Workgroup: Network Working Group
Internet-Draft:
draft-ietf-sidrops-signed-tal-10
Published: 10 July 2022
Intended Status: Standards Track
Expires: 11 January 2023

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RPKI Signed Object for Trust Anchor Key

Abstract

A Trust Anchor Locator (TAL) is used by Relying Parties (RPs) in the
   Resource Public Key Infrastructure (RPKI) to locate and validate a
   Trust Anchor (TA) Certification Authority (CA) certificate used in
   RPKI validation. This document defines an RPKI signed object for a
   Trust Anchor Key (TAK), that can be used by a TA to signal the
   location(s) of the accompanying CA certificate for the current key
   to RPs, as well as the successor key and the location(s) of its CA
   certificate. This object helps to support planned key rolls without
   impacting RPKI validation.

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1. Requirements Notation

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.

2. Overview

A TAL [RFC8630] is used by an RP in the RPKI to locate and validate
TA CA certificates used in RPKI validation. However, until now there
has been no in-band way of notifying RPs of updates to a TAL. In-
band notification means that TAs can be more confident of RPs being
aware of key roll operations.

This document defines a new RPKI signed object that can be used to
document the location(s) of the TA CA certificate for the current TA
key, as well as the value of the successor key and the location(s)
of its TA CA certificate. This allows RPs to be notified
automatically of such changes, and enables TAs to stage a successor
key so that planned key rolls can be performed without risking the
invalidation of the RPKI tree under the TA. We call this object the
Trust Anchor Key (TAK) object.

When RPs are first bootstrapped, they use a TAL to discover the key
and location(s) of the CA certificate for a TA. The RP can then
retrieve and validate the CA certificate, and subsequently validate
the manifest [RFC6486] and CRL published by that TA (section 5 of
[RFC6487]). However, before processing any other objects it will
first validate the TAK object, if present. If the TAK object lists
only the current key, then the RP continues processing as per
normal. If the TAK object includes a successor key, the RP starts an
acceptance timer, and then continues processing as per normal. If,
during the following validation runs up until the expiry of the
acceptance timer, the RP has not observed any changes to the keys
and certificate URLs listed in the TAK object, then the RP will
fetch the successor key, update its local state with that key and
its associated certification location(s), and continue processing
using that key.

The primary motivation for this work is being able to migrate from a
Hardware Security Module (HSM) produced by one vendor to one
produced by another, where the first vendor does not support
exporting keys for use by the second. There may be other scenarios
in which key rollover is useful, though.

3. TAK Object Definition

The TAK object makes use of the template for RPKI digitally signed
objects [RFC6488], which defines a Cryptographic Message Syntax
(CMS) [RFC5652] wrapper for the content as well as a generic
validation procedure for RPKI signed objects. Therefore, to complete

the specification of the TAK object (see Section 4 of [RFC6488]),
this document defines:

  *The OID (in Section 3.1) that identifies the signed object as
   being a TAK. (This OID appears within the eContentType in the
   encapContentInfo object, as well as the content-type signed
   attribute in the signerInfo object.)

  *The ASN.1 syntax for the TAK eContent, in Section 3.2.

  *The additional steps required to validate a TAK, in Section 3.3.

3.1. The TAK Object Content Type

This document requests an OID for the TAK object as follows:

```
id-ct-signed-Tal OBJECT IDENTIFIER ::=
   { iso(1) member-body(2) us(840) rsadsi(113549) pkcs(1) pkcs9(9)
     smime(16) id-smime ct(1) TBD }
```

This OID MUST appear both within the eContentType in the
encapContentInfo object, as well as the content-type signed
attribute in the signerInfo object (see [RFC6488]).

3.2. The TAK Object eContent

The content of a TAK object is ASN.1 encoded using the Distinguished
Encoding Rules (DER) [X.690], and is defined per the module in
Appendix A.

3.2.1. TAKey

This structure defines a TA key, similarly to [RFC8630]. It contains
a sequence of one or more URIs and a SubjectPublicKeyInfo.

