Network Working Group Y. Nir

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A Quick Crash Recovery Method for IKE draft-nir-qcr-00.txt

Status of this Memo

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Abstract

This document describes an extension to the IKEv2 protocol that allows for faster crash recovery using a saved token method.

When an IPsec tunnel between two IKEv2 implementations is disconnected due to a restart of one peer, it can take as much as several minutes to recover. In this text

we propose an extension to the protocol, that allows for recovery within a few seconds of the reboot.

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1. Introduction

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IKEv2, as described in **[RFC4306] (Kaufman, C., "Internet Key Exchange (IKEv2) Protocol," December 2005.)** has a method for recovering from a reboot of one peer. As long as traffic flows in both directions, the rebooted peer should re-establish the tunnels immediately. However, in many cases the rebooted peer is a VPN gateway that protects only servers, or else the non-rebooted peers have a dynamic IP address. In such cases, the rebooted peer will not re-establish the tunnels.

Section 2 (RFC 4306 Crash Recovery) describes the current procedure, and explains why crash recovery can take up to several minutes. The method proposed here, is to send a token in the IKE_AUTH exchange that establishes the tunnel. That token can be maintained on the peer in some kind of persistent storage such as a disk or a database, and can be used to delete the IKE SA after a crash. Deleting the IKE SA results is a quick re-establishment of the IPsec tunnel.

1.1. Conventions Used in This Document

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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] (Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels," March 1997.)**.

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2. RFC 4306 Crash Recovery

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When one peer reboots, the other peer does not get any notification, so IPsec traffic can still flow. The rebooted peer will not be able to decrypt it, however, and the only remedy is to send an unprotected INFORMATIONAL exchange with an INVALID_SPI notification as described in section 3.10.1 of **[RFC4306] (Kaufman, C., "Internet Key Exchange (IKEv2) Protocol," December 2005.)**. That section also describes the processing of such a notification: "If this Informational Message is sent outside the context of an IKE_SA, it should be used by the recipient only as a "hint" that something might be wrong (because it could easily be forged)."

Since the INVALID_SPI can only be used as a hint, the non-rebooted peer has to determine whether the IPsec SA, and indeed the parent IKE SA are still valid. The method of doing this is described in section 2.4 of **[RFC4306] (Kaufman, C., "Internet Key Exchange (IKEv2) Protocol," December 2005.)**. This method, called "liveness check" involves sending a protected empty INFORMATIONAL message, and awaiting a response. This procedure is sometimes refered to as "Dead Peer Detection" or DPD.

Section 2.4 does not mandate how many times the INFORMATIONAL message should be retransmitted, or for how long, but does recommend the following: "It is suggested that messages be retransmitted at least a dozen times over a period of at least several minutes before giving up on an SA". Clearly, implementations differ, but all will take a significant amount of time.

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3. Protocol Outline

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Supporting implementations will send a notification, called a "QCR token", as described in **Section 4.1 (Notification Format)** in the last packets of the IKE_AUTH exchange. These are the final request and final response that contain the AUTH payloads. The generation of these tokens is a local matter for implementations, but considerations are described in **Section 5 (Token Generation and Verification)**.

A supporting implementation receiving such a token SHOULD store it in such a way, that it will survive a reboot. When a supporting implementation receives a protected IKE request message with unknown IKE SPIs, it should scan its saved token store. If a token matching the IKE SPIs is found, it SHOULD send it to the requesting peer in an unprotected IKE message as described in **Section 4.3 (Informational Exchange)**.

When a supporting implementation receives the QCR notification token in an unprotected INFORMATIONAL exchange, it MUST verify that the TOKEN_SECRET_DATA field is associated with the IKE SPIs in the IKE_SPI fields of the IKE packet. If the verification fails, it SHOULD log the event. If it succeeds, it MUST delete the IKE SA associated with the IKE_SPI fields, and all dependant child SAs. This event MAY also be logged.

