ipsecme
Internet-Draft
Intended status: Standards Track
Expires: 31 August 2026

J. Hu
Nokia
Y. Morioka
NTT DOCOMO, INC.
G. Wang
Huawei

27 February 2026

# Post-Quantum Traditional (PQ/T) Hybrid PKI Authentication in the Internet Key Exchange Version 2 (IKEv2)
## draft-hu-ipsecme-pqt-hybrid-auth-04

## Abstract

One IPsec area that would be impacted by Cryptographically Relevant Quantum Computer (CRQC) is IKEv2 authentication based on traditional asymmetric cryptographic algorithms: e.g RSA, ECDSA, which are widely deployed authentication options of IKEv2. There are new Post-Quantum Cryptographic (PQC) algorithms for digital signature like NIST [ML-DSA], However, it takes time for new cryptographic algorithms to mature, There is security risk to use only the new algorithm before it is field proven. This document describes a hybrid PKI authentication scheme for IKEv2 that incorporates both traditional and PQC digital signature algorithms, so that authentication is secure as long as one algorithm in the hybrid scheme is secure.

## About This Document

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

The latest revision of this draft can be found at https://example.com/LATEST. Status information for this document may be found at https://datatracker.ietf.org/doc/draft-hu-ipsecme-pqt-hybrid-auth/.

Discussion of this document takes place on the WG Working Group mailing list (mailto:ipsec@ietf.org), which is archived at https://mailarchive.ietf.org/arch/browse/ipsec/. Subscribe at https://www.ietf.org/mailman/listinfo/ipsec/.

Source for this draft and an issue tracker can be found at https://github.com/USER/REPO.

## Status of This Memo

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

This Internet-Draft will expire on 31 August 2026.

## Copyright Notice



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# 1. Change log

## 1.1. changes in -04

* align to draft-ietf-lamps-pq-composite-sigs-14
* add text to clarify two setup types
* add text to describe the example exchange in section 5
* clarify using of pre-hash alg
* clarify sign operation in type-2
* ietf-lamps-cert-binding-for-multi-auth is now RFC9763
* ietf-lamps-dilithium-certificates is now RFC9881
* editorial changes

## 1.2. changes in -03

* version bump to keep doc alive

## 1.3. Changes in -02

* clarify the approach in the document is general
* dropping support for PreHash ML-DSA, change example to Pure Signature ML-DSA
* adding more details in signing process to align with ietf-lamps-pq-composite-sigs-04
* add text in Security Considerations to emphasize prohibit of key reuse
* clarify the both C and S bit MAY be 1 at the same time
* clarify the receiver behavior when the announcement contains no algid
* typo fixes

### 1.4. Changes in -01

* Only use SUPPORTED_AUTH_METHODS for algorithm combination announcement, no longer use SIGNATURE_HASH_ALGORITHMS

* add flag field in the announcement

* clarify two types of PKI setup

* add some clarifications on how AUTH payload is computed

## 2. Introduction

A Cryptographically Relevant Quantum Computer (CRQC) could break traditional asymmetric cryptographic algorithms: e.g RSA, ECDSA, which are widely deployed authentication options of IKEv2. New Post-Quantum Cryptographic (PQC) algorithms for digital signature were recently published like NIST [ML-DSA], However, by considering potential flaws in the new algorithm's specifications and implementations, it will take time for these new PQC algorithms to be field proven. So it is risky to only use PQC algorithms before they are mature. There is more detailed discussion on motivation of a hybrid approach for authentication in Section 1.2 of [I-D.ietf-pquip-hybrid-signature-spectrums].

This document describes a post-quantum traditional (PQ/T) hybrid digital signature authentication scheme for IKEv2 that incorporates both traditional and PQC digital signature algorithms, so that authentication is secure as long as one algorithm in the hybrid scheme is secure.

Each IPsec peer announces the support of hybrid authentication via SUPPORTED_AUTH_METHODS notification as defined in [RFC9593], generates and verifies AUTH payload using composite signature using the procedures defined in [I-D.ietf-lamps-pq-composite-sigs].

