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Hash Of Root Key Certificate Extension
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Abstract

This document specifies the Hash Of Root Key certificate extension. This certificate extension is carried in the self-signed certificate for a trust anchor, which is often called a Root Certification Authority (CA) certificate. This certificate extension unambiguously identifies the next public key that will be used by the trust anchor at some point in the future.

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1. Introduction

This document specifies the Hash Of Root Key X.509 version 3 certificate extension. The extension is an optional addition to the Internet X.509 Public Key Infrastructure Certificate and Certificate Revocation List (CRL) Profile [RFC5280]. The certificate extension facilitates the orderly transition from one Root Certification Authority (CA) public key to the next. It does so by publishing the hash value of the next generation public key in the current self-signed certificate. This allows a relying party to unambiguously recognize the next generation public key when it becomes available, install that public key in the trust anchor store, and remove the previous public key from the trust anchor store.

A Root CA Certificate MAY include the Hashed Root Key certificate extension to provide the hash value of the next public key that will be used by the Root CA.

1.1. Terminology

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

1.2. ASN.1

Certificates [RFC5280] are generated using ASN.1 [X680]; certificates are always encoded with the Distinguished Encoding Rules (DER) [X690].

2. Overview

Before the initial deployment of the Root CA, the following are generated:

```
R1 = The initial Root key pair
C1 = Self-signed certificate for R1, which also contains H2
R2 = The second generation Root key pair
H2 = Thumbprint (hash) of the public key of R2
```

C1 is a self-signed certificate, and it contains H2 within the HashOfRootKey extension. C1 is distributed as part of the initial the system deployment. The HashOfRootKey certificate extension is described in Section 3.

When the time comes to replace the initial Root CA certificate, R1, the following are generated:

```
R3 = The third generation Root key pair
H3 = Thumbprint (hash) the public key of R3
C2 = Self-signed certificate for R2, which contains H3
```

This is an iterative process. That is, R4 and H4 are generated when it is time for C3 to replace C2. And so on.

The successors to the Root CA self-signed certificate can be delivered by any means. Whenever a new Root CA certificate is received, the recipient is able to verify that the potential Root CA certificate links back to a previously authenticated Root CA certificate with the hashOfRootKey certificate extension. That is, validate the self-signed signature and verify that the hash of the DER-encoded SubjectPublicKeyInfo from the potential Root CA certificate matches the value from the HashOfRootKey certificate extension of the current Root CA certificate. If the signature does not validate or the hash values do not match, then potential Root CA certificate is not a valid replacement, and the recipient continues to use the current Root CA certificate.

3. Hash Of Root Key Certificate Extension

The HashOfRootKey certificate extension MUST NOT be critical.

The following ASN.1 [X680][X690] syntax defines the HashOfRootKey certificate extension:

```
ext-HashOfRootKey EXTENSION ::= {    -- Only in Root CA certificates
   SYNTAX         HashedRootKey
   IDENTIFIED BY  id-ce-hashOfRootKey
   CRITICALITY    {FALSE} }

HashedRootKey ::= SEQUENCE {
   hashAlg        AlgorithmIdentifier,  -- Hash algorithm used
   hashValue      OCTET STRING }        -- Hash of DER-encoded
                                        --   SubjectPublicKeyInfo

id-ce-hashOfRootKey  ::=  OBJECT IDENTIFIER { 1 3 6 1 4 1 51483 2 1 }
```

The definitions of EXTENSION and HashAlgorithm can be found in [RFC5912].

The hashAlg indicates the one-way hash algorithm that was used to compute the hash value.

The hashValue contains the hash value computed from the next generation public key. The public key is DER-encoded SubjectPublicKeyInfo as defined in [RFC5280].

4. IANA Considerations

This document makes no requests of the IANA.

5. Operational Considerations

Guidance on the transition from one trust anchor to another is available in [RFC2510]. In particular, the oldWithNew and newWithOld advice ensures that relying parties are able to validate certificates issued under the current Root CA certificate and the next generation Root CA certificate throughout the transition. Further, this technique ovoids the need for all relying parties to make the transition at the same time.

6. Security Considerations

The security considerations from [RFC5280] apply, especially the discussion of self-issued certificates.

The Hash Of Root Key certificate extension facilitates the orderly transition from one Root CA public key to the next by publishing the hash value of the next generation public key in the current certificate. This allows a relying party to unambiguously recognize the next generation public key when it becomes available; however, the full public key is not disclosed until the Root CA releases the next generation certificate. In this way, attackers cannot begin to analyze the public key before the next generation Root CA certificate is released.