A supporting implementation MAY immediately create new SAs using an Initial exchange, or it may wait for subsequent traffic to trigger the creation of new SAs.

There is ongoing work on IKEv2 Session Resumption **[resumption] (Sheffer, Y., Tschofenig, H., Dondeti, L., and V. Narayanan, "IPsec Gateway Failover Protocol," November 2007.)**. The current proposal is orthogonal to Session Resumption, and in fact using Session Resumption instead of a regular IKE exchange, the new SA can be created with minimal overhead.

4.1. Notification Format

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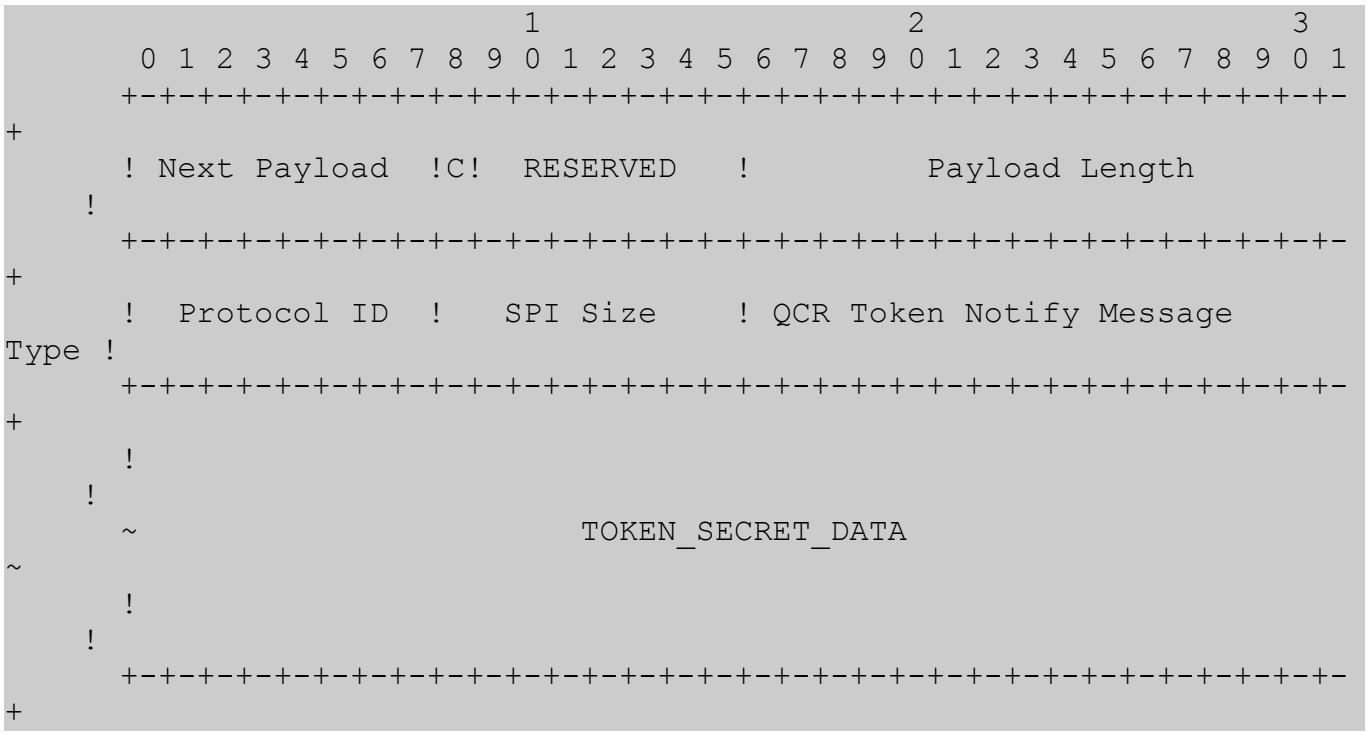
The notification payload called "QCR token" is formatted as follows:



- Protocol ID (1 octet) MUST contain 1, as this message is related to an IKE SA.
- SPI Size (1 octet) MUST be zero, in conformance with **[RFC4306] (Kaufman, C., "Internet Key Exchange (IKEv2) Protocol," December 2005.)**.
- QCR Token Notify Message Type (2 octets) - Must be xxxxx, the value assigned for QCR token notifications. TBA by IANA.
- TOKEN_SECRET_DATA (16-256 octets) contains a generated token as described in **Section 5 (Token Generation and Verification)**.