The approach specified in this document is a general framework for all PQC and traditional algorithms. The combinations of ML-DSA variants and traditional algorithms given in this document are instantiations of the general framework.

There are two types of PQ/T hybrid PKI setup:

1. Type-1: A single certificate that has a composite key as defined in [I-D.ietf-lamps-pq-composite-sigs], which contains two component keys: one traditional key + one PQC key.

2. Type-2: Two certificates, one certificate with traditional algorithm key and one certificate with PQC algorithm key as described in [RFC9763], Each certificate MAY contain RelatedCertificate extension to associate with the other certificate.

A given deployment could use either type to provide PQ/T hybrid PKI. This document supports both types.

## 3. Conventions and Definitions

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.

Cryptographically Relevant Quantum Computer (CRQC): A quantum computer that is capable of breaking real world cryptographic systems.

Post-Quantum Cryptographic (PQC) algorithms: Asymmetric Cryptographic algorithms are thought to be secure against CRQC.

Traditional Cryptographic algorithms: Existing asymmetric Cryptographic algorithms could be broken by CRQC, like RSA, ECDSA ..etc.

## 4. IKEv2 Key Exchange

There is no changes introduced in this document to the IKEv2 key exchange process, although it MUST be also resilient to CRQC when using along with the PQ/T hybrid authentication, for example key exchange using the PPK as defined in [RFC8784], or hybrid key exchanges that includes PQC algorithm like [ML-KEM] via multiple key exchange process as defined in [I-D.ietf-ipsecme-ikev2-mlkem].

## 5. Exchanges

The hybrid authentication exchanges is illustrated in an example depicted in Figure 1, using PPK as defined in [RFC8784] during key exchange. However, other PQC key exchanges could also be used since how key exchange is done is independent from authentication.

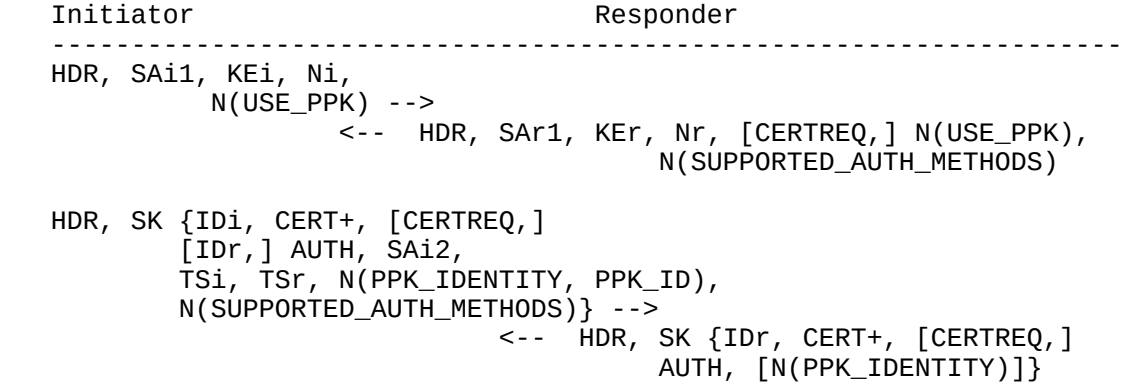


Figure 1: Hybrid Authentication Exchanges with RFC8784 Key Exchange

1. Responder announces the hybrid authentication support via SUPPORTED_AUTH_METHODS notification in IKE_SA_INIT response message. The notification includes the combinations of PQC, traditional, hash algorithm and type of hybrid PKI setup that responder supports.

2. Initiator chooses a combination from responder's SUPPORTED_AUTH_METHODS, uses the combination to generate the AUTH payload, along with corresponding signing certificate(s) in CERT payload(s), and includes its support of hybrid combinations in SUPPORTED_AUTH_METHODS notification of IKE_AUTH request message.

3. Responder chooses a combination from initiator's SUPPORTED_AUTH_METHODS, uses the combination to generate the AUTH payload, and includes corresponding signing certificate(s) in CERT payload(s) of IKE_AUTH response message.