3.2.1.1. certificateURIs

This field is equivalent to the URI section defined in section 2.2
of [RFC8630]. It MUST contain at least one CertificateURI element.
Each CertificateURI element contains the IA5String representation of
either an rsync URI [RFC5781], or an HTTPS URI [RFC7230].

3.2.1.2. subjectPublicKeyInfo

This field contains a SubjectPublicKeyInfo (section 4.1.2.7 of
[RFC5280]) in DER format [X.690].

3.2.2. TAK

3.2.2.1. version

The version number of the TAK object MUST be 0.

3.2.2.2. current

This field contains the TA key of the repository in which the TAK object is published.

3.2.2.3. predecessor

This field contains the TA key that was in use for this TA immediately prior to the current TA key, if applicable.

3.2.2.4. successor

This field contains the TA key to be used in place of the current key, after expiry of the relevant acceptance timer.

3.3. TAK Object Validation

To determine whether a TAK object is valid, the RP MUST perform the following checks in addition to those specified in [RFC6488]:

  * The eContentType OID matches the OID described in Section 3.1.

  * The TAK object appears as the product of a TA CA certificate (i.e. the TA CA certificate is itself the issuer of the EE certificate of the TAK object).

  * The TA CA has published only one TAK object in its repository for this key, and this object appears on the manifest as the only entry using the ".tak" extension (see [RFC6481]).

  * The EE certificate of this TAK object describes its Internet Number Resources (INRs) using the "inherit" attribute.

  * The decoded TAK content conforms to the format defined in Section 3.2.

  * The SubjectPublicKeyInfo value of the current TA key in the TAK object matches that of the TA CA certificate used to issue the EE certificate of the TAK object.

If any of these checks does not succeed, the RP MUST ignore the TAK object, and proceed as though it were not listed on the manifest.

The RP is not required to compare its current set of certificateURIs for the current key with those listed in the TAK object. The RP MAY alert the user that these sets of certificateURIs do not match, with a view to the user manually updating the set of certificateURIs in their configuration. The RP MUST NOT automatically update its configuration to use these certificateURIs in the event of inconsistency, though, because migration of users to new certificateURIs should happen by way of the successor key process.

4. **TAK Object Generation and Publication**

A TA MAY choose to use TAK objects to communicate its current, predecessor, and successor keys. If a TA chooses to use TAK objects, then it SHOULD generate and publish TAK objects under each of its keys.

A non-normative guideline for naming this object is that the filename chosen for the TAK object in the publication repository be a value derived from the public key part of the entity's key pair, using the algorithm described for CRLs in section 2.2 of [RFC6481] for generation of filenames. The filename extension of ".tak" MUST be used to denote the object as a TAK.

In order to generate a TAK object, the TA MUST perform the following actions:

  *The TA MUST generate a key pair for a "one-time-use" EE
   certificate to use for the TAK.

  *The TA MUST generate a one-time-use EE certificate for the TAK.

  *This EE certificate MUST have an SIA extension access description
   field with an accessMethod OID value of id-ad-signedObject, where
   the associated accessLocation references the publication point of
   the TAK as an object URL.

  *As described in [RFC6487], an [RFC3779] extension is required in
   the EE certificate used for this object. However, because the
   resource set is irrelevant to this object type, this certificate
   MUST describe its Internet Number Resources (INRs) using the
   "inherit" attribute, rather than explicit description of a
   resource set.

  *This EE certificate MUST have a "notBefore" time that matches or
   predates the moment that the TAK will be published.

  *This EE certificate MUST have a "notAfter" time that reflects the
   intended duration for which this TAK will be published. If the EE
   certificate for a TAK object is expired, it MUST no longer be

published, but it MAY be replaced by a newly generated TAK object
   with equivalent content and an updated "notAfter" time.

   *The current TA key for the TAK MUST match that of the TA CA
   certificate under which the TAK was issued.

