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JOSE and COSE Encoding for SPHINCS+

Abstract

This document describes JSON and CBOR serializations for SPHINCS+, a Post-Quantum Cryptography (PQC) signature suite.

This document does not define any new cryptography, only serializations of existing cryptographic systems.

This document registers key types for JOSE and COSE, specifically HASH.

Key types in this document are specified by the cryptographic algorithm family in use by a particular algorithm as discussed in RFC7517.

This document registers signature algorithms types for JOSE and COSE, specifically SPHINCS+256s and others as required for use of various parameterizations of the SPHINCS+ post-quantum signature scheme.

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1. Notational Conventions

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. Terminology

The following terminology is used throughout this document:

PK : The public key for the signature scheme.

SK : The secret key for the signature scheme.

signature : The digital signature output.

message : The input to be signed by the signature scheme.

sha256 : The SHA-256 hash function defined in [[RFC6234](#)].

shake256 : The SHAKE256 hash function defined in [[RFC8702](#)].

3. SPHINCS-PLUS

This section defines core operations used by the signature scheme, as proposed in [[SPHINCS-PLUS](#)].

3.1. Overview

This section of the document describes the hash-based signature scheme SPHINCS+. The scheme is based on the concept of authenticating a large number or few-time signatures keypair using a combination of Merkle-tree signatures, a so-called hypertree. For each message to be signed a (pseudo-)random FTS keypair is selected with which the message can be signed. Combining this signature along with an authentication path through the hyper-tree consisting of hash-based many-time signatures then gives the SPHINC+ signature. The parameter set is strategically chosen such that the probability of signing too many messages with a specific FTS keypair to impact security is small enough to prevent forgery attacks. A trade-off in parameter set can be made on security guarantees, performance and signature size.

SPHINCS+ is a post-quantum approach to digital signatures that is promises Post-Quantum Existential Unforgeability under Chosen Message Attack (PQ-EU-CMA), while ensuring that the security levels reached meet security needs for resistance to both classical and quantum attacks. The algorithm itself is based on the hardness assumptions of its underlying hash functions, which can be chosen from the set Haraka, SHA-256 or SHAKE256. For all security levels the only operations required are calls to these hash functions on various combinations of parameters and internal states.

Contrary to CRYSTALS-Dilithium and Falcon, SPHINCS+ is not based on any algebraic structure. This reduces the possible attack surface of the algorithm.

SPHINCS+ brings several advantages over other approaches to signature suites:

- *Post-quantum in nature - use of cryptographically secure hash functions and other approaches that should remain hard problems even when under an attack utilizing quantum approaches
- *Minimal security assumptions - compared to other schemes does not base its security on a new paradigm. The security is solely based on the security of the assumptions of the underlying hash function.
- *Performance and Optimization - based on combining a great many hash function calls of SHA-256, SHAKE256 or Haraka means existing

(secure) SW and HW implementations of those hash functions can be re-used for increased performance

- *Private and Public Key Size - compared to other post-quantum approaches a very small key size is the form of hash inputs-outputs. This then has the drawback that either a large signature or low signing speed has to be accepted
- *Cryptanalysis assurance - attacks (both pre-quantum and quantum) are easy to relate to existing attacks on hash functions. This allows for precise quantification of the security levels
- *Overlap with stateful hash-based algorithms - means there are possibilities to combine implementations with those of XMSS and LMS. For example, both have the same underlying hash functions and utilize existing HW acceleration. Furthermore, an API to a XMSS implementation can be directly used by the subroutines of SpHincS+
- *Inherent resistance against side-channel attacks - since its core primitive is a hash function, it thereby is hard to attack with side-channels.

The primary known disadvantage to SPHINCS+ is the size signatures, or the speed of signing, depending on the chosen parameter set. Especially in IoT applications this might pose a problem. Additionally hash-based schemes are also vulnerable to differential and fault attacks.

3.2. Core Operations

Core operations used by the signature scheme should be implemented according to the details in [[SPHINCS-PLUS](#)]. Core operations include key generation, sign, and verify.