### 5.1. Announcement

Announcement of support hybrid authentication is through SUPPORTED_AUTH_METHODS notification as defined in [RFC9593], which includes a list of acceptable authentication methods announcements. This document defines a hybrid authentication announcement with following format:

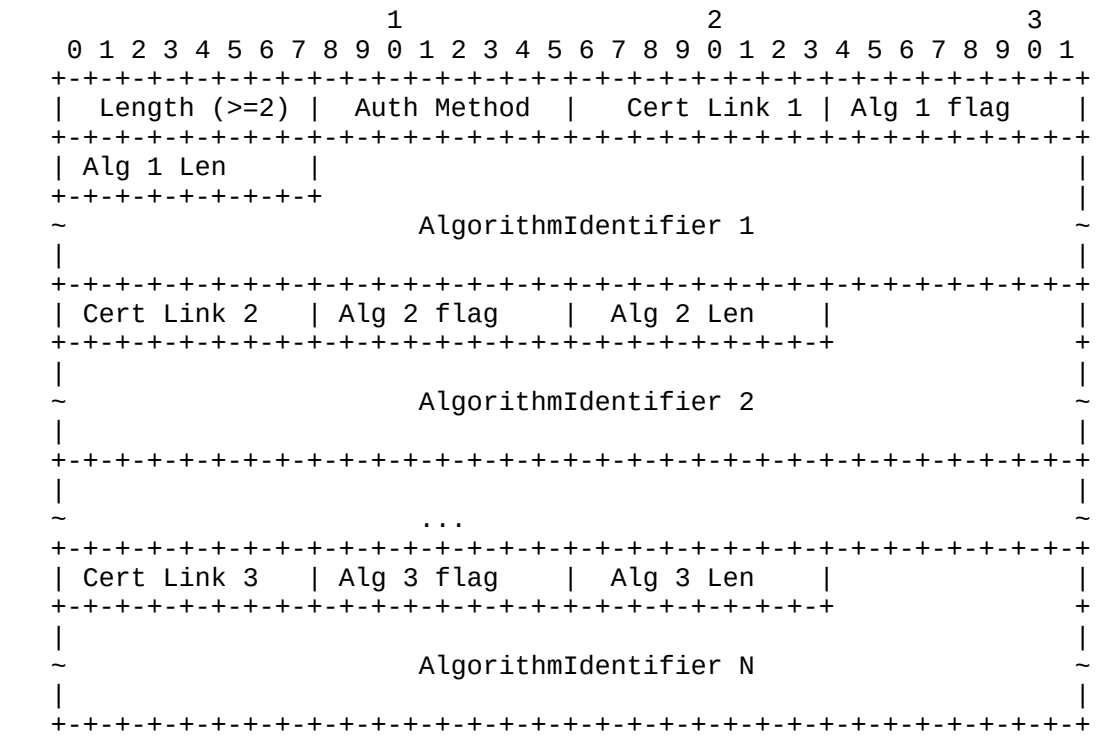


Figure 2: Hybrid Authentication Announcement

The announcement includes a list of N algorithms could be used for hybrid signature

* Auth Method: A new value to be allocated by IANA

* Cert Link N: Links corresponding signature algorithm N with a particular CA, as defined in Section 3.2.2 of [RFC9593]

* Alg N Flag:

  - C: set to 1 if the algorithm could be used in type-1 setup

  - S: set to 1 if the algorithm could be used in type-2 setup

  - Both C and S MAY be set to 1 but MUST NOT set to zero at the same time

  - RESERVED: set to 0

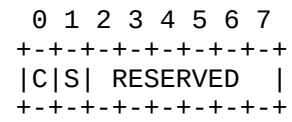


Figure 3: Algorithm Flag

* AlgorithmIdentifier N: The variable-length ASN.1 object that is encoded using Distinguished Encoding Rules (DER) [X.690] and identifies the algorithm of a composite signature as defined in Section 7 of [I-D.ietf-lamps-pq-composite-sigs].

#### 5.1.1. Sending Announcement

As defined in [RFC9593], the responder includes SUPPORTED_AUTH_METHODS in IKE_SA_INIT response (and potentially also in IKE_INTERMEDIATE response), while the initiator includes the notification in IKE_AUTH request.

