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Use of SHA-2 Algorithms with RSA in DNSKEY and RRSIG Resource Records for DNSSEC

Abstract

This document describes how to produce RSA/SHA-256 and RSA/SHA-512 DNSKEY and RRSIG resource records for use in the Domain Name System Security Extensions (RFC 4033, RFC 4034, and RFC 4035).

Status of This Memo

This document specifies an Internet standards track protocol for the Internet community, and requests discussion and suggestions for improvements. Please refer to the current edition of the "Internet Official Protocol Standards" (STD 1) for the standardization state and status of this protocol. Distribution of this memo is unlimited.

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1. Introduction

The Domain Name System (DNS) is the global, hierarchical distributed database for Internet Naming. The DNS has been extended to use cryptographic keys and digital signatures for the verification of the authenticity and integrity of its data. [RFC4033], [RFC4034], and [RFC4035] describe these DNS Security Extensions, called DNSSEC.

RFC 4034 describes how to store DNSKEY and RRSIG resource records, and specifies a list of cryptographic algorithms to use. This document extends that list with the algorithms RSA/SHA-256 and RSA/SHA-512, and specifies how to store DNSKEY data and how to produce RRSIG resource records with these hash algorithms.

Familiarity with DNSSEC, RSA, and the SHA-2 [FIPS.180-3.2008] family of algorithms is assumed in this document.

To refer to both SHA-256 and SHA-512, this document will use the name SHA-2. This is done to improve readability. When a part of text is specific for either SHA-256 or SHA-512, their specific names are used. The same goes for RSA/SHA-256 and RSA/SHA-512, which will be grouped using the name RSA/SHA-2.

The term "SHA-2" is not officially defined but is usually used to refer to the collection of the algorithms SHA-224, SHA-256, SHA-384, and SHA-512. Since SHA-224 and SHA-384 are not used in DNSSEC, SHA-2 will only refer to SHA-256 and SHA-512 in this document.

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 [RFC2119].

2. DNSKEY Resource Records

The format of the DNSKEY RR can be found in [RFC4034]. [RFC3110] describes the use of RSA/SHA-1 for DNSSEC signatures.

2.1. RSA/SHA-256 DNSKEY Resource Records

RSA public keys for use with RSA/SHA-256 are stored in DNSKEY resource records (RRs) with the algorithm number 8.

For interoperability, as in [RFC3110], the key size of RSA/SHA-256 keys MUST NOT be less than 512 bits and MUST NOT be more than 4096 bits.

2.2. RSA/SHA-512 DNSKEY Resource Records

RSA public keys for use with RSA/SHA-512 are stored in DNSKEY resource records (RRs) with the algorithm number 10.

The key size of RSA/SHA-512 keys MUST NOT be less than 1024 bits and MUST NOT be more than 4096 bits.

3. RRSIG Resource Records

The value of the signature field in the RRSIG RR follows the RSASSA-PKCS1-v1_5 signature scheme and is calculated as follows. The values for the RDATA fields that precede the signature data are specified in [RFC4034].

hash = SHA-XXX(data)

Here XXX is either 256 or 512, depending on the algorithm used, as specified in FIPS PUB 180-3; "data" is the wire format data of the resource record set that is signed, as specified in [RFC4034].

signature = (00 | 01 | FF* | 00 | prefix | hash) ** e (mod n)

Here "|" is concatenation; "00", "01", "FF", and "00" are fixed octets of corresponding hexadecimal value; "e" is the private exponent of the signing RSA key; and "n" is the public modulus of the signing key. The FF octet MUST be repeated the exact number of times so that the total length of the concatenated term in parentheses equals the length of the modulus of the signer's public key ("n").

The "prefix" is intended to make the use of standard cryptographic libraries easier. These specifications are taken directly from the specifications of RSASSA-PKCS1-v1_5 in PKCS #1 v2.1 (Section 8.2 of [RFC3447]), and EMSA-PKCS1-v1_5 encoding in PKCS #1 v2.1 (Section 9.2 of [RFC3447]). The prefixes for the different algorithms are specified below.

3.1. RSA/SHA-256 RRSIG Resource Records

RSA/SHA-256 signatures are stored in the DNS using RRSIG resource records (RRs) with algorithm number 8.

The prefix is the ASN.1 DER SHA-256 algorithm designator prefix, as specified in PKCS #1 v2.1 [RFC3447]:

hex 30 31 30 0d 06 09 60 86 48 01 65 03 04 02 01 05 00 04 20

3.2. RSA/SHA-512 RRSIG Resource Records

RSA/SHA-512 signatures are stored in the DNS using RRSIG resource records (RRs) with algorithm number 10.

The prefix is the ASN.1 DER SHA-512 algorithm designator prefix, as specified in PKCS #1 v2.1 [RFC3447]:

hex 30 51 30 0d 06 09 60 86 48 01 65 03 04 02 03 05 00 04 40

4. Deployment Considerations

4.1. Key Sizes

Apart from the restrictions in Section 2, this document will not specify what size of keys to use. That is an operational issue and depends largely on the environment and intended use. A good starting point for more information would be NIST SP 800-57 [NIST800-57].