3.3. Using SPHINCS-PLUS with JOSE

This sections is based on [CBOR Object Signing and Encryption \(COSE\)](#) and [JSON Object Signing and Encryption \(JOSE\)](#)

3.3.1. SPHINCS-PLUS Key Representations

A new key type (kty) value "HASH" (for keys related to the family of algorithms that utilize hash based approaches to post-quantum cryptography) is defined for public key algorithms that use base 64 encoded strings of the underlying binary material as private and public keys and that support cryptographic sponge functions. It has the following parameters:

*The parameter "kty" MUST be "HASH".

*The parameter "alg" MUST be specified, and its value MUST be one of the values specified the below table

alg	Description
SPHINCS+128s	SPHINCS+ with parameter set of 128s
SPHINCS+128f	SPHINCS+ with parameter set of 128f

alg	Description
SPHINCS+192s	SPHINCS+ with parameter set of 192s
SPHINCS+192f	SPHINCS+ with parameter set of 192f
SPHINCS+256s	SPHINCS+ with parameter set of 256s
SPHINCS+256f	SPHINCS+ with parameter set of 256f

Table 1

*The parameter "pset" MAY be specified to indicate the parameter set in use for the algorithm, but SHOULD also reflect the targeted NIST level for the algorithm in combination with the specified parameter set. For "alg" "HAS" one of the described parameter sets as listed in the section SPHINCS+ Algorithms MUST be specified.

*The parameter "x" MUST be present and contain the public key encoded using the base64url [RFC4648] encoding.

*The parameter "d" MUST be present for private keys and contain the private key encoded using the base64url encoding. This parameter MUST NOT be present for public keys.

When calculating JWK Thumbprints [RFC7638], the four public key fields are included in the hash input in lexicographic order: "kty", "alg", and "x".

When using a JWK for this algorithm, the following checks are made:

*The "kty" field MUST be present, and it MUST be "HASH" for JOSE.

*The "alg" field MUST be present, and it MUST represent the algorithm and parameter set.

*If the "key_ops" field is present, it MUST include "sign" when creating a HASH signature.

*If the "key_ops" field is present, it MUST include "verify" when verifying a HASH signature.

*If the JWK "use" field is present, its value MUST be "sig".

3.3.2. SPHINCS-PLUS Algorithms

In order to reduce the complexity of the key representation and signature representations we register a unique algorithm name per pset. This allows us to omit registering the pset term, and reduced the likelihood that it will be misused. These alg values are used in both key representations and signatures.

Sphincs+ targets different security levels (128-, 192- and 256-bit security) and tradeoffs between size and speed. For each security level a small (s) and fast (f) parameter set is provided.

kty	alg	Parameter Set
HASH	SPHINCS+128s	128s
HASH	SPHINCS+128f	128f
HASH	SPHINCS+192s	192s
HASH	SPHINCS+192f	192f
HASH	SPHINCS+256s	256s
HASH	SPHINCS+256f	256f

Table 2

3.4. Using SPHINCS-PLUS with COSE

The approach taken here matches the work done to support secp256k1 in JOSE and COSE in [[RFC8812](#)].

The following tables map terms between JOSE and COSE for signatures.

Name	Value	Description	Recommended
SPHINCS+128s	TBD	SPHINCS+ with parameter set 128s	No
SPHINCS+128f	TBD	SPHINCS+ with parameter set 128f	No
SPHINCS+192s	TBD	SPHINCS+ with parameter set 192s	No
SPHINCS+192f	TBD	SPHINCS+ with parameter set 192f	No
SPHINCS+256s	TBD	SPHINCS+ with parameter set 256s	No
SPHINCS+256f	TBD	SPHINCS+ with parameter set 256f	No

Table 3

The following tables map terms between JOSE and COSE for key types.

Name	Value	Description	Recommended
HASH	TBD	kty for hash based digital signature	No

Table 4

4. Security Considerations

The following considerations SHOULD apply to all parameter sets described in this specification, unless otherwise noted.

Care should be taken to ensure "kty" and intended use match, the algorithms described in this document share many properties with other cryptographic approaches from related families that are used for purposes other than digital signatures.

4.1. Validating public keys

All algorithms in that operate on public keys require first validating those keys. For the sign, verify and proof schemes, the use of KeyValidate is REQUIRED.

4.2. Side channel attacks

Implementations of the signing algorithm SHOULD protect the secret key from side-channel attacks. Multiple best practices exist to protect against side-channel attacks. Any implementation of the the Sphincs+ signing algorithms SHOULD utilize the following best practices at a minimum:

- *Constant timing - the implementation should ensure that constant time is utilized in operations
- *Sequence and memory access persistence - the implementation SHOULD execute the exact same sequence of instructions (at a machine level) with the exact same memory access independent of which polynomial is being operated on.
- *Uniform sampling - care should be given in implementations to preserve the property of uniform sampling in implementation and to prevent information leakage.

4.3. Randomness considerations

It is recommended that the all nonces are from a trusted source of randomness.

5. IANA Considerations

The following has NOT YET been added to the "JSON Web Key Types" registry:

- *Name: "HASH"
- *Description: Hash based post-quantum signature algorithm key pairs
- *JOSE Implementation Requirements: Optional
- *Change Controller: IESG
- *Specification Document(s): Section 3.1 of this document (TBD)

The following has NOT YET been added to the "JSON Web Key Parameters" registry:

- *Parameter Name: "pset"
- *Parameter Description: The parameter set of the crypto system
- *Parameter Information Class: Public
- *Used with "kty" Value(s): "HASH"
- *Change Controller: IESG
- *Specification Document(s): Section 2 of this document (TBD)

The following has NOT YET been added to the "JSON Web Key Parameters" registry:

- *Parameter Name: "d"
- *Parameter Description: The private key
- *Parameter Information Class: Private
- *Used with "kty" Value(s): "HASH"
- *Change Controller: IESG
- *Specification Document(s): Section 2 of RFC 8037

The following has NOT YET been added to the "JSON Web Key Parameters" registry:

- *Parameter Name: "x"
- *Parameter Description: The public key
- *Parameter Information Class: Public
- *Used with "kty" Value(s): "HASH"
- *Change Controller: IESG
- *Specification Document(s): Section 2 of RFC 8037

The following has NOT YET been added to the "JSON Web Signature and Encryption Algorithms" registry:

- *Algorithm Name: "SPHINCS+128s"
- *Algorithm Description: SPHINCS+128s signature algorithms
- *Algorithm Usage Location(s): "alg"
- *JOSE Implementation Requirements: Optional
- *Change Controller: IESG
- *Specification Document(s): Section 5.1 of this document (TBD)
- *Algorithm Analysis Documents(s): (TBD)

The following has NOT YET been added to the "JSON Web Signature and Encryption Algorithms" registry:

- *Algorithm Name: "SPHINCS+128f"
- *Algorithm Description: SPHINCS+128f signature algorithms
- *Algorithm Usage Location(s): "alg"
- *JOSE Implementation Requirements: Optional
- *Change Controller: IESG
- *Specification Document(s): Section 5.1 of this document (TBD)
- *Algorithm Analysis Documents(s): (TBD)

The following has NOT YET been added to the "JSON Web Signature and Encryption Algorithms" registry:

- *Algorithm Name: "SPHINCS+192s"
- *Algorithm Description: SPHINCS+192s signature algorithms
- *Algorithm Usage Location(s): "alg"
- *JOSE Implementation Requirements: Optional
- *Change Controller: IESG
- *Specification Document(s): Section 5.1 of this document (TBD)
- *Algorithm Analysis Documents(s): (TBD)

The following has NOT YET been added to the "JSON Web Signature and Encryption Algorithms" registry:

- *Algorithm Name: "SPHINCS+192f"
- *Algorithm Description: SPHINCS+192f signature algorithms
- *Algorithm Usage Location(s): "alg"
- *JOSE Implementation Requirements: Optional
- *Change Controller: IESG
- *Specification Document(s): Section 5.1 of this document (TBD)
- *Algorithm Analysis Documents(s): (TBD)

