

Secure Shell Maintenance
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Stateless Hash-Based Signatures for the Secure Shell (SSH) Protocol
draft-josefsson-ssh-sphincs-00

Abstract

This document describes the use of Sphincs+/SLH-DSA digital signatures in the Secure Shell (SSH) protocol.

About This Document

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Discussion of this document takes place on the SSHM Working Group mailing list (<mailto:ssh@ietf.org>), which is archived at
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Source for this draft and an issue tracker can be found at
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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).

This document specifies how Sphincs+/SLH-DSA is used in SSH.

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 Algorithm

This document describes a public key algorithm for use with SSH, as per [RFC4253], Section 6.6. The name of the algorithm is "ssh-slh-dsa-sha2-256f" to match SLH-DSA-SHA2-256F [NIST.FIPS.205]. This algorithm only supports signing and not encryption.

SSH implementations SHOULD 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.

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.

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.

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.

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

Table 1: 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-SHA2-256F	THIS-RFC

Table 2: 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 3: SSH DNS SSHFP RR Fingerprint Types

11. Security Considerations

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 continuously 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-----
b3BlbnNzaC1rZXktdjEAAAABAG5vbmUAAAAEbm9uZQAAAAAAAAABAAAAYwAAABtzc2gtc2xoLWRz
YS1zaGEyLTIlNmYAAABAPS6Ma/U7TKh4/I8HoTobiV+lsQnpkHZL7oztSTxgWoJYTDYEDQpwtY9
IJfwQDvK778DQCr9dxlgWb1HYDwYMAAAAQAS6f2dEun9nQAAABtzc2gtc2xoLWRzYS1zaGEyLTIl
NmYAAABAPS6Ma/U7TKh4/I8HoTobiV+lsQnpkHZL7oztSTxgWoJYTDYEDQpwtY9IJfwQDvK778D
QCr9dxlgWb1HYDwYMAAAAIBlB//OALih6/bAIOUGOGuaSKuK86IySusLX5xiqsPmJmE32DHkfIgg
mmvckaPbwnliYgL0mV/aAetfELu7XoqHPS6Ma/U7TKh4/I8HoTobiV+lsQnpkHZL7oztSTxgWoJY
TDYEDQpwtY9IJfwQDvK778DQCr9dxlgWb1HYDwYMAAAAahqYXNAa2FrYQECawQF
-----END OPENSSH PRIVATE KEY-----
```

13.2. Public-Key

Public key:

```
ssh-slh-dsa-sha2-256f AAAAG3NzaC1zcGhpbnNzcGxlc0BvcGVuc3NoLmNvbQAAAEA9Loxr9TtMqHj8jwehOhu
JX7WxCemQdkvujO1JPGBaglhMNgRh1CnC3L0gl/BA08rvvwNAKv13HwBZvUdgPBgw 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-----

U1NIU01HAAAAQAAGMAAAAbc3NoLXNwaGluY3NwbHVzQG9wZW5zc2guY29tAAAAQD0uJG
v100yoePyPB6E6G4lftbEJ6ZB2S+6M7Uk8YFqCWew2BGHUKcLcvSCX8EA7yu+/A0Aq/Xcd
YFm9R2A8GDAAAAAMbXktbmFtZXNwYWNlAAAAAAAAAAZzaGE1MTIAAHSDAAAAG3NzaC1zcG
hpbmNzcGxlC0BvcGVuc3NoLmNvbQAAdGCZtKlW9NaIGAV9HcHArLgyCGRb/a+f8/EDt1bL
BHvVMQiGVR4guZ1g20dasKIXznf8YqoYQeSXEkTX7ukD+Go+icRJoTQj7n0RaKjaWz/aM
PliKeNN1hhfyOMP9nCzUKSB0lcBelIDnHTMZDuX7wUVTu4WTcd4WrTb5Qos+fxY2cBUM9p
QeUPm2WpwkqVjpd8e4bG5ku2q4Q3jCHsambOH5VqZI+khzQ5w3M+blwMXfWVwEd8O7t++U
Nq/wqhFFSWvuiZ3OY9FgO04KsBC313OHv04jJV83MaIaKJLRpTXQl8YX/poz3WNeX3oIYV
23KZm3cBqfnq8xgvf281s46DNdfJNm69Qt6qfM54Ypc9lHYeX+Vb3S0o1NTRp8xGom6b4S
uVp7ZG2/hOXvn0qg3eqDB5vMhEOeh/alwc4O9UvcxIMw5f7qEqk4keNB5IJrgsHcFaRdWd
X+v3PdMsFvouxreWnwaZvWnqGH4UdoUOKBA8Tbix7VqWMC1m9QgSlMTFAGirgW0Wsa4Kqz
7YaxkJdsz7+b/+RLp+NSVriVQFxnZNw/QjRaKs7ca46MNxswq28T6ED6eFrXg68VMwQ2rY
7FlwKkUwq05u57Wrmc0pEQWdnt/n4nodVlGRxDqrvsCFxXN6MdgqMpA/kbqNKVGvRnOwJb
lp/1Bp28wavddPQdzmyalloaXYflhetqVATBnZoWPVlWhswoI/LVyP/NpfWSBt70xBE/op
g82Fx0GvVa32WyA2Qlhrdoqnr9uS6ej5pa7rt06lFHnEnRT+x2kcDXoqhYiWcUFPrEssfM
ppB0r7G16IjCdcoug4w7ujtmWdVIOYkb5cJGjK8/KwjOCdNne+ZHhUGt6tDowCeSsOZ8kM
7oDv/q2U2I67m5SUC8MpV+wFJSK7tKU35YzcYrzYH3nW8wIlsUknlgSPC50GdFkXKEMML5
QCD0Dqk3o5Sc+831PelzR4+rv7MU80xLcU2Hk8FRpNc/DQPzXkpQtv4YTxiH4qjzrpHrQ
8Jt1JYU0N8WuFXvyD0TYWNIWM9Jui0zZl1CbaIsvBJZ6hB1K1jNULzEDyF3nA722FjEbEq
aeqlgI9nw/tc3MF5MLx58XEh1DE7glt0R9FAx9mXZftjEk628qCqVzM7cJx3OdbuJ3330W
LfNpl74tXMYD55os4zAwhJQywt4chUXmCL+wFsdLWF4ieIKwKIOG9999dSDXjhTSQBrWsl
eN1lM350BvPGUaPuu3/tOfes+3SCBu5PlD9RcMK5rhaZ2Pg2FVordq7VmmMTg/O0k0vonR
slbB8rht0ugc00vcMdOnVOWmAVZlGHG5H4T/DcnmEazam8KsR/iwkpbhnl6OzY4VN19AA3
wCkvzoqh1TS0avoLwjLb2gi0n0m576Giyz/JnQkSiJNzspFS/fNX+UaULAYW4uNRE+4EHT
ls6ii574ItuPhhWLCbXm2HnZA9sjXNy/8Z+KtEl+xTaUj0kGzR49wL6+cNymjmHRQHicWO
lluA9A/EitKLBl6uqV7ktroYPumA+qSr8F2gsN5YtlUaq4qeod56gmISPw366J+ByhSCMy
mTnRneUyp3p2Z4l5vnofnmgiNWb9+yLXtOMwSQM4o+nynEyEga/NAPN0URIUezBThph/Eb
DmpbdqGy23tpjdrIYapy7RYuayS/BEeVbBxvMik0baYkli6PlVMMuuGnJIMLSzoUhlNT1E
zJh0GNNxmPDEok7Chx1JmCc99w5bpEXCLQ62d5JZWcZFsaET0nlLjQ4TI3ueTVaCcsFnRu
XwvjE9/acnzfUFLT2bPwhNvaL/WqG/ncH+iMxf9Pml719EXI9/hOu/Ua6gHlAUS/YyS+Le
ANr6L3GY8NuJzx+lteljw9d5E70U2fNinWk8dedZ+99HUBz0juwGiz0JJFeoPLABmt/24n
/OILN6V+/4S33Vr0T6SUPG0qNCJXDcEcMLzx6P7BqOBCIWRhwMVkb7SPXXqmcFHiLiBXcE
Ro3AYUwsn7AxzVQ+tzJE0j5zyxHa8hneSrNv569xz/H0sKLZET4r96akb+u0aIVO6uba+O
AWF7YTVIfilTaQn5BXJUY5jS8L1Mo7r+2JshFFPRNGTG3jPP01UOqhlRntILmeQzxn+dEB
h+iSi7V5wbFtKtjM4iKMYvdbDkJlsn8Y6rCA1PXGoHr6sAlyfQtZ7kS5qow738TGHhwr5R
jeWzd2zibwKDbOBMU60DHXr73AHdkBPAIzYp4eS9P+ITeLFU2vunuHC3liZyqo0ZVAXaDv
ha0+/AJiMnld+tWEqXipk9VcrDiPfYxdiWLTv+ZNl3OBOE+KOCrvLAqSqRKIXQfougZD
bexgUnZfmap/oYeykIKFhJQQiZ48vkK94CDa0zrBUqp9I5zjZnRKkjYWIqSNa7h66e6iPU
wiBba+znaxJPGbLjseAUeSE4/ThCm0zBcvBxr48fE7TrmvFkwMjgYTn77Vs0IVybmZWxSw
vIg/947tcF6aPpRZeJCYj56mkhdDGBiNpNMZSPKGEUOQ+PfXf3vNsEehkni9LqiPVdo77A
j78hCPqHFHLwOueW8QIhkWGM1/+9TM3X+Mo4fEIYd5hQzd3PCTIVkaISHZPfhwclce6xEH
tTa95J3X5KtiLhW2Nc+BlR5y6J3C19lM8yCA4FD6tPOwirIoYAVFgI3KgnAOMbCWS5/rAi
ZOiAGfnSlt9DoHTJubfQhICMvc7aQ/raxkWLoCkCIEIIa8YuIqfnZaPlh9t9F92Fdgru
4wMWU9pl05bYGZD5s+a7DVlyx2+lTaUKCDpFpB7CHV19Vacm/Iqr5479YHu4JEIu/ycqhq
/Pk5OEjsM1MzCqIVgVcwhzlmXJfMOWLyynKESW2X76RjyMCYgNUjFBeu+SD6FCcu9W3CPI
lsUVACDoWlly9l+7lSCSxOJfWAVO9Shwgp5sXN0URbCTxhlrUaIEPPsCfQdnk//K2iz4y7
MbMvCTZIL1clSExBzS717jzHU/xB/uxOLqVoyxqeGjHosAxUirtlsMDYFOXR2RsW2c8cZh

zsKxJ5gbSHDP6rq9UgdQZHHJ75rs9r8ULb7beU4J9MKZnHgfeo4gXabJl282DoVjfuYyoo
7i037w9ZXrx/9J7PDvyUZTw+5qTTguZpyAQulQs9uOqKJakJYSJyErwCOMESc8f0rom2Cm
W42bIAB8RF0Sg+g7xOtek3edLbETUfVFR1Rinl6fw6W433SMNQzyFW49PGVs5MMg4UT8r6
ApG2slcQipV8qQoCzFvvJ6dMs9C+HlEicju6XFYhO9H3ha00kSVBye9RnDhedyL6BB12Hu
GCn3EsZW/eBEMzK56SoVWIMddC4l6mavDHDuATDRzP/ycw8fF9nF+baE3SONGuuZiFNir8
iRtPVarxU3vUFORSxXGm7SLvVW+TiXxTeO8hMKHFGjH3mLF2U3AZhE5MzRxvvUeVBrpO3Q
HQinkPG39mMcF8Z2DKaYUumQimh/FAKg6ouIRRnz4/cF8Pl43sF7KrB2PCxpyqLZeq8QGe
BDSb6LKGBejIhC7mc/JMN4eelg3lsLQRaHkD+Fx57wuzbKnmClaQ9773RP7XbGzt2ByzXB
ml1uesOUYblghilH3EUIV3EnciYrzlLddakfy+UazDPsm7P3HZjY7Sks5UrS7eqRjh2JAV
bjzxdf+D9GKRdunXP7+QGdMJuJVHwUps0jvfvjV7//4AAFN7btb7RK6rLVyuTFURQyU5gGk
VucVxB09ilCWEikFhfFJUkOgQQjVy4v3J93PuYGvc5sjldP50tLlgIQ/AF72YBPo+l2j/o
4mXxYVrrz8sspswrn9xnqQaLrBfrEUfVa50PvaYOS6gZffIGri0ky7q2xSnnxgEeePTlwL
s5VOvnbkJDJyMBROHZGK3oJA2ps89GgruoGtPbMP7+FEjClpeltHlovYOA6cQ15etQPS7V
mhVYPyAnlmsF8MpZZFvDZL2w0qOS+AEonzZpZ28V9Eo7ygWstbvQPe3vBtKBjPgpU2/6+F
f3YNgrvAlj2HTg55Sbmy/6aelLfcb7FaPxAYAKTqX2lHasf0cOMAAH9G7cQctmoUiDUwX2
2eIM/3/qB0FYOb98JM5/cDVxMYmokzxoC8VHFFvK9yRzhxrRBmrehXbIzaaMQz6vAqGTGz
wagT9YkexUvjpX7iLiGt+Seegh4ckQYj09M19hcs89EjSs9mG85Ooon09eVdqQV0S3hr1v
fr8F952GIIz6524+446JPOOKPJgM+iP/oGahDwQnNTC8zYLx2OxHkXV0ytvSQ/urWgtjs4
z38Dmb2B/FpbMpfN0jDWC90mmhTmZvB6/GrQR8qqeBdfMlEUfgASmu5vT9nWMDp4yGfMN
hS0bW28Et95FrV9487fc88yPzfsjXBvC8mm+q4m05jce/XlE6Q6nmimMuyE44x16QQn7DH
w23AmqO7EakYQ4C03UFxQMZHIje+lchhwjG26A22+veDnojUxBEMJ8V6dHfZVkwYnNT9Q8
G56b+CKTbvScOC7w0NMAmCodNRqPut3BPkA3zz4IlezS+Yl0GwXNVUyBmX+uKGFxG6G+R
ED7b2+HTlXMI+kXWUbcij9uR8RBBSR3yWB9jrSht5rMeAyfczzBd8rS6ozkcttNKz4elIp
krnFWFmbGj+/lfQvoOGdvzdedcy0Rgfip+L334VviljFpgqT2BV5tooJ09KXiMpoY2aBK
huY4SQzLmCJ9eNqZnSmzjc+x+ypjSw53sXWruRg886sxeAgzSI/MAHMEOKtqmTPPDi7EYKF
ziw4+W4nb4kC/mwFxmNjEqsJu4u0oKPS8sww/Z3WOCdEz3nW0MymJ3jxDJ/OfSb4jSCII3
PvoLonrCaSeChyxIQxfVSxP8bRkk/HSZrX7lflkgRzTEFOPdshCyTEEmd5uASg4S77+I+yX
K3M6weiVxqTfGmTVKUPHnE7p8yZ74Yq5vwVqlrsvXjz3PMQxBaZQQ3YJdUqkl+UqYXs0S3
gQosH9wflQ9/denu2Tt/TGrsaxArL5TVhPM8KAWH60vNFBfHuBqSVOjGJA0Jmaf8TtxtroX
SjEWEHktn6oqsun9dxCkqmxMxLsCor2Ad9NglhntC45rYwYtoX/ltij7oyw9dUh0Ihk3VJ
dHae35InwIzjX8AceYLTiN622wgmiysX3Jf6vyLG0qI5ERKfxCARjhBx4pvVBImhXGhXm2
tcW2No9xSxVd6xhqAKvVRQKRnWNp7/RNnLojqjcjoc9Zka4MlaEXKGewgxgQ38by9OTumB
NB6XX0aX4hWxwToq3I4b3zzaLBZBkKXsO+RlImDRYlbdH/CdZd3Wr3pfzBO0pSkbbJilDO
d0MZwOXiOSg9TfqtNmF8X6haMKNYw5DLCTtCAzHHSdQYhWAUJfK3Xvinzsf6JUc07bs+ej
wd5zi44r4N9gpMW5Vu/ranIcIZlICmqaybbg0PEPoMY1/gGmNqvmPP3KYXA6rAlUJzVLkt
+Yrl0otYpAIR/Ac3XysEswS2rRHo+cwBZsUX99P5N8rbGYaTmYilXvsnt7ROPqShfbmZhd
ketWp40C0L4g2WTGHj3XuVljHHFcPmk+XDWSMERLFPf/hK3sri7DRrxPzjc0xWf/OSocS5
jr43KflP5Adu38hPma6FeaoHOa9CTbt/KDNepUguu4T+Wji+JXz9XffNxxG7S+fgZxgs0mN
yRO+4fLUnxIRX93rsuPaVzFVi/7g9wqOWyr1TVdKhoQKYhNIJl4InKkE4BmzF5CLABAj9v
/TwHZwDtfb/KoGN+VuW5wD0DIhD4FRsn9eGL+nyoDHTGjqb7KhrN4+8s4vyH/Udlv93n7a
sH5DIwMg30CUG6HIVetPy3bci3zY700/Dbalnmwkt0WSL0LcJgJBbM3aH1dAEDte0SHD4
luTKbJohf94Ad/nrWammFCbtzxV/g7phi22I8/U/br0iRMVWWIGkbTil9n/FNcvTgSCw0j
eDd0temON56LDzsVyCJtxtQ7s+DtCdu0UyFv66GYX3xujfi/yCZad+FJSGXhUtxt06N8+F
+SEX1jPUeciFylxXkg2IV894Med18rJri+CQuNp/olmD8w0SNHYVy835Dgpd1TXrJkmYwx
A3wb9rPxR3aIbPpj9UXBkSBpePvnKW3ri8qpSrh3wo3W+L4XXtAj/tZOxtiSM5sDazPzuH
Z9poBC/o9ieVjAkrXMsD5wUDp9BpgY2S6Jw+IvA05R+m8R3d5RyByDzx4IMw7cmdTrTLpf
LaDobx7SQVtvJ6ayWnur+KvRMByDE7712naI8LLFJsh0wbBjkeYXX91f6YhOWorOPCm5Ye
GjfqBeGjsKrSrg6d+ntvx3Fd4UQSLiIng5fOMuJHq8kksAWQC+4IKq4SZrhYcTBFgkPYA

cxE3tGEftesWl08DVJNypRFDbnNtLfTIVUWSNKKaX2DZaZ3/88LRMEcv58YUcj+X8I7KnX
bCAwtMI2RbSRFbsWNNMY8sz3Pt9ob/yYJ7uXs609BhzP4inM++u8mXyordtQJJOA6SyQgHc
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