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A Voucher Artifact for Bootstrapping Protocols

Abstract

This document defines a strategy to securely assign a pledge to an owner using an artifact signed, directly or indirectly, by the pledge’s manufacturer. This artifact is known as a "voucher".

This document defines an artifact format as a YANG-defined JSON document that has been signed using a Cryptographic Message Syntax (CMS) structure. Other YANG-derived formats are possible. The voucher artifact is normally generated by the pledge’s manufacturer (i.e., the Manufacturer Authorized Signing Authority (MASA)).

This document only defines the voucher artifact, leaving it to other documents to describe specialized protocols for accessing it.

Status of This Memo

This is an Internet Standards Track document.

This document is a product of the Internet Engineering Task Force (IETF). It represents the consensus of the IETF community. It has received public review and has been approved for publication by the Internet Engineering Steering Group (IESG). Further information on Internet Standards is available in Section 2 of RFC 7841.

Information about the current status of this document, any errata, and how to provide feedback on it may be obtained at https://www.rfc-editor.org/info/rfc8366.

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1. Introduction

This document defines a strategy to securely assign a candidate device (pledge) to an owner using an artifact signed, directly or indirectly, by the pledge's manufacturer, i.e., the Manufacturer Authorized Signing Authority (MASA). This artifact is known as the "voucher".

The voucher artifact is a JSON [RFC8259] document that conforms with a data model described by YANG [RFC7950], is encoded using the rules defined in [RFC8259], and is signed using (by default) a CMS structure [RFC5652].

The primary purpose of a voucher is to securely convey a certificate, the "pinned-domain-cert", that a pledge can use to authenticate subsequent interactions. A voucher may be useful in several contexts, but the driving motivation herein is to support secure bootstrapping mechanisms. Assigning ownership is important to bootstrapping mechanisms so that the pledge can authenticate the network that is trying to take control of it.

The lifetimes of vouchers may vary. In some bootstrapping protocols, the vouchers may include a nonce restricting them to a single use, whereas the vouchers in other bootstrapping protocols may have an indicated lifetime. In order to support long lifetimes, this document recommends using short lifetimes with programmatic renewal, see Section 6.1.

This document only defines the voucher artifact, leaving it to other documents to describe specialized protocols for accessing it. Some bootstrapping protocols using the voucher artifact defined in this document include: [ZERO-TOUCH], [SECUREJOIN], and [KEYINFRA]).

2. Terminology

This document uses the following terms:

Artifact: Used throughout to represent the voucher as instantiated in the form of a signed structure.

Domain: The set of entities or infrastructure under common administrative control. The goal of the bootstrapping protocol is to enable a pledge to discover and join a domain.

Imprint: The process where a device obtains the cryptographic key material to identify and trust future interactions with a network. This term is taken from Konrad Lorenz's work in biology with new ducklings: "during a critical period, the duckling would assume that anything that looks like a mother duck is in fact their mother" [Stajano99theresurrecting]. An equivalent for a device is to obtain the fingerprint of the network's root certification authority certificate. A device that imprints on an attacker suffers a similar fate to a duckling that imprints on a hungry wolf. Imprinting is a term from psychology and ethology, as described in [imprinting].

Join Registrar (and Coordinator): A representative of the domain that is configured, perhaps autonomically, to decide whether a new device is allowed to join the domain. The administrator of the domain interfaces with a join registrar (and Coordinator) to control this process. Typically, a join registrar is "inside" its domain. For simplicity, this document often refers to this as just "registrar".

MASA (Manufacturer Authorized Signing Authority): The entity that, for the purpose of this document, signs the vouchers for a manufacturer's pledges. In some bootstrapping protocols, the MASA may have an Internet presence and be integral to the bootstrapping process, whereas in other protocols the MASA may be an offline service that has no active role in the bootstrapping process.

Owner: The entity that controls the private key of the "pinned-domain-cert" certificate conveyed by the voucher.

Pledge: The prospective device attempting to find and securely join a domain. When shipped, it only trusts authorized representatives of the manufacturer.

Registrar: See join registrar.

TOFU (Trust on First Use): Where a pledge device makes no security decisions but rather simply trusts the first domain entity it is contacted by. Used similarly to [RFC7435]. This is also known as the "resurrecting duckling" model.

Voucher: A signed statement from the MASA service that indicates to a pledge the cryptographic identity of the domain it should trust.

3. Requirements Language

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.

