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Stateless Hash-Based Signatures for Secure Shell (SSH)
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Abstract

This document describes the use of Sphincs+/SLH-DSA digital signatures, standalone and as a hybrid with Ed25519/Ed448, in the Secure Shell (SSH) protocol.

About This Document

This note is to be removed before publishing as an RFC.

Status information for this document may be found at https://datatracker.ietf.org/doc/draft-josefsson-ssh-sphincs/.

Discussion of this document takes place on the SSHM Working Group mailing list (mailto:ssh@ietf.org), which is archived at https://mailarchive.ietf.org/arch/browse/ssh/.

Source for this draft and an issue tracker can be found at https://gitlab.com/jas/ietf-ssh-sphincs.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

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This Internet-Draft will expire on 23 April 2026.

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1. Introduction

Secure Shell (SSH) [RFC4251] is a secure remote-login protocol. It provides for an extensible variety of public key algorithms for identifying servers and users to one another.

Sphincs+ [SPHINCS] is a stateless hash-based digital signature system, standardized in [NIST.FIPS.205] as Stateless Hash-Based Digital Signature Algorithm (SLH-DSA).

EdDSA [RFC8032] is a digital signature system, with Ed25519 and Ed448 as common variants.

This document specify how Sphincs+/SLH-DSA is used in SSH. This document specify how Ed25519 and ML-DSA-65 may be used in SSH, using the hybrid signature scheme from [MOTHMA].

2. Conventions Used In This Document

The descriptions of key and signature formats use the notation introduced in [RFC4251], Section 3, and the string data type from [RFC4251], Section 5. Identifiers and terminology from SPHINCS [NIST.FIPS.205] are used throughout the document.

3. Requirements Language

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.

4. Public Key Algorithms

This document describes a set of public key algorithm for use with SSH, as per [RFC4253], Section 6.6. The names of the algorithm in SSH are as follows, mapping it to the [NIST.FIPS.205] and [MOTHMA] name. These algorithms only supports signing and not encryption.

SSH algorithm	SPHINCS+ identifer
"ssh-slh-dsa-sha2-128s"	SLH-DSA-SHA2-128S
"ssh-slh-dsa-sha2-128f"	SLH-DSA-SHA2-128F
"ssh-slh-dsa-shake-128s"	SLH-DSA-SHAKE-128S
"ssh-slh-dsa-shake-128f"	SLH-DSA-SHAKE-128F
"ssh-slh-dsa-sha2-256s"	SLH-DSA-SHA2-256S
"ssh-slh-dsa-sha2-256f"	SLH-DSA-SHA2-256F
"ssh-slh-dsa-shake-256s"	SLH-DSA-SHAKE-256S
"ssh-slh-dsa-shake-256f"	SLH-DSA-SHAKE-256F

Table 1: SSH Public Key Algorithms (standalone)

The hybrids with Ed25519/Ed448 are as follows:

SSH algorithm	Mothma identifer
"ssh-ed25519-slh-dsa-shake-128s"	Mothma-Ed25519-SLH-DSA-SHAKE-128S
"ssh-ed25519-slh-dsa-shake-128f"	Mothma-Ed25519-SLH-DSA-SHAKE-128F
"ssh-ed448-slh-dsa-shake-256s"	Mothma-Ed448-SLH-DSA-SHAKE-256S
"ssh-ed448-slh-dsa-shake-256f"	Mothma-Ed448-SLH-DSA-SHAKE-256F

Table 2: SSH Public Key Algorithms (hybrid)

SSH implementations MUST implement these signature algorithms.

5. Public Key Format

The "ssh-slh-dsa-sha2-256f" key format has the following encoding:

string "ssh-slh-dsa-sha2-256f"

string key

Here, ’key’ is the public key described in [NIST.FIPS.205], for the SLH-DSA-SHA2-256F algorithm, Section 10.1.

The other variants follow analogous, with the Mothma variants being per [MOTHMA].

6. Signature Algorithm

Signatures are generated according to the procedure in Sections 10.2 [NIST.FIPS.205], using the "pure" version of SLH-DSA-SHA2-256F.

7. Signature Format

The "ssh-ed25519" key format has the following encoding:

string "ssh-slh-dsa-sha2-256f"

string signature

Here, ’signature’ is the signature produced in accordance with the previous section.

The other variants follow analogous, with the Mothma variants being per [MOTHMA].

8. Verification Algorithm

Signatures are verified according to the procedure in [NIST.FIPS.205], Section 10.3, using the "pure" version of SLH-DSA-SHA2-256F.

The other variants follow analogous, with the Mothma variants being per [MOTHMA].