4.2. Signature Sizes

In this family of signing algorithms, the size of signatures is related to the size of the key and not to the hashing algorithm used in the signing process. Therefore, RRSIG resource records produced with RSA/SHA-256 or RSA/SHA-512 will have the same size as those produced with RSA/SHA-1, if the keys have the same length.

5. Implementation Considerations

5.1. Support for SHA-2 Signatures

DNSSEC-aware implementations SHOULD be able to support RRSIG and DNSKEY resource records created with the RSA/SHA-2 algorithms as defined in this document.

5.2. Support for NSEC3 Denial of Existence

[RFC5155] defines new algorithm identifiers for existing signing algorithms, to indicate that zones signed with these algorithm identifiers can use NSEC3 as well as NSEC records to provide denial of existence. That mechanism was chosen to protect implementations predating RFC 5155 from encountering resource records about which they could not know. This document does not define such algorithm aliases.

A DNSSEC validator that implements RSA/SHA-2 MUST be able to validate negative answers in the form of both NSEC and NSEC3 with hash algorithm 1, as defined in [RFC5155]. An authoritative server that does not implement NSEC3 MAY still serve zones that use RSA/SHA-2 with NSEC denial of existence.

6. Examples

6.1. RSA/SHA-256 Key and Signature

Given a private key with the following values (in Base64):

```
Private-key-format: v1.2
Algorithm:       8 (RSASHA256)
Modulus:         wVwaxrHF2CK64aYKRUibLiH30KpPuPBjel7E8ZydQW1HYWHfoGm
                 idzC2RnhwCC293hCzw+TFR2nqn8OVSY5t2Q==
PublicExponent:  AQAB
PrivateExponent: UR44xX6zB3eaeyvTRzmskHADrPCmPWnr8dxsNwiDGHzrMKLN+i/
                 HAam+97HxIKVWNDH2ba9Mf1SA8xu9dcHZAQ==
Prime1:          4c8IvFu1AVXGWeFLLFh5vs7fbdzdC6U82fduE6KkSWk=
Prime2:          2zZpBE8ZXVnL74QjG4zINlDfH+EOEtjJJ3RtaYDugvE=
Exponent1:       G2xAPFfK0KGxGANDVNxd1K1c9wOmmJ51mGbzKFFNMFk=
Exponent2:       GYxP1Pa7CAwtHm8SAGX594qZVofOMhgd6YFCNyeVpKE=
Coefficient:     icQdNRjlZGPmuJm2TIadubcO8X7V4y07aVhX464tx8Q=
```

The DNSKEY record for this key would be:

```
example.net.     3600  IN  DNSKEY  (256 3 8 AwEAAcFcGsaxxdgiuuGmCkVI
                 my4h99CqT7jwY3pexPGcnUFtR2Fh36BponcwtkZ4cAgtvd4Qs8P
                 kxUdp6p/DlUmObdk= );{id = 9033 (zsk), size = 512b}
```

With this key, sign the following RRSet, consisting of 1 A record:

```
www.example.net. 3600  IN  A  192.0.2.91
```

If the inception date is set at 00:00 hours on January 1st, 2000, and the expiration date at 00:00 hours on January 1st, 2030, the following signature should be created:

```
www.example.net. 3600  IN  RRSIG  (A 8 3 3600 20300101000000
                 20000101000000 9033 example.net. kRCOH6u7l0QGy9qpC9
                 l1sLncJcOKFLJ7GhiUOibu4teYp5VE9RncriShZNz85mwlMgNEa
                 cFYK/lPtPiVYP4bwg==);{id = 9033}
```

