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Storing Certificates in the Domain Name System (DNS) draft-ietf-dnsext-rfc2538bis-09

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Abstract

Cryptographic public keys are frequently published and their authenticity demonstrated by certificates. A CERT resource record (RR) is defined so that such certificates and related certificate revocation lists can be stored in the Domain Name System (DNS).

This document obsoletes RFC 2538.

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1. Introduction

Public keys are frequently published in the form of a certificate and their authenticity is commonly demonstrated by certificates and related certificate revocation lists (CRLs). A certificate is a binding, through a cryptographic digital signature, of a public key, a validity interval and/or conditions, and identity, authorization, or other information. A certificate revocation list is a list of certificates that are revoked, and incidental information, all signed by the signer (issuer) of the revoked certificates. Examples are X.509 certificates/CRLs in the X.500 directory system or OpenPGP certificates/revocations used by OpenPGP software.

Section 2 below specifies a CERT resource record (RR) for the storage of certificates in the Domain Name System [1] [2].

Section 3 discusses appropriate owner names for CERT RRs.

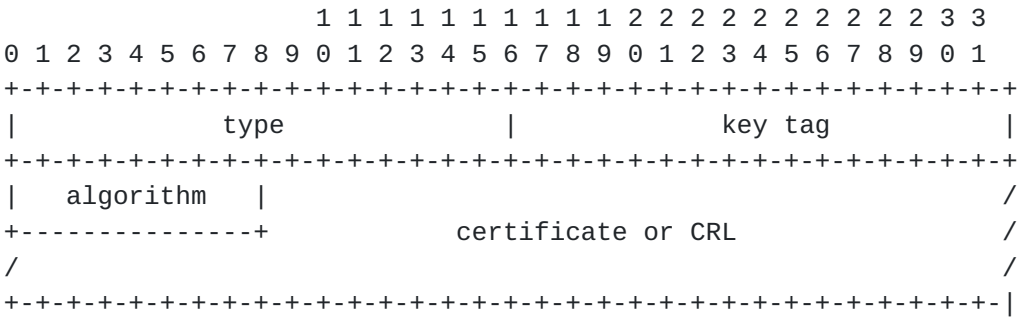
Sections 4, 5, and 6 below cover performance, IANA, and security considerations, respectively.

Section 9 explain the changes in this document compared to RFC 2538.

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [3].

2. The CERT Resource Record

The CERT resource record (RR) has the structure given below. Its RR type code is 37.



The type field is the certificate type as defined in section 2.1 below.

The key tag field is the 16 bit value computed for the key embedded in the certificate, using the RRSIG Key Tag algorithm described in

Appendix B of [12]. This field is used as an efficiency measure to pick which CERT RRs may be applicable to a particular key. The key tag can be calculated for the key in question and then only CERT RRs with the same key tag need be examined. Note that two different keys can have the same key tag. However, the key MUST be transformed to the format it would have as the public key portion of a DNSKEY RR before the key tag is computed. This is only possible if the key is applicable to an algorithm and complies to limits (such as key size) defined for DNS security. If it is not, the algorithm field MUST be zero and the tag field is meaningless and SHOULD be zero.

The algorithm field has the same meaning as the algorithm field in DNSKEY and RRSIG RRs [12], except that a zero algorithm field indicates the algorithm is unknown to a secure DNS, which may simply be the result of the algorithm not having been standardized for DNSSEC [11].

2.1. Certificate Type Values

The following values are defined or reserved:

Value	Mnemonic	Certificate Type
0		reserved
1	PKIX	X.509 as per PKIX
2	SPKI	SPKI certificate
3	PGP	OpenPGP packet
4	IPKIX	The URL of an X.509 data object
5	ISPKI	The URL of an SPKI certificate
6	IPGP	The URL of an OpenPGP packet
7	ACPKIX	Attribute Certificate
8	IACPKIX	The URL of an Attribute Certificate
9-252		available for IANA assignment
253	URI	URI private
254	OID	OID private
255-65023		available for IANA assignment
65024-65534		experimental
65535		reserved

These values represent the initial content of the IANA registry, see section 8.