4. Survey of Voucher Types

A voucher is a cryptographically protected statement to the pledge device authorizing a zero-touch "imprint" on the join registrar of the domain. The specific information a voucher provides is influenced by the bootstrapping use case.

The voucher can impart the following information to the join registrar and pledge:

Assertion Basis: Indicates the method that protects the imprint (this is distinct from the voucher signature that protects the voucher itself). This might include manufacturer-asserted ownership verification, assured logging operations, or reliance on pledge endpoint behavior such as secure root of trust of measurement. The join registrar might use this information. Only some methods are normatively defined in this document. Other methods are left for future work.

Authentication of Join Registrar: Indicates how the pledge can authenticate the join registrar. This document defines a mechanism to pin the domain certificate. Pinning a symmetric key, a raw key, or "CN-ID" or "DNS-ID" information (as defined in [RFC6125]) is left for future work.

Anti-Replay Protections: Time- or nonce-based information to constrain the voucher to time periods or bootstrap attempts.

A number of bootstrapping scenarios can be met using differing combinations of this information. All scenarios address the primary threat of a Man-in-The-Middle (MiTM) registrar gaining control over the pledge device. The following combinations are "types" of vouchers:

Voucher Type	Assertion		Registrar ID		Validity	
	Log-ged	Veri-fied	Trust Anchor	CN-ID or DNS-ID	RTC	Nonce
Audit	X		X			X
Nonceless Audit	X		X		X	
Owner Audit	X	X	X		X	X
Owner ID		X	X	X	X	
Bearer out-of-scope	X		wildcard		optional	

NOTE: All voucher types include a 'pledge ID serial-number' (not shown here for space reasons).

Audit Voucher: An Audit Voucher is named after the logging assertion mechanisms that the registrar then "audits" to enforce local policy. The registrar mitigates a MiTM registrar by auditing that an unknown MiTM registrar does not appear in the log entries. This does not directly prevent the MiTM but provides a response mechanism that ensures the MiTM is unsuccessful. The advantage is that actual ownership knowledge is not required on the MASA service.

Nonceless Audit Voucher: An Audit Voucher without a validity period statement. Fundamentally, it is the same as an Audit Voucher except that it can be issued in advance to support network partitions or to provide a permanent voucher for remote deployments.

Ownership Audit Voucher: An Audit Voucher where the MASA service has verified the registrar as the authorized owner. The MASA service mitigates a MiTM registrar by refusing to generate Audit Vouchers for unauthorized registrars. The registrar uses audit techniques to supplement the MASA. This provides an ideal sharing of policy decisions and enforcement between the vendor and the owner.

Ownership ID Voucher: Named after inclusion of the pledge's CN-ID or DNS-ID within the voucher. The MASA service mitigates a MiTM registrar by identifying the specific registrar (via WebPKI) authorized to own the pledge.

Bearer Voucher: A Bearer Voucher is named after the inclusion of a registrar ID wildcard. Because the registrar identity is not indicated, this voucher type must be treated as a secret and protected from exposure as any 'bearer' of the voucher can claim the pledge device. Publishing a nonceless bearer voucher effectively turns the specified pledge into a "TOFU" device with minimal mitigation against MiTM registrars. Bearer vouchers are out of scope.

5. Voucher Artifact

The voucher's primary purpose is to securely assign a pledge to an owner. The voucher informs the pledge which entity it should consider to be its owner.

This document defines a voucher that is a JSON-encoded instance of the YANG module defined in Section 5.3 that has been, by default, CMS signed.

This format is described here as a practical basis for some uses (such as in NETCONF), but more to clearly indicate what vouchers look like in practice. This description also serves to validate the YANG data model.

Future work is expected to define new mappings of the voucher to Concise Binary Object Representation (CBOR) (from JSON) and to change the signature container from CMS to JSON Object Signing and Encryption (JOSE) or CBOR Object Signing and Encryption (COSE). XML or ASN.1 formats are also conceivable.

This document defines a media type and a filename extension for the CMS-encoded JSON type. Future documents on additional formats would define additional media types. Signaling is in the form of a MIME Content-Type, an HTTP Accept: header, or more mundane methods like use of a filename extension when a voucher is transferred on a USB key.

