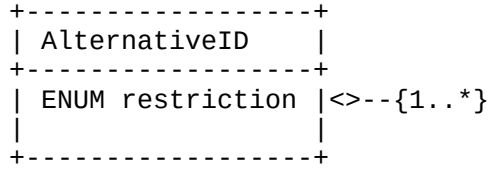

Figure 4: The AlternativeID Class

The aggregate class that constitutes AlternativeID is:

IncidentID
One or more. The incident tracking number of another CSIRT.

The AlternativeID class has one attribute:

restriction
Optional. ENUM. This attribute has been defined in Section 3.2.

3.6. RelatedActivity Class

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

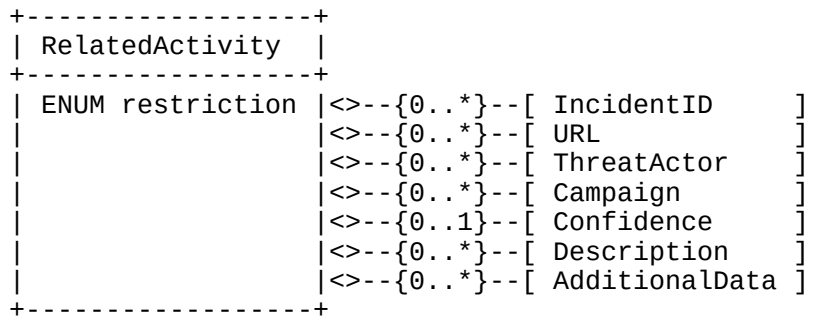

Figure 5: RelatedActivity Class

The aggregate classes that constitutes RelatedActivity are:

IncidentID
: One or more. The incident tracking number of a related incident.

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

ThreatActor
: One or more. The threat actor to whom the described activity is attributed.

Campaign
: One or more. The campaign of a given threat actor to whom the described activity is attributed.

Confidence
: Zero or one. An estimate of the confidence in attributing this RelatedActivity to the event described in the document.

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

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

RelatedActivity MUST at least have one instance of IncidentID, URL, ThreatActor, or Campaign.

The RelatedActivity class has one attribute:

restriction
: Optional. ENUM. See Section 3.3.1.

3.7. ThreatActor Class

The ThreatActor class describes a given actor.

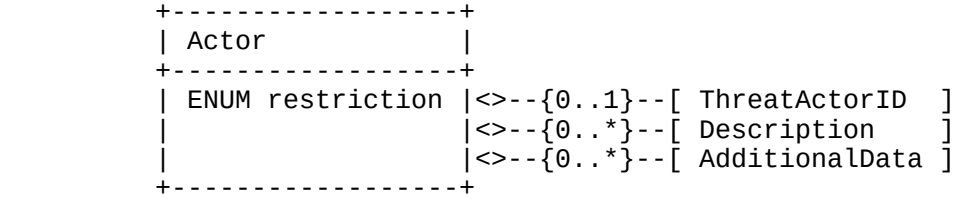

Figure 6: ThreatActor Class

The aggregate classes that constitutes ThreatActor are:

ThreatActorID
: One or more. STRING. An identifier for the ThreatActor.

Description
: One or more. ML_STRING. A description of the ThreatActor.

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

ThreatActor MUST have at least one instance of a ThreatActorID or Description.

The ThreatActor class has one attribute:

restriction
: Optional. ENUM. See Section 3.3.1.

3.8. Campaign Class

The Campaign class describes a ...

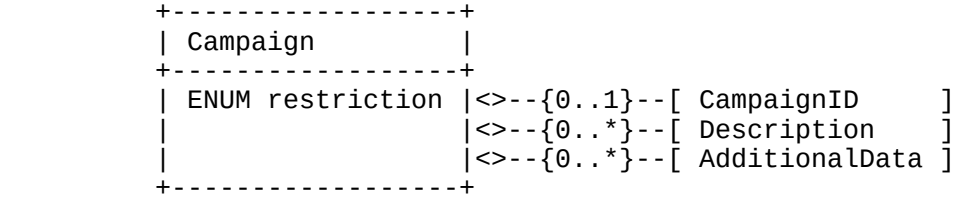

Figure 7: Campaign Class

The aggregate classes that constitutes Campaign are:

CampaignID
One or more. STRING. An identifier for the Campaign.

Description
One or more. ML_STRING. A description of the Campaign.

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

Campaign MUST have at least one instance of a Campaign or Description.

The Campaign class has one attribute:

restriction
Optional. ENUM. See Section 3.3.1.

3.9. AdditionalData Class

The AdditionalData class serves as an extension mechanism for information not otherwise represented in the data model. For relatively simple information, atomic data types (e.g., integers, strings) are provided with a mechanism to annotate their meaning. The class can also be used to extend the data model (and the associated Schema) to support proprietary extensions by encapsulating entire XML documents conforming to another Schema. A detailed discussion for extending the data model and the schema can be found in Section 5.

Unlike XML, which is self-describing, atomic data must be documented to convey its meaning. This information is described in the 'meaning' attribute. Since these description are outside the scope of the specification, some additional coordination may be required to ensure that a recipient of a document using the AdditionalData classes can make sense of the custom extensions.

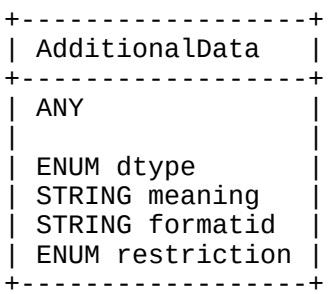

Figure 8: The AdditionalData Class

The AdditionalData class has four attributes:

dtype
: Required. 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 "AdditionalData-dtype" IANA registry per Table 1.

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.

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

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

restriction
Optional. ENUM. See Section 3.3.1.

3.10. 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 inheriting definition of Contact provides a way to relate information without requiring the explicit use of identifiers in the classes 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. As such, multiple points of contact might be specified in a single instance of a Contact class. Each child Contact class logically inherits contact information from its ancestors.

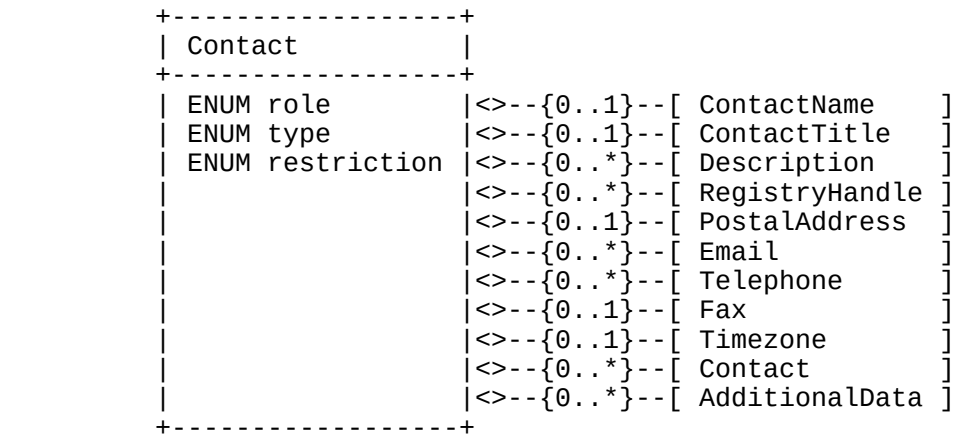

Figure 9: The Contact Class

The aggregate classes that constitute the Contact class are:

ContactName
: Zero or one. 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 one. ML_STRING. The title for the individual named in the ContactName.

Description
: Zero or more. ML_STRING. A free-form description of this contact. In the case of a person, this is often the organizational title of the individual.

RegistryHandle
: Zero or more. A handle name into the registry of the contact.

PostalAddress
: Zero or one. The postal address of the contact.

Email
: Zero or more. The email address of the contact.

Telephone
: Zero or more. The telephone number of the contact.

Fax
: Zero or one. The facsimile telephone number of the contact.

Timezone
Zero or one. TIMEZONE. The timezone in which the contact resides formatted according to Section 2.9.

Contact
Zero or more. A Contact instance contained within another Contact instance inherits the values of the parent(s). This recursive 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. 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. This is not enforced in the IODEF schema as there is no simple way to accomplish it.

The Contact class has three attributes:

role
Required. ENUM. Indicates the role the contact fulfills. This attribute is defined as an enumerated list. These values are maintained in the "Contact-role" IANA registry per Table 1.

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. zone. An entity with authority over a DNS zone.

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

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

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

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

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

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

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

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

15. vendor. The vendor that produces an asset.

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

17. victim. A victim in the incident.

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

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 Table 1.

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

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

restriction
Optional. ENUM. This attribute is defined in Section 3.2.

3.10.1. RegistryHandle Class

The RegistryHandle class represents a handle into an Internet registry or community-specific database. The handle is specified in the element content and the type attribute specifies the database.

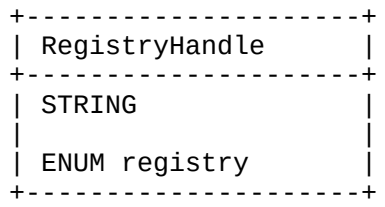

Figure 10: The RegistryHandle Class

The RegistryHandle class has one attributes:

registry
Required. ENUM. The database to which the handle belongs. These values are maintained in the "RegistryHandle-registry" IANA registry per Table 1. 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

3.10.2. PostalAddress Class

The PostalAddress class specifies a postal address formatted according to the POSTAL data type (Section 2.11).

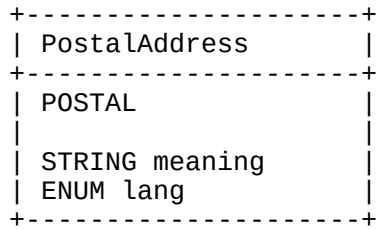

Figure 11: The PostalAddress Class

The PostalAddress class has two attributes:

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

lang
Optional. ENUM. A valid language code per [RFC5646] constrained by the definition of "xs:language". The interpretation of this code is described in Section 6.

3.10.3. Email Class

The Email class specifies an email address formatted according to EMAIL data type (Section 2.14).

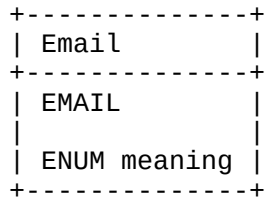

Figure 12: The Email Class

The Email class has one attribute:

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

3.10.4. Telephone and Fax Classes

The Telephone and Fax classes specify a voice or fax telephone number respectively, and are formatted according to PHONE data type (Section 2.13).

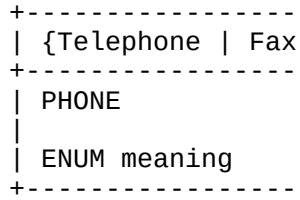

Figure 13: The Telephone and Fax Classes

The Telephone class has one attribute:

meaning

Optional. ENUM. A free-form description of the element content (e.g., hours of coverage for a given number).

3.11. Time Classes

The data model uses five different classes to represent a timestamp. Their definition is identical, but each has a distinct name to convey a difference in semantics.

The element content of each class is a timestamp formatted according to the DATETIME data type (see Section 2.8).

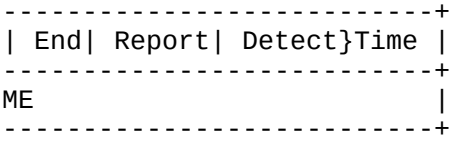

Figure 14: The Time Classes

3.11.1. StartTime Class

The StartTime class represents the time the incident began.

3.11.2. EndTime Class

The EndTime class represents the time the incident ended.

3.11.3. DetectTime Class

The DetectTime class represents the time the first activity of the incident was detected.

3.11.4. ReportTime Class

The ReportTime class represents the time the incident was reported. This timestamp MUST be the time at which the IODEF document was generated.

3.11.5. DateTime

The DateTime class is a generic representation of a timestamp. Infer its semantics from the parent class in which it is aggregated.

3.12. Discovery Class

The Discovery class describes how an incident was detected.

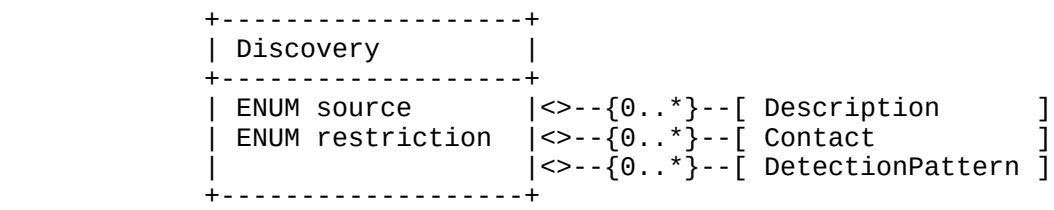

Figure 15: The Discovery Class

The Discovery class is composed of three aggregate classes.

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.

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

The Discovery class has two attribute:

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 Table 1.

  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.

restriction
Optional. ENUM. This attribute is defined in Section 3.2.

3.12.1. 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 describes in either free-form or machine readable form.

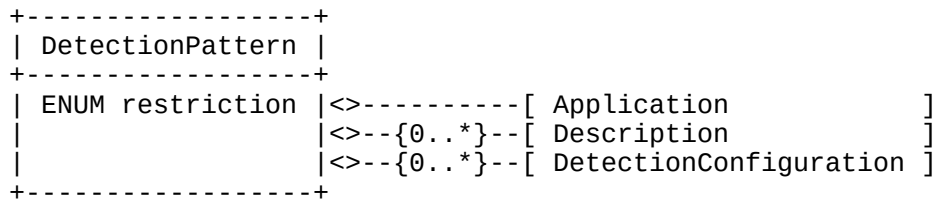

Figure 16: The DetectionPattern Class

The DetectionPattern class is composed of three aggregate classes.

Application
: One. 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 Method class has one attribute:

restriction
: Optional. ENUM. This attribute is defined in Section 3.2.

3.13. Method Class

The Method class describes the tactics, techniques, or procedures used by the intruder in the incident. This class consists of both a list of references describing the attack method and a free form description.

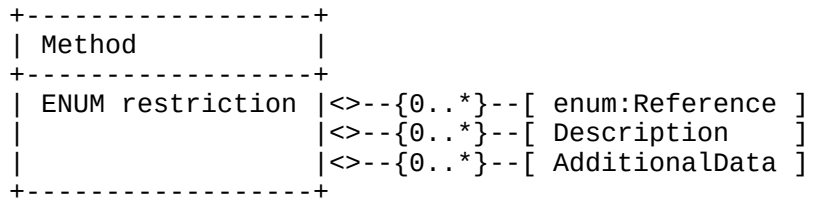

Figure 17: The Method Class

The Method class is composed of three aggregate classes.

enum:Reference
Zero or more. A reference to a vulnerability, malware sample, advisory, or analysis of an attack technique per [RFC-ENUM].

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

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

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

The Method class has one attribute:

restriction
Optional. ENUM. This attribute is defined in Section 3.2.

3.14. Assessment Class

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

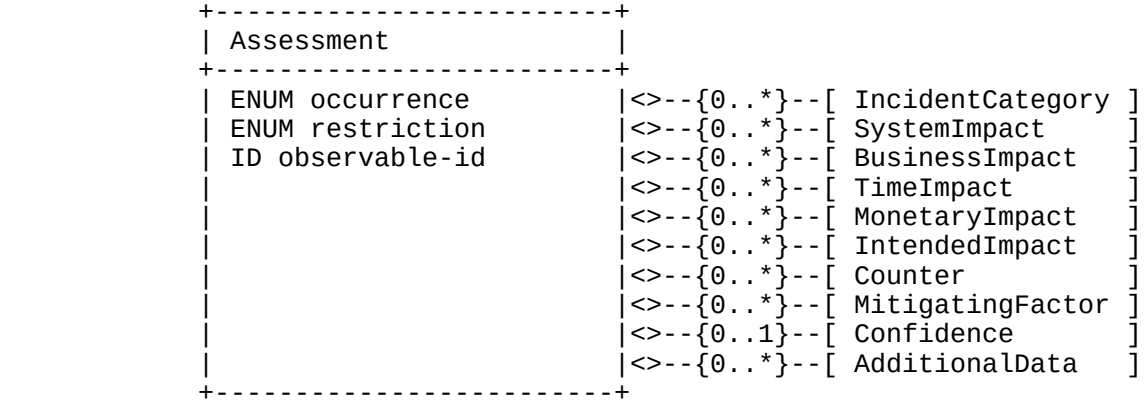

Figure 18: Assessment Class

The aggregate classes that constitute Assessment are:

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

SystemImpact
Zero or more. Technical characterization of the impact of the activity on the victim's enterprise.