The following has NOT YET been added to the "JSON Web Signature and Encryption Algorithms" registry:

- *Algorithm Name: "SPHINCS+256s"
- *Algorithm Description: SPHINCS+256s signature algorithms
- *Algorithm Usage Location(s): "alg"
- *JOSE Implementation Requirements: Optional
- *Change Controller: IESG
- *Specification Document(s): Section 5.1 of this document (TBD)
- *Algorithm Analysis Documents(s): (TBD)

The following has NOT YET been added to the "JSON Web Signature and Encryption Algorithms" registry:

- *Algorithm Name: "SPHINCS+256f"
- *Algorithm Description: SPHINCS+256f signature algorithms
- *Algorithm Usage Location(s): "alg"
- *JOSE Implementation Requirements: Optional
- *Change Controller: IESG
- *Specification Document(s): Section 5.1 of this document (TBD)
- *Algorithm Analysis Documents(s): (TBD)

6. Appendix

- *JSON Web Signature (JWS) - [RFC7515](#)
- *JSON Web Encryption (JWE) - [RFC7516](#)
- *JSON Web Key (JWK) - [RFC7517](#)
- *JSON Web Algorithms (JWA) - [RFC7518](#)
- *JSON Web Token (JWT) - [RFC7519](#)
- *JSON Web Key Thumbprint - [RFC7638](#)
- *JWS Unencoded Payload Option - [RFC7797](#)
- *CFRG Elliptic Curve ECDH and Signatures - [RFC8037](#)
- *SPHINCS+ - [SPHINCS-PLUS](#)

6.1. Test Vectors

6.1.1. HASH SPHINCS+256s

6.1.1.1. publicKeyJwk

```
{"kty":"HASH","alg":"SPHINCS+256s","x":"C_NSiMVMN6kpAv\  
\1021izzVkl7cN0ls-tX3xL8VeIOHwzfwmMJ37LvTLVXZQMFyXFTilBcLjcbPNqRCMXi\  
\z_c1A"}
```

6.1.1.2. privateKeyJwk

```
{"kty":"HASH","alg":"SPHINCS+256s","x":"C_NSiMVMN6kpAv\  
\1021izzVkl7cN0ls-tX3xL8VeIOHwzfwmMJ37LvTLVXZQMFyXFTilBcLjcbPNqRCMXi\  
\z_c1A","d":"-gEaHimlK26FRDpf33I6BKsfT3muN8xd0yonyYSgHtEoDxDBsTe30nU\  
\080WZrFwJxvKyVxo6HCHthjbmJX9LqSQvzUojFTDepKQL9TttYs81ZJe3DdJbPrV98S\  
\FXiDh1s38JjCd-y70y1V2UDBclxU4pQXC43GzzakQjF4s_3NQ"}
```

6.1.1.3. jws

eyJhbGciOiJTUEhJTkNTKy1TSEFLRS0yNTZzLXJvYnVzdCJ9.OTA4NWQyYmVmNjkyODZ\
\hNmNiYjUxNjIzYzhmYTI1ODYyOTk0NWNkNTVjYtCwNWNjNGU2NjcwMDM5Njg5NGUwYw\
\.YHQAELZyZybZFn_t59KRvg10Aja5g-Jp10exC8JGFsv8kMeyWoroy-T5ANx2lKE-cz\
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\o1svC0FY-6dWrVsq5bPttFnfXTdkjm0pZPDut72F2JCjb8f_Cp15s7tFlQ0RCDYmBLX\
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\EPC3vdkXNHwWQ_4G0f0fSmNzfa2mLbjbMRF1Ky0ZvNw90C11SP-fpo_m3pD70qtyUg\
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\RQmtBnuUkgbLYMHxCzNoPEv6qhrzRHq91VVHCgJG7AyRaLrZXPruoD7inByh1s1Q3n2\
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