5.1. Tree Diagram

The following tree diagram illustrates a high-level view of a voucher document. The notation used in this diagram is described in [RFC8340]. Each node in the diagram is fully described by the YANG module in Section 5.3. Please review the YANG module for a detailed description of the voucher format.

```
module: ietf-voucher

  yang-data voucher-artifact:
      +---- voucher
         +---- created-on                         yang:date-and-time
         +---- expires-on?                        yang:date-and-time
         +---- assertion                          enumeration
         +---- serial-number                      string
         +---- idevid-issuer?                     binary
         +---- pinned-domain-cert                 binary
         +---- domain-cert-revocation-checks?     boolean
         +---- nonce?                             binary
         +---- last-renewal-date?                 yang:date-and-time
```

5.2. Examples

This section provides voucher examples for illustration purposes. These examples conform to the encoding rules defined in [RFC8259].

The following example illustrates an ephemeral voucher (uses a nonce). The MASA generated this voucher using the 'logged' assertion type, knowing that it would be suitable for the pledge making the request.


```
{
  "ietf-voucher:voucher": {
    "created-on": "2016-10-07T19:31:42Z",
    "assertion": "logged",
    "serial-number": "JADA123456789",
    "idevid-issuer": "base64encodedvalue==",
    "pinned-domain-cert": "base64encodedvalue==",
    "nonce": "base64encodedvalue=="
  }
}
```

The following example illustrates a non-ephemeral voucher (no nonce). While the voucher itself expires after two weeks, it presumably can be renewed for up to a year. The MASA generated this voucher using the 'verified' assertion type, which should satisfy all pledges.


```
{
  "ietf-voucher:voucher": {
    "created-on": "2016-10-07T19:31:42Z",
    "expires-on": "2016-10-21T19:31:42Z",
    "assertion": "verified",
    "serial-number": "JADA123456789",
    "idevid-issuer": "base64encodedvalue==",
    "pinned-domain-cert": "base64encodedvalue==",
    "domain-cert-revocation-checks": "true",
    "last-renewal-date": "2017-10-07T19:31:42Z"
  }
}
```