4.2. Authentication Exchange

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For clarity, only the EAP version of an AUTH exchange will be presented here. The non-EAP version is very similar. The figure below is based on appendix A.3 of **[RFC4718] (Eronen, P. and P. Hoffman, "IKEv2 Clarifications and Implementation Guidelines," October 2006.)**.

```
   first request        --> IDi,
                            [N(INITIAL_CONTACT)],
                            [[N(HTTP_CERT_LOOKUP_SUPPORTED)],
CERTREQ+],
                            [IDr],
                            [CP(CFG_REQUEST)],
                            [N(IPCOMP_SUPPORTED)+],
                            [N(USE_TRANSPORT_MODE)],
                            [N(ESP_TFC_PADDING_NOT_SUPPORTED)],
                            [N(NON_FIRST_FRAGMENTS_ALSO)],
                            SA, TSi, TSr,
                            [V+]

   first response       <-- IDr, [CERT+], AUTH,
                            EAP,
                            [V+]

                       / --> EAP
   repeat 1..N times   |
                       \ <-- EAP

   last request         --> AUTH
                            [N(QCR_TOKEN)]

   last response        <-- AUTH,
                            [N(QCR_TOKEN)]
                            [CP(CFG_REPLY)],
                            [N(IPCOMP_SUPPORTED)],
                            [N(USE_TRANSPORT_MODE)],
                            [N(ESP_TFC_PADDING_NOT_SUPPORTED)],
                            [N(NON_FIRST_FRAGMENTS_ALSO)],
                            SA, TSi, TSr,
                            [N(ADDITIONAL_TS_POSSIBLE)],
                            [V+]
```

Note that the QCR_TOKEN notification is marked as optional because it is not required by this specification that both sides send QCR tokens. If only one peer sends the QCR token, then a reboot of the other peer will not be recoverable by this method. This may be acceptable if traffic typically originates from the other peer.

In any case, the lack of a QCR_TOKEN notification MUST NOT be taken as an indication that the peer does not support this standard. Conversely, if a peer does not understand this notification, it will simply ignore it. Therefore a peer MAY send this notification freely, even if it doesnÕt know whether the other side supports it.

4.3. Informational Exchange

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This informational exchange is non-protected, and is sent as a response to a protected IKE request, which uses an IKE SA that is unknown.

```
            request             --> N(QCR_TOKEN)

            response            <--
```

The QCR_TOKEN is the only notification in the request. Similar to the description in section 2.21 of **[RFC4306] (Kaufman, C., "Internet Key Exchange (IKEv2) Protocol," December 2005.)**, The IKE SPI and message ID fields in the packet headers are taken from the protected IKE request.

If the QCR_TOKEN verifies OK, an empty response MUST be sent. If the QCR_TOKEN cannot be validated, a response SHOULD NOT be sent. **Section 5 (Token Generation and Verification)** defines token verification.

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5. Token Generation and Verification

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No token generation method is mandated by this document. Two methods are documented in **Section 5.1 (A Stateful Method of Token Generation)** and **Section 5.2 (A Stateless Method of Token Generation)**, but they only serve as examples.

The following lists the requirements from a token generation mechanism:

- Tokens should be at least 16 octets log, and no more than 256 octets long, to facilitate storage.
- It should not be possible for an external attacker to guess the QCR token generated by an implementation. Cryptographic mechanisms such as PRