Use of RSA Keys with SHA-256 and SHA-512 in the Secure Shell (SSH) Protocol

Abstract

   This memo updates RFCs 4252 and 4253 to define new public key
   algorithms for use of RSA keys with SHA-256 and SHA-512 for server
   and client authentication in SSH connections.

Status of This Memo

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1. Overview and Rationale

Secure Shell (SSH) is a common protocol for secure communication on the Internet. In [RFC4253], SSH originally defined the public key algorithms "ssh-rsa" for server and client authentication using RSA with SHA-1, and "ssh-dss" using 1024-bit DSA and SHA-1. These algorithms are now considered deficient. For US government use, NIST has disallowed 1024-bit RSA and DSA, and use of SHA-1 for signing [NIST.800-131A].

This memo updates RFCs 4252 and 4253 to define new public key algorithms allowing for interoperable use of existing and new RSA keys with SHA-256 and SHA-512.

1.1. Requirements 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. Wire Encoding Terminology

The wire encoding types in this document -- "boolean", "byte", "string", "mpint" -- have meanings as described in [RFC4251].

2. Public Key Format vs. Public Key Algorithm

In [RFC4252], the concept "public key algorithm" is used to establish a relationship between one algorithm name, and:

A. procedures used to generate and validate a private/public keypair;
B. a format used to encode a public key; and
C. procedures used to calculate, encode, and verify a signature.

This document uses the term "public key format" to identify only A and B in isolation. The term "public key algorithm" continues to identify all three aspects -- A, B, and C.

3. New RSA Public Key Algorithms

This memo adopts the style and conventions of [RFC4253] in specifying how use of a public key algorithm is indicated in SSH.

The following new public key algorithms are defined:

```
  rsa-sha2-256        RECOMMENDED    sign    Raw RSA key
  rsa-sha2-512        OPTIONAL       sign    Raw RSA key
```

These algorithms are suitable for use both in the SSH transport layer [RFC4253] for server authentication and in the authentication layer [RFC4252] for client authentication.

Since RSA keys are not dependent on the choice of hash function, the new public key algorithms reuse the "ssh-rsa" public key format as defined in [RFC4253]:

```
string     "ssh-rsa"
mpint      e
mpint      n
```

All aspects of the "ssh-rsa" format are kept, including the encoded string "ssh-rsa". This allows existing RSA keys to be used with the new public key algorithms, without requiring re-encoding or affecting already trusted key fingerprints.

Signing and verifying using these algorithms is performed according to the RSASSA-PKCS1-v1_5 scheme in [RFC8017] using SHA-2 [SHS] as hash.

For the algorithm "rsa-sha2-256", the hash used is SHA-256.
For the algorithm "rsa-sha2-512", the hash used is SHA-512.

The resulting signature is encoded as follows:

```
string     "rsa-sha2-256" / "rsa-sha2-512"
string     rsa_signature_blob
```

The value for 'rsa_signature_blob' is encoded as a string that contains an octet string S (which is the output of RSASSA-PKCS1-v1_5) and that has the same length (in octets) as the RSA modulus. When S contains leading zeros, there exist signers that will send a shorter encoding of S that omits them. A verifier MAY accept shorter encodings of S with one or more leading zeros omitted.

3.1. Use for Server Authentication

To express support and preference for one or both of these algorithms
for server authentication, the SSH client or server includes one or
both algorithm names, "rsa-sha2-256" and/or "rsa-sha2-512", in the
name-list field "server_host_key_algorithms" in the SSH_MSG_KEXINIT
packet [RFC4253]. If one of the two host key algorithms is
negotiated, the server sends an "ssh-rsa" public key as part of the
negotiated key exchange method (e.g., in SSH_MSG_KEXDH_REPLY) and
encodes a signature with the appropriate signature algorithm name --
either "rsa-sha2-256" or "rsa-sha2-512".

3.2. Use for Client Authentication

To use this algorithm for client authentication, the SSH client sends
an SSH_MSG_USERAUTH_REQUEST message [RFC4252] encoding the
"publickey" method and encoding the string field "public key
algorithm name" with the value "rsa-sha2-256" or "rsa-sha2-512". The
"public key blob" field encodes the RSA public key using the
"ssh-rsa" public key format.