9. SSHFP DNS Resource Records

Usage and generation of the SSHFP DNS resource record is described in [RFC4255]. This section illustrates the generation of SSHFP resource records for SLH-DSA/Sphincs+ keys, and this document also specifies the corresponding code point to "SSHFP RR Types for public key algorithms" in the "DNS SSHFP Resource Record Parameters" IANA registry [IANA-SSHFP].

The generation of SSHFP resource records keys for SLH-DSA/Sphincs+ is described as follows.

The encoding of SLH-DSA/Sphincs+ public keys is described in [NIST.FIPS.205], Section 10.1.

The public keys are short, so there is no need to use a hash algorithm to shorten them. We therefor describe a new "Fingerprint Type" value TBD2 to refer to the raw public-key value without hashing.

The SSHFP Resource Record for a SLH-DSA/Sphincs+ key fingerprint would, for example, be:

```
pqserver.example.com. IN SSHFP TBD1 TBD2 (
                  a87f1b687ac0e57d2a081a2f2826723
                  34d90ed316d2b818ca9580ea384d92401 )
```

Replace TBD1 and TBD2 with the values eventually allocated by IANA. There will be one TBD1 value per algorithm.

10. IANA Considerations

This document augments the Public Key Algorithm Names in [RFC4250], Section 4.11.3.

IANA is requested to add the following entry to "Public Key Algorithm Names" in the "Secure Shell (SSH) Protocol Parameters" registry [IANA-SSH]:

Public Key Algorithm Name	Key Size	Signature Size	Reference
ssh-slh-dsa-sha2-256f	64	49856	THIS-RFC
ssh-slh-dsa-sha2-128s	FIXME	FIXME	THIS-RFC
ssh-slh-dsa-sha2-128f	FIXME	FIXME	THIS-RFC
ssh-slh-dsa-shake-128s	FIXME	FIXME	THIS-RFC
ssh-slh-dsa-shake-128f	FIXME	FIXME	THIS-RFC
ssh-slh-dsa-sha2-256s	FIXME	FIXME	THIS-RFC
ssh-slh-dsa-sha2-256f	FIXME	FIXME	THIS-RFC
ssh-slh-dsa-shake-256s	FIXME	FIXME	THIS-RFC
ssh-slh-dsa-shake-256f	FIXME	FIXME	THIS-RFC
ssh-ed25519-slh-dsa-shake-128s	FIXME	FIXME	THIS-RFC
ssh-ed25519-slh-dsa-shake-128f	FIXME	FIXME	THIS-RFC
ssh-ed448-slh-dsa-shake-256s	FIXME	FIXME	THIS-RFC
ssh-ed448-slh-dsa-shake-256f	FIXME	FIXME	THIS-RFC

Table 3: SSH Public Key Code Points

IANA is requested to add the following entry to "SSHFP RR Types for public key algorithms" in the "DNS SSHFP Resource Record Parameters" registry [IANA-SSHFP]:

Value	Description	Reference
TBD1	SSH-SLH-DSA-SHA2-128S	THIS-RFC
TBD1	SSH-SLH-DSA-SHA2-128F	THIS-RFC
TBD1	SSH-SLH-DSA-SHAKE-128S	THIS-RFC
TBD1	SSH-SLH-DSA-SHAKE-128F	THIS-RFC
TBD1	SSH-SLH-DSA-SHA2-256S	THIS-RFC
TBD1	SSH-SLH-DSA-SHA2-256F	THIS-RFC
TBD1	SSH-SLH-DSA-SHAKE-256S	THIS-RFC
TBD1	SSH-SLH-DSA-SHAKE-256F	THIS-RFC
TBD1	SSH-ED25519-SLH-DSA-SHAKE-128S	THIS-RFC
TBD1	SSH-ED25519-SLH-DSA-SHAKE-128F	THIS-RFC
TBD1	SSH-ED448-SLH-DSA-SHAKE-256S	THIS-RFC
TBD1	SSH-ED448-SLH-DSA-SHAKE-256F	THIS-RFC

Table 4: SSH DNS SSHFP RR Public Key Algorithm Types

IANA is requested to add the following entry to "SSHFP RR types for fingerprint types" in the "DNS SSHFP Resource Record Parameters" registry [IANA-SSHFP]:

Value	Description	Reference
TBD2	raw	THIS-RFC

Table 5: SSH DNS SSHFP RR Fingerprint Types

11. Security Considerations

The security considerations of all references apply.

The security considerations in [RFC4251], Section 9 apply to all SSH implementations, including those using Sphincs+/SLH-DSA.

The security considerations in SPHINCS [NIST.FIPS.205] apply to all uses of Sphincs+/SLH-DSA, including those in SSH.