5. Relying Party Use

Relying Parties MUST keep a record of the current key for each
configured TA, as well as the URI(s) where the CA certificate for
this key may be retrieved. This record is typically bootstrapped by
the use of a pre-configured (and unsigned) TAL file [RFC8630].

When performing top-down validation, RPs MUST first validate and
process the TAK object for its current known key, by performing the
following steps:

   *A CA certificate is retrieved and validated from the known URIs
    as described in sections 3 and 4 of [RFC8630].

   *The manifest and CRL for this certificate are then validated as
    described in [RFC6487] and [RFC6486].

   *The TAK object, if present, is validated as described in Section
    3.3.

If the TAK object includes a successor key, then the RP must verify
the successor key by doing the following:

   *performing top-down validation using the successor key, in order
    to validate the TAK object for the successor TA;

   *ensuring that a valid TAK object exists for the successor TA;

   *ensuring that the successor TAK object's current key matches the
    initial TAK object's successor key; and

   *ensuring that the successor TAK object's predecessor key matches
    the initial TAK object's current key.

If any of these steps fails, then the successor key has failed
verification.

If the successor key passes verification, and the RP has not seen
that successor key on the previous successful validation run for
this TA, then the RP:

   *sets an acceptance timer of 30 days for this successor key for
    this TA;

*cancels the existing acceptance timer for this TA (if
   applicable); and

  *continues standard top-down validation as described in [RFC6487]
   using the current key.

If the successor key passes verification, and the RP has seen that
successor key on the previous successful validation run for this TA:

  *if the relevant acceptance timer has not expired, the RP
   continues standard top-down validation using the current key;

  *otherwise, the RP updates its current known key details for this
   TA to be those of the successor key, and then begins top-down
   validation again using the successor key.

If the successor key does not pass verification, or if the TAK
object does not include a successor key, the RP cancels the existing
acceptance timer for this TA (if applicable).

An RP MUST NOT use a successor key for top-down validation outside
of the process described above, except for the purpose of testing
that the new key is working correctly. This allows a TA to publish a
successor key for a period of time, allowing RPs to test it, while
still being able to rely on RPs using the current key for their
production RPKI operations.

A successor key may have the same SubjectPublicKeyInfo value as the
current key: this will be the case where a TA is updating the
certificateURIs for that key.

6. Maintaining Multiple TA Keys

Although an RP that can process TAK objects will only ever use one
key for validation (either the current key, or the successor key,
once the relevant acceptance timer has expired), an RP that cannot
process TAK objects will continue to use the key details per its TAL
(or equivalent manual configuration) indefinitely. As a result, even
when a TA is using a TAK object in order to migrate clients to a new
key, the TA may have to maintain the previous key for a period of
time alongside the new key in order to ensure continuity of service
for older clients.

For each TA key that a TA is maintaining, the signed material for
these keys MUST be published under different directories in the
context of the 'id-ad-caRepository' and 'id-ad-rpkiManifest' Subject
Information Access descriptions contained on the CA certificates
[RFC6487]. Publishing objects under the same directory is
potentially confusing for RPs, and could lead to object invalidity
in the event of file name collisions.

Also, the CA certificates for each maintained key, and the contents published by each key, MUST be equivalent (except for the TAK object). In other words, for the purposes of RPKI validation, it MUST NOT make a difference which of the keys is used as a starting point.

This means that the IP and AS resources contained on all current CA certificates for the maintained TA keys MUST be the same. Furthermore, for any delegation of IP and AS resources to a child, the TA MUST have an equivalent CA certificate published under each of its keys. Any updates in delegations MUST be reflected under each of its keys. A TA SHOULD NOT publish any other objects besides a CRL, a Manifest, a single TAK object, and any number of CA certificates for delegation to child CAs.

If a TA uses a single remote publication server for its keys, per [RFC8181], then it MUST include all <publish/> and <withdraw/> PDUs for the products of each of its keys in a single query, in order to ensure that they will reflect the same content at all times.

