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

This memo updates RFC 4252 and RFC 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.

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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 [800-131A].

This memo updates RFC 4252 and RFC 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", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119].

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.
- 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 containing S - an octet string which is the output of RSASSA-PKCS1-v1_5, of length equal to the length in octets of the RSA modulus.

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 decided to be safe to accept.

3.3. Discovery of public key algorithms supported by servers

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

Servers that accept `rsa-sha2-*` signatures for client authentication SHOULD implement the extension negotiation mechanism defined in [EXT-INFO], 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 is requested to update the "Secure Shell (SSH) Protocol Parameters" registry established with [RFC4250], to extend the table Public Key Algorithm Names [IANA-PKA]:

- To the immediate right of the column Public Key Algorithm Name, a new column is to be added, titled Public Key Format. For existing entries, the column Public Key Format should be assigned the same value found under Public Key Algorithm Name.
- Immediately following the existing entry for "ssh-rsa", two sibling entries are to be added:

P. K. Alg. Name	P. K. Format	Reference	Note
<code>rsa-sha2-256</code>	<code>ssh-rsa</code>	[this document]	Section 3
<code>rsa-sha2-512</code>	<code>ssh-rsa</code>	[this document]	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 [800-131A], disallows the use of 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 they have reason to 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 PKCS#1 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 PKCS#1 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

- [SHS] National Institute of Standards and Technology (NIST), United States of America, "Secure Hash Standard (SHS)", FIPS Publication 180-4, August 2015, <<http://dx.doi.org/10.6028/NIST.FIPS.180-4>>.
- [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.
- [RFC4251] Lehtinen, S. and C. Lonvick, Ed., "The Secure Shell (SSH) Protocol Architecture", RFC 4251, January 2006.
- [RFC4252] Ylonen, T. and C. Lonvick, Ed., "The Secure Shell (SSH) Authentication Protocol", RFC 4252, January 2006.
- [RFC4253] Ylonen, T. and C. Lonvick, Ed., "The Secure Shell (SSH) Transport Layer Protocol", RFC 4253, January 2006.
- [EXT-INFO] Bider, D., "Extension Negotiation in Secure Shell (SSH)", draft-ietf-curdle-ssh-ext-info-15.txt, September 2017, <<https://tools.ietf.org/html/draft-ietf-curdle-ssh-ext-info-15>>.

6.2. Informative References

- [800-131A] National Institute of Standards and Technology (NIST), "Transitions: Recommendation for Transitioning the Use of Cryptographic Algorithms and Key Lengths", NIST Special Publication 800-131A, Revision 1, November 2015, <<http://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-131Ar1.pdf>>.
- [RFC4250] Lehtinen, S. and C. Lonvick, Ed., "The Secure Shell (SSH) Protocol Assigned Numbers", RFC 4250, January 2006.
- [RFC8017] Moriarty, K., Kaliski, B., Jonsson, J. and Rusch, A., "PKCS #1: RSA Cryptography Specifications Version 2.2", RFC 8017, November 2016.
- [IANA-PKA] "Secure Shell (SSH) Protocol Parameters", <<https://www.iana.org/assignments/ssh-parameters/ssh-parameters.xhtml#ssh-parameters-19>>.

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