5.3. YANG Module

Following is a YANG [RFC7950] module formally describing the voucher's JSON document structure.

```
<CODE BEGINS> file "ietf-voucher@2018-05-09.yang"
module ietf-voucher {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-voucher";
  prefix vch;

  import ietf-yang-types {
    prefix yang;
    reference "RFC 6991: Common YANG Data Types";
  }
  import ietf-restconf {
    prefix rc;
    description
      "This import statement is only present to access
       the yang-data extension defined in RFC 8040.";
    reference "RFC 8040: RESTCONF Protocol";
  }

  organization
    "IETF ANIMA Working Group";
  contact
    "WG Web:   <https://datatracker.ietf.org/wg/anima/>
     WG List:  <mailto:anima@ietf.org>
     Author:   Kent Watsen
               <mailto:kwatsen@juniper.net>
```

```
     Author:   Max Pritikin
               <mailto:pritikin@cisco.com>
     Author:   Michael Richardson
               <mailto:mcr+ietf@sandelman.ca>
     Author:   Toerless Eckert
               <mailto:tte+ietf@cs.fau.de>";
  description
    "This module defines the format for a voucher, which is produced by
     a pledge's manufacturer or delegate (MASA) to securely assign a
     pledge to an 'owner', so that the pledge may establish a secure
     connection to the owner's network infrastructure.

     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.

     Copyright (c) 2018 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 8366; see the RFC
     itself for full legal notices.";

  revision 2018-05-09 {
    description
      "Initial version";
    reference "RFC 8366: Voucher Profile for Bootstrapping Protocols";
  }

  // Top-level statement
  rc:yang-data voucher-artifact {
    uses voucher-artifact-grouping;
  }

  // Grouping defined for future augmentations

  grouping voucher-artifact-grouping {
    description
      "Grouping to allow reuse/extensions in future work.";
    container voucher {
```

```
      description
        "A voucher assigns a pledge to an owner (pinned-domain-cert).";
      leaf created-on {
        type yang:date-and-time;
        mandatory true;
        description
          "A value indicating the date this voucher was created.  This
           node is primarily for human consumption and auditing.  Future
           work MAY create verification requirements based on this
           node.";
      }
      leaf expires-on {
        type yang:date-and-time;
        must 'not(../nonce)';
        description
          "A value indicating when this voucher expires.  The node is
           optional as not all pledges support expirations, such as
           pledges lacking a reliable clock.

           If this field exists, then the pledges MUST ensure that
           the expires-on time has not yet passed.  A pledge without
           an accurate clock cannot meet this requirement.

           The expires-on value MUST NOT exceed the expiration date
           of any of the listed 'pinned-domain-cert' certificates.";
      }
      leaf assertion {
        type enumeration {
          enum verified {
            description
              "Indicates that the ownership has been positively
               verified by the MASA (e.g., through sales channel
               integration).";
          }
          enum logged {
            description
              "Indicates that the voucher has been issued after
               minimal verification of ownership or control.  The
               issuance has been logged for detection of
               potential security issues (e.g., recipients of
               vouchers might verify for themselves that unexpected
               vouchers are not in the log).  This is similar to
               unsecured trust-on-first-use principles but with the
               logging providing a basis for detecting unexpected
               events.";
          }
          enum proximity {
```

```
            description
              "Indicates that the voucher has been issued after
               the MASA verified a proximity proof provided by the
               device and target domain.  The issuance has been logged
               for detection of potential security issues.  This is
               stronger than just logging, because it requires some
               verification that the pledge and owner are
               in communication but is still dependent on analysis of
               the logs to detect unexpected events.";
          }
        }
        mandatory true;
        description
          "The assertion is a statement from the MASA regarding how
           the owner was verified.  This statement enables pledges
           to support more detailed policy checks.  Pledges MUST
           ensure that the assertion provided is acceptable, per
           local policy, before processing the voucher.";
      }
      leaf serial-number {
        type string;
        mandatory true;
        description
          "The serial-number of the hardware.  When processing a
           voucher, a pledge MUST ensure that its serial-number
           matches this value.  If no match occurs, then the
           pledge MUST NOT process this voucher.";
      }
      leaf idevid-issuer {
        type binary;
        description
          "The Authority Key Identifier OCTET STRING (as defined in
           Section 4.2.1.1 of RFC 5280) from the pledge's IDevID
           certificate.  Optional since some serial-numbers are
           already unique within the scope of a MASA.
           Inclusion of the statistically unique key identifier
           ensures statistically unique identification of the hardware.
           When processing a voucher, a pledge MUST ensure that its
           IDevID Authority Key Identifier matches this value.  If no
           match occurs, then the pledge MUST NOT process this voucher.

           When issuing a voucher, the MASA MUST ensure that this field
           is populated for serial-numbers that are not otherwise unique
           within the scope of the MASA.";
      }
      leaf pinned-domain-cert {
        type binary;
        mandatory true;
```

```
          description
            "An X.509 v3 certificate structure, as specified by RFC 5280,
             using Distinguished Encoding Rules (DER) encoding, as defined
             in ITU-T X.690.

             This certificate is used by a pledge to trust a Public Key
             Infrastructure in order to verify a domain certificate
             supplied to the pledge separately by the bootstrapping
             protocol.  The domain certificate MUST have this certificate
             somewhere in its chain of certificates.  This certificate
             MAY be an end-entity certificate, including a self-signed
             entity.";
          reference
            "RFC 5280:
               Internet X.509 Public Key Infrastructure Certificate
               and Certificate Revocation List (CRL) Profile.
             ITU-T X.690:
                Information technology - ASN.1 encoding rules:
                Specification of Basic Encoding Rules (BER),
                Canonical Encoding Rules (CER) and Distinguished
                Encoding Rules (DER).";
        }
        leaf domain-cert-revocation-checks {
          type boolean;
          description
            "A processing instruction to the pledge that it MUST (true)
             or MUST NOT (false) verify the revocation status for the
             pinned domain certificate.  If this field is not set, then
             normal PKIX behavior applies to validation of the domain
             certificate.";
        }
        leaf nonce {
          type binary {
            length "8..32";
          }
          must 'not(../expires-on)';
          description
            "A value that can be used by a pledge in some bootstrapping
             protocols to enable anti-replay protection.  This node is
             optional because it is not used by all bootstrapping
             protocols.

             When present, the pledge MUST compare the provided nonce
             value with another value that the pledge randomly generated
             and sent to a bootstrap server in an earlier bootstrapping
             message.  If the values do not match, then the pledge MUST
             NOT process this voucher.";
        }
```

```
      leaf last-renewal-date {
        type yang:date-and-time;
        must '../expires-on';
        description
          "The date that the MASA projects to be the last date it
           will renew a voucher on.  This field is merely informative;
           it is not processed by pledges.

           Circumstances may occur after a voucher is generated that
           may alter a voucher's validity period.  For instance, a
           vendor may associate validity periods with support contracts,
           which may be terminated or extended over time.";
      }
    } // end voucher
  } // end voucher-grouping
}
```

<CODE ENDS>

5.4. CMS Format Voucher Artifact

The IETF evolution of PKCS#7 is CMS [RFC5652]. A CMS-signed voucher, the default type, contains a ContentInfo structure with the voucher content. An eContentType of 40 indicates that the content is a JSON-encoded voucher.

The signing structure is a CMS SignedData structure, as specified by Section 5.1 of [RFC5652], encoded using ASN.1 Distinguished Encoding Rules (DER), as specified in ITU-T X.690 [ITU.X690.2015].

To facilitate interoperability, Section 8.3 in this document registers the media type "application/voucher-cms+json" and the filename extension ".vcj".

The CMS structure MUST contain a 'signerInfo' structure, as described in Section 5.1 of [RFC5652], containing the signature generated over the content using a private key trusted by the recipient. Normally, the recipient is the pledge and the signer is the MASA. Another possible use could be as a "signed voucher request" format originating from the pledge or registrar toward the MASA. Within this document, the signer is assumed to be the MASA.

Note that Section 5.1 of [RFC5652] includes a discussion about how to validate a CMS object, which is really a PKCS7 object (cmsVersion=1). Intermediate systems (such the Bootstrapping Remote Secure Key Infrastructures (BRSKI) registrar) that might need to evaluate the voucher in flight MUST be prepared for such an older format. No signaling is necessary, as the manufacturer knows the capabilities of the pledge and will use an appropriate format voucher for each pledge.

The CMS structure SHOULD also contain all of the certificates leading up to and including the signer's trust anchor certificate known to the recipient. The inclusion of the trust anchor is unusual in many applications, but third parties cannot accurately audit the transaction without it.

The CMS structure MAY also contain revocation objects for any intermediate certificate authorities (CAs) between the voucher issuer and the trust anchor known to the recipient. However, the use of CRLs and other validity mechanisms is discouraged, as the pledge is unlikely to be able to perform online checks and is unlikely to have a trusted clock source. As described below, the use of short-lived vouchers and/or a pledge-provided nonce provides a freshness guarantee.

6. Design Considerations

6.1. Renewals Instead of Revocations

The lifetimes of vouchers may vary. In some bootstrapping protocols, the vouchers may be created and consumed immediately, whereas in other bootstrapping solutions, there may be a significant time delay between when a voucher is created and when it is consumed. In cases when there is a time delay, there is a need for the pledge to ensure that the assertions made when the voucher was created are still valid.

A revocation artifact is generally used to verify the continued validity of an assertion such as a PKIX certificate, web token, or a "voucher". With this approach, a potentially long-lived assertion is paired with a reasonably fresh revocation status check to ensure that the assertion is still valid. However, this approach increases solution complexity, as it introduces the need for additional protocols and code paths to distribute and process the revocations.

Addressing the shortcomings of revocations, this document recommends instead the use of lightweight renewals of short-lived non-revocable vouchers. That is, rather than issue a long-lived voucher, where the 'expires-on' leaf is set to some distant date, the expectation is for the MASA to instead issue a short-lived voucher, where the 'expires-on' leaf is set to a relatively near date, along with a promise (reflected in the 'last-renewal-date' field) to reissue the voucher again when needed. Importantly, while issuing the initial voucher may incur heavyweight verification checks ("Are you who you say you are?" "Does the pledge actually belong to you?"), reissuing the voucher should be a lightweight process, as it ostensibly only updates the voucher's validity period. With this approach, there is only the one artifact, and only one code path is needed to process it; there is no possibility of a pledge choosing to skip the revocation status check because, for instance, the OCSP Responder is not reachable.

While this document recommends issuing short-lived vouchers, the voucher artifact does not restrict the ability to create long-lived voucher, if required; however, no revocation method is described.

Note that a voucher may be signed by a chain of intermediate CAs leading up to the trust anchor certificate known by the pledge. Even though the voucher itself is not revocable, it may still be revoked, per se, if one of the intermediate CA certificates is revoked.

6.2. Voucher Per Pledge

The solution described herein originally enabled a single voucher to apply to many pledges, using lists of regular expressions to represent ranges of serial-numbers. However, it was determined that blocking the renewal of a voucher that applied to many devices would be excessive when only the ownership for a single pledge needed to be blocked. Thus, the voucher format now only supports a single serial-number to be listed.

7. Security Considerations

7.1. Clock Sensitivity

An attacker could use an expired voucher to gain control over a device that has no understanding of time. The device cannot trust NTP as a time reference, as an attacker could control the NTP stream.

There are three things to defend against this: 1) devices are required to verify that the expires-on field has not yet passed, 2) devices without access to time can use nonces to get ephemeral vouchers, and 3) vouchers without expiration times may be used, which will appear in the audit log, informing the security decision.

This document defines a voucher format that contains time values for expirations, which require an accurate clock in order to be processed correctly. Vendors planning on issuing vouchers with expiration values must ensure that devices have an accurate clock when shipped from manufacturing facilities and take steps to prevent clock tampering. If it is not possible to ensure clock accuracy, then vouchers with expirations should not be issued.

7.2. Protect Voucher PKI in HSM

Pursuant the recommendation made in Section 6.1 for the MASA to be deployed as an online voucher signing service, it is RECOMMENDED that the MASA’s private key used for signing vouchers is protected by a hardware security module (HSM).

7.3. Test Domain Certificate Validity When Signing

If a domain certificate is compromised, then any outstanding vouchers for that domain could be used by the attacker. The domain administrator is clearly expected to initiate revocation of any domain identity certificates (as is normal in PKI solutions).

Similarly,they are expected to contact the MASA to indicate that an outstanding (presumably short lifetime) voucher should be blocked from automated renewal. Protocols for voucher distribution are RECOMMENDED to check for revocation of domain identity certificates before the signing of vouchers.

7.4. YANG Module Security Considerations

The YANG module specified in this document defines the schema for data that is subsequently encapsulated by a CMS signed-data content type, as described in Section 5 of [RFC5652]. As such, all of the YANG modeled data is protected from modification.

Implementations should be aware that the signed data is only protected from external modification; the data is still visible. This potential disclosure of information doesn't affect security so much as privacy. In particular, adversaries can glean information such as which devices belong to which organizations and which CRL Distribution Point and/or OCSP Responder URLs are accessed to validate the vouchers. When privacy is important, the CMS signed-data content type SHOULD be encrypted, either by conveying it via a mutually authenticated secure transport protocol (e.g., TLS [RFC5246]) or by encapsulating the signed-data content type with an enveloped-data content type (Section 6 of [RFC5652]), though details for how to do this are outside the scope of this document.

The use of YANG to define data structures, via the 'yang-data' statement, is relatively new and distinct from the traditional use of YANG to define an API accessed by network management protocols such as NETCONF [RFC6241] and RESTCONF [RFC8040]. For this reason, these guidelines do not follow template described by Section 3.7 of [YANG-GUIDE].

8. IANA Considerations

8.1. The IETF XML Registry

This document registers a URI in the "IETF XML Registry" [RFC3688]. IANA has registered the following:

URI: urn:ietf:params:xml:ns:yang:ietf-voucher
Registrant Contact: The ANIMA WG of the IETF.
XML: N/A, the requested URI is an XML namespace.

8.2. The YANG Module Names Registry

This document registers a YANG module in the "YANG Module Names" registry [RFC6020]. IANA has registered the following:

```
name:         ietf-voucher
namespace:    urn:ietf:params:xml:ns:yang:ietf-voucher
prefix:       vch
reference:    RFC 8366
```

8.3. The Media Types Registry

This document registers a new media type in the "Media Types" registry [RFC6838]. IANA has registered the following:

Type name: application

Subtype name: voucher-cms+json

Required parameters: none

Optional parameters: none

Encoding considerations: CMS-signed JSON vouchers are ASN.1/DER encoded.

Security considerations: See Section 7

Interoperability considerations: The format is designed to be broadly interoperable.

Published specification: RFC 8366

Applications that use this media type: ANIMA, 6tisch, and NETCONF zero-touch imprinting systems.

Fragment identifier considerations: none

Additional information:

Deprecated alias names for this type: none

Magic number(s): None

File extension(s): .vcj

Macintosh file type code(s): none

Person and email address to contact for further information:
IETF ANIMA WG

Intended usage: LIMITED

Restrictions on usage: NONE

Author: ANIMA WG

Change controller: IETF

Provisional registration? (standards tree only): NO

8.4. The SMI Security for S/MIME CMS Content Type Registry

IANA has registered the following OID in the "SMI Security for S/MIME CMS Content Type (1.2.840.113549.1.9.16.1)" registry:

Decimal	Description	References
40	id-ct-animaJSONVoucher	RFC 8366

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