BusinessImpact
Zero or more. Impact of the activity on the business functions of the victim organization.

TimeImpact
Zero or more. Impact of the activity measured with respect to time.

MonetaryImpact
Zero or more. Impact of the activity measured with respect to financial loss.

IntendedImpact
Zero or more. Intended impact to the victim by the attacker. Identically defined as Section 3.14.2 but describes intent rather than the realized impact.

Counter
Zero or more. A counter with which to summarize the magnitude of the activity.

MitigatingFactor
Zero or one. ML_STRING. A description of a mitigating factor an impact.

Confidence
Zero or one. An estimate of confidence in the assessment.

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

A least one instance of the possible three impact classes (i.e., Impact, TimeImpact, or MonetaryImpact) MUST be present.

The Assessment class has three attributes:

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. This attribute is defined in Section 3.2.

observable-id
Optional. ID. See Section 3.3.2.

3.14.1. SystemImpact Class

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

This class is based on [RFC4765].

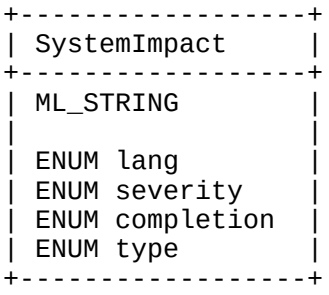

Figure 19: SystemImpact Class

The element content will be a free-form textual description of the impact.

The SystemImpact class has four attributes:

lang
Optional. ENUM. A valid language code per [RFC5646] constrained by the definition of "xs:language". The interpretation of this code is described in Section 6.

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 Table 1.

1. takeover-account. Control was taken of a given account (e.g., a social media 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 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.

3.14.2. BusinessImpact Class

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

The element body describes the impact to the organization as a free-form text string. The two attributes characterize the impact.

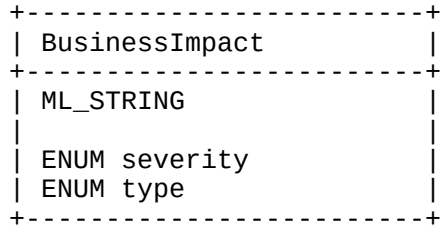

Figure 20: BusinessImpact Class

The element content will be a free-form textual description of the impact to the organization.

The BusinessImpact class has two attributes:

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 Table 1.

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.

type
Required. ENUM. Characterizes the effect this incident had on the business. The permitted values are shown below. There is no default value. These values are maintained in the "BusinessImpact-type" IANA registry per Table 1.

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.

3.14.3. 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.

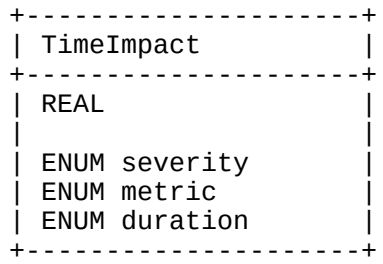

Figure 21: TimeImpact Class

The element content is a positive, floating point (REAL) number specifying a unit of time. The duration and metric attributes will imply the semantics of the element content.

The TimeImpact class has three attributes:

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 metric in which the time is expressed. The permitted values are shown below. There is no default value. These values are maintained in the "TimeImpact-metric" IANA registry per Table 1.

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.

duration
Optional. ENUM. Defines a unit of time, that when combined with the metric attribute, fully describes a metric of impact that will be conveyed in the element content. The permitted values are shown below. The default value is "hour". These values are maintained in the "TimeImpact-duration" IANA registry per Table 1.

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.

3.14.4. 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.

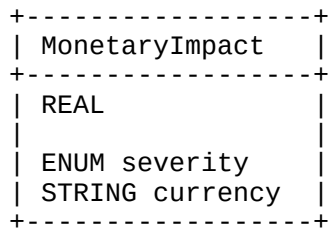

Figure 22: MonetaryImpact Class

The element content is a positive, floating point number (REAL) specifying a unit of currency described in the currency attribute.

The MonetaryImpact class has two attributes:

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 monetary impact is expressed. The permitted values are defined in "Codes for the representation of currencies and funds" of [ISO4217]. There is no default value.

3.14.5. Confidence Class

The Confidence class represents a best estimate of the validity and accuracy of the described impact (see Section 3.14) of the incident activity. This estimate can be expressed as a category or a numeric calculation.

This class if based upon [RFC4765].

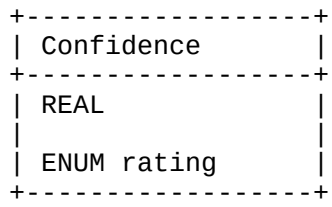

Figure 23: Confidence Class

The element content expresses 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 Confidence class has one attribute.

rating
: Required. ENUM. A rating of the analytical validity of the specified Assessment. The permitted values are shown below. There is no default value.

1. low. Low confidence in the validity.

2. medium. Medium confidence in the validity.

3. high. High confidence in the validity.

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.

3.15. 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.

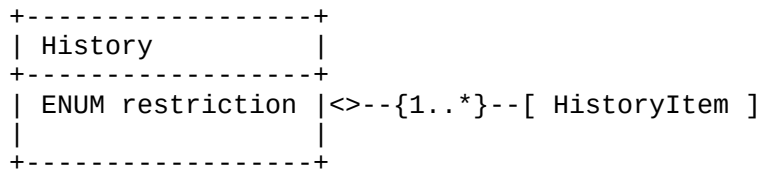

Figure 24: The History Class

The class that constitutes History is:

HistoryItem
: One or many. Entry in the history log of significant events or actions performed by the involved parties.

The History class has one attribute:

restriction
: Optional. ENUM. This attribute is defined in Section 3.2. The default value is "default".

3.15.1. HistoryItem Class

The HistoryItem class is an entry in the History (Section 3.15) 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 description, but each can be categorized with the type attribute.

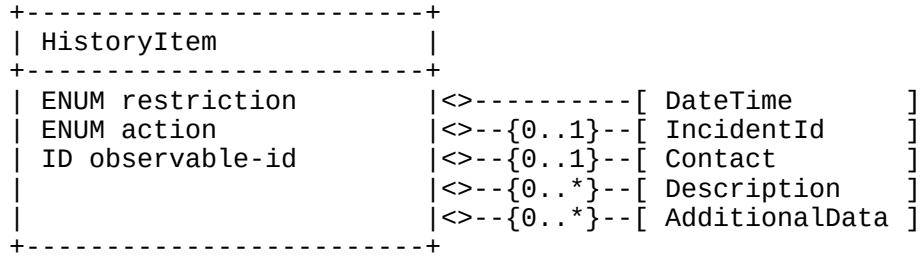

Figure 25: HistoryItem Class

The aggregate classes that constitute HistoryItem are:

DateTime
: One. Timestamp of this entry in the history log (e.g., when the action described in the Description was taken).

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 incident tracking number. When a single organization is maintaining the log, this class can be ignored.

Contact
Zero or One. Provides contact information for the person that performed the action documented in this class.

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

DefinedCOA
Zero or more. ML_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".

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

The HistoryItem class has three attributes:

restriction
Optional. ENUM. See Section 3.3.1.

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 3.17.

observable-id
Optional. ID. See Section 3.3.2.

3.16. EventData Class

The EventData class describes a particular event of the incident for a given set of hosts or networks. This description includes the systems from which the activity originated and those targeted, an assessment of the techniques used by the intruder, the impact of the activity on the organization, and any forensic evidence discovered.

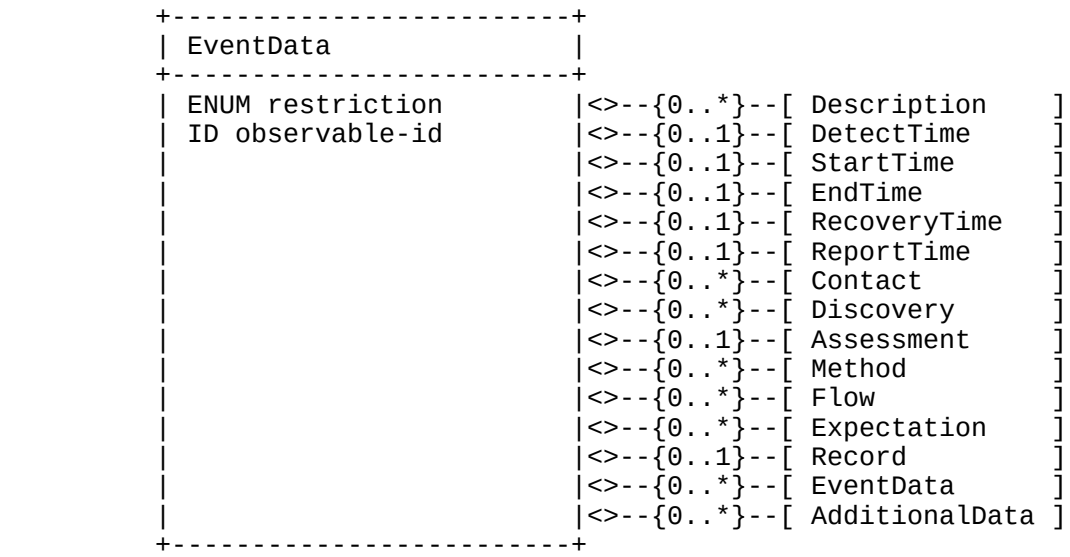

Figure 26: The EventData Class

The aggregate classes that constitute EventData are:

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

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

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

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

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

ReportTime
: One. The time the event was reported.

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

Discovery

Zero or more. The means by which the event was detected.

Assessment
Zero or one. The impact of the event on the target and the actions taken.

Method
Zero or more. The technique used by the intruder in the event.

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

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

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

EventData
Zero or more. EventData instances contained within another EventData instance inherit the values of the parent(s); this recursive definition can be used to group common data pertaining to multiple events. When EventData elements are defined recursively, only the leaf instances (those EventData instances not containing other EventData instances) represent actual events.

AdditionalData
Zero or more. 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. This is not enforced in the IODEF schema as there is no simple way to accomplish it.

The EventData class has two attributes:

restriction
Optional. ENUM. This attribute is defined in Section 3.2. The default value is "default".

observable-id
Optional. ID. See Section 3.3.2.

3.16.1. Relating the Incident and EventData Classes

There is substantial overlap 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 most common case, the EventData class will provide more specific information for the general description provided in the Incident class. However, it may also be possible that the overall summarized information about the incident conflicts with some individual information in an EventData class when there is a substantial composition of various events in the incident. In such a case, the interpretation of the more specific EventData MUST supersede the more generic information provided in Incident.

3.16.2. Cardinality of EventData

The EventData class can be thought of as a 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. With an instance of the EventData class, hosts (i.e., System class) are grouped around these common properties.

The recursive definition (or instance property inheritance) of the EventData class (the EventData class is aggregated into the EventData class) provides a way to relate information without requiring the explicit use of unique attribute identifiers in the classes or duplicating information. Instead, the relative depth (nesting) of a class is used to group (relate) information.

For example, an EventData class might be used to describe two machines involved in an incident. This description can be achieved using multiple instances of the Flow class. It happens that there is a common technical contact (i.e., Contact class) for these two machines, but the impact (i.e., Assessment class) on them is different. A depiction of the representation for this situation can be found in Figure 27.

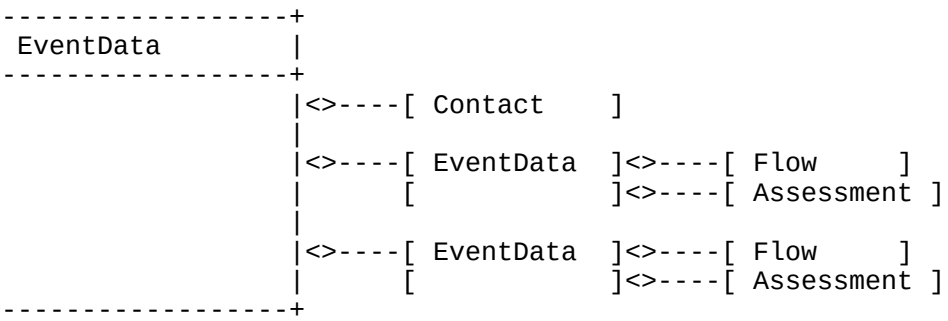

Figure 27: Recursion in the EventData Class

3.17. Expectation Class

The Expectation class conveys to the recipient of the IODEF document the actions the sender is requesting. The scope of the requested action is limited to purview of the EventData class in which this class is aggregated.

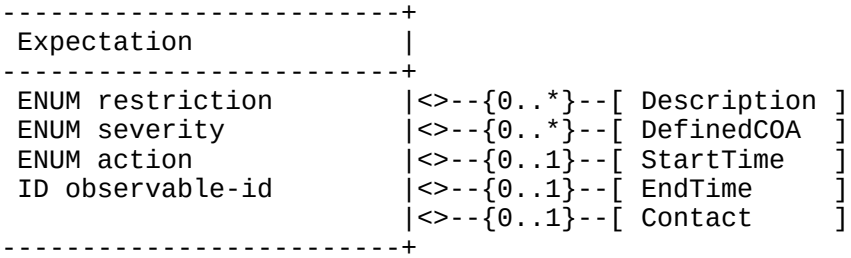

Figure 28: The Expectation Class

The aggregate classes that constitute Expectation are:

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

DefinedCOA
: Zero or more. ML_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. 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. 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, clock drift, and so on, 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 expected actor for the action.

The Expectations class has four attributes:

restriction
Optional. ENUM. This attribute is defined in Section 3.2. The default value is "default".

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

action
Optional. ENUM. Classifies the type of action requested. This attribute is an enumerated list with a default value of "other". These values are maintained in the "Expectation-action" IANA registry per Table 1.

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 intended recipient for further analysis.

13. honeypot. Redirect traffic to a honeypot for further analysis.

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

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

16. harden-asset. Change the configuration an asset (e.g., reduce the number of services or user accounts) to reduce the attack surface.

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

18. status-triage. Conveys receipts and the triaging of an incident.

19. status-new-info. Conveys that new information was received for this incident.

20. watch-and-report. Watch for the described activity and share if seen.

21. training. Train user to identify or mitigate a threat.

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

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

observable-id
Optional. ID. See Section 3.3.2.

3.18. Flow Class

The Flow class groups related the source and target hosts.

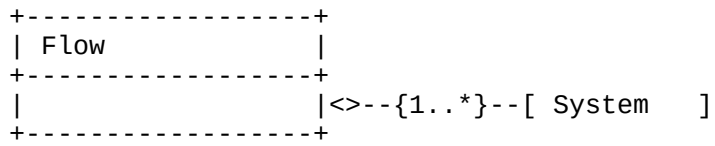

Figure 29: The Flow Class

The aggregate class that constitutes Flow is:

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

The Flow class has no attributes.

3.19. System Class

The System class describes a system or network involved in an event. The systems or networks represented by this class are categorized according to the role they played in the incident through the category attribute. The value of this category attribute dictates the semantics of the aggregated classes in the System class. If the category attribute has a value of "source", then the aggregated classes denote the machine and service from which the activity is originating. With a category attribute value of "target" or "intermediary", then the machine or service is the one targeted in the activity. A value of "sensor" dictates that this System was part of an instrumentation to monitor the network.

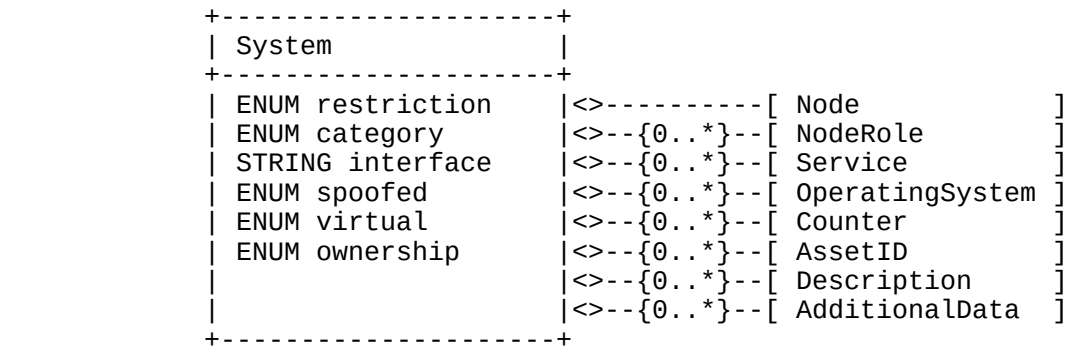

Figure 30: The System Class

The aggregate classes that constitute System are:

Node
One. A host or network involved in the incident.

NodeRole
Zero or more. The intended purpose of the system.

Service
Zero or more. A network service running on the system.

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

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

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

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

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

The System class has six attributes:

restriction
Optional. ENUM. This attribute is defined in Section 3.2.

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 Table 1. The possible values are:

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.

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 probably 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". The possible values are:

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 sender of the IODEF document. These values are maintained in the "System-ownership" IANA registry per Table 1. The possible values are:

1. organization. The System is owned by the organization.

2. personal. The System is owned by employee or affiliate of the organization.

3. partner. The System is owned by a partner of the organization.

4. customer. The System is owned by a customer of the organization.

5. no-relationship. The System is owned by an entity that has no known relationship with the organization.

6. unknown. The ownership of the System is unknown.

3.20. Node Class

The Node class names an asset or network.

This class was derived from [RFC4765].

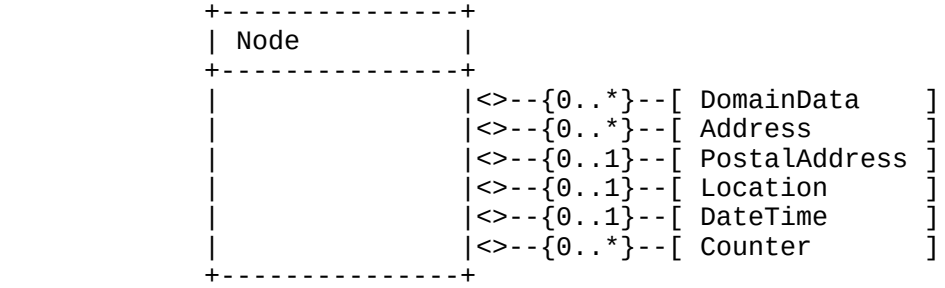

Figure 31: The Node Class

The aggregate classes that constitute Node are:

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

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.

PostalAddress
Zero or one. The postal address of the asset.

Location
Zero or one. ML_STRING. A free-from 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.

The Node class has no attributes.

3.20.1. Address Class

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

This class was derived from [RFC4765].

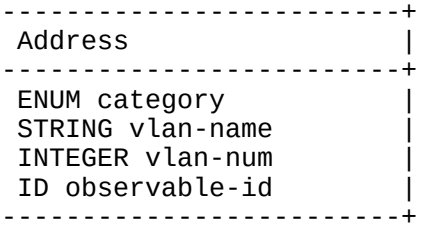

Figure 32: The Address Class

The Address class has four attributes:

category
Optional. ENUM. The type of address represented. The permitted values for this attribute are shown below. The default value is "ipv4-addr". These values are maintained in the "Address-category" IANA registry per Table 1.

1. asn. Autonomous System Number

2. atm. Asynchronous Transfer Mode (ATM) address

3. e-mail. Electronic mail address (RFC 822)

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 (a.b.c.d/nn)

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

7. ipv6-addr. IPv6 host address

8. ipv6-net. IPv6 network address, slash, significant bits

9. ipv6-net-mask. IPv6 network address, slash, network mask

10. mac. Media Access Control (MAC) address

11. site-uri. A URL or URI for a resource.

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

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

observable-id
Optional. ID. See Section 3.3.2.

3.20.2. NodeRole Class

The NodeRole class describes the function performed by a particular .

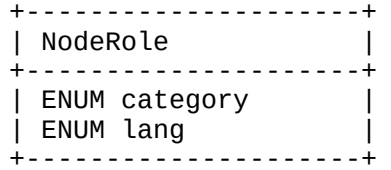

Figure 33: The NodeRole Class

The NodeRole class has two attributes:

category
Required. ENUM. Functionality provided by a node. These values are maintained in the "NodeRole-category" IANA registry per Table 1.

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 is serves as a kiosk
6. client-mobile. Client is a 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 (e.g., SMB, CVS, AFS)
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 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. 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 attacker.

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.

lang
Optional. ENUM. A valid language code per [RFC5646] constrained by the definition of "xs:language". The interpretation of this code is described in Section 6.

3.20.3. Counter Class

The Counter class summarize multiple occurrences of some event, or conveys counts or rates on various features (e.g., packets, sessions, events).

The value of the counter is the element content with its units represented in the type attribute. A rate for a given feature can be expressed by setting the duration attribute. The complete semantics are entirely context dependent based on the class in which the Counter is aggregated.

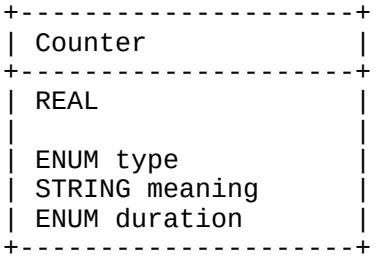

Figure 34: The Counter Class

The Counter class has three attribute:

type
Required. ENUM. Specifies the units of the element content. These values are maintained in the "Counter-type" IANA registry per Table 1.

1. byte. Count of bytes.

2. packet. Count of packets.

3. flow. Count of network flow records.

4. session. Count of sessions.

5. alert. Count of notifications generated by another system (e.g., IDS or SIM).

6. message. Count of messages (e.g., mail messages).

7. event. Count of events.

8. host. Count of hosts.

9. site. Count of site.

10. organization. Count of organizations.

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

duration
Optional. ENUM. If present, the Counter class represents a rate rather than a count over the entire event. In that case, this attribute specifies the denominator of the rate (where the type attribute specified the nominator). The possible values of this attribute are defined in Section 3.14.3

3.21. DomainData Class

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

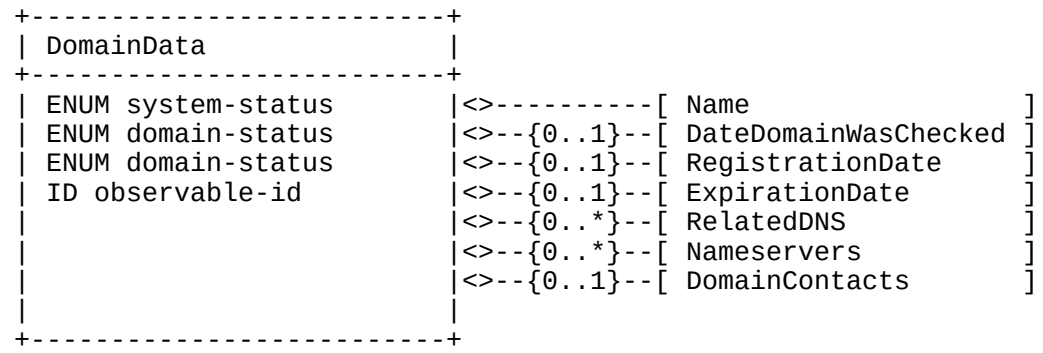

Figure 35: The DomainData Class

The aggregate classes that constitute DomainData are:

Name
: One. ML_STRING. The domain name of the Node (e.g., fully qualified domain name).

DateDomainWasChecked
: Zero or one. DATETIME. A timestamp of when the Name was resolved.

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

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

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

Nameservers
: Zero or more. The name servers identified for the domain listed in Name.

DomainContacts
: Zero or one. Contact information for the domain listed in Name supplied by the registrar or through a whois query.

The DomainData class has four attribute:

system-status

Required. ENUM. Assesses the domain's involvement in the event. These values are maintained in the "DomainData-system-status" IANA registry per Table 1.

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.

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 Table 1.

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 under 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.

observable-id

Optional. ID. See Section 3.3.2.

3.21.1. RelatedDNS

The RelatedDNS class describes additional record types associated with a given domain name. The record type is described in the record-type attribute and the value of the record is the element content. ... TODO Issue #39 ...

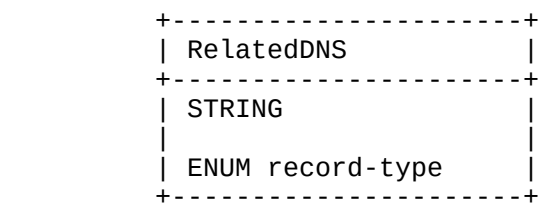

Figure 36: The RelatedDNS Class

The RelatedDNS class has one attribute:

record-type
Required. ENUM. The DNS record type. ... TODO values need to be listed ...

3.21.2. Nameservers Class

The Nameservers class describes the name servers associated with a given domain.

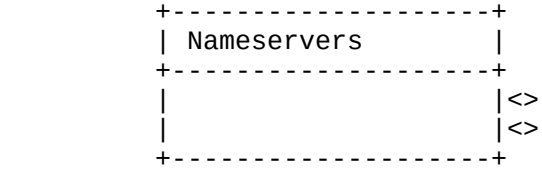

Figure 37: The Nameservers Class

The aggregate classes that constitute Nameservers are:

Server
One. ML_STRING. The domain name of the name server.

Address
One or more. The address of the name server. See Section 3.20.1.

3.21.3. 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 many Contact classes.

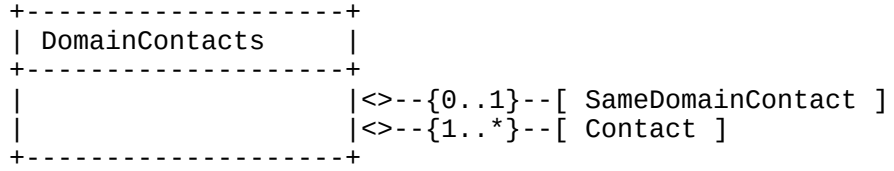

Figure 38: The DomainContacts Class

The aggregate classes that constitute DomainContacts are:

SameDomainContact
: Zero or one. ML_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 in lieu of explicit definition with the Contact class.

Contact
: One or more. Contact information for the domain. See Section 3.10.

3.22. Service Class

The Service class describes a network service of a host or network. The service is identified by specific port or list of ports, along with the application listening on that port.

When Service occurs as an aggregate class of a System that is a source, then this service is the one from which activity of interest is originating. Conversely, when Service occurs as an aggregate class of a System that is a target, then that service is the one to which activity of interest is directed.

This class was derived from [RFC4765].

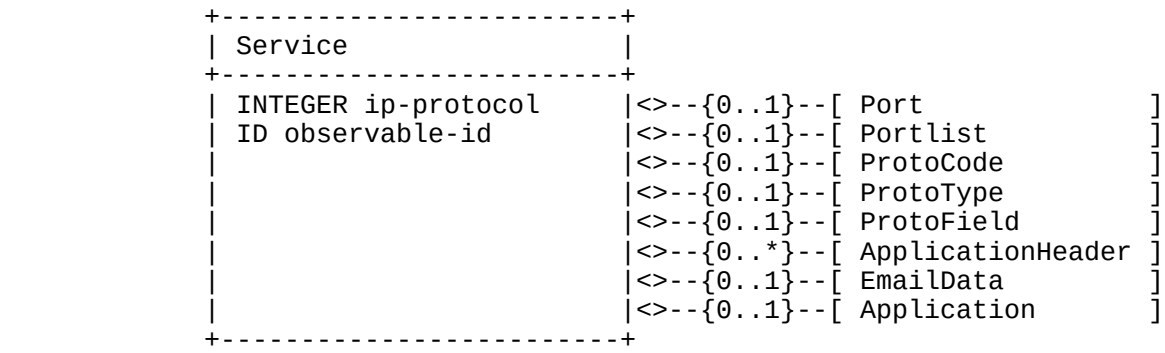

Figure 39: The Service Class

The aggregate classes that constitute Service are:

Port
: Zero or one. INTEGER. A port number.

Portlist
: Zero or one. PORTLIST. A list of port numbers formatted according to Section 2.10.

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 more. An application layer (layer 7) protocol header. See Section 3.22.1.

EmailData
: Zero or one. Headers associated with an email. See Section 3.24.

Application
: Zero or one. The application bound to the specified Port or Portlist. See Section 3.22.2.

Either a Port or Portlist class MUST be specified for a given instance of a Service class.

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 Service class has two attributes:

ip-protocol
: Required. INTEGER. The IANA assigned IP protocol number per [IANA.Protocols].

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

3.22.1. ApplicationHeader Class

The ApplicationHeader class allows the representation of arbitrary fields from an application layer protocol header and its corresponding value.

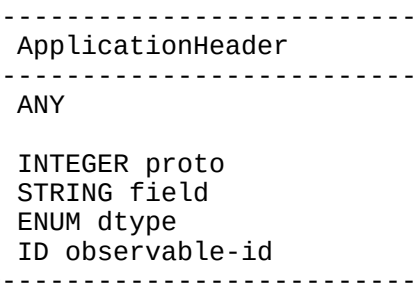

Figure 40: The ApplicationHeader Class

The ApplicationHeader class has four attributes:

proto

Required. INTEGER. The IANA assigned port number per [IANA.Ports] corresponding to the application layer protocol whose field will be represented.

field
Required. STRING. The name of the protocol field whose value will be found in the element body.

dtype
Required. ENUM. The data type of the element content. The permitted values for this attribute are shown below. The default value is "string".

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. integer. The element content is of type INTEGER.

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

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

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

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

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

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

observable-id
Optional. ID. See Section 3.3.2.

3.22.2. Application Class

The Application class describes an application running on a System providing a Service.

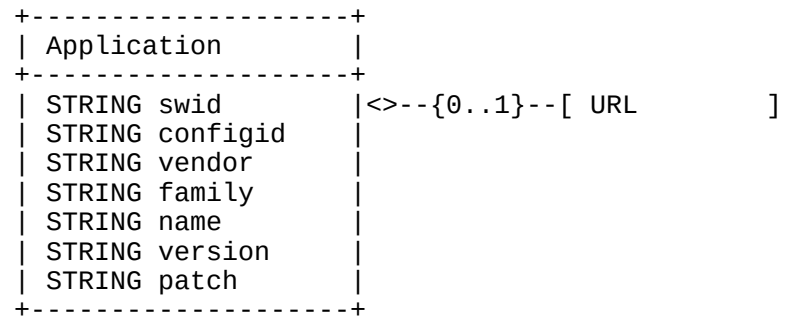

Figure 41: The Application Class

The aggregate class that constitute Application is:

URL
: Zero or one. URL. A URL describing the application.

The Application class has seven attributes:

swid
: Optional. STRING. An identifier that can be used to reference this software, where the default value is "0".

configid
: Optional. STRING. An identifier that can be used to reference a particular configuration of this software, where the default value is "0".

vendor
: Optional. STRING. Vendor name of the software.

family
: Optional. STRING. Family of the software.

name
: Optional. STRING. Name of the software.

version
: Optional. STRING. Version of the software.

patch
: Optional. STRING. Patch or service pack level of the software.

3.23. OperatingSystem Class

The OperatingSystem class describes the operating system running on a System. The definition is identical to the Application class (Section 3.22.2).

3.24. EmailData Class

The EmailData class describes headers from an email message. Common headers have dedicated classes, but arbitrary headers can also be described.

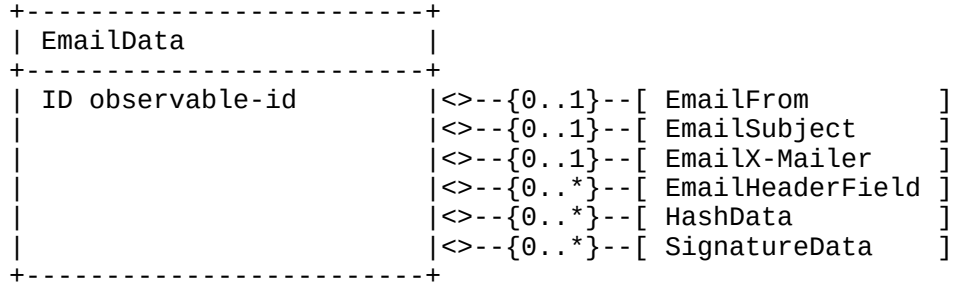

Figure 42: EmailData Class

The aggregate class that constitutes EmailData are:

EmailFrom
: Zero or one. The value of the "From:" header field in an email. See Section 3.6.2 of [RFC5322].

EmailSubject
: Zero or one. The value of the "Subject:" header field in an email. See Section 3.6.4 of [RFC5322].

EmailX-Mailer
: Zero or one. The value of the "X-Mailer:" header field in an email.

EmailHeaderField
: Zero or one. The value of an arbitrary header field in the email. See Section 3.22.1. The attributes of EmailHeaderField MUST be set as follows: proto="25" and dtype="string". The name of the email header field MUST be set in the field attribute.

HashData
: Zero or One. Hash(es) associated with this email.

SignatureData
Zero or One. Signature(s) associated with this email.

The EmailData class has one attribute:

observable-id
Optional. ID. See Section 3.3.2.

3.25. Record Class

The Record class is a container class for log and audit data that provides supportive information about the incident. The source of this data will often be the output of monitoring tools. These logs substantiate the activity described in the document.

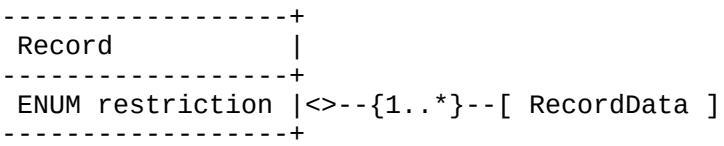

Figure 43: Record Class

The aggregate class that constitutes Record is:

RecordData
One or more. Log or audit data generated by a particular type of sensor. Separate instances of the RecordData class SHOULD be used for each sensor type.

The Record class has one attribute:

restriction
Optional. ENUM. This attribute has been defined in Section 3.2.

3.25.1. RecordData Class

The RecordData class groups log or audit data from a given sensor (e.g., IDS, firewall log) and provides a way to annotate the output.

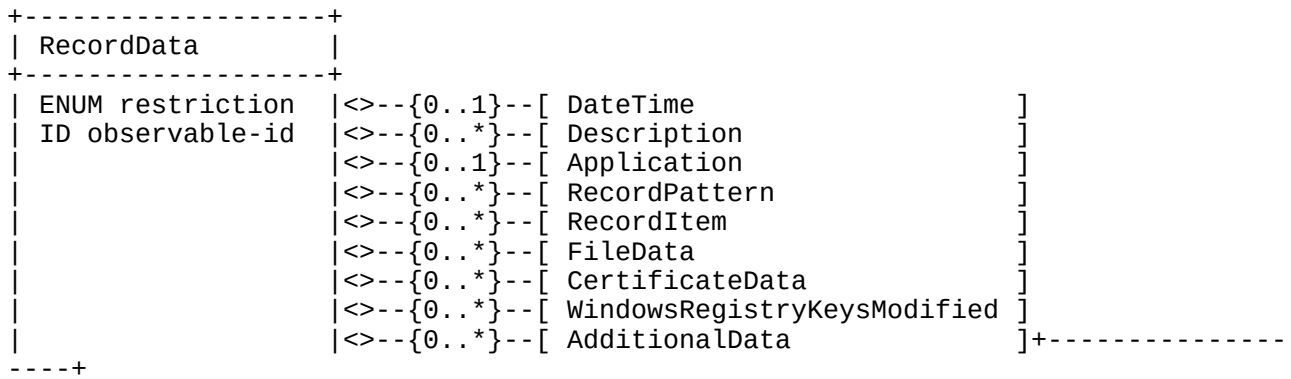

Figure 44: The RecordData Class

The aggregate classes that constitutes RecordData is:

DateTime
: Zero or one. Timestamp of the RecordItem data.

Description
: Zero or more. ML_STRING. Free-form textual description of the provided RecordItem data. At minimum, this description should convey the significance of the provided RecordItem data.

Application
: Zero or one. Information about the sensor used to generate the RecordItem data.

RecordPattern
: Zero or more. A search string to precisely find the relevant data in a RecordItem.

RecordItem
: Zero or more. Log, audit, or forensic data.

FileData
: Zero or one. The file name and hash of a file indicator.

WindowsRegistryKeysModified
: Zero or more. The registry keys that were modified that are indicator(s).

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

The RecordData class has two attribute:

restriction
Optional. ENUM. See Section 3.3.1.

observable-id
Optional. ID. See Section 3.3.2.

3.25.2. RecordPattern Class

The RecordPattern class describes where in the content of the RecordItem 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.

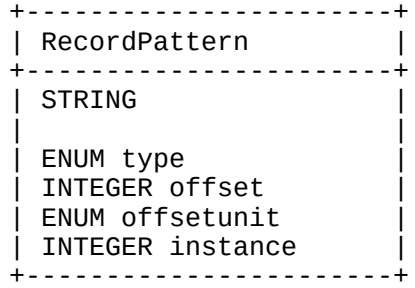

Figure 45: The RecordPattern Class

The specific pattern to search with in the RecordItem is defined in the body of the element. It is further annotated by four attributes:

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 Table 1.

1. regex. regular expression as defined by POSIX Extended Regular Expressions (ERE) in Chaper 9 of [IEEE.POSIX].

2. binary. Binhex encoded binary pattern, per the HEXBIN data type.

3. xpath. XML Path (XPath) [W3C.XPATH]

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 Table 1.

1. line. Offset is a count of lines.

2. byte. Offset is a count of bytes.

instance
Optional. INTEGER. Number of types to apply the specified pattern.

3.25.3. RecordItem Class

The RecordItem class provides a way to incorporate relevant logs, audit trails, or forensic data to support the conclusions made during the course of analyzing the incident. The class supports both the direct encapsulation of the data, as well as, provides primitives to reference data stored elsewhere.

This class is identical to AdditionalData class (Section 3.9).

3.26. 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].

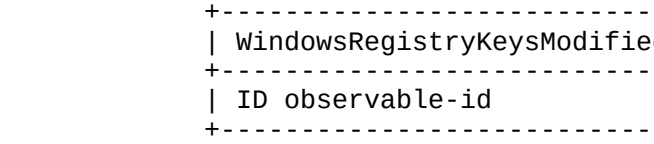

Figure 46: The WindowsRegistryKeysModified Class

The aggregate class that constitutes the WindowsRegistryKeysModified class is:

Key
One or many. The Window registry key.

The WindowsRegistryKeysModified class has one attribute:

observable-id
Optional. ID. See Section 3.3.2.

3.26.1. Key Class

The Key class describes a particular Windows operating system registry key name and value pair, and the operation performed on it.

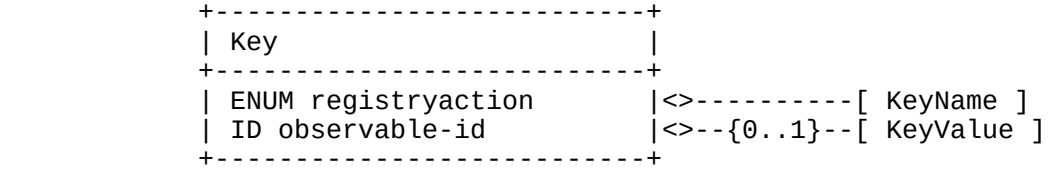

Figure 47: The Key Class

The aggregate classes that constitutes Key are:

KeyName
: One. STRING. The name of the Windows operating system registry key (e.g.,[HKEY_LOCAL_MACHINE\Software\Test\KeyName])

KeyValue
: Zero or one. STRING. The value of the associated registry key encoded as in Microsoft .reg files [KB310516].

The Key class has two attributes:

registryaction
: Optional. ENUM. The type of action taken on the registry key. These values are maintained in the "Key-registryaction" IANA registry per Table 1.

  1. add-key. Registry key added.

  2. add-value. Value added to registry key.

  3. delete-key. Registry key deleted.

  4. delete-value. Value deleted from registry key.

  5. modify-key. Registry key modified.

  6. modify-value. Value modified for registry key.

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

3.27. CertificateData Class

The CertificateData class describes X.509 certificates.

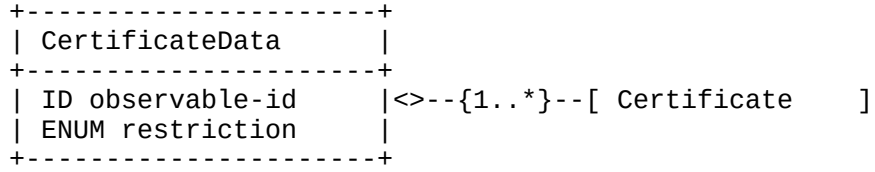

Figure 48: The CertificateData Class

The aggregate classes that constitutes CertificateData are:

Certificate
: One or more. A certificate.

The CertificateData class has two attribute:

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

restriction
: Optional. ENUM. See Section 3.3.1.

3.27.1. Certificate Class

The Certificate class describes a given X.509 certificate or certificate chain.

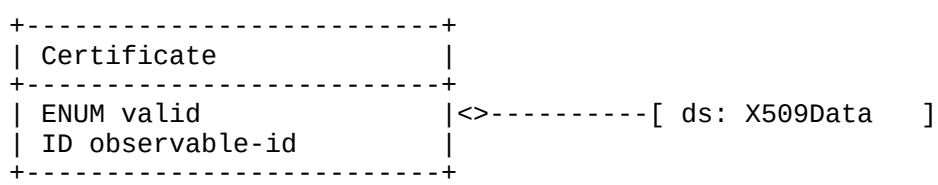

Figure 49: The Certificate Class

The aggregate classes that constitutes Certificate are:

ds:X509Data
: One. A given X.509 certificate or chain. See Section 4.4.4 of [W3C.XMLSIG].

The Certificate class has one attribute:

valid
Optional. Indicates whether a given certificate has a valid signature. An invalid signature may be due to an invalid certificate chain, a signature not decoding properly, or a certificate contents not matching the hash.

1. yes. The certificate is valid.

2. no. The certificate is not valid.

observable-id
Optional. ID. See Section 3.3.2.

3.28. FileData Class

The FileData class describes files of interest identified during the analysis of an incident.

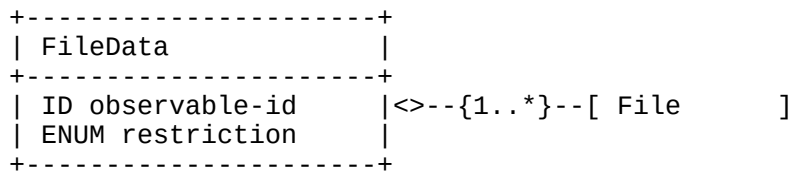

Figure 50: The FileData Class

The aggregate class that constitutes FileData is:

File
One or more. A description of a file.

The FileData class has two attribute:

observable-id
Optional. ID. See Section 3.3.2.

restriction
Optional. ENUM. See Section 3.3.1.

3.28.1. File Class

The File class describes a file and its associated meta data.

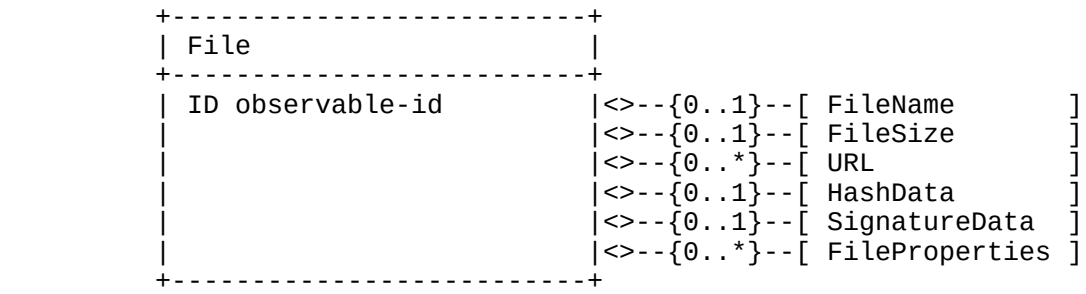

Figure 51: The File Class

The aggregate classes that constitutes File are:

FileName
: Zero or One. ML_STRING. The name of the file.

FileSize
: Zero or One. INTEGER. The size of the file in bytes.

URL
: Zero or more. A reference to the file.

HashData
: Zero or One. Hash(es) associated with this file.

SignatureData
: Zero or One. Signature(s) associated with this file.

FileProperties
: Zero or more. Mechanism by which to extend the data model to describe properties of the file. See Section 3.9.

The File class has one attribute:

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

3.29. HashData Class

The HashData class describes different types of hashes on an given object (e.g., file, part of a file, email).

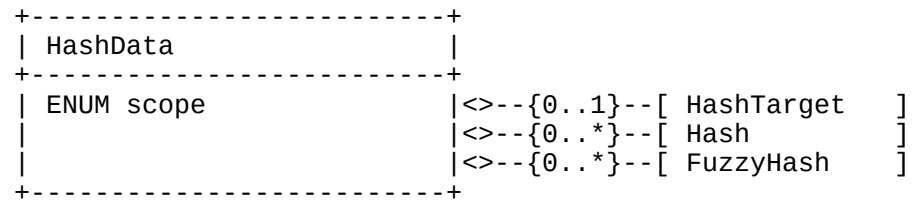

Figure 52: The HashData Class

The aggregate classes that constitutes HashData are:

HashTarget
: Zero or One. An identifier that references a a subset of the object per the @scope attribute.

Hash
: Zero or more. The hash generated on the object.

FuzzyHash
: Zero or more. The fuzzy hash of the object.

A single instance of Hash or FuzzyHash MUST be present.

The HashData class has one attribute:

scope
: Required. ENUM. Describes the scope of the hash on a type of object. These values are maintained in the "HashData-scope" IANA registry per Table 1.

  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. This 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 HashTargetId class 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. This resource is identified by an ordinal number (starting at 1) corresponding to the oder 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.

3.29.1. Hash Class

The Hash class describes a specific hash value, algorithm, and an application used to generate it.

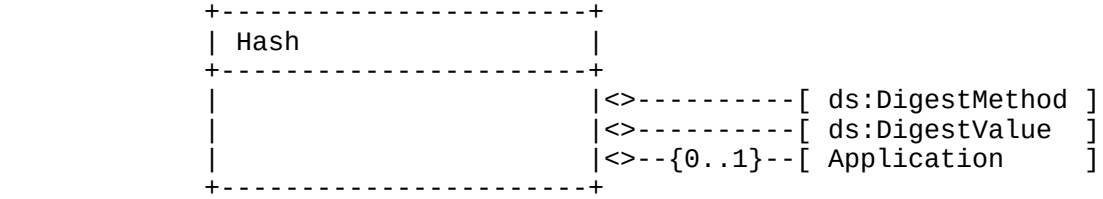

Figure 53: The Hash Class

The aggregate classes that constitutes Hash 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 computer hash value. See Section 4.3.3.6 of [W3C.XMLSIG].

Application
Zero or One. The application used to calculate the hash.

The HashData class has no attribute:

3.29.2. FuzzyHash Class

The FuzzyHash class describes a fuzzy hash (in an extensible way) and the application used to generate it.

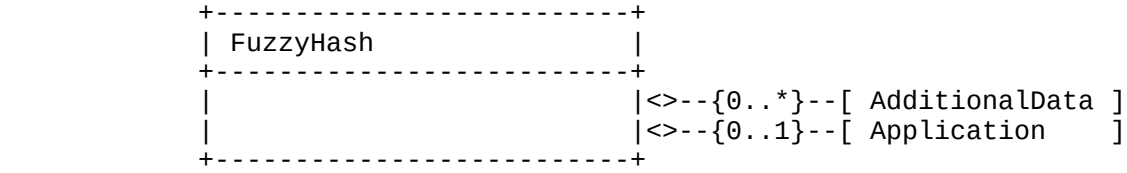

Figure 54: The FuzzyHash Class

The aggregate classes that constitutes FuzzyHash are:

AdditionalData
: Zero or more. Mechanism by which to extend the data model. See Section 3.9.

Application
: Zero or One. The application used to calculate the hash.

The FuzzyData class has no attribute:

3.30. SignatureData Class

The SignatureData class describes different signatures on an given object.

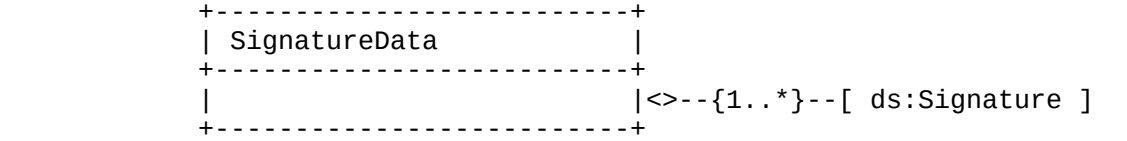

Figure 55: The SignatureData Class

The aggregate classes that constitutes SignatureData are:

Signature
: One or more. An given signature. See Section 4.2 of [W3C.XMLSIG]

The SignatureData class has no attribute:

3.31. IndicatorData Class

The IndicatorData class describes the indicators identified from analysis of an incident.

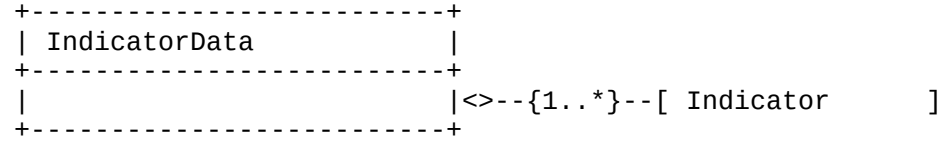

Figure 56: The IndicatorData Class

The aggregate class that constitutes IndicatorData is:

Indicator
: One or more. An indicator from the incident.

The IndicatorData class has no attributes.

3.32. Indicator Class

The Indicator class describes a cyber indicator. An indicator consists of observable features and phenomenon that aid in the forensic or proactive detection of malicious activity, and associated meta-data. This indicator can be described outright or reference observable features and phenomenon described elsewhere in the incident information. Portions of an incident description can be composed to define an indicator, as can the indicators themselves.

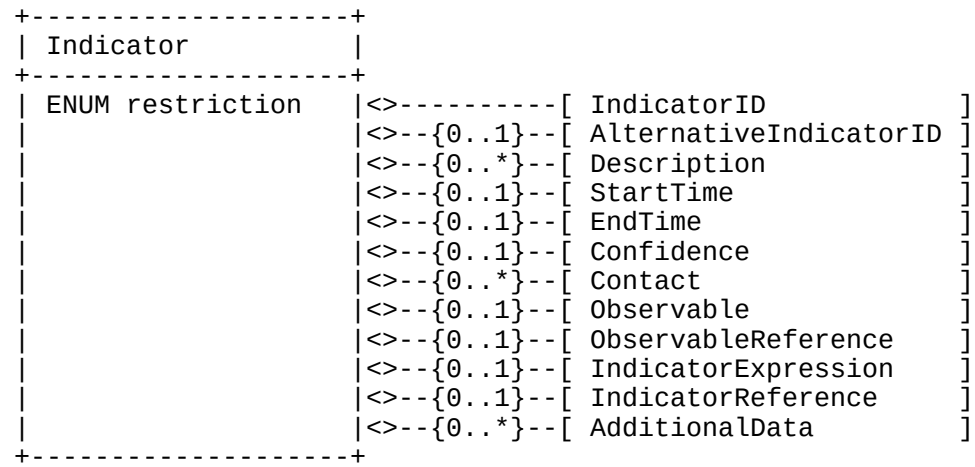

Figure 57: The Indicator Class

The aggregate classes that constitute Indicator are:

IndicatorID
One. An identifier for this indicator. See Section 3.32.1

AlternativeIndicatorID
Zero or one. An alternative identifier for this indicator. See Section 3.32.2

Description
Zero or more. ML_STRING. A free-form textual 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 3.14.5.

Contact
Zero or more. Contact information for this indicator. See Section 3.10.

Observable
Zero or one. An observable feature or phenomenon of this indicator. See Section 3.32.3.

ObservableReference
Zero or one. A reference to a feature or phenomenon defined elsewhere in the document. See Section 3.32.5.

IndicatorExpression
Zero or one. A composition of observables. See Section 3.32.4.

IndicatorReference
Zero or one. A reference to an indicator.

AdditionalData
Zero or more. Mechanism by which to extend the data model. See Section 3.9

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 Indicator class has one attribute:

restriction
Optional. ENUM. See Section 3.3.1.

3.32.1. 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.

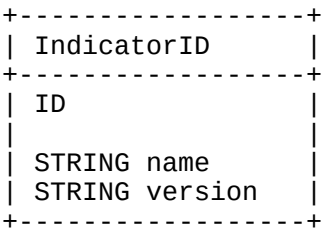

Figure 58: The IndicatorID Class

The IndicatorID class has two attributes:

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.

3.32.2. AlternativeIndicatorID Class

The AlternativeIndicatorID class lists alternative identifiers for an indicator.

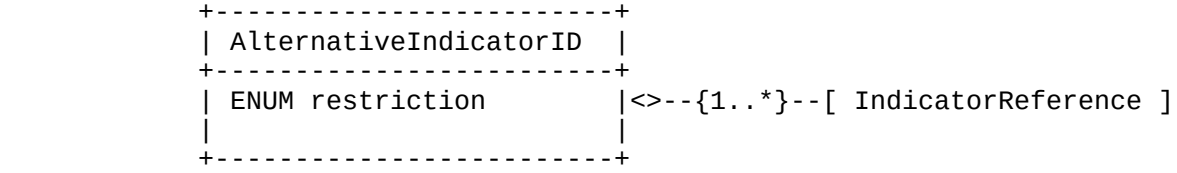

Figure 59: The AlternativeIndicatorID Class

The aggregate class that constitutes AlternativeIndicatorID is:

IndicatorReference
: One or more. A reference to an indicator.

The AlternativeIndicatorID class has one attribute:

restriction
: Optional. ENUM. This attribute has been defined in Section 3.2.

3.32.3. Observable Class

The Observable class describes a feature and phenomenon that can be observed or measured for the purposes of detecting malicious behavior.

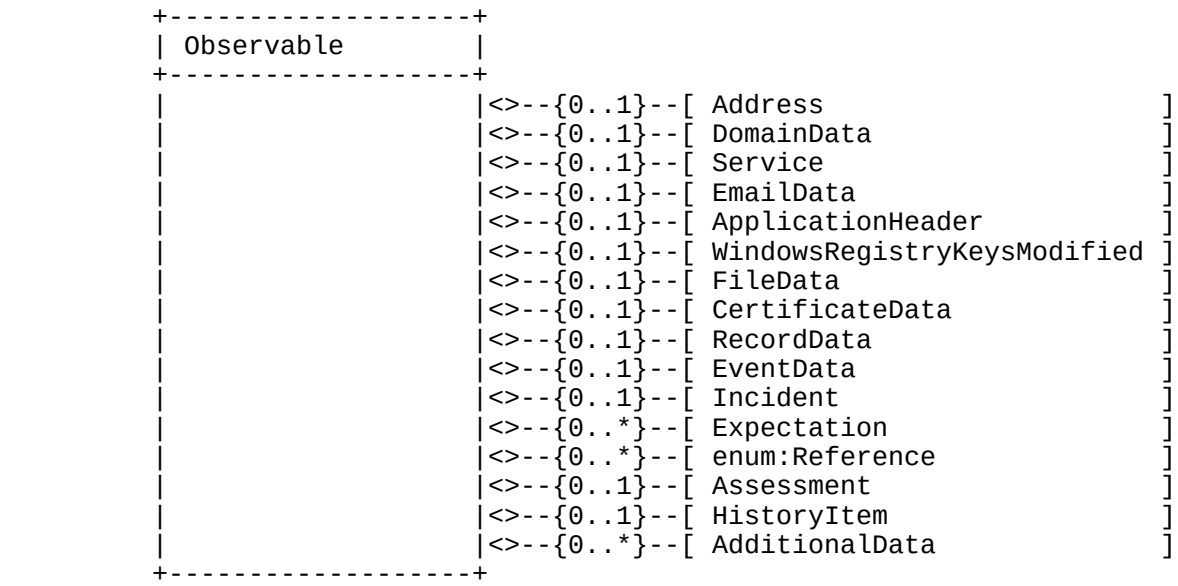

Figure 60: The Observable Class

The aggregate classes that constitute Observable are:

Address
: Zero or One. An Address observable. See Section 3.20.1.

DomainData
: Zero or One. A DomainData observable. See Section 3.21.

Service
: Zero or One. A Service observable. See Section 3.22.

EmailData
: Zero or One. A EmailData observable. See Section 3.24.

ApplicationHeader
: Zero or One. An ApplicationHeader observable. See Section 3.22.1.

WindowsRegistryKeysModified
: Zero or One. A WindowsRegistryKeysModified observable. See Section 3.26.

FileData
: Zero or One. A FileData observable. See Section 3.28.

CertificateData
Zero or One. A CertificateData observable. See Section 3.27.

RecordData
Zero or One. A RecordData observable. See Section 3.25.1.

EventData
Zero or One. An EventData observable. See Section 3.16.

Incident
Zero or One. An Incident observable. See Section 3.2.

EventData
Zero or One. An EventData observable. See Section 3.16.

Expectation
Zero or One. An Expectation observable. See Section 3.17.

enum:Reference
Zero or One. A Reference observable. See [RFC-ENUM].

Assessment
Zero or One. An Assessment observable. See Section 3.14.

HistoryItem
Zero or One. A HistoryItem observable. See Section 3.15.1.

AdditionalData
Zero or more. Mechanism by which to extend the data model. See Section 3.9.

The Observable class MUST have exactly one of the possible child classes.

The Observable class has no attributes.

3.32.4. 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. Nesting an IndicatorExpression in itself is akin to a parenthesis in the expression.

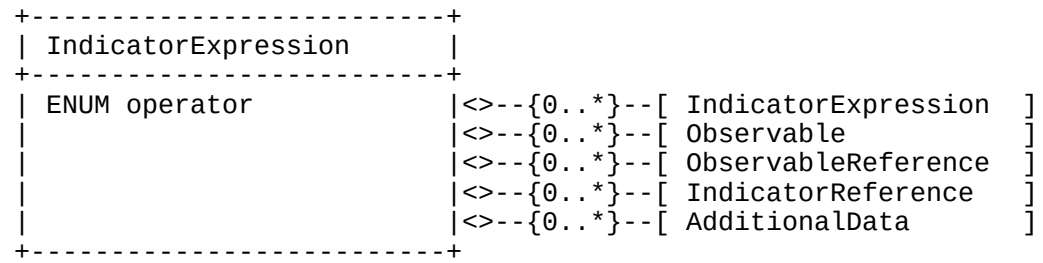

Figure 61: The IndicatorExpression Class

The aggregate classes that constitute IndicatorExpression are:

IndicatorExpression
: Zero or more. An expression composed of other observables or indicators.

Observable
: Zero or more. A description of an observable.

ObservableReference
: Zero or more. A reference to another observable.

IndicatorReference
: Zero or more. A reference to another indicator.

AdditionalData
: Zero or more. Mechanism by which to extend the data model. See Section 3.9

... TODO Additional text is required to describe the valid combinations of classes and how the operator class should be applied ...

The IndicatorExpression class has one attributes:

operator
: Optional. ENUM. The operator to be applied between the child elements.

  1. not. negation operator.

  2. and. conjunction operator.

  3. or. disjunction operator.

  4. xor. exclusive disjunction operator.

3.32.5. ObservableReference Class

The ObservableReference describes a reference to an observable feature or phenomenon described elsewhere in the document.

This class has no content.

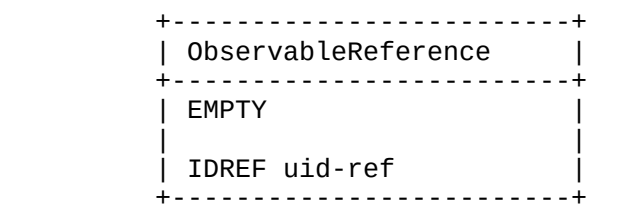

Figure 62: The ObservableReference Class

The ObservableReference class has one attributes:

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 the observable-id attribute.

3.32.6. IndicatorReference Class

The IndicatorReference describes a reference to an indicator. This reference may be to an indicator described in the IODEF document or in a previously exchanged IODEF document.

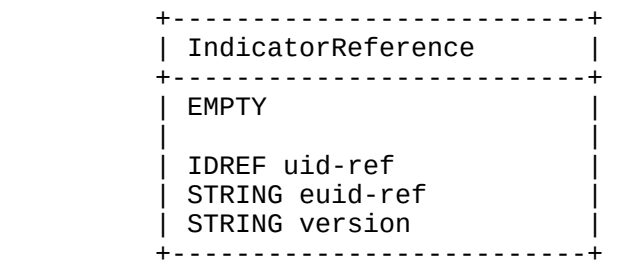

Figure 63: The IndicatorReference Class

The IndicatorReference class has one attributes:

uid-ref
: Optional. IDREF. An identifier that serves as a reference to an Indicator class in the IODEF document. The referenced Indicator class will have this identifier set in the 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.

4. Processing Considerations

This section defines additional requirements on creating and parsing IODEF documents.

4.1. Encoding

Every IODEF document MUST begin with an XML declaration, and MUST specify the XML version used. If UTF-8 encoding is not used, the character encoding MUST also be explicitly specified. The IODEF conforms to all XML data encoding conventions and constraints.

The XML declaration with no character encoding will read as follows:

```
<?xml version="1.0" ?>
```

When a character encoding is specified, the XML declaration will read like the following:

```
<?xml version="1.0" encoding="charset" ?>
```

Where "charset" is the name of the character encoding as registered with the Internet Assigned Numbers Authority (IANA), see [RFC2978].

The following characters have special meaning in XML and MUST be escaped with their entity reference equivalent: "&", "<", ">", "\"" (double quotation mark), and "’" (apostrophe). These entity references are "&", "<", ">", """, and "'" respectively.

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

The 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 the schema is not sufficient for a semantically valid IODEF document. There is additional specification in the text of Section 3 that cannot be readily encoded in the schema and it must also be considered by an IODEF parser. The following is a list of discrepancies in what is more strictly specified in the normative text (Section 3), but not enforced in the IODEF schema:

- The elements or attributes that are defined as POSTAL, NAME, PHONE, and EMAIL data-types are implemented as "xs:string", but more rigid formatting requirements are specified in the text.

- The IODEF-Document@lang and MLStringType@lang attributes are declared as an "xs:language" that constrains values with a regular expression. However, the value of this attribute still needs to be validated against the list of possible enumerated values is defined in [RFC5646].

- The MonetaryImpact@currency attribute is declared as an "xs:string", but the list of valid values as defined in [ISO4217].

- All of the aggregated classes Contact and EventData are optional in the schema, but at least one of these aggregated classes MUST be present.

- There are multiple conventions that can be used to categorize a system using the NodeRole class or to specify software with the Application and OperatingSystem classes. IODEF parsers MUST accept incident reports that do not use these fields in accordance with local conventions.

- The Confidence@rating attribute determines whether the element content of Confidence should be empty.

- The Address@type attribute determines the format of the element content.

- The attributes AdditionalData@dtype and RecordItem@dtype derived from iodef:ExtensionType determine the semantics and formatting of the element content.

- Symmetry in the enumerated ports of a Portlist class is required between sources and targets. See Section 3.22.

- 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 corresponded IANA registry. See Table 1. Hence, the schema to validate a given document MUST be dynamically generated from these registry values.

4.4. Incompatibilities with v1

Version 2 of the IODEF data model makes a number of changes to [RFC5070]. Largely, these changes were additive in nature -- classes and enumerated values were added. The following is a list of incompatibilities where the data model has changed between versions:

- The IODEF-Document@version attribute is set to "2.0".

- 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 [RFC-ENUM].

- Extending enumerated values is now handled through collection of IANA registries. All attributes of with a name prefixed by "ext-" have been removed.

- The data previously represented in the Impact class is now in the SystemImpact and IncidentCategory classes. The Impact class has been removed.

5. Extending the IODEF

In order to support the changing activity of CSIRTS, the IODEF data model will need to evolve along with them. This section discusses how new data elements that have no current representation in the data model can be incorporated into the IODEF. These techniques are

designed so that adding new data will not require a change to the IODEF schema. With proven value, well documented extensions can be incorporated into future versions of the specification. However, this approach also supports private extensions relevant only to a closed consortium.

5.1. Extending the Enumerated Values of Attributes

Select enumerated value of the attributes defined in the data model can be extended by adding entries to the corresponding IANA registry. See Table 1.

5.2. Extending Classes

The classes of the data model can be extended only through the use of the AdditionalData and RecordItem classes. These container classes, collectively referred to as the extensible classes, are implemented with the iodef:ExtensionType data type in the schema. 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 more complicated 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 of extensible class 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:

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 makes reading an

extended IODEF document look like any other IODEF document. The names of all elements are capitalized. For elements with composed names, a capital letter is used for each word. Attribute names are lower case. Attributes with composed names are separated by a hyphen.

4. Parsers that encounter an unrecognized element in a namespace that they do support MUST reject the document as a syntax error.

5. There are security and performance implications in requiring implementations to dynamically download schemas at run time. Thus, implementations SHOULD NOT download schemas at runtime, unless implementations take appropriate precautions and are prepared for potentially significant network, processing, and time-out demands.

6. Some users of the IODEF may have private schema definitions that might not be available on the Internet. In this situation, if a IODEF document leaks out of the private use space, references to some of those document schemas may not be resolvable. This has two implications. First, references to private schemas may never resolve. As such, in addition to the suggestion that implementations do not download schemas at runtime mentioned above, 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-1.0"
        schemaLocation=" urn:ietf:params:xml:schema:iodef-1.0"/>

     <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-1.0"
     xmlns:iodef=" urn:ietf:params:xml:ns:iodef-1.0"
     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>
</IODEF-Document
```

6. Internationalization Issues

Internationalization and localization is of specific concern to the IODEF, since it is only through collaboration, often across language barriers, that certain incidents be resolved. The IODEF supports this goal by depending on XML constructs, and through explicit design choices in the data model.

Since IODEF is implemented as an XML Schema, it implicitly supports all the different character encodings, such as UTF-8 and UTF-16, possible with XML. Additionally, each IODEF document MUST specify the language in which their contents are 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@lang) and letting all other elements inherit that definition. All IODEF classes with a free-form text definition (i.e., all those defined of type iodef:MLStringType) can also specify a language different from the rest of the document. The valid language codes for the "xml:lang" attribute are described in [RFC5646].

The data model supports multiple translations of free-form text. In the places where free-text is used for descriptive purposes, the given class always has a one-to-many cardinality to its parent (e.g., Description class). The intent is to allow the identical text to be encoded in different instances of the same class, but each being in a different language. This approach allows an IODEF document author to send recipients speaking different languages an identical document. The IODEF parser SHOULD extract the appropriate language relevant to the recipient.

While the intent of the data model is to provide internationalization and localization, the intent is not to do so at the detriment of

interoperability. While the IODEF does support 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 text based data elements are written in a language unfamiliar to the analyst.

7. Examples

This section provides examples of an incident encoded in the IODEF. These examples do not necessarily represent the only way to encode a particular incident.

7.1. Worm

An example of a CSIRT reporting an instance of the Code Red worm.

```
<?xml version="1.0" encoding="UTF-8"?>
<!-- This example demonstrates a report for a very
     old worm (Code Red) -->
<IODEF-Document version="2.00" lang="en"
  xmlns="urn:ietf:params:xml:ns:iodef-1.0"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:schemaLocation="urn:ietf:params:xml:schema:iodef-1.0">
  <Incident purpose="reporting">
    <IncidentID name="csirt.example.com">189493</IncidentID>
    <ReportTime>2001-09-13T23:19:24+00:00</ReportTime>
    <Description>Host sending out Code Red probes</Description>
    <!-- An administrative privilege was attempted, but failed -->
    <Assessment>
      <Impact completion="failed" type="admin"/>
    </Assessment>
    <Contact role="creator" type="organization">
      <ContactName>Example.com CSIRT</ContactName>
      <RegistryHandle registry="arin">example-com</RegistryHandle>
      <Email>contact@csirt.example.com</Email>
    </Contact>
    <EventData>
      <Flow>
        <System category="source">
          <Node>
            <Address category="ipv4-addr">192.0.2.200</Address>
            <Counter type="event">57</Counter>
          </Node>
        </System>
        <System category="target">
          <Node>
```

```
              <Address category="ipv4-net">192.0.2.16/28</Address>
            </Node>
            <Service ip_protocol="6">
              <Port>80</Port>
            </Service>
          </System>
        </Flow>
        <Expectation action="block-host" />
        <!-- <RecordItem> has an excerpt from a log -->
        <Record>
          <RecordData>
            <DateTime>2001-09-13T18:11:21+02:00</DateTime>
            <Description>Web-server logs</Description>
            <RecordItem dtype="string">
          192.0.2.1 - - [13/Sep/2001:18:11:21 +0200] "GET /default.ida?
          XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
          XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
          XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
          XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
            </RecordItem>
              <!-- Additional logs -->
            <RecordItem dtype="url">
               http://mylogs.example.com/logs/httpd_access</RecordItem>
          </RecordData>
        </Record>
      </EventData>
      <History>
        <!-- Contact was previously made with the source network
             owner -->
        <HistoryItem action="contact-source-site">
          <DateTime>2001-09-14T08:19:01+00:00</DateTime>
          <Description>Notification sent to
                       constituency-contact@192.0.2.200</Description>
        </HistoryItem>
      </History>
    </Incident>
  </IODEF-Document>
```

7.2. Reconnaissance

An example of a CSIRT reporting a scanning activity.

```
<?xml version="1.0" encoding="UTF-8" ?>
<!-- This example describes reconnaissance activity: one-to-one
     and one-to-many scanning -->
<IODEF-Document version="2.00" lang="en"
```

```
     xmlns="urn:ietf:params:xml:ns:iodef-1.0"
     xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
     xsi:schemaLocation="urn:ietf:params:xml:schema:iodef-1.0">
     <Incident purpose="reporting">
       <IncidentID name="csirt.example.com">59334</IncidentID>
       <ReportTime>2006-08-02T05:54:02-05:00</ReportTime>
       <Assessment>
         <Impact type="recon" completion="succeeded" />
       </Assessment>
       <Method>
         <!-- Reference to the scanning tool "nmap" -->
         <Reference>
           <ReferenceName>nmap</ReferenceName>
           <URL>http://nmap.toolsite.example.com</URL>
         </Reference>
       </Method>
       <!-- Organizational contact and that for staff in that
            organization -->
       <Contact role="creator" type="organization">
         <ContactName>CSIRT for example.com</ContactName>
         <Email>contact@csirt.example.com</Email>
         <Telephone>+1 412 555 12345</Telephone>
         <!-- Since this <Contact> is nested, Joe Smith is part of
              the CSIRT for example.com -->
         <Contact role="tech" type="person" restriction="need-to-know">
           <ContactName>Joe Smith</ContactName>
           <Email>smith@csirt.example.com</Email>
         </Contact>
       </Contact>
       <EventData>
         <!-- Scanning activity as follows:
           192.0.2.1:60524 >> 192.0.2.3:137
                  192.0.2.1:60526 >> 192.0.2.3:138
                  192.0.2.1:60527 >> 192.0.2.3:139
                  192.0.2.1:60531 >> 192.0.2.3:445
         -->
         <Flow>
           <System category="source">
             <Node>
               <Address category="ipv4-addr">192.0.2.200</Address>
             </Node>
             <Service ip_protocol="6">
               <Portlist>60524,60526,60527,60531</Portlist>
             </Service>
           </System>
           <System category="target">
             <Node>
               <Address category="ipv4-addr">192.0.2.201</Address>
```

```
            </Node>
            <Service ip_protocol="6">
              <Portlist>137-139,445</Portlist>
            </Service>
          </System>
        </Flow>
        <!-- Scanning activity as follows:
              192.0.2.2 >> 192.0.2.3/28:445 -->
        <Flow>
          <System category="source">
            <Node>
              <Address category="ipv4-addr">192.0.2.240</Address>
            </Node>
          </System>
          <System category="target">
            <Node>
              <Address category="ipv4-net">192.0.2.64/28</Address>
            </Node>
            <Service ip_protocol="6">
              <Port>445</Port>
            </Service>
          </System>
        </Flow>
      </EventData>
    </Incident>
  </IODEF-Document>
```

7.3. Bot-Net Reporting

An example of a CSIRT reporting a bot-network.

```
<?xml version="1.0" encoding="UTF-8" ?>
<!-- This example describes a compromise and subsequent installation
     of bots -->
<IODEF-Document version="2.00" lang="en"
  xmlns="urn:ietf:params:xml:ns:iodef-1.0"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:schemaLocation="urn:ietf:params:xml:schema:iodef-1.0">
  <Incident purpose="mitigation">
    <IncidentID name="csirt.example.com">908711</IncidentID>
    <ReportTime>2006-06-08T05:44:53-05:00</ReportTime>
    <Description>Large bot-net</Description>
    <Assessment>
      <Impact type="dos" severity="high" completion="succeeded" />
    </Assessment>
    <Method>
```

```
        <!-- References a given piece of malware, "GT Bot" -->
        <Reference>
          <ReferenceName>GT Bot</ReferenceName>
        </Reference>
        <!-- References the vulnerability used to compromise the
             machines -->
        <Reference>
          <ReferenceName>CA-2003-22</ReferenceName>
          <URL>http://www.cert.org/advisories/CA-2003-22.html</URL>
          <Description>Root compromise via this IE vulnerability to
                       install the GT Bot</Description>
        </Reference>
      </Method>
      <!-- A member of the CSIRT that is coordinating this
           incident -->
      <Contact type="person" role="irt">
        <ContactName>Joe Smith</ContactName>
        <Email>jsmith@csirt.example.com</Email>
      </Contact>
      <EventData>
        <Description>These hosts are compromised and acting as bots
                     communicating with irc.example.com.</Description>
        <Flow>
          <!-- bot running on 192.0.2.1 and sending DoS traffic at
               10,000 bytes/second -->
          <System category="source">
            <Node>
              <Address category="ipv4-addr">192.0.2.1</Address>
            </Node>
            <Counter type="byte" duration="second">10000</Counter>
            <Description>bot</Description>
          </System>
          <!-- a second bot on 192.0.2.3 -->
          <System category="source">
            <Node>
              <Address category="ipv4-addr">192.0.2.3</Address>
            </Node>
            <Counter type="byte" duration="second">250000</Counter>
            <Description>bot</Description>
          </System>
          <!-- Command-and-control IRC server for these bots-->
          <System category="intermediate">
            <Node>
              <NodeName>irc.example.com</NodeName>
              <Address category="ipv4-addr">192.0.2.20</Address>
              <DateTime>2006-06-08T01:01:03-05:00</DateTime>
            </Node>
            <Description>
```

```
              IRC server on #give-me-cmd channel
            </Description>
          </System>
        </Flow>
        <!-- Request to take these machines offline -->
        <Expectation action="investigate">
          <Description>
            Confirm the source and take machines off-line and
            remediate
          </Description>
        </Expectation>
      </EventData>
    </Incident>
  </IODEF-Document>
```

7.4. Watch List

An example of a CSIRT conveying a watch-list.

```
<?xml version="1.0" encoding="UTF-8" ?>
<!-- This example demonstrates a trivial IP watch-list -->
<!-- @formatid is set to "watch-list-043" to demonstrate how
     additional semantics about this document could be conveyed
     assuming both parties understood it-->
<IODEF-Document version="2.00" lang="en" formatid="watch-list-043"
  xmlns="urn:ietf:params:xml:ns:iodef-1.0"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:schemaLocation="urn:ietf:params:xml:schema:iodef-1.0">
  <Incident purpose="reporting" restriction="private">
    <IncidentID name="csirt.example.com">908711</IncidentID>
    <ReportTime>2006-08-01T00:00:00-05:00</ReportTime>
    <Description>
      Watch-list of known bad IPs or networks
    </Description>
    <Assessment>
      <Impact type="admin" completion="succeeded" />
      <Impact type="recon" completion="succeeded" />
    </Assessment>
    <Contact type="organization" role="creator">
      <ContactName>CSIRT for example.com</ContactName>
      <Email>contact@csirt.example.com</Email>
    </Contact>
    <!-- Separate <EventData> is used to convey
         different <Expectation> -->
    <EventData>
      <Flow>
```

```
          <System category="source">
            <Node>
              <Address category="ipv4-addr">192.0.2.53</Address>
            </Node>
            <Description>Source of numerous attacks</Description>
          </System>
        </Flow>
        <!-- Expectation class indicating that sender of list would
             like to be notified if activity from the host is seen -->
        <Expectation action="contact-sender" />
      </EventData>
      <EventData>
        <Flow>
          <System category="source">
            <Node>
              <Address category="ipv4-net">192.0.2.16/28</Address>
            </Node>
            <Description>
              Source of heavy scanning over past 1-month
            </Description>
          </System>
        </Flow>
        <Flow>
          <System category="source">
            <Node>
              <Address category="ipv4-addr">192.0.2.241</Address>
            </Node>
            <Description>C2 IRC server</Description>
          </System>
        </Flow>
        <!-- Expectation class recommends that these networks
             be filtered -->
        <Expectation action="block-host" />
      </EventData>
    </Incident>
  </IODEF-Document>
```

8. The IODEF Schema

```
<xs:schema targetNamespace="urn:ietf:params:xml:ns:iodef-2.0"
           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:xs="http://www.w3.org/2001/XMLSchema"
           xmlns:ds="http://www.w3.org/2000/09/xmldsig#"
           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/xml-registry/schema/iodef-enum-1.0.xsd" />
  <xs:annotation>
    <xs:documentation>
       Incident Object Description Exchange Format v2.0, RFC5070-bis
    </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 name="lang"
                      type="xs:language" use="required"/>
        <xs:attribute name="formatid"
                      type="xs:string"/>
      </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"/>
          <xs:element ref="iodef:GenerationTime"
                    minOccurs="0"/>
          <xs:element ref="iodef:Description"
                    minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Discovery"
                    minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Assessment"
                    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:History"
                    minOccurs="0"/>
          <xs:element ref="iodef:AdditionalData"
                    minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="purpose" use="required">
          <xs:simpleType>
            <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:restriction>
          </xs:simpleType>
        </xs:attribute>
        <xs:attribute name="lang"
                    type="xs:language"/>
        <xs:attribute name="restriction"
                    type="iodef:restriction-type" default="private"/>
        <xs:attribute name="observable-id"
                    type="xs:ID" use="optional"/>
      </xs:complexType>
    </xs:element>
  <!--
   ================================================================
   ==  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"
                        default="public"/>
        </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"/>
      </xs:complexType>
    </xs:element>
  <!--
   ========================================================================
   ==  RelatedActivity class                                             ==
   ========================================================================
  -->
    <xs:element name="RelatedActivity">
      <xs:complexType>
        <xs:sequence>
          <xs:choice maxOccurs="unbounded">
            <xs:element ref="iodef:IncidentID"
                        maxOccurs="unbounded"/>
            <xs:element ref="iodef:URL"
                        maxOccurs="unbounded"/>
            <xs:element ref="iodef:ThreatActor"
                        maxOccurs="unbounded"/>
            <xs:element ref="iodef:Campaign"
                        maxOccurs="unbounded"/>
```

```
          </xs:choice>
          <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"/>
      </xs:complexType>
    </xs:element>

  <!--
   ========================================================================
   ==  ThreatActor class                                                 ==
   ========================================================================
  -->
    <xs:element name="ThreatActor">
      <xs:complexType>
        <xs:sequence>
          <xs:choice>
            <xs:sequence>
              <xs:element ref="iodef:ThreatActorID" />
              <xs:element ref="iodef:Description"
                          minOccurs="0" maxOccurs="unbounded"/>
            </xs:sequence>
            <xs:element ref="iodef:Description"
                        minOccurs="1" maxOccurs="unbounded"/>
          </xs:choice>
          <xs:element ref="iodef:AdditionalData"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="restriction"
                      type="iodef:restriction-type"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="ThreatActorID" type="xs:string"/>

  <!--
   ========================================================================
   ==  Campaign class                                                    ==
   ========================================================================
  -->
    <xs:element name="Campaign">
      <xs:complexType>
        <xs:sequence>
          <xs:choice>
```

```
            <xs:sequence>
              <xs:element ref="iodef:CampaignID"/>
              <xs:element ref="iodef:Description"
                          minOccurs="0" maxOccurs="unbounded"/>
            </xs:sequence>
            <xs:element ref="iodef:Description"
                        minOccurs="1" maxOccurs="unbounded"/>
          </xs:choice>
          <xs:element ref="iodef:AdditionalData"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="restriction"
                      type="iodef:restriction-type"/>
      </xs:complexType>
    </xs:element>
    <xs:element name="CampaignID" type="xs:string"/>

  <!--
   ================================================================
   ==  AdditionalData class                                      ==
   ================================================================
  -->
    <xs:element name="AdditionalData" type="iodef:ExtensionType"/>
  <!--
   ================================================================
   ==   Contact class                                            ==
   ================================================================
  -->
    <xs:element name="Contact">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:ContactName"
                      minOccurs="0"/>
          <xs:element ref="iodef:ContactTitle"
                      minOccurs="0"/>
          <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"/>
          <xs:element ref="iodef:Email"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Telephone"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:Fax"
                      minOccurs="0"/>
          <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" use="required">
          <xs:simpleType>
            <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="zone"/>
              <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:restriction>
          </xs:simpleType>
        </xs:attribute>
        <xs:attribute name="type" use="required">
          <xs:simpleType>
            <xs:restriction base="xs:NMTOKEN">
              <xs:enumeration value="person"/>
              <xs:enumeration value="organization"/>
            </xs:restriction>
          </xs:simpleType>
        </xs:attribute>
        <xs:attribute name="restriction"
                    type="iodef:restriction-type"/>
      </xs:complexType>
    </xs:element>
    <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">
              <xs:simpleType>
                <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:restriction>
              </xs:simpleType>
            </xs:attribute>
          </xs:extension>
        </xs:simpleContent>
      </xs:complexType>
    </xs:element>

    <xs:element name="PostalAddress">
      <xs:complexType>
        <xs:simpleContent>
          <xs:extension base="iodef:MLStringType">
            <xs:attribute name="meaning"
                          type="xs:string" use="optional"/>
          </xs:extension>
        </xs:simpleContent>
      </xs:complexType>
    </xs:element>
    <xs:element name="Email" type="iodef:ContactMeansType"/>
    <xs:element name="Telephone" type="iodef:ContactMeansType"/>
    <xs:element name="Fax" type="iodef:ContactMeansType"/>

    <xs:complexType name="ContactMeansType">
      <xs:simpleContent>
        <xs:extension base="xs:string">
          <xs:attribute name="meaning"
                        type="xs:string" use="optional"/>
        </xs:extension>
      </xs:simpleContent>
    </xs:complexType>

  <!--
   ================================================================
   ==  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"/>
    <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>
  <!--
   ================================================================
   ==  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"
                      default="default"/>
      </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 name="DefinedCOA"
```

```
                    type="iodef:MLStringType"
                    minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="iodef:AdditionalData"
                    minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="restriction"
                    type="iodef:restriction-type"/>
        <xs:attribute name="action"
                    type="iodef:action-type" use="required"/>
        <xs:attribute name="observable-id"
                    type="xs:ID" use="optional"/>
      </xs:complexType>
    </xs:element>
  <!--
   ================================================================
   ==  Expectation class                                         ==
   ================================================================
  -->
    <xs:element name="Expectation">
      <xs:complexType>
        <xs:sequence>
          <xs:element ref="iodef:Description"
                    minOccurs="0" maxOccurs="unbounded"/>
          <xs:element name="DefinedCOA"
                    type="iodef:MLStringType"
                    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="restriction"
                    type="iodef:restriction-type"
                    default="default"/>
        <xs:attribute name="severity"
                    type="iodef:severity-type"/>
        <xs:attribute name="action"
                    type="iodef:action-type" default="other"/>
        <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"
                      use="optional" default="unknown">
          <xs:simpleType>
            <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:restriction>
          </xs:simpleType>
        </xs:attribute>
        <xs:attribute name="restriction"
                      type="iodef:restriction-type"/>
      </xs:complexType>
    </xs:element>

    <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"/>
      </xs:complexType>
    </xs:element>

  <!--
   ========================================================================
   ==  Method class                                                      ==
   ========================================================================
  -->
    <xs:element name="Method">
      <xs:complexType>
        <xs:sequence>
          <xs:choice maxOccurs="unbounded">
            <xs:element ref="enum:Reference"/>
            <xs:element ref="iodef:Description"/>
          </xs:choice>
          <xs:element ref="iodef:AdditionalData"
                      minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="restriction"
                      type="iodef:restriction-type"/>
      </xs:complexType>
    </xs:element>

  <!--
   ========================================================================
   ==  Assessment class                                                  ==
   ========================================================================
  -->
    <xs:element name="Assessment">
      <xs:complexType>
        <xs:sequence>
          <xs:element name="IncidentCategory"
                      type="iodef:MLStringType"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:choice maxOccurs="unbounded">
            <xs:element ref="iodef:SystemImpact"/>
            <xs:element name="BusinessImpact"
                        type="iodef:BusinessImpactType/>
            <xs:element ref="iodef:TimeImpact"/>
            <xs:element ref="iodef:MonetaryImpact"/>
            <xs:element name="IntendedImpact"
```

```
                    type="iodef:BusinessImpactType/>
        </xs:choice>
        <xs:element ref="iodef:Counter"
                    minOccurs="0" maxOccurs="unbounded"/>
        <xs:element name="MitigatingFactor"
                    type="iodef:MLStringType"
                    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"/>
      <xs:attribute name="observable-id"
                    type="xs:ID" use="optional"/>
    </xs:complexType>
  </xs:element>
  <xs:element name="SystemImpact">
    <xs:complexType>
      <xs:simpleContent>
        <xs:extension base="iodef:MLStringType">
          <xs:attribute name="severity"
                        type="iodef:severity-type"/>
          <xs:attribute name="completion">
            <xs:simpleType>
              <xs:restriction base="xs:NMTOKEN">
                <xs:enumeration value="failed"/>
                <xs:enumeration value="succeeded"/>
              </xs:restriction>
            </xs:simpleType>
          </xs:attribute>
          <xs:attribute name="type"
                        use="optional">
            <xs:simpleType>
              <xs:restriction base="xs:NMTOKEN">
                <xs:enumeration value="admin"/>
                <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="availibility-account"/>
                <xs:enumeration value="availibility-service"/>
                <xs:enumeration value="availibility-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:restriction>
            </xs:simpleType>
          </xs:attribute>
        </xs:extension>
      </xs:simpleContent>
    </xs:complexType>
  </xs:element>
  <xs:complexType name="BusinessImpactType">
    <xs:simpleContent>
      <xs:extension base="iodef:MLStringType">
        <xs:attribute name="severity"
                      use="optional">
          <xs:simpleType>
            <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:restriction>
          </xs:simpleType>
        </xs:attribute>
        <xs:attribute name="type"
                      use="optional">
          <xs:simpleType>
            <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:restriction>
          </xs:simpleType>
        </xs:attribute>
      </xs:extension>
    </xs:simpleContent>
  </xs:complexType>

  <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"
                        use="required">
            <xs:simpleType>
              <xs:restriction base="xs:NMTOKEN">
                <xs:enumeration value="labor"/>
                <xs:enumeration value="elapsed"/>
                <xs:enumeration value="downtime"/>
              </xs:restriction>
            </xs:simpleType>
          </xs:attribute>
          <xs:attribute name="duration"
                        type="iodef:duration-type"/>
        </xs:extension>
      </xs:simpleContent>
    </xs:complexType>
  </xs:element>
  <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 mixed="true">
        <xs:attribute name="rating" use="required">
          <xs:simpleType>
            <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:restriction>
          </xs:simpleType>
        </xs:attribute>
      </xs:complexType>
    </xs:element>
  <!--
   ====================================================================
   == 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"
                    default="default"/>
        <xs:attribute name="observable-id"
                    type="xs:ID" use="optional"/>
      </xs:complexType>
    </xs:element>
  <!--
   ====================================================================
   ==  Flow class                                                    ==
   ====================================================================
  -->
    <!-- Added System unbounded for use only when the source or
         target watchlist is in use, otherwise only one system entry
         is expected.
      -->
    <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" maxOccurs="unbounded"/>
          <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="restriction"
                    type="iodef:restriction-type"/>
        <xs:attribute name="category">
          <xs:simpleType>
            <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:restriction>
          </xs:simpleType>
        </xs:attribute>
        <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">
          <xs:simpleType>
            <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:restriction>
          </xs:simpleType>
        </xs:attribute>
      </xs:complexType>
    </xs:element>
  <!--
   ================================================================
   == 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"/>
          <xs:element ref="iodef:NodeRole"
                      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" default="ipv4-addr">
              <xs:simpleType>
                <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-mask"/>
                  <xs:enumeration value="ipv6-addr"/>
                  <xs:enumeration value="ipv6-net"/>
                  <xs:enumeration value="ipv6-net-mask"/>
                  <xs:enumeration value="site-uri"/>
                </xs:restriction>
              </xs:simpleType>
            </xs:attribute>
            <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:element name="Location" type="iodef:MLStringType"/>

    <xs:element name="NodeRole">
      <xs:complexType>
        <xs:simpleContent>
          <xs:extension base="iodef:MLStringType">
            <xs:attribute name="category" use="required">
              <xs:simpleType>
                <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:restriction>
              </xs:simpleType>
            </xs:attribute>
          </xs:extension>
        </xs:simpleContent>
      </xs:complexType>
    </xs:element>

  <!--
   ================================================================
   ==  Service Class                                             ==
   ================================================================
  -->
    <xs:element name="Service">
      <xs:complexType>
        <xs:sequence>
          <xs:choice minOccurs="0">
            <xs:element name="Port"
                        type="xs:integer"/>
            <xs:element name="Portlist"
                        type="iodef:PortlistType"/>
          </xs:choice>
          <xs:element name="ProtoType"
                      type="xs:integer" minOccurs="0"/>
          <xs:element name="ProtoCode"
                      type="xs:integer" minOccurs="0"/>
          <xs:element name="ProtoField"
                      type="xs:integer" minOccurs="0"/>
          <xs:element name="ApplicationHeader"
                      type="iodef:ApplicationHeaderType"
                      minOccurs="0" maxOccurs="unbounded"/>
          <xs:element ref="EmailData" minOccurs="0"/>
```

```
          <xs:element ref="iodef:Application"
                      minOccurs="0"/>
        </xs:sequence>
        <xs:attribute name="ip-protocol"
                      type="xs:integer" use="required"/>
        <xs:attribute name="observable-id"
                      type="xs:ID" use="optional"/>
      </xs:complexType>
    </xs:element>
    <xs:simpleType name="PortlistType">
      <xs:restriction base="xs:string">
        <xs:pattern value="\d+(\-\d+)?(,\d+(\-\d+)?)*"/>
      </xs:restriction>
    </xs:simpleType>
  <!--
   ================================================================
   ==  Counter class                                             ==
   ================================================================
  -->
    <xs:element name="Counter">
      <xs:complexType>
        <xs:simpleContent>
          <xs:extension base="xs:double">
            <xs:attribute name="type" use="required">
              <xs:simpleType>
                <xs:restriction base="xs:NMTOKEN">
                  <xs:enumeration value="byte"/>
                  <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:restriction>
              </xs:simpleType>
            </xs:attribute>
            <xs:attribute name="meaning"
                          type="xs:string" use="optional"/>
            <xs:attribute name="duration"
                          type="iodef:duration-type"/>
          </xs:extension>
        </xs:simpleContent>
      </xs:complexType>
    </xs:element>
```

```
  <!--
   ====================================================================
   ==  EmailData class                                                ==
   ====================================================================
  -->
   <xs:element name="EmailData">
     <xs:complexType>
       <xs:sequence>
         <xs:element name="EmailFrom"
                     type="iodef:MLStringType" minOccurs="0"/>
         <xs:element name="EmailSubject"
                     type="iodef:MLStringType" minOccurs="0"/>
         <xs:element name="EmailX-Mailer"
                     type="iodef:MLStringType" minOccurs="0"/>
         <xs:element name="EmailHeaderField"
                     type="iodef:ApplicationHeaderType"
                     minOccurs="0"/>
        <xs:element ref="iodef:HashData"
                    minOccurs="0" />
        <xs:element ref="SignatureData"
                    minOccurs="0" />
       </xs:sequence>
       <xs:attribute name="observable-id"
                     type="xs:ID" use="optional"/>
     </xs:complexType>
   </xs:element>

  <!--
   ====================================================================
   ==   DomainData class - from RFC5901                              ==
   ====================================================================
  -->
  <xs:element name="DomainData">
    <xs:complexType>
      <xs:sequence>
        <xs:element name="Name"
                    type="iodef:MLStringType" maxOccurs="1" />
        <xs:element name="DateDomainWasChecked"
                    type="xs:dateTime"
                    minOccurs="0" maxOccurs="1" />
        <xs:element name="RegistrationDate"
                    type="xs:dateTime"
                    minOccurs="0" maxOccurs="1" />
        <xs:element name="ExpirationDate"
                    type="xs:dateTime"
                    minOccurs="0" maxOccurs="1" />
        <xs:element name="RelatedDNS"
                    type="iodef:RelatedDNSEntryType"
```

```
                    minOccurs="0" maxOccurs="unbounded" />
        <xs:element ref="iodef:Nameservers"
                    minOccurs="0" maxOccurs="unbounded" />
        <xs:element ref="iodef:DomainContacts"
                    minOccurs="0" maxOccurs="1" />
      </xs:sequence>

      <xs:attribute name="system-status">
        <xs:simpleType>
          <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:restriction>
        </xs:simpleType>
      </xs:attribute>
      <xs:attribute name="domain-status">
        <xs:simpleType>
          <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:restriction>
        </xs:simpleType>
      </xs:attribute>
      <xs:attribute name="observable-id"
                    type="xs:ID" use="optional"/>
    </xs:complexType>
  </xs:element>

    <xs:element name="RelatedDNS"
                type="iodef:RelatedDNSEntryType"/>
    <xs:complexType name="RelatedDNSEntryType">
     <xs:simpleContent>
      <xs:extension base="xs:string">
      <xs:attribute name="record-type" use="optional">
        <xs:simpleType>
          <xs:restriction base="xs:NMTOKEN">
            <xs:enumeration value="A"/>
```

```
            <xs:enumeration value="AAAA"/>
            <xs:enumeration value="AFSDB"/>
            <xs:enumeration value="APL"/>
            <xs:enumeration value="AXFR"/>
            <xs:enumeration value="CAA"/>
            <xs:enumeration value="CERT"/>
            <xs:enumeration value="CNAME"/>
            <xs:enumeration value="DHCID"/>
            <xs:enumeration value="DLV"/>
            <xs:enumeration value="DNAME"/>
            <xs:enumeration value="DNSKEY"/>
            <xs:enumeration value="DS"/>
            <xs:enumeration value="HIP"/>
            <xs:enumeration value="IXFR"/>
            <xs:enumeration value="IPSECKEY"/>
            <xs:enumeration value="LOC"/>
            <xs:enumeration value="MX"/>
            <xs:enumeration value="NAPTR"/>
            <xs:enumeration value="NS"/>
            <xs:enumeration value="NSEC"/>
            <xs:enumeration value="NSEC3"/>
            <xs:enumeration value="NSEC3PARAM"/>
            <xs:enumeration value="OPT"/>
            <xs:enumeration value="PTR"/>
            <xs:enumeration value="RRSIG"/>
            <xs:enumeration value="RP"/>
            <xs:enumeration value="SIG"/>
            <xs:enumeration value="SOA"/>
            <xs:enumeration value="SPF"/>
            <xs:enumeration value="SRV"/>
            <xs:enumeration value="SSHFP"/>
            <xs:enumeration value="TA"/>
            <xs:enumeration value="TKEY"/>
            <xs:enumeration value="TLSA"/>
            <xs:enumeration value="TSIG"/>
            <xs:enumeration value="TXT"/>
          </xs:restriction>
        </xs:simpleType>
      </xs:attribute>
    </xs:extension>
  </xs:simpleContent>
</xs:complexType>

<xs:element name="Nameservers">
  <xs:complexType>
    <xs:sequence>
      <xs:element name="Server" type="iodef:MLStringType"/>
      <xs:element ref="iodef:Address" maxOccurs="unbounded"/>
```

```
      </xs:sequence>
    </xs:complexType>
  </xs:element>

  <xs:element name="DomainContacts">
    <xs:complexType>
      <xs:choice>
        <xs:element name="SameDomainContact"
                    type="iodef:MLStringType"/>
        <xs:element ref="iodef:Contact"
                    maxOccurs="unbounded" minOccurs="1"/>
      </xs:choice>
    </xs:complexType>
  </xs:element>


 <!--
  ========================================================================
  ==  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"/>
     </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"
                     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"/>
        <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" use="required">
              <xs:simpleType>
                <xs:restriction base="xs:NMTOKEN">
                  <xs:enumeration value="regex"/>
                  <xs:enumeration value="binary"/>
                  <xs:enumeration value="xpath"/>
                </xs:restriction>
              </xs:simpleType>
            </xs:attribute>
            <xs:attribute name="offset"
                          type="xs:integer" use="optional"/>
            <xs:attribute name="offsetunit"
                          use="optional" default="line">
              <xs:simpleType>
                <xs:restriction base="xs:NMTOKEN">
                  <xs:enumeration value="line"/>
                  <xs:enumeration value="byte"/>
                </xs:restriction>
              </xs:simpleType>
            </xs:attribute>
            <xs:attribute name="instance"
                          type="xs:integer" use="optional"/>
          </xs:extension>
        </xs:simpleContent>
      </xs:complexType>
    </xs:element>
    <xs:element name="RecordItem"
                type="iodef:ExtensionType"/>
  <!--
   ========================================================================
   ==  Class to describe Windows Registry Keys                           ==
   ========================================================================
```