The PKIX type is reserved to indicate an X.509 certificate conforming to the profile defined by the IETF PKIX working group [9]. The certificate section will start with a one-octet unsigned OID length and then an X.500 OID indicating the nature of the remainder of the certificate section (see 2.3 below). (NOTE: X.509 certificates do not include their X.500 directory type designating OID as a prefix.)

The SPKI type is reserved to indicate the SPKI certificate format [15], for use when the SPKI documents are moved from experimental status.

The PGP type indicates an OpenPGP packet as described in [6] and its extensions and successors. Two uses are to transfer public key material and revocation signatures. The data is binary, and MUST NOT be encoded into an ASCII armor. An implementation SHOULD process transferable public keys as described in section 10.1 of [6], but it MAY handle additional OpenPGP packets.

The ACPKIX type indicate an Attribute Certificate format [10].

The IPKIX, ISPKI, IPGP, IACPKIX types indicate a URL which will serve the content that would have been in the "certificate, CRL or URL" field of the corresponding types; PKIX, SPKI, PGP, or ACPKIX respectively. The IPKIX, ISPKI, IPGP and IACPKIX types are known as "indirect". These types MUST be used when the content is too large to fit in the CERT RR, and MAY be used at the implementer's discretion. They SHOULD NOT be used where the DNS message is 512 octets or smaller, and could thus be expected to fit a UDP packet.

The URI private type indicates a certificate format defined by an absolute URI. The certificate portion of the CERT RR MUST begin with a null terminated URI [5] and the data after the null is the private format certificate itself. The URI SHOULD be such that a retrieval from it will lead to documentation on the format of the certificate. Recognition of private certificate types need not be based on URI equality but can use various forms of pattern matching so that, for example, subtype or version information can also be encoded into the URI.

The OID private type indicates a private format certificate specified by an ISO OID prefix. The certificate section will start with a one-octet unsigned OID length and then a BER encoded OID indicating the nature of the remainder of the certificate section. This can be an X.509 certificate format or some other format. X.509 certificates that conform to the IETF PKIX profile SHOULD be indicated by the PKIX type, not the OID private type. Recognition of private certificate types need not be based on OID equality but can use various forms of pattern matching such as OID prefix.

2.2. Text Representation of CERT RRs

The RDATA portion of a CERT RR has the type field as an unsigned decimal integer or as a mnemonic symbol as listed in section 2.1 above.

The key tag field is represented as an unsigned decimal integer.

The algorithm field is represented as an unsigned decimal integer or a mnemonic symbol as listed in [12].

The certificate / CRL portion is represented in base 64 [16] and may be divided up into any number of white space separated substrings, down to single base 64 digits, which are concatenated to obtain the full signature. These substrings can span lines using the standard parenthesis.

Note that the certificate / CRL portion may have internal sub-fields, but these do not appear in the master file representation. For example, with type 254, there will be an OID size, an OID, and then the certificate / CRL proper. But only a single logical base 64 string will appear in the text representation.

2.3. X.509 OIDs

OIDs have been defined in connection with the X.500 directory for user certificates, certification authority certificates, revocations of certification authority, and revocations of user certificates. The following table lists the OIDs, their BER encoding, and their length-prefixed hex format for use in CERT RRs:

```
id-at-userCertificate
    = { joint-iso-ccitt(2) ds(5) at(4) 36 }
       == 0x 03 55 04 24
id-at-cACertificate
    = { joint-iso-ccitt(2) ds(5) at(4) 37 }
       == 0x 03 55 04 25
id-at-authorityRevocationList
    = { joint-iso-ccitt(2) ds(5) at(4) 38 }
       == 0x 03 55 04 26
id-at-certificateRevocationList
    = { joint-iso-ccitt(2) ds(5) at(4) 39 }
       == 0x 03 55 04 27
```

3. Appropriate Owner Names for CERT RRs

It is recommended that certificate CERT RRs be stored under a domain name related to their subject, i.e., the name of the entity intended to control the private key corresponding to the public key being certified. It is recommended that certificate revocation list CERT RRs be stored under a domain name related to their issuer.

