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Discovering and Retrieving Software Transparency and Vulnerability Information

Abstract

To improve cybersecurity posture, automation is necessary to locate what software is running on a device, whether that software has known vulnerabilities, and what, if any recommendations suppliers may have. This memo specifies a model to provide access to this information. It may optionally be discovered through manufacturer usage descriptions.

Status of This Memo

Copyright Notice

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1. Introduction

A number of activities have been working to improve visibility to what software is running on a system, and what vulnerabilities that software may have[EO2021].

Put simply, we seek to answer two classes of questions **at scale**:

* Is this system vulnerable to a particular vulnerability?

* Which devices in a particular environment contain vulnerabilities that require some action?

This memo doesn't specify the format of this information, but rather only how to locate and retrieve these objects.

Software bills of materials (SBOMs) are descriptions of what software, including versioning and dependencies, a device contains. There are different SBOM formats such as Software Package Data Exchange [SPDX] or CycloneDX[CycloneDX12].

System vulnerabilities may similarly be described using several data formats, including the aforementioned CycloneDX, Common Vulnerability Reporting Framework [CVRF], the Common Security Advisory Format [CSAF]. This information is typically used to report to customers the state of a system.

These two classes of information can be used in concert. For instance, a network management tool may discover that a system makes use of a particular software component that has a known vulnerability, and a vulnerability report may be used to indicate what if any versions of software correct that vulnerability, or whether the system exercises the vulnerable code at all.

Both classes of information elements are optional under the model specified in this memo. One can provide only an SBOM, only vulnerability information, or both an SBOM and vulnerability information.

Note that SBOM formats may also carry other information, the most common being any licensing terms. Because this specification is neutral regarding content, it is left for format developers such as the Linux Foundation, OASIS, and ISO to decide what attributes they will support.

This memo does not specify how vulnerability information may be retrieved directly from the endpoint. That's because vulnerability information changes occur at different rates to software updates. However, some SBOM formats may also contain vulnerability information.

SBOMs and vulnerability information are advertised and retrieved through the use of a YANG augmentation of the Manufacturer User Description (MUD) model [RFC8520]. Note that the schema creates a grouping that can also be used independently of MUD. Moreover, other MUD features, such as access controls, needn't be present.

The mechanisms specified in this document are meant to satisfy several use cases:

* A network-layer management system retrieving information from an IoT device as part of its ongoing lifecycle. Such devices may or may not have query interfaces available.

* An application-layer management system retrieving vulnerability or SBOM information in order to evaluate the posture of an application server of some form. These application servers may themselves be containers or hypervisors. Discovery of the topology of a server is beyond the scope of this memo.

To satisfy these two key use cases, objects may be found in one of three ways:

*on devices themselves

*on a web site (e.g., via URI)

*through some form of out-of-band contact with the supplier.

In the first case, devices will have interfaces that permit direct retrieval. Examples of these interfaces might be an HTTP, COAP or [OpenC2] endpoint for retrieval. There may also be private interfaces as well.

In the second case, when a device does not have an appropriate retrieval interface, but one is directly available from the manufacturer, a URI to that information MUST be discovered.

In the third case, a supplier may wish to make an SBOM or vulnerability information available under certain circumstances, and may need to individually evaluate requests. The result of that evaluation might be the SBOM or vulnerability itself or a restricted URL or no access.

To enable application-layer discovery, this memo defines a well-known URI [RFC8615]. Management or orchestration tools can query this well-known URI to retrieve a system's SBOM or vulnerability information. Further queries may be necessary based on the content and structure of the response.

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

1.1. How This Information Is Retrieved

For devices that can emit a URL or can establish a well-known URI, the mechanism may be highly automated. For devices that have a URL in either their documentation or within a QR code on a box, the mechanism is semi-automated (someone has to scan the QR code or enter the URL).

Note that vulnerability and SBOM information is likely to change at different rates. The MUD semantics provide a way for manufacturers to control how often tooling should check for those changes through the cache-validity node.

1.2. Formats

There are multiple ways to express both SBOMs and vulnerability information. When these are retrieved either directly from the device or directly from a web server, tools will need to observe the content-type header to determine precisely which format is being transmitted. Because IoT devices in particular have limited capabilities, use of a specific Accept: header in HTTP or the Accept Option in CoAP is NOT RECOMMENDED. Instead, backend tooling is encouraged to support all known formats, and SHOULD silently discard SBOM information sent with a media type that is not understood.

Some formats may support both vulnerability and software inventory information. When both vulnerability and software inventory information is available from the same location, both sbom and vuln nodes MUST indicate that. Network management systems retrieving this information MUST take note that the identical resource is being retrieved rather than retrieving it twice.

1.3. Discussion points

The following is discussion to be removed at time of RFC publication.

* Is the model structured correctly?

* Are there other retrieval mechanisms that need to be specified?

* Do we need to be more specific in how to authenticate and retrieve SBOMs?

* What are the implications if the MUD URL is an extension in a certificate (e.g. an IDevID cert)?

2. The well-known transparency endpoint set

Two well known endpoints are defined:

* "/.well-known/sbom" retrieves an SBOM.

* "/.well-known/openc2" is the HTTPS binding to OpenC2.

As discussed previously, the precise format of a response is based on the Content-type provided.

3. The mud-transparency extension model extension

We now formally define this extension. This is done in two parts. First, the extension name "transparency" is listed in the "extensions" array of the MUD file. N.B., this schema extension is intended to be used wherever it might be appropriate (e.g., not just MUD).

Second, the "mud" container is augmented with a list of SBOM sources.

This is done as follows:

```
module: ietf-mud-transparency

  augment /mud:mud:
    +--rw transparency
       +--rw (sbom-retrieval-method)?
       |  +--:(cloud)
       |  |  +--rw sboms* [version-info]
       |  |     +--rw version-info    string
       |  |     +--rw sbom-url?       inet:uri
       |  +--:(local-well-known)
       |  |  +--rw sbom-local-well-known?   enumeration
       |  +--:(sbom-contact-info)
       |     +--rw sbom-contact-uri         inet:uri
       +--rw (vuln-retrieval-method)?
          +--:(cloud)
          |  +--rw vuln-url?                inet:uri
          +--:(vuln-contact-info)
             +--rw contact-uri              inet:uri
```

4. The mud-sbom augmentation to the MUD YANG model

```
<CODE BEGINS>file "ietf-mud-transparency@2021-10-22.yang"
module ietf-mud-transparency {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-mud-transparency";
  prefix mudtx;

  import ietf-inet-types {
    prefix inet;
    reference "RFC 6991";
}
  import ietf-mud {
    prefix mud;
    reference "RFC 8520";
  }

  organization
    "IETF OPSAWG (Ops Area) Working Group";
  contact
    "WG Web: http://tools.ietf.org/wg/opsawg/
     WG List: opsawg@ietf.org

     Editor: Eliot Lear lear@cisco.com
     Editor: Scott Rose scott.rose@nist.gov";
  description
    "This YANG module augments the ietf-mud model to provide for
     reporting of SBOMs and vulnerability information.

     Copyright (c) 2020 IETF Trust and the persons identified as
     authors of the code.  All rights reserved.

     Redistribution and use in source and binary forms, with or
     without modification, is permitted pursuant to, and subject to
     the license terms contained in, the Simplified BSD License set
     forth in Section 4.c of the IETF Trust's Legal Provisions
     Relating to IETF Documents
     (https://trustee.ietf.org/license-info).

     This version of this YANG module is part of RFC XXXX
     (https://www.rfc-editor.org/info/rfcXXXX);
     see the RFC itself for full legal notices.

     The key words 'MUST', 'MUST NOT', 'REQUIRED', 'SHALL', 'SHALL
     NOT', 'SHOULD', 'SHOULD NOT', 'RECOMMENDED', 'NOT RECOMMENDED',
     'MAY', and 'OPTIONAL' in this document are to be interpreted as
     described in BCP 14 (RFC 2119) (RFC 8174) when, and only when,
     they appear in all capitals, as shown here.  ";

  revision 2021-07-06 {
    description
      "Initial proposed standard.";
    reference
      "RFC XXXX: Discovering and Retrieving Software Transparency
       and Vulnerability Information";
  }

  grouping transparency-extension {
    description
      "Transparency extension grouping";
    container transparency {
      description
        "container of methods to get an SBOM.";
      choice sbom-retrieval-method {
        description
          "How to find SBOM information";
        case cloud {
          list sboms {
            key "version-info";
            description
              "A list of SBOMs tied to different s/w
               or h/w versions.";
            leaf version-info {
              type string;
              description
                "The version to which this SBOM refers.";
            }
            leaf sbom-url {
              type inet:uri;
              description
                "A statically located URI.";
            }
          }
        }
        case local-well-known {
          leaf sbom-local-well-known {
            type enumeration {
              enum http {
                description
                  "Use http (insecure) to retrieve
                   SBOM information.  This method is NOT RECOMMENDED,
                   but may be unavoidable for certain classes of
                   deployment, where TLS has not or cannot be implemented";
              }
              enum https {
                description
                  "Use https (secure) to retrieve SBOM information.";
              }
              enum coap {
                description
                  "Use COAP (insecure) to retrieve SBOM.  This method
                  is NOT RECOMMENDED, although it may be unavoidable
                  for certain classes of implementations/deployments.";
              }
              enum coaps {
                description
                  "Use COAPS (secure) to retrieve SBOM";
              }
              enum openc2 {
                description
                  "Use OpenC2 endpoint.
                   This is https://{host}/.well-known/openc2";
              }
            }
            description
              "Which communication protocol to choose.";
          }
        }
        case sbom-contact-info {
          leaf sbom-contact-uri {
            type inet:uri;
            mandatory true;
            description
              "This MUST be either a tel, http, https, or
               mailto uri schema that customers can use to
               contact someone for SBOM information.";
          }
        }
      }
      choice vuln-retrieval-method {
        description
          "How to find vulnerability information";
        case cloud {
          leaf vuln-url {
            type inet:uri;
            description
              "A statically located URL.";
          }
        }
        case vuln-contact-info {
          leaf contact-uri {
            type inet:uri;
            mandatory true;
            description
              "This MUST be either a tel, http, https, or
               mailto uri schema that customers can use to
               contact someone for vulnerability information.";
          }
        }
      }
```

```
      }
    }

    augment "/mud:mud" {
      description
        "Add extension for software transparency.";
      uses transparency-extension;
    }
  }

  <CODE ENDS>
```

5. Examples

In this example MUD file that uses a cloud service, the modelX presents a location of the SBOM in a URL. Note, the ACLs in a MUD file are NOT required, although they are a very good idea for IP-based devices.

5.1. Without ACLS

This first MUD file demonstrates how to get SBOM and vulnerability information without ACLs.

```
{
  "ietf-mud:mud": {
    "mud-version": 1,
    "extensions": [
      "ol",
      "transparency"
    ],
    "ol": {
      "owners": [
        "Copyright (c) Example, Inc. 2022. All Rights Reserved"
      ],
      "spdx-tag": "0BSD"
    },
    "mudtx:transparency": {
      "sbom-local-well-known": "https",
      "vuln-url": "https://iot.example.com/info/modelX/csaf.json"
    },
    "mud-url": "https://iot.example.com/modelX.json",
    "mud-signature": "https://iot.example.com/modelX.p7s",
    "last-update": "2022-01-05T13:29:12+00:00",
    "cache-validity": 48,
    "is-supported": true,
    "systeminfo": "retrieving vuln and SBOM info via a cloud service",
    "mfg-name": "Example, Inc.",
    "documentation": "https://iot.example.com/doc/modelX",
    "model-name": "modelX"
  }
}
```

The second example demonstrates that just SBOM information is included.

```
{
  "ietf-mud:mud": {
    "mud-version": 1,
    "extensions": [
      "ol",
      "transparency"
    ],
    "ol": {
      "owners": [
        "Copyright (c) Example, Inc. 2022. All Rights Reserved"
      ],
      "spdx-tag": "0BSD"
    },
    "mudtx:transparency": {
      "sbom-local-well-known": "https"
    },
    "mud-url": "https://iot.example.com/modelX.json",
    "mud-signature": "https://iot.example.com/modelX.p7s",
    "last-update": "2022-01-05T13:29:47+00:00",
    "cache-validity": 48,
    "is-supported": true,
    "systeminfo": "retrieving vuln and SBOM info via a cloud service",
    "mfg-name": "Example, Inc.",
    "documentation": "https://iot.example.com/doc/modelX",
    "model-name": "modelX"
  }
}
```

5.2. SBOM Located on the Device

In this example, the SBOM is retrieved from the device, while vulnerability information is available from the cloud. This is likely a common case, because vendors may learn of vulnerability information more frequently than they update software.

```
{
  "ietf-mud:mud": {
    "mud-version": 1,
    "extensions": [
      "transparency"
    ],
    "mudtx:transparency": {
      "sbom-local-well-known": "https",
      "vuln-url": "https://iot-device.example.com/info/modelX/csaf.json"
    },
    "mud-url": "https://iot-device.example.com/modelX.json",
    "mud-signature": "https://iot-device.example.com/modelX.p7s",
    "last-update": "2022-01-05T13:25:14+00:00",
    "cache-validity": 48,
    "is-supported": true,
    "systeminfo": "retrieving vuln and SBOM info via a cloud service",
    "mfg-name": "Example, Inc.",
    "documentation": "https://iot-device.example.com/doc/modelX",
    "model-name": "modelX"
  }
}
```

5.3. Further contact required.

In this example, the network manager must take further steps to retrieve SBOM information. Vulnerability information is still available.

```
{
 "ietf-mud:mud": {
  "mud-version": 1,
  "extensions": [
    "transparency"
  ],
  "ietf-mud-transparency:transparency": {
    "contact-info": "https://iot-device.example.com/contact-info.html",
    "vuln-url": "https://iot-device.example.com/info/modelX/csaf.json"
  },
  "mud-url": "https://iot-device.example.com/modelX.json",
  "mud-signature": "https://iot-device.example.com/modelX.p7s",
  "last-update": "2021-07-09T06:16:42+00:00",
  "cache-validity": 48,
  "is-supported": true,
  "systeminfo": "retrieving vuln and SBOM info via a cloud service",
  "mfg-name": "Example, Inc.",
  "documentation": "https://iot-device.example.com/doc/modelX",
  "model-name": "modelX"
 }
}
```

5.4. With ACLS

Finally, here is a complete example where the device provides SBOM and vulnerability information, as well as access-control information.

```
{
  "ietf-mud:mud": {
    "mud-version": 1,
    "extensions": [
      "ol",
      "transparency"
    ],
    "ol": {
      "owners": [
        "Copyright (c) Example, Inc. 2022. All Rights Reserved"
      ],
      "spdx-tag": "0BSD"
    },
    "mudtx:transparency": {
      "sbom-local-well-known": "https",
      "vuln-url": "https://iot.example.com/info/modelX/csaf.json"
    },
    "mud-url": "https://iot.example.com/modelX.json",
    "mud-signature": "https://iot.example.com/modelX.p7s",
    "last-update": "2022-01-05T13:30:31+00:00",
    "cache-validity": 48,
    "is-supported": true,
    "systeminfo": "retrieving vuln and SBOM info via a cloud service",
    "mfg-name": "Example, Inc.",
    "documentation": "https://iot.example.com/doc/modelX",
    "model-name": "modelX",
    "from-device-policy": {
      "access-lists": {
        "access-list": [
          {
            "name": "mud-65443-v4fr"
          }
        ]
      }
    },
    "to-device-policy": {
      "access-lists": {
        "access-list": [
          {
            "name": "mud-65443-v4to"
          }
        ]
      }
    }
  },
  "ietf-access-control-list:acls": {
    "acl": [
      {
        "name": "mud-65443-v4to",
            "type": "ipv4-acl-type",
            "aces": {
              "ace": [
                {
                  "name": "cl0-todev",
                  "matches": {
                    "ipv4": {
                      "ietf-acldns:src-dnsname": "iotserver.example.com"
                    }
                  },
                  "actions": {
                    "forwarding": "accept"
                  }
                }
              ]
            }
          },
          {
            "name": "mud-65443-v4fr",
            "type": "ipv4-acl-type",
            "aces": {
              "ace": [
                {
                  "name": "cl0-frdev",
                  "matches": {
                    "ipv4": {
                      "ietf-acldns:dst-dnsname": "iotserver.example.com"
                    }
                  },
                  "actions": {
                    "forwarding": "accept"
                  }
                }
              ]
            }
          }
        ]
      }
    }
```

At this point, the management system can attempt to retrieve the SBOM, and determine which format is in use through the content-type header on the response to a GET request, independently repeat the process for vulnerability information, and apply ACLs, as appropriate.

6. Security Considerations

The YANG module specified in this document defines a schema for data that is designed to be accessed via network management protocols such as NETCONF [RFC6241] or RESTCONF [RFC8040]. The lowest NETCONF layer is the secure transport layer, and the mandatory-to-implement secure transport is Secure Shell (SSH) [RFC6242]. The lowest RESTCONF layer is HTTPS, and the mandatory-to-implement secure transport is TLS [RFC8446].

N.B., for MUD, the mandatory method of retrieval is TLS.

The Network Configuration Access Control Model (NACM) [RFC8341] provides the means to restrict access for particular NETCONF or RESTCONF users to a preconfigured subset of all available NETCONF or RESTCONF protocol operations and content.

There are a number of data nodes defined in this YANG module that are writable/creatable/deletable (i.e., config true, which is the default). These data nodes may be considered sensitive or vulnerable in some network environments. Write operations (e.g., edit-config) to these data nodes without proper protection can have a negative effect on network operations. These are the subtrees and data nodes and their sensitivity/vulnerability:

The ietf-mud-transparency module has no operational impact on the element itself, and is used to discover state information that may be available on or off the element. In as much as the module itself is made writeable, this only indicates a change in how to retrieve what read-only elements. However, that does not mean there are no risks. These are discussed below, and are applicable to all nodes within the transparency container.

If an attacker modifies the elements, they may misdirect automation to retrieve a different set of URLs than was intended by the designer. This in turn leads to two specific sets of risks:

*the information retrieved would be false.

*the URLs themselves point to malware.

To address either risk, any change in a URL, and in particular to the authority section, should be treated with some suspicion. One mitigation would be to test any cloud-based URL against a reputation service.

Some of the readable data nodes in this YANG module may be considered sensitive or vulnerable in some network environments. It is thus important to control read access (e.g., via get, get-config, or notification) to these data nodes. These are the subtrees and data nodes and their sensitivity/vulnerability:

SBOMs provide an inventory of software. If software is available to an attacker, the attacker may well already be able to derive this very same software inventory. Manufacturers MAY restrict access to SBOM information using appropriate authorization semantics within HTTP. In particular, if a system attempts to retrieve an SBOM via HTTP and the client is not authorized, the server MUST produce an appropriate error, with instructions on how to register a particular client. One example may be to issue a certificate to the client for this purpose after a registration process has taken place. Another example would involve the use of OAUTH in combination with a federations of SBOM servers.

Another risk is a skew in the SBOM listing and the actual software inventory of a device/container. For example, a manufacturer may update the SBOM on its server, but an individual device has not been upgraded yet. This may result in an incorrect policy being applied to a device. A unique mapping of a device's software version and its SBOM can minimize this risk.

To further mitigate attacks against a device, manufacturers SHOULD recommend access controls.

Vulnerability information is generally made available to such databases as NIST's National Vulnerability Database. It is possible that vendor may wish to release information early to some customers. We do not discuss here whether that is a good idea, but if it is employed, then appropriate access controls and authorization SHOULD be applied to the vulnerability resource.

7. IANA Considerations

7.1. MUD Extension

The IANA is requested to add "transparency" to the MUD extensions registry as follows:

```
Extension Name: transparency
Standard reference: This document
```

7.2. YANG Registration

The following YANG module should be registered in the "YANG Module Names" registry:

Name: ietf-mud
URN: urn:ietf:params:xml:ns:yang:ietf-mud-transparency
Prefix: mudtx
Registrant contact: The IESG
Reference: This memo

7.3. Well-Known Prefix

The following well known URIs are requested in accordance with [RFC8615]:

URI suffix: "sbom"
Change controller: "IETF"
Specification document: This memo
Related information: See ISO/IEC 19970-2 and SPDX.org

URI suffix: "openc2"
Change controller: "IETF"
Specification document: This memo
Related information: OpenC2 Project

8. Acknowledgments

Thanks to Russ Housley, Dick Brooks, Tom Petch, Nicolas Comstedt, who provided revew comments.

9. References

9.1. Normative References

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Appendix A. Changes from Earlier Versions

Draft -04: * Address review comments

Draft -02:

*include vulnerability information

Draft -01:

*some modest changes

Draft -00:

*Initial revision

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