The Root CA needs to ensure that the public key in the next generation certificate is as strong or stronger than the key that it is replacing.

The Root CA needs to employ a hash function that is resistant to preimage attacks [RFC4270]. A first-preimage attack against the hash function would allow an attacker to find another input that results published hash value. For the attack to be successful, the input would have to be a valid SubjectPublicKeyInfo that contains the public key that corresponds to a private key known to the attacker. A second-preimage attack becomes possible once the Root CA releases the next generation public key, which makes the input to the hash function becomes available to the attacker and everyone else. Again, the attacker needs to find a valid SubjectPublicKeyInfo that contains the public key that corresponds to a private key known to the attacker.

If an early release of the next generation public key occurs and the Root CA is concerned that attackers were given too much lead time to analyze that public key, then the Root CA can transition to a freshly generated key pair by rapidly performing two transitions. The first transition takes the Root CA to the key pair that suffered the early release, and it causes the Root CA to generate the subsequent Root key pair. The second transition occurs when the Root CA is confident that the population of relying parties have completed the first transition, and it takes the Root CA to the freshly generated key pair. Of course, the second transition also causes the Root CA to generate the Root key pair for future use.

7. Acknowledgements

The Secure Electronic Transaction (SET) [SET] specification published by MasterCard and VISA in 1997 includes a very similar certificate extension. The SET certificate extension has essentially the same semantics, but the syntax fairly different.

CTIA - The Wireless Association is developing a public key infrastructure that will make use of the certificate extension described in this document.

Many thanks to Jim Schaad and Stefan Santesson. Their review and comments have greatly improved the document, especially the Operational Considerations and Security Considerations sections.

8. References

8.1. Normative References

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[RFC8174] Leiba, B., "Ambiguity of Uppercase vs Lowercase in RFC 2119 Key Words", BCP 14, RFC 8174, DOI 10.17487/RFC8174, May 2017, <https://www.rfc-editor.org/info/rfc8174>.

[X680] ITU-T, "Information technology -- Abstract Syntax Notation One (ASN.1): Specification of basic notation", ITU-T Recommendation X.680, 2015.

[X690] ITU-T, "Information Technology -- ASN.1 encoding rules: Specification of Basic Encoding Rules (BER), Canonical Encoding Rules (CER) and Distinguished Encoding Rules (DER)", ITU-T Recommendation X.690, 2015.

8.2. Informative References

[SET] MasterCard and VISA, "SET Secure Electronic Transaction Specification -- Book 2: Programmer's Guide, Version 1.0", May 1997.

Appendix A. ASN.1 Module

The following ASN.1 module provides the complete definition of the HashOfRootKey certificate extension.

```
HashedRootKeyCertExtn { 1 3 6 1 4 1 51483 0 1 }

DEFINITIONS IMPLICIT TAGS ::=
BEGIN

-- EXPORTS All

IMPORTS

AlgorithmIdentifier{}, DIGEST-ALGORITHM
  FROM AlgorithmInformation-2009  -- [RFC5912]
    { iso(1) identified-organization(3) dod(6) internet(1)
      security(5) mechanisms(5) pkix(7) id-mod(0)
      id-mod-algorithmInformation-02(58) }

EXTENSION
  FROM PKIX-CommonTypes-2009
    { iso(1) identified-organization(3) dod(6) internet(1)
      security(5) mechanisms(5) pkix(7) id-mod(0)
      id-mod-pkixCommon-02(57) } ;

--
-- Expand the certificate extensions list in [RFC5912]
--

CertExtensions EXTENSION ::= {
   ext-HashOfRootKey, ... }

--
-- HashOfRootKey Certificate Extension
--

ext-HashOfRootKey EXTENSION ::= {    -- Only in Root CA certificates
   SYNTAX         HashedRootKey
   IDENTIFIED BY  id-ce-hashOfRootKey
   CRITICALITY    {FALSE} }

HashedRootKey  ::=  SEQUENCE {
   hashAlg        HashAlgorithmId,   -- Hash algorithm used
   hashValue      OCTET STRING }     -- Hash of DER-encoded
                                     --   SubjectPublicKeyInfo

HashAlgorithmId  ::=  AlgorithmIdentifier {DIGEST-ALGORITHM,{ ... }}

id-ce-hashOfRootKey OBJECT IDENTIFIER  ::=  { 1 3 6 1 4 1 51483 2 1 }

END
```

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