The sender includes a hybrid authentication announcement in SUPPORTED_AUTH_METHODS, which contains 0 or N composite signature AlgorithmIdentifiers sender accepts. Each AlgorithmIdentifier identifies a combination of algorithms as specified in Section 6 of [I-D.ietf-lamps-pq-composite-sigs]:

* a traditional PKI algorithm (e.g. id-RSASA-PSS)

* a PQC algorithm (e.g. id-ML-DSA-44)

* a pre-hash algorithm (e.g. id-sha256)

In case of type-2 setup, even though the certificate is not a composite key certificate, system still uses a composite signature algorithm that corresponds to the combination of two certificates PKI algorithms and hash algorithm(s).

C and S bits in flag field are set according to whether sender accepts the algorithm combination in type-1/type-2 setup.

Announcement without any AlgorithmIdentifiers signals that there is no particular restrictions on algorithm.

### 5.1.2. Receiving Announcement

If hybrid authentication announcement is received, and the receiver chooses to authenticate itself using hybrid authentication, then based on its local policy and certificates, one AlgorithmIdentifier (which identifies a combination of algorithms) in the hybrid authentication announcement and a PKI setup (type-1 or type-2) is chosen to create its AUTH and CERT payload(s).

If there is no AlgorithmIdentifier in the announcement, the receiver MAY choose AlgorithmIdentifier just according to its local policy and certificates.

## 5.2. AUTH & CERT payload

The IKEv2 AUTH payload has following format as defined in Section 3.8 of [RFC7296]:

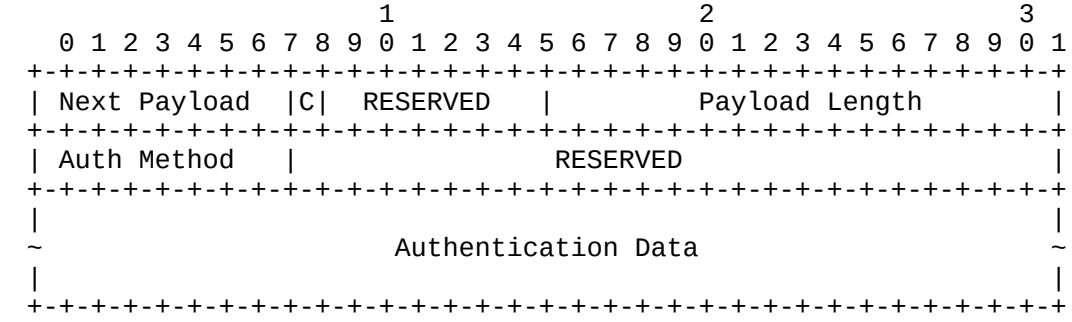


Figure 4: AUTH payload

For hybrid authentication, the AUTH Method has value defined in Section 5.1

The Authentication Data field follows format defined in Section 3 of [RFC7427]:

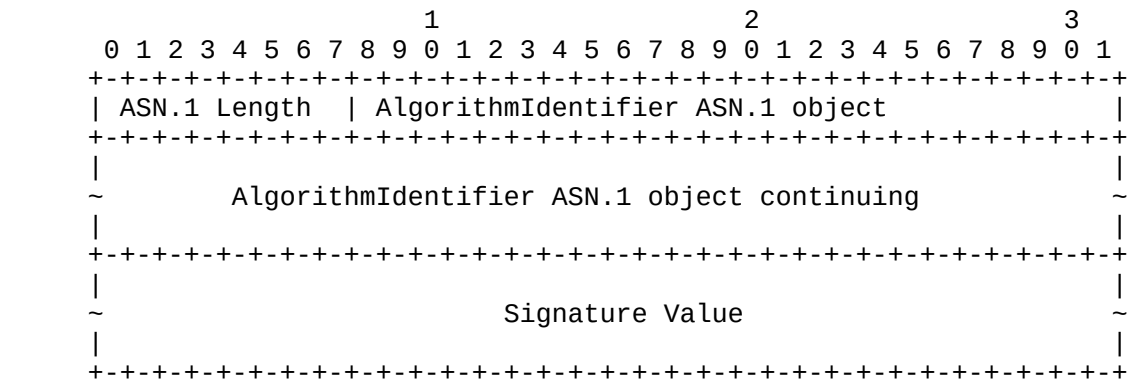


Figure 5: Authentication Data in hybrid AUTH payload

Based on selected AlgorithmIdentifier and setup type, the Signature Value is created via procedure defined in Section 5.2.1, Section 5.2.2.