If a TA uses multiple publication servers, then it is by definition inevitable that the content of different keys will be out of sync at times. In such cases, the TA SHOULD ensure that the duration of these moments are limited to the shortest possible time. Furthermore, the following should be observed:

  *In cases where a CA certificate is revoked completely, or replaced by a certificate with a reduced set of resources, these changes will not take effect fully until all the relevant repository publication points have been updated. Given that TA key operations are normally performed infrequently, this is unlikely to be a problem: if the revocation or shrinking of an issued CA certificate is staged for days/weeks, then experiencing a delay of several minutes for the repository publication points to be updated is fairly insignificant.

  *In cases where a CA certificate is replaced by a certificate with an extended set of resources, the TA MUST inform the receiving CA only after all of its repository publication points have been updated. This ensures that the receiving CA will not issue any products that could be invalid if an RP uses a TA key just before the CA certificate was due to be updated.

Finally, note that the publication locations of CA certificates for delegations to child CAs under each key will be different, and therefore the Authority Information Access 'id-ad-caIssuers' values (section 4.8.7 of [RFC6487]) on certificates issued by the child CAs may not be as expected when performing top-down validation, depending on the TA key that is used. However, these values are not

critical to top-down validation, so RPs performing such validation MUST NOT reject a certificate simply because this value is not as expected.

7. Performing TA Key Rolls

In this section we will describe how present-day RPKI TAs that use only one key pair, and that do not use TAK objects, can use a TAK object to perform a planned key roll.

7.1. Phase 1: Add a TAK for Key 'A'

Before adding a successor key, a TA may want to confirm that it can maintain a TAK object for its current key only. We will refer to this key as key 'A' throughout this section.

7.2. Phase 2: Add a Key 'B'

The TA can now generate a new key pair for key 'B'. This key MUST now be used to create a new CA certificate for this key, and to issue equivalent CA certificates for delegations to child CAs, as described in [Section 6](#).

At this point, the TA can also construct a new TAL file [RFC8630] for key 'B', and test locally that the validation outcome for the new key is equivalent to that of the other current key(s).

When the TA is certain that both keys are equivalent, and wants to initiate the migration from 'A' to 'B', it issues a new TAK object under key 'A', with key 'A' as the current key for that object, key 'B' as the successor key, and no predecessor key. It also issues a TAK object under key 'B', with key 'B' as the current key for that object, key 'A' as the predecessor key, and no successor key.

Once this has happened, RP clients will start seeing the new key and setting acceptance timers accordingly.

7.3. Phase 3: Update TAL to point to 'B'

At about the time that the TA expects clients to start setting key 'B' as the current key, the TA must release a new TAL file for key 'B'. It SHOULD use a different set of URIs in the TAL compared to the TAK file, so that the TA can learn the proportion of RPs that can successfully validate and use the updated TAK objects.

To support RPs that do not take account of TAK objects, the TA should continue operating key 'A' for a period of time after the expected migration of clients to 'B'. The length of that period of time is a local policy matter for that TA: it might operate the key until no clients are attempting to validate using it, for example.

7.4. Phase 4: Remove Key 'A'

The TA SHOULD now remove all content from the repository used by key 'A', and destroy the private key for key 'A'. RPs attempting to rely on a TAL for key 'A' from this point will not be able to perform RPKI validation for the TA, and will have to update their local state manually, by way of a new TAL file.

8. Using TAK objects to distribute TAL data

Relying Parties must be configured with RPKI Trust Anchor data in order to function correctly. This Trust Anchor data is typically distributed in the Trust Anchor Locator (TAL) format defined in RFC 8630. A TAK object can also serve as a format for distribution of this data, though, because the TAKey data stored in the TAK object contains the same data that would appear in a TAL for the associated Trust Anchor.

Relying Parties may support conversion of TAK objects into TAL files. Relying Parties that support conversion MUST validate the TAK object using the process from section 3.3. One exception to the standard validation process in this context is that a Relying Party MAY treat a TAK object as valid, even though it is associated with a Trust Anchor that the Relying Party is not currently configured to trust. If the Relying Party is relying on this exception when converting a given TAK object, the Relying Party MUST communicate that fact to the user.