Following some of the guidelines below may result in DNS names with

characters that require DNS quoting as per section 5.1 of RFC 1035 [2].

The choice of name under which CERT RRs are stored is important to clients that perform CERT queries. In some situations, the clients may not know all information about the CERT RR object it wishes to retrieve. For example, a client may not know the subject name of an X.509 certificate, or the e-mail address of the owner of an OpenPGP key. Further, the client might only know the hostname of a service that uses X.509 certificates or the Key ID of an OpenPGP key.

Therefore, two owner name guidelines are defined: content-based owner names and purpose-based owner names. A content-based owner name is derived from the content of the CERT RR data; for example, the Subject field in an X.509 certificate or the User ID field in OpenPGP keys. A purpose-based owner name is a name that a client retrieving CERT RRs ought to already know; for example, the host name of an X.509 protected service or the Key ID of an OpenPGP key. The content-based and purpose-based owner name may be the same; for example, when a client looks up a key based on the From: address of an incoming e-mail.

Implementations SHOULD use the purpose-based owner name guidelines described in this document, and MAY use CNAME RRs at content-based owner names (or other names), pointing to the purpose-based owner name.

Note that this section describes an application-based mapping from the name space used in a certificate to the name space used by DNS. The DNS does not infer any relationship amongst CERT resource records based on similarities or differences of the DNS owner name(s) of CERT resource records. For example, if multiple labels are used when mapping from a CERT identifier to a domain name then care must be taken in understanding wildcard record synthesis.

3.1. Content-based X.509 CERT RR Names

Some X.509 versions, such as the PKIX profile of X.509 [9], permit multiple names to be associated with subjects and issuers under "Subject Alternative Name" and "Issuer Alternative Name". For example, the PKIX profile has such Alternate Names with an ASN.1 specification as follows:

```
GeneralName ::= CHOICE {
     otherName                       [0]     OtherName,
     rfc822Name                      [1]     IA5String,
     dNSName                         [2]     IA5String,
     x400Address                     [3]     ORAddress,
     directoryName                   [4]     Name,
     ediPartyName                    [5]     EDIPartyName,
     uniformResourceIdentifier       [6]     IA5String,
     iPAddress                       [7]     OCTET STRING,
     registeredID                    [8]     OBJECT IDENTIFIER }
```

The recommended locations of CERT storage are as follows, in priority order:

1. If a domain name is included in the identification in the certificate or CRL, that ought be used.
2. If a domain name is not included but an IP address is included, then the translation of that IP address into the appropriate inverse domain name ought to be used.
3. If neither of the above is used, but a URI containing a domain name is present, that domain name ought to be used.
4. If none of the above is included but a character string name is included, then it ought to be treated as described for OpenPGP names below.
5. If none of the above apply, then the distinguished name (DN) ought to be mapped into a domain name as specified in [4].

Example 1: An X.509v3 certificate is issued to /CN=John Doe /DC=Doe/ DC=com/DC=xy/O=Doe Inc/C=XY/ with Subject Alternative Names of (a) string "John (the Man) Doe", (b) domain name john-doe.com, and (c) URI <https://www.secure.john-doe.com:8080/>. The storage locations recommended, in priority order, would be

1. john-doe.com,
2. www.secure.john-doe.com, and
3. Doe.com.xy.

Example 2: An X.509v3 certificate is issued to /CN=James Hacker/ L=Basingstoke/O=Widget Inc/C=GB/ with Subject Alternate names of (a) domain name widget.foo.example, (b) IPv4 address 10.251.13.201, and (c) string "James Hacker <hacker@mail.widget.foo.example>". The storage locations recommended, in priority order, would be

1. widget.foo.example,
2. 201.13.251.10.in-addr.arpa, and
3. hacker.mail.widget.foo.example.

3.2. Purpose-based X.509 CERT RR Names

Due to the difficulty for clients that do not already possess a certificate to reconstruct the content-based owner name, purpose-

based owner names are recommended in this section. Recommendations for purpose-based owner names vary per scenario. The following table summarizes the purpose-based X.509 CERT RR owner name guidelines for use with S/MIME [17], SSL/TLS [13], and IPsec [14]:

Scenario	Owner name
S/MIME Certificate	Standard translation of an RFC 2822 email address. Example: An S/MIME certificate for "postmaster@example.org" will use a standard hostname translation of the owner name, "postmaster.example.org".
TLS Certificate	Hostname of the TLS server.
IPsec Certificate	Hostname of the IPsec machine and/or, for IPv4 or IPv6 addresses, the fully qualified domain name in the appropriate reverse domain.

An alternate approach for IPsec is to store raw public keys [18].

3.3. Content-based OpenPGP CERT RR Names

OpenPGP signed keys (certificates) use a general character string User ID [6]. However, it is recommended by OpenPGP that such names include the RFC 2822 [8] email address of the party, as in "Leslie Example <Leslie@host.example>". If such a format is used, the CERT ought to be under the standard translation of the email address into a domain name, which would be leslie.host.example in this case. If no RFC 2822 name can be extracted from the string name, no specific domain name is recommended.

If a user has more than one email address, the CNAME type can be used to reduce the amount of data stored in the DNS. Example:

```
$ORIGIN example.org.
smith        IN CERT PGP 0 0 <OpenPGP binary>
john.smith   IN CNAME smith
js           IN CNAME smith
```

3.4. Purpose-based OpenPGP CERT RR Names

Applications that receive an OpenPGP packet containing encrypted or signed data but do not know the email address of the sender will have difficulties constructing the correct owner name and cannot use the content-based owner name guidelines. However, these clients commonly know the key fingerprint or the Key ID. The key ID is found in OpenPGP packets, and the key fingerprint is commonly found in

auxiliary data that may be available. In this case, use of an owner name identical to the key fingerprint and the key ID expressed in hexadecimal [16] is recommended. Example:

```
$ORIGIN example.org.
0424D4EE81A0E3D119C6F835EDA21E94B565716F IN CERT PGP ...
F835EDA21E94B565716F                     IN CERT PGP ...
B565716F                                 IN CERT PGP ...
```

If the same key material is stored for several owner names, the use of CNAME may help to avoid data duplication. Note that CNAME is not always applicable, because it maps one owner name to the other for all purposes, which may be sub-optimal when two keys with the same Key ID are stored.

3.5. Owner names for IPKIX, ISPKI, IPGP, and IACPKIX

These types are stored under the same owner names, both purpose- and content-based, as the PKIX, SPKI, PGP and ACPKIX types.

4. Performance Considerations

The Domain Name System (DNS) protocol was designed for small transfers, typically below 512 octets. While larger transfers will perform correctly and work is underway to make larger transfers more efficient, it is still advisable at this time to make every reasonable effort to minimize the size of certificates stored within the DNS. Steps that can be taken may include using the fewest possible optional or extension fields and using short field values for necessary variable length fields.

The RDATA field in the DNS protocol may only hold data of size 65535 octets (64kb) or less. This means that each CERT RR MUST NOT contain more than 64kb of payload, even if the corresponding certificate or certificate revocation list is larger. This document addresses this by defining "indirect" data types for each normal type.

Deploying CERT RRs to support digitally signed e-mail change the access patterns of DNS lookups from per-domain to per-user. If digitally signed e-mail, and a key/certificate lookup based on CERT RRs, is deployed on a wide scale, this may lead to an increased DNS load, with potential performance and cache effectiveness consequencess. Whether this load increase will be noticable or not is not known.

5. Contributors

The majority of this document is copied verbatim from RFC 2538, by Donald Eastlake 3rd and Olafur Gudmundsson.

6. Acknowledgements

Thanks to David Shaw and Michael Graff for their contributions to earlier works that motivated, and served as inspiration for, this document.

This document was improved by suggestions and comments from Olivier Dubuisson, Scott Hollenbeck, Russ Housley, Peter Koch, Olaf M. Kolkman, Ben Laurie, Edward Lewis, John Loughney, Allison Mankin, Douglas Otis, Marcos Sanz, Pekka Savola, Jason Sloderbeck, Samuel Weiler, and Florian Weimer. No doubt the list is incomplete. We apologize to anyone we left out.