6.2. RSA/SHA-512 Key and Signature

Given a private key with the following values (in Base64):


```
Private-key-format: v1.2
Algorithm:       10 (RSASHA512)
Modulus:         0eg1M5b563zoq4k5ZEOnWmd2/BvpjzedJVdfIsDcMuuhE5SQ3pf
                 Q7qmdaeMlC6Nf8DKGoUPGPXe06cP27/WRODtxXquSUytkO0kJDk
                 8KX8PtA0+yBWwy7UnZDyCkynO00Uuk8HPVtZeMO1pHtlAGVnc8V
                 jXZlNKdyit99waaE4s=
PublicExponent:  AQAB
PrivateExponent: rFS1IPbJllFFgFc33B5DDlC1egO8e81P4fFadODbp56V7sphKa6
                 AZQCx8NYAew6VXFFPAKTw41QdHnK5kIYOwxvfFDjDcUGza88qbj
                 yrDPSJenkeZbISMUSSqy7AMFzEolkk6WSn6k3thUVRgSlqDoOV3
                 SEIAsrB043XzGrKIVE=
Prime1:          8mbtsu9Tl9v7tKSHdCIeprLIQXQLzxlSZun5T1n/OjvXSUtvD7x
                 nZJ+LHqaBj1dIgMbCq2U8O04QVcK3TS9GiQ==
Prime2:          3a6gkfs74d0Jb7yL4j4adAif4fcp7ZrGt7G5NRVDDY/Mv4TERAK
                 Ma0TKN3okKE0A7X+Rv2K84mhT4QLDlllEcw==
Exponent1:       v3D5A9uuCn5rgVR7wgV8ba0/KSpsdSiLgsoA42GxiB1gvvs7gJM
                 MmVTDu/ZG1p1ZnpLbhh/S/Qd/MSwyNlxC+Q==
Exponent2:       m+ezf9dsDvYQK+gzjOLWYeKq5xWYBEYFGa3BLocMiF4oxkzOZ3J
                 PZSWU/h1Fjp5RV7aPP0Vmx+hNjYMPIQ8Y5w==
Coefficient:     Je5YhYpUron/WdOXjxNAxDubAp3i5X7UOUfhJcyIggqwY86IE0Q
                 /Bk0Dw4SC9zxnsimmdBXW2Izd8Lwuk8FQcQ==
```


The DNSKEY record for this key would be:


```
example.net.    3600  IN  DNSKEY  (256 3 10 AwEAAdHoNTOW+et86KuJOWRD
                p1pndvwb6Y83nSVXXyLA3DLroROUkN6X0O6pnWnjJQujX/AyhqFD
                xj13tOnD9u/1kTg7cV6rklMrZDtJCQ5PCl/D7QNPsgVsMu1J2Q8g
                pMpztNFLpPBz1bWXjDtaR7ZQBlZ3PFY12ZTSncorffcGmhOL
                );{id = 3740 (zsk), size = 1024b}
```


With this key, sign the following RRSet, consisting of 1 A record:

```
www.example.net. 3600  IN  A  192.0.2.91
```

If the inception date is set at 00:00 hours on January 1st, 2000, and the expiration date at 00:00 hours on January 1st, 2030, the following signature should be created:


```
www.example.net. 3600  IN  RRSIG  (A 10 3 3600 20300101000000
                 20000101000000 3740 example.net. tsb4wnjRUDnB1BUi+t
                 6TMTXThjVnG+eCkWqjvvjhzQL1d0YRoOe0CbxrVDYd0xDtsuJRa
                 eUw1ep94PzEWzr0iGYgZBWm/zpq+9fOuagYJRfDqfReKBzMweOL
                 DiNa8iP5g9vMhpuv6OPlvpXwm9Sa9ZXIbNl1MBGk0fthPgxdDLw
                 =);{id = 3740}
```

7. IANA Considerations

This document updates the IANA registry "DNS SECURITY ALGORITHM NUMBERS -- per [RFC4035]" (http://www.iana.org/protocols). The following entries are added to the registry:

Value	Description	Mnemonic	Zone Signing	Trans. Sec.	References
8	RSA/SHA-256	RSASHA256	Y	*	RFC 5702
10	RSA/SHA-512	RSASHA512	Y	*	RFC 5702

* There has been no determination of standardization of the use of this algorithm with Transaction Security.

8. Security Considerations

8.1. SHA-1 versus SHA-2 Considerations for RRSIG Resource Records

Users of DNSSEC are encouraged to deploy SHA-2 as soon as software implementations allow for it. SHA-2 is widely believed to be more resilient to attack than SHA-1, and confidence in SHA-1's strength is being eroded by recently announced attacks. Regardless of whether or not the attacks on SHA-1 will affect DNSSEC, it is believed (at the time of this writing) that SHA-2 is the better choice for use in DNSSEC records.

SHA-2 is considered sufficiently strong for the immediate future, but predictions about future development in cryptography and cryptanalysis are beyond the scope of this document.

The signature scheme RSASSA-PKCS1-v1_5 is chosen to match the one used for RSA/SHA-1 signatures. This should ease implementation of the new hashing algorithms in DNSSEC software.

8.2. Signature Type Downgrade Attacks

Since each RRSet MUST be signed with each algorithm present in the DNSKEY RRSet at the zone apex (see Section 2.2 of [RFC4035]), a malicious party cannot filter out the RSA/SHA-2 RRSIG and force the validator to use the RSA/SHA-1 signature if both are present in the zone. This should provide resilience against algorithm downgrade attacks, if the validator supports RSA/SHA-2.

9. Acknowledgments

This document is a minor extension to [RFC4034]. Also, we try to follow the documents [RFC3110] and [RFC4509] for consistency. The authors of and contributors to these documents are gratefully acknowledged for their hard work.

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10. References

10.1. Normative References

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10.2. Informative References

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[RFC5155] Laurie, B., Sisson, G., Arends, R., and D. Blacka, "DNS Security (DNSSEC) Hashed Authenticated Denial of Existence", RFC 5155, March 2008.

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