When converting a TAK object, a Relying Party MUST default to producing a TAL file based on the 'current' TAKey in the TAK object, though it MAY optionally support producing TAL files based on the 'predecessor' and 'successor' TAKeys.

If TAK object validation fails, then the Relying Party MUST NOT produce a TAL file based on the TAK object.

9. Deployment Considerations

Including TAK objects while RPs do not support this standard will result in those RPs rejecting these objects. It is not expected that this will result in the invalidation of any other object under a Trust Anchor.

The mechanism introduced here can only be relied on once a majority of RPs support it. Defining when that moment arrives is something that cannot be established at the time of writing this document. The use of unique URIs for keys in TAK objects, different from those used for the corresponding TAL files, should help TAs understand the proportion of RPs that support this mechanism.

Some RPs may purposefully not support this mechanism: for example,
they may be implemented or configured such that they are unable to
update local current key data. TAs should take this into
consideration when planning key rollover. However, these RPs would
ideally still notify their operators of planned key rollovers, so
that the operator could update the relevant configuration manually.

10. Security Considerations

A TA needs to consider the length of time for which it will maintain
previously-current keys and their associated repositories. An RP
that is seeded with old TAL data will run for 30 days using the
previous key before migrating to the next key, due to the acceptance
timer requirements, and this 30-day delay applies to each new key
that has been issued since the old TAL data was initially published.
It may be better in these instances to have the old publication URLs
simply fail to resolve, so that the RP reports an error to its
operator and the operator seeds it with up-to-date TAL data
immediately.

Once a TA has decided not to maintain a previously-current key and
its associated repository, it needs to consider how to protect
against an adversary gaining access to that key and its associated
publication points in order to send invalid/incorrect data to RPs
seeded with the TAL data for that key. One possible mitigation here
is to reuse the TA CA certificate URLs from that TAL data for newer
keys.

The use of acceptance timers means that an adversary that gains
access to a TA's current key is not able to migrate RPs to a new key
without delay. Although access to that key does permit arbitrary
action within the corresponding TA (assuming that the adversary has
control over the relevant publication points), being unable to
migrate RPs to a new key means that it is possible for the TA
operator to regain control over the key and the TA itself, such that
it may not be necessary for all RPs to carry out manual
reconfiguration.

If an adversary gains access to the key listed as the successor to a
TA's current key (i.e. listed as the successor, but the acceptance
timer period has not yet elapsed since it was listed), the TA
operator can recover from this by simply removing the successor key
from the TAK object.

In general, the risk of key compromise can be mitigated by the use
of Hardware Security Modules (HSMs) by TAs, which will guard against
theft of a private key, as well as operational processes to guard
against (accidental) misuse of the keys in an HSM by operators.

Alternate models of TAL update exist and can be complementary to
this mechanism. For example, TAs can liaise directly with validation
software developers to include updated and reissued TAL files in new
code releases, and use existing code update mechanisms in the RP
community to distribute the changes.

11. IANA Considerations

11.1. OID

IANA is asked to add the following to the "RPKI Signed Objects"
registry:

```
Decimal | Description                    | References
--------+-------------------------------+--------------
TBD     | Trust Anchor Key              | [section 3.1]
```

11.2. File Extension

IANA is asked to add an item for the Signed TAL file extension to
the "RPKI Repository Name Scheme" created by [RFC6481] as follows:

```
Extension |   RPKI Object              | References
----------+----------------------------------------
 .tak     |   Trust Anchor Key         | [this document]
```

11.3. Module Identifier

IANA is asked to register an object identifier for one module
identifier in the "SMI Security for S/MIME Module Identifier
(1.2.840.113549.1.9.16.0)" registry as follows:

```
Decimal | Description                    | References
--------+-------------------------------+--------------
TBD     | Trust Anchor Key              | [section 3.1]
```

   *Description: RPKISignedTrustAnchorList-2021

   *OID: 1.2.840.113549.1.9.16.0.TBD

   *Specification: [this document]

12. Implementation Status

NOTE: Please remove this section and the reference to RFC 7942 prior
to publication as an RFC.