### 5.2.1. Type-1

Assume selected AlgorithmIdentifier is A.

1. There is no change on data to be signed, e.g. InitiatorSignedOctets/ResponderSignedOctets as defined in Section 2.15 of [RFC7296]

2. Follow Sign operation identified by A, e.g. Section 3.2 of [I-D.ietf-lamps-pq-composite-sigs]. The ctx input is the string of "IKEv2-PQT-Hybrid-Auth". This step outputs the composite signature, a CompositeSignatureValue.

3. CompositeSignatureValue is serialized per Section 4.3 of [I-D.ietf-lamps-pq-composite-sigs], and the output is used as Signature Value in the Authentication Data field.

Note: [I-D.ietf-lamps-pq-composite-sigs] uses a pre-hash algorithm with [ML-DSA] pure mode (Algorithm 2), not the HashML-DSA as defined in [ML-DSA], see Section 2.1 of [I-D.ietf-lamps-pq-composite-sigs] for the rationale.

Following is an initiator example:

1. A is id-MLDSA44-RSA2048-PSS-SHA256, which uses PQC ML-DSA-44 and traditional RSASSA-PSS with pre-hash function SHA256

2. Follow Section 3.2 of [I-D.ietf-lamps-pq-composite-sigs] with following inputs:

   * sk is the private key of the signing composite key certificate

   * M is InitiatorSignedOctets

   * ctx is "IKEv2-PQT-Hybrid-Auth"

The signing composite certificate MUST be the first CERT payload.

#### 5.2.2. Type-2

1. Combine PQC key and traditional key into composite key using SerializePrivateKey operation as defined in Section 4.2 of [I-D.ietf-lamps-pq-composite-sigs].

2. Follow Sign operation as Section 5.2.1

Note: Section 6 of [RFC9881] defines 3 options for ML-DSA private key storage, this document requires options that include seed since Sign operation of [I-D.ietf-lamps-pq-composite-sigs] only supports seed.

With example in Section 5.2.1:

* sk is the combined private key, e.g. output of SerializePrivateKey

* M is InitiatorSignedOctets

* ctx is "IKEv2-PQT-Hybrid-Auth"

The signing PQC certificate MUST be the first CERT payload in the IKEv2 message, while traditional certificate MUST be the second CERT payload.

##### 5.2.2.1. RelatedCertificate

In type-2 setup, the signing certificate MAY contain RelatedCertificate extension, then the receiver SHOULD verify the extension according to Section 4.2 of [RFC9763]. Failed verification SHOULD fail authentication.

## 6. Security Considerations

The security of general PQ/T hybrid authentication is discussed in [I-D.ietf-pquip-hybrid-signature-spectrums].

This document uses mechanisms defined in [I-D.ietf-lamps-pq-composite-sigs], [RFC7427] and [RFC9593], so the security discussion in the corresponding RFCs also apply.

One important security consideration mentioned in [I-D.ietf-lamps-pq-composite-sigs] worth repeating here is that component key used in either Section 5.2.1 or Section 5.2.2 MUST NOT be reused in any other cases including single-algorithm case.

## 7. IANA Considerations

This document requests a value in "IKEv2 Authentication Method" subregistry under IANA "Internet Key Exchange Version 2 (IKEv2) Parameters" registry

## 8. References

### 8.1. Normative References

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## Acknowledgments

TODO acknowledge.

## Authors' Addresses

Jun Hu
Nokia
United States of America
Email: jun.hu@nokia.com

Yasufumi Morioka
NTT DOCOMO, INC.
Japan
Email: yasufumi.morioka.dt@nttdocomo.com

Guilin Wang
Huawei
Singapore
Email: Wang.Guilin@huawei.com