7. Security Considerations

By definition, certificates contain their own authenticating signature. Thus, it is reasonable to store certificates in non-secure DNS zones or to retrieve certificates from DNS with DNS security checking not implemented or deferred for efficiency. The results may be trusted if the certificate chain is verified back to a known trusted key and this conforms with the user's security policy.

Alternatively, if certificates are retrieved from a secure DNS zone with DNS security checking enabled and are verified by DNS security, the key within the retrieved certificate may be trusted without verifying the certificate chain if this conforms with the user's security policy.

If an organization chooses to issue certificates for its employees, placing CERT RR's in the DNS by owner name, and if DNSSEC (with NSEC) is in use, it is possible for someone to enumerate all employees of the organization. This is usually not considered desirable, for the same reason enterprise phone listings are not often publicly published and are even mark confidential.

Using the URI type introduces another level of indirection that may open a new vulnerability. One method to secure that indirection is to include a hash of the certificate in the URI itself.

If DNSSEC is used, then the non-existence of a CERT RR and, consequently, certificates or revocation lists can be securely

asserted. Without DNSSEC, this is not possible.

8. IANA Considerations

IANA needs to create a new registry for CERT RR, certificate types. The initial contents of this registry is:

[[RFC Editor: Replace xxxx below with the number of this RFC.]]

Decimal	Type	Meaning	Reference
0		Reserved	RFC xxxx
1	PKIX	X.509 as per PKIX	RFC xxxx
2	SPKI	SPKI certificate	RFC xxxx
3	PGP	OpenPGP packet	RFC xxxx
4	IPKIX	The URL of an X.509 data object	RFC xxxx
5	ISPKI	The URL of an SPKI certificate	RFC xxxx
6	IPGP	The URL of an OpenPGP packet	RFC xxxx
7	ACPKIX	Attribute Certificate	RFC xxxx
8	IACPKIX	The URL of an Attribute Certificate	RFC xxxx
9-252		Available for IANA assignment by IETF Standards action	
253	URI	URI private	RFC xxxx
254	OID	OID private	RFC xxxx
255-65023		Available for IANA assignment by IETF Consensus	
65024-65534		Experimental	RFC xxxx
65535		Reserved	RFC xxxx

Certificate types 0x0000 through 0x00FF and 0xFF00 through 0xFFFF can only be assigned by an IETF standards action [7]. This document assigns 0x0001 through 0x0008 and 0x00FD and 0x00FE. Certificate types 0x0100 through 0xFEFF are assigned through IETF Consensus [7] based on RFC documentation of the certificate type. The availability of private types under 0x00FD and 0x00FE ought to satisfy most requirements for proprietary or private types.

The CERT RR reuses the DNS Security Algorithm Numbers registry. In particular, the CERT RR requires that algorithm number 0 remain reserved, as described in Section 2. The IANA is directed to reference the CERT RR as a user of this registry and value 0, in particular.

9. Changes since RFC 2538

1. Editorial changes to conform with new document requirements, including splitting reference section into two parts and updating the references to point at latest versions, and to add some additional references.
2. Improve terminology. For example replace "PGP" with "OpenPGP", to align with RFC 2440.
3. In section 2.1, clarify that OpenPGP public key data are binary, not the ASCII armored format, and reference 10.1 in RFC 2440 on how to deal with OpenPGP keys, and acknowledge that implementations may handle additional packet types.
4. Clarify that integers in the representation format are decimal.
5. Replace KEY/SIG with DNSKEY/RRSIG etc, to align with DNSSECbis terminology. Improve reference for Key Tag Algorithm calculations.
6. Add examples that suggest use of CNAME to reduce bandwidth.
7. In section 3, appended the last paragraphs that discuss "content-based" vs "purpose-based" owner names. Add section 3.2 for purpose-based X.509 CERT owner names, and section 3.4 for purpose-based OpenPGP CERT owner names.
8. Added size considerations.
9. The SPKI types has been reserved, until RFC 2692/2693 is moved from the experimental status.
10. Added indirect types IPKIX, ISPKI, IPGP, and IACPKIX.
11. An IANA registry of CERT type values was created.

Appendix A. Copying conditions

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