This section records the status of known implementations of the
protocol defined by this specification at the time of posting of
this Internet-Draft, and is based on a proposal described in

[RFC7942]. The description of implementations in this section is intended to assist the IETF in its decision processes in progressing drafts to RFCs. Please note that the listing of any individual implementation here does not imply endorsement by the IETF. Furthermore, no effort has been spent to verify the information presented here that was supplied by IETF contributors. This is not intended as, and must not be construed to be, a catalog of available implementations or their features. Readers are advised to note that other implementations may exist.

According to RFC 7942, "this will allow reviewers and working groups to assign due consideration to documents that have the benefit of running code, which may serve as evidence of valuable experimentation and feedback that have made the implemented protocols more mature. It is up to the individual working groups to use this information as they see fit".

12.1. APNIC

*Responsible Organization: Asia-Pacific Network Information Centre

*Location: https://github.com/APNIC-net/rpki-signed-tal-demo

*Description: A proof-of-concept for relying party TAK usage.

*Level of Maturity: This is a proof-of-concept implementation.

*Coverage: This implementation includes all of the features described in version 08 of this specification. The repository includes a link to various test TALs that can be used for testing TAK scenarios, too.

*Contact Information: Tom Harrison, tomh@apnic.net

13. Revision History

03 - Last draft under Tim's authorship.

04 - First draft with George's authorship. No substantive revisions.

05 - First draft with Tom's authorship. No substantive revisions.

06 - Rob Kisteleki's critique.

07 - Switch to two-key model.

08 - Keepalive.

09 - Acceptance timers, predecessor keys, no long-lived CRL/MFT.

10 - Using TAK objects for distribution of TAL data.

14. Acknowledgments

   The authors wish to thank Martin Hoffmann for a thorough review of
   the document, Russ Housley for multiple reviews of the ASN.1
   definitions and for providing a new module for the TAK object, and
   Job Snijders for the suggestion about using TAK objects for
   distribution of TAL data.

15. References

15.1. Normative References

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Appendix A. ASN.1 Module

   This appendix includes the ASN.1 module for the TAK object.

```
<CODE BEGINS>


RPKISignedTrustAnchorList-2021
    { iso(1) member-body(2) us(840) rsadsi(113549) pkcs(1)
      pkcs9(9) smime(16) mod(0) TBD }

DEFINITIONS EXPLICIT TAGS ::=
BEGIN

IMPORTS

CONTENT-TYPE
    FROM CryptographicMessageSyntax-2009 -- in [RFC5911]
    { iso(1) member-body(2) us(840) rsadsi(113549) pkcs(1)
      pkcs-9(9) smime(16) modules(0) id-mod-cms-2004-02(41) }

SubjectPublicKeyInfo
    FROM PKIX1Explicit-2009 -- in [RFC5912]
    { iso(1) identified-organization(3) dod(6) internet(1)
      security(5) mechanisms(5) pkix(7) id-mod(0)
      id-mod-pkix1-explicit-02(51) } ;

ct-signedTAL CONTENT-TYPE ::=
    { TYPE TAK IDENTIFIED BY
      id-ct-signedTAL }

id-ct-signedTAL OBJECT IDENTIFIER ::= { iso(1) member-body(2)
    us(840) rsadsi(113549) pkcs(1) pkcs9(9) smime(16) ct(1) TBD }

CertificateURI ::= IA5String

TAKey ::= SEQUENCE {
    certificateURIs  SEQUENCE SIZE (1..MAX) OF CertificateURI,
    subjectPublicKeyInfo  SubjectPublicKeyInfo
}

TAK ::= SEQUENCE {
    version     INTEGER DEFAULT 0,
    current     TAKey,
    predecessor [0] TAKey OPTIONAL,
    successor   [1] TAKey OPTIONAL
}

END


<CODE ENDS>
```

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