```
  -->
    <xs:element name="WindowsRegistryKeysModified">
    <xs:complexType>
      <xs:sequence>
        <xs:element name="Key" maxOccurs="unbounded">
          <xs:complexType>
            <xs:sequence>
               <xs:element name="KeyName" type="xs:string"/>
               <xs:element name="Value"
                           type="xs:string" minOccurs="0"/>
            </xs:sequence>
            <xs:attribute name="registryaction">
              <xs:simpleType>
                <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:restriction>
              </xs:simpleType>
            </xs:attribute>
           </xs:complexType>
         </xs:element>
       </xs:sequence>
       <xs:attribute name="observable-id"
                     type="xs:ID" use="optional"/>
     </xs:complexType>
     </xs:element>

<!--
================================================================
==  Classes to describe a file                                ==
================================================================
-->

   <xs:element name="FileData">
     <xs:complexType>
       <xs:sequence>
         <xs:element ref="iodef:File"
                     minOccurs="1" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="observable-id"
                    type="xs:ID" use="optional"/>
        <xs:attribute name="restriction"
                    type="iodef:restriction-type"/>
        </xs:complexType>
```

```
   </xs:element>

   <xs:element name="File">
     <xs:complexType>
       <xs:sequence>
        <xs:element name="FileName" type="iodef:MLStringType"
                    minOccurs="0" />
        <xs:element name="FileSize" type="xs:integer"
                    minOccurs="0" />
        <xs:element ref="iodef:URL"
                    minOccurs="0" maxOccurs="unbounded"/>
        <xs:element ref="iodef:HashData"
                    minOccurs="0" />
        <xs:element ref="ds:Signature"
                    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="FileProperties"
                type="iodef:ExtensionType"/>

<!--
=====================================================================
==  Classes to describe a hash                                     ==
=====================================================================
-->

  <xs:element name="HashData">
  <xs:complexType>
    <xs:sequence>
        <xs:element name="HashTarget" type="iodef:MLStringType"
                    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" use="required">
        <xs:simpleType>
          <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:restriction>
        </xs:simpleType>
      </xs:attribute>
    </xs:complexType>
    </xs:element>

  <xs:element name="Hash">
   <xs:complexType>
    <xs:sequence>
        <xs:element ref="ds:DigestMethod" />
        <xs:element ref="ds:DigestValue" />
        <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:AdditionalData" />
        <xs:element ref="iodef:Application"
                    minOccurs="0"/>
      </xs:sequence>
   </xs:complexType>
  </xs:element>

<!--
================================================================
==  Classes to describe a signature                           ==
================================================================
-->

  <xs:element name="SignatureData">
   <xs:complexType>
    <xs:sequence>
        <xs:element ref="ds:Signature"
                    maxOccurs="unbounded" />
      </xs:sequence>
   </xs:complexType>
  </xs:element>

<!--
```

```
==================================================================
==  Classes to describe a certficate                            ==
==================================================================
-->

  <xs:element name="CertificateData">
   <xs:complexType>
      <xs:sequence>
        <xs:element ref="iodef:Certificate"
                    maxOccurs="unbounded"/>
      </xs:sequence>
      <xs:attribute name="observable-id"
                    type="xs:ID" use="optional"/>
      <xs:attribute name="restriction"
                    type="iodef:restriction-type"/>
    </xs:complexType>
   </xs:element>

  <xs:element name="Certificate">
   <xs:complexType>
    <xs:sequence>
        <xs:element ref="ds:X509Data" />
    </xs:sequence>
    <xs:attribute name="virtual" type="yes-no-type"
                  use="optional" />
    <xs:attribute name="observable-id"
                  type="xs:ID" use="optional"/>
   </xs:complexType>
  </xs:element>

  <!--
   ==================================================================
   ==  Classes that describe software                              ==
   ==================================================================
  -->
    <xs:complexType name="SoftwareType">
      <xs:sequence>
        <xs:element ref="iodef:URL"
                    minOccurs="0"/>
      </xs:sequence>
      <xs:attribute name="swid"
                    type="xs:string" default="0"/>
      <xs:attribute name="configid"
                    type="xs:string" default="0"/>
      <xs:attribute name="vendor"
                    type="xs:string"/>
      <xs:attribute name="family"
                    type="xs:string"/>
```

```
      <xs:attribute name="name"
                    type="xs:string"/>
      <xs:attribute name="version"
                    type="xs:string"/>
      <xs:attribute name="patch"
                    type="xs:string"/>
    </xs:complexType>
    <xs:element name="Application"
                type="iodef:SoftwareType"/>
    <xs:element name="OperatingSystem"
                type="iodef:SoftwareType"/>

  <!--
   ========================================================================
   == IndicatorData classes                                              ==
   ========================================================================
-->
   <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:sequence>
      <xs:attribute name="restriction"
                    type="iodef:restriction-type"/>
    </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"/>
    </xs:complexType>
  </xs:element>

  <xs:element name="Observable">
    <xs:complexType>
      <xs:sequence>
        <xs:element ref="iodef:Address"
                    minOccurs="0"/>
        <xs:element ref="iodef:DomainData"
                    minOccurs="0"/>
        <xs:element ref="iodef:EmailData"
                    minOccurs="0"/>
        <xs:element name="ApplicationHeader"
                    type="iodef:ApplicationHeaderType"
                    minOccurs="0"/>
        <xs:element ref="iodef:WindowsRegistryKeysModified"
                    minOccurs="0"/>
        <xs:element ref="iodef:FileData"
                    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" maxOccurs="unbounded"/>
        <xs:element ref="enum:Reference"
                    minOccurs="0" maxOccurs="unbounded"/>
        <xs:element ref="iodef:Assessment"
                    minOccurs="0"/>
        <xs:element ref="iodef:HistoryItem"
                    minOccurs="0"/>
        <xs:element ref="iodef:AdditionalData"
                    minOccurs="0"/>
      </xs:sequence>
      <xs:attribute name="restriction"
                  type="iodef:restriction-type"/>
    </xs:complexType>
  </xs:element>

  <xs:element name="IndicatorExpression">
    <xs:complexType>
      <xs:sequence>
        <xs:choice>
          <xs:element ref="iodef:IndicatorExpression"
                      minOccurs="0"/>
          <xs:element ref="iodef:Observable"
                      minOccurs="0" />
          <xs:element ref="iodef:ObservableReference"
                      minOccurs="0"/>
          <xs:element ref="iodef:IndicatorReference"
                      minOccurs="0"/>
        </xs:choice>
        <xs:element ref="iodef:AlternativeIndicatorID"
                    minOccurs="0" maxOccurs="unbounded"/>
      </xs:sequence>
      <xs:attribute name="operator" use="required">
        <xs:simpleType>
          <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:attribute>
    </xs:complexType>
  </xs:element>
```

```
   <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>
<!--
   ========================================================================
   == Miscellaneous simple classes                                       ==
   ========================================================================
  -->
    <xs:element name="Description"
                type="iodef:MLStringType"/>
    <xs:element name="URL"
                type="xs:anyURI"/>
  <!--
   ========================================================================
   == 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="lang"
                        type="xs:language" use="optional"/>
        </xs:extension>
      </xs:simpleContent>
    </xs:complexType>

    <xs:complexType name="ExtensionType" mixed="true">
      <xs:sequence>
```

```
        <xs:any namespace="##any" processContents="lax"
                minOccurs="0" maxOccurs="unbounded"/>
      </xs:sequence>
      <xs:attribute name="dtype"
                    type="iodef:dtype-type" use="required"/>
      <xs:attribute name="meaning"
                    type="xs:string"/>
      <xs:attribute name="formatid"
                    type="xs:string"/>
      <xs:attribute name="restriction"
                    type="iodef:restriction-type"/>
    </xs:complexType>

    <xs:complexType name="ApplicationHeaderType" mixed="true">
      <xs:sequence>
         <xs:any namespace="##any" processContents="lax"
                 minOccurs="0" maxOccurs="unbounded"/>
      </xs:sequence>
      <xs:attribute name="proto"
                    type="xs:integer" use="required"/>
      <xs:attribute name="field"
                    type="xs:string" use="required"/>
      <xs:attribute name="dtype"
                    type="iodef:proto-dtype-type"
                    use="required"/>
      <xs:attribute name="observable-id"
                    type="xs:ID" use="optional"/>
    </xs:complexType>

  <!--
   ================================================================
   == Global attribute type declarations                         ==
   ================================================================
  -->
    <xs:simpleType name="yes-no-type">
      <xs:restriction base="xs:NMTOKEN">
        <xs:enumeration value="yes"/>
        <xs:enumeration value="no"/>
      </xs:restriction>
    </xs:simpleType>

    <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: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: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: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:restriction>
    </xs:simpleType>

    <xs:simpleType name="proto-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="real"/>
        <xs:enumeration value="string"/>
        <xs:enumeration value="xml"/>
```

```
      </xs:restriction>
    </xs:simpleType>
</xs:schema>
```

9. Security Considerations

The IODEF data model itself does not directly introduce security issues. Rather, it simply defines a representation for incident information. As the data encoded by the IODEF might be considered privacy sensitive by the parties exchanging the information or by those described by it, care needs to be taken in ensuring the appropriate disclosure during both document exchange and subsequent processing. The former must be handled by a messaging format, but the latter risk must be addressed by the systems that process, store, and archive IODEF documents and information derived from them.

Executable content could be embedded into the IODEF document directly or through an extension. The IODEF parser should handle this content with care to prevent unintentional automated execution.

The contents of an IODEF document may include a request for action or an IODEF parser may independently have logic to take certain actions based on information that it finds. For this reason, care must be taken by the parser to properly authenticate the recipient of the document and ascribe an appropriate confidence to the data prior to action.

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.

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. The issue of enforcement is not a technical problem.

10. IANA Considerations

This document registers a namespace, XML schema, and a number of registries that map to enumerated values defined in the schema.

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 the "IODEF Schema" in Section 8 of this document.

10.2. Enumerated Value Registries

This document creates xx 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. An enumerated value for a given IODEF attribute.
  - 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]

The registries to be created are named in the table below in the "Registry Name" column. 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 attribute or 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. 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	Section 3.2
Contact-role	Contact@role	Section 3.10
Contact-type	Contact@type	Section 3.10
RegistryHandle-registry	RegistryHandle@registry	Section 3.10.1
Expectation-action	iodef:action-type	Section 3.17
Discovery-source	Discovery@source	Section 3.12
SystemImpact-type	SystemImpact@type	Section 3.14.1
BusinessImpact-severity	BusinessImpact@severity	Section 3.14.2
BusinessImpact-type	BusinessImpact@type	Section 3.14.2
TimeImpact-metrics	TimeImpact@metric	Section 3.14.3
TimeImpact-duration	iodef:duration-type	Section 3.14.3
NodeRole-category	NodeRole@category	Section 3.20.2
System-category	System@category	Section 3.19
System-ownership	System@ownership	Section 3.19
Address-category	Address@category	Section

Counter-type	Counter@type	3.20.1 Section 3.20.3
DomainData-system-status	DomainData@system-status	Section 3.21
DomainData-domain-status	DomainData@domain-status	Section 3.21
RelatedDNS-record-type	RelatedDNS@record-type	Section 3.21.1
RecordPattern-type	RecordPattern@type	Section 3.25.2
RecordPattern-offsetunit	RecordPattern@offsetunit	Section 3.25.2
Key-registryaction	Key@registryaction	Section 3.26.1
HashData-scope	HashData@scope	Section 3.29
AdditionalData-dtype	iodef:dtype-type	Section 3.9
EmailHeaderField-proto-dtype	iodef:proto-dtype-type	Section 3.22.1

Table 1: IANA Enumerated Value Registries

11. Acknowledgments

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- Brian Trammell, ETH Zurich
- Patrick Cain, Cooper-Cain Group, Inc.
- ... TODO many more to add ...

12. References

12.1. Normative References

[W3C.XML] World Wide Web Consortium, "Extensible Markup Language (XML) 1.0 (Second Edition)", W3C Recommendation , October 2000, <http://www.w3.org/TR/2000/REC-xml-20001006>.

[W3C.SCHEMA] World Wide Web Consortium, "XML XML Schema Part 1: Structures Second Edition", W3C Recommendation , October 2004, <http://www.w3.org/TR/xmlschema-1/>.

[W3C.SCHEMA.DTYPES] World Wide Web Consortium, "XML Schema Part 2: Datatypes Second Edition", W3C Recommendation , October 2004, <http://www.w3.org/TR/xmlschema-2/>.

[W3C.XMLNS] World Wide Web Consortium, "Namespaces in XML", W3C Recommendation , January 1999, <http://www.w3.org/TR/REC-xml-names/>.

[W3C.XPATH] World Wide Web Consortium, "XML Path Language (XPath) 2.0", W3C Candidate Recommendation , June 2006, <http://www.w3.org/TR/xpath20/>.

[W3C.XMLSIG] World Wide Web Consortium, "XML Signature Syntax and Processing 2.0", W3C Candidate Recommendation , June 2008, <http://www.w3.org/TR/xmldsig-core/>.

[IEEE.POSIX] Institute of Electrical and Electronics Engineers, "Information Technology - Portable Operating System Interface (POSIX) - Part 1: Base Definitions", IEEE 1003.1, June 2001.

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", RFC 2119, March 1997.

[RFC5646] Philips, A. and M. Davis, "Tags for Identifying of Languages", RFC 5646, September 2009.

[RFC3986] Berners-Lee, T., Fielding, R., and L. Masinter, "Uniform Resource Identifiers (URI): Generic Syntax", RFC 3986, January 2005‘.

[RFC2978] Freed, N. and J. Postel, "IANA Charset Registration Procedures", BCP 2978, October 2000.

[RFC4519] Sciberras, A., "Schema for User Applications", RFC 4519, June 2006.

[RFC5322] Resnick, P., "Internet Message Format", RFC 5322, October 2008.

[RFC3339] Klyne, G. and C. Newman, "Date and Time on the Internet: Timestamps", RFC 3339, July 2002.

[RFC-ENUM] Montville, A. and D. Black, "IODEF Enumeration Reference Format", RFC ENUM, November 2014.

[ISO8601] International Organization for Standardization, "International Standard: Data elements and interchange formats - Information interchange - Representation of dates and times", ISO 8601, Second Edition, December 2000.

[ISO4217] International Organization for Standardization, "International Standard: Codes for the representation of currencies and funds, ISO 4217:2001", ISO 4217:2001, August 2001.

[RFC3688] Mealling, M., "The IETF XML Registry", RFC 3688, January 2004.

[RFC3275] Eastlake, D., Reagle, J., and D. Solo, "(Extensible Markup Language) XML-Signature Syntax and Processing", RFC 3275, March 2002.

[IANA.Ports] Internet Assigned Numbers Authority, "Service Name and Transport Protocol Port Number Registry", January 2014, <http://www.iana.org/assignments/service-names-port-numbers/service-names-port-numbers.txt>.

[IANA.Protocols] Internet Assigned Numbers Authority, "Assigned Internet Protocol Numbers", January 2014, <http://www.iana.org/assignments/protocol-numbers/protocol-numbers.txt>.

12.2. Informative References

[RFC5070] Danyliw, R., Meijer, J., and Y. Demchenko, "Incident Object Description Exchange Format", RFC 5070, December 2007.

[refs.requirements] Keeni, G., Demchenko, Y., and R. Danyliw, "Requirements for the Format for Incident Information Exchange (FINE)", Work in Progress, June 2006.

[RFC4765] Debar, H., Curry, D., Debar, H., and B. Feinstein, "Intrusion Detection Message Exchange Format", RFC 4765, March 2007.

[RFC6545] Moriarty, K., "Real-time Inter-network Defense (RID)", RFC 6545, April 2012.

[RFC6546] Trammell, B., "Transport of Real-time Inter-network Defense (RID) Messages over HTTP/TLS", RFC 6546, April 2012.

[RFC5901] Cain, P. and D. Jevans, "Extensions to the IODEF-Document Class for Reporting Phishing", RFC 5901, July 2010.

[NIST800.61rev2] Cichonski, P., Millar, T., Grance, T., and K. Scarfone, "NIST Special Publication 800-61 Revision 2: Computer Security Incident Handling Guide", January 2012, <http://csrc.nist.gov/publications/nistpubs/800-61rev2/SP800-61rev2.pdf>.

[RFC3982] Newton, A. and M. Sanz, "IRIS: A Domain Registry (dreg) Type for the Internet Registry Information Service (IRIS)", RFC 3982, January 2005.

[KB310516] Microsoft Corporation, "How to add, modify, or delete registry subkeys and values by using a registration entries (.reg) file", December 2007.

[RFC4180] Shafranovich, Y., "Common Format and MIME Type for Comma-Separated Values (CSV) File", RFC 4180, October 2005.

[RFC5226] Narten, T. and H. Alvestrand, "Guidelines for Writing an IANA Considerations Section in RFCs", RFC 5226, May 2008.

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