For example, as defined in [RFC4252] and [RFC4253], an SSH
"publickey" authentication request using an "rsa-sha2-512" signature
would be properly encoded as follows:

```
    byte        SSH_MSG_USERAUTH_REQUEST
    string      user name
    string      service name
    string      "publickey"
    boolean     TRUE
    string      "rsa-sha2-512"
    string      public key blob:
        string      "ssh-rsa"
        mpint       e
        mpint       n
    string      signature:
        string      "rsa-sha2-512"
        string      rsa_signature_blob
```

If the client includes the signature field, the client MUST encode
the same algorithm name in the signature as in
SSH_MSG_USERAUTH_REQUEST -- either "rsa-sha2-256" or "rsa-sha2-512".
If a server receives a mismatching request, it MAY apply arbitrary
authentication penalties, including but not limited to authentication
failure or disconnect.

OpenSSH 7.2 (but not 7.2p2) incorrectly encodes the algorithm in the signature as "ssh-rsa" when the algorithm in SSH_MSG_USERAUTH_REQUEST is "rsa-sha2-256" or "rsa-sha2-512". In this case, the signature does actually use either SHA-256 or SHA-512. A server MAY, but is not required to, accept this variant or another variant that corresponds to a good-faith implementation and is considered safe to accept.

3.3. Discovery of Public Key Algorithms Supported by Servers

Implementation experience has shown that there are servers that apply authentication penalties to clients attempting public key algorithms that the SSH server does not support.

Servers that accept rsa-sha2-* signatures for client authentication SHOULD implement the extension negotiation mechanism defined in [RFC8308], including especially the "server-sig-algs" extension.

When authenticating with an RSA key against a server that does not implement the "server-sig-algs" extension, clients MAY default to an "ssh-rsa" signature to avoid authentication penalties. When the new rsa-sha2-* algorithms have been sufficiently widely adopted to warrant disabling "ssh-rsa", clients MAY default to one of the new algorithms.

4. IANA Considerations

IANA has updated the "Secure Shell (SSH) Protocol Parameters" registry, established with [RFC4250], to extend the table "Public Key Algorithm Names" [IANA-PKA] as follows.

- To the immediate right of the column "Public Key Algorithm Name", a new column has been added, titled "Public Key Format". For existing entries, the column "Public Key Format" has been assigned the same value as under "Public Key Algorithm Name".

- Immediately following the existing entry for "ssh-rsa", two sibling entries have been added:

P. K. Alg. Name	P. K. Format	Reference	Note
rsa-sha2-256	ssh-rsa	RFC 8332	Section 3
rsa-sha2-512	ssh-rsa	RFC 8332	Section 3

5. Security Considerations

   The security considerations of [RFC4251] apply to this document.

5.1. Key Size and Signature Hash

   The National Institute of Standards and Technology (NIST) Special
   Publication 800-131A, Revision 1 [NIST.800-131A] disallows RSA and
   DSA keys shorter than 2048 bits for US government use. The same
   document disallows the SHA-1 hash function for digital signature
   generation, except under NIST's protocol-specific guidance.

   It is prudent to follow this advice also outside of US government
   use.

5.2. Transition

   This document is based on the premise that RSA is used in
   environments where a gradual, compatible transition to improved
   algorithms will be better received than one that is abrupt and
   incompatible. It advises that SSH implementations add support for
   new RSA public key algorithms along with SSH_MSG_EXT_INFO and the
   "server-sig-algs" extension to allow coexistence of new deployments
   with older versions that support only "ssh-rsa". Nevertheless,
   implementations SHOULD start to disable "ssh-rsa" in their default
   configurations as soon as the implementers believe that new RSA
   signature algorithms have been widely adopted.

5.3. PKCS #1 v1.5 Padding and Signature Verification

   This document prescribes RSASSA-PKCS1-v1_5 signature padding because:

   (1) RSASSA-PSS is not universally available to all implementations;
   (2) PKCS #1 v1.5 is widely supported in existing SSH
        implementations;
   (3) PKCS #1 v1.5 is not known to be insecure for use in this scheme.

   Implementers are advised that a signature with RSASSA-PKCS1-v1_5
   padding MUST NOT be verified by applying the RSA key to the
   signature, and then parsing the output to extract the hash. This may
   give an attacker opportunities to exploit flaws in the parsing and
   vary the encoding. Verifiers MUST instead apply RSASSA-PKCS1-v1_5
   padding to the expected hash, then compare the encoded bytes with the
   output of the RSA operation.

6. References

6.1. Normative References

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