Cryptographic algorithms and parameters are usually broken or weakened over time. Implementers and users need to continously re-evaluate that cryptographic algorithms continue to provide the expected level of security.

12. Acknowledgments

The text of [RFC8709] was used as a template for this document.

13. Test vectors

The following illustrate test vectors using file formats used by, for example, OpenSSH.

13.1. Private Key

Private key:

```
-----BEGIN OPENSSH PRIVATE KEY-----
b3BlbnNzaC1rZXktdjEAAAAABG5vbmUAAAAEbm9uZQAAAAAAAAABAAAAYwAAABtzc2gtc2xoLWRz
YS1zaGEyLTI1NmYAAABAPS6Ma/U7TKh4/I8HoTobiV+1sQnpkHZL7oztSTxgWoJYTDYEYdQpwty9
IJfwQDvK778DQCr9dx1gWb1HYDwYMAAAAQAS6f2dEun9nQAAABtzc2gtc2xoLWRzYS1zaGEyLTI1
NmYAAABAPS6Ma/U7TKh4/I8HoTobiV+1sQnpkHZL7oztSTxgWoJYTDYEYdQpwty9IJfwQDvK778D
QCr9dx1gWb1HYDwYMAAAAIBlB//OALih6/bAIOUGOGuaSKuK86IySusLX5xiqsPmJmE32DHKfIgg
mmvckaPbwnliYgL0mV/aAetfELu7XoqHPS6Ma/U7TKh4/I8HoTobiV+1sQnpkHZL7oztSTxgWoJY
TDYEYdQpwty9IJfwQDvK778DQCr9dx1gWb1HYDwYMAAAAAhqYXNAa2FrYQECAwQF
-----END OPENSSH PRIVATE KEY-----
```

13.2. Public-Key

Public key:

```
ssh-slh-dsa-sha2-256f AAAAG3NzaC1zcGhpbmNzcGx1c0BvcGVuc3NoLmNvbQAAAEA9Loxr9TtMqHj8jwehOhu
JX7WxCemQdkvujO1JPGBaglhMNgRh1CnC3L0gl/BAO8rvvwNAKv13HWBZvUdgPBgw jas@kaka
```

13.3. Message

The namespace context string used is "my-namespace", and the message is (including final newline):

```
Hello world!
```

13.4. Signature

Signature:

```
-----BEGIN SSH SIGNATURE-----
U1NIU0lHAAAAAQAAAGMAAAAbc3NoLXNwaGluY3NwbHVzQG9wZW5zc2guY29tAAAAQD0ujG
v1O0yoePyPB6E6G4lftbEJ6ZB2S+6M7Uk8YFqCWEw2BGHUKcLcvSCX8EA7yu+/A0Aq/Xcd
YFm9R2A8GDAAAAAMbXktbmFtZXNwYWNlAAAAAAAAAAZzaGE1MTIAAHSDAAAAG3NzaC1zcG
hpbmNzcGx1c0BvcGVuc3NoLmNvbQAAdGCZtK1w9NaIGAV9HcHArlgyCGRb/a+f8/EDt1bL
BHVvMQiGVR4guZ1g20dasKIxJznf8YqoYQeSXEktX7ukD+Go+icRJoTQj7n0RaKjaWz/aM
P1iKeNN1hhfyOMP9nCzUKSBOlcBe1IDnHTMZDuX7wUVTu4WTcd4WrTb5Qos+fxY2cBUM9p
QeUPm2WpwkqVjpd8e4bG5ku2q4Q3jCHsambOH5VqZI+khzQ5w3M+b1wMXfWVwEd8O7t++U
Nq/wqhFFSWvuiZ3OY9FgO04KsBC313OHv04jJV83MaIaKJLRpTXQl8YX/poz3WNeX3oIYV
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ls6iI574ItuPhhWLCbXm2HnZA9sjXNy/8Z+KtEl+xTaUj0kGzR49wL6+cNymjmHRQHicWO
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```

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ziw4+W4nb4kC/mwFxNmjEqsJu4u0oKPs8sww/Z3WOCdEz3nW0MymJ3jxDJ/OfSb4jSCII3
PvoLonrCaSeChyxIQxfVSxP8bRkk/HSZrX7lfkgRztEFOpDshCyTEEmd5uASg4S77+I+yX
K3M6weiVxqTfGmTVKUPHnE7p8yZ74Yq5vwVqlrsvXjz3PMQxBaZQQ3YJdUqkl+UqYXs0S3
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NB6XX0aX4hWxwToq3I4b3zzaLBZBkKXsO+RlImDRYlbDH/CdZd3Wr3pfzBO0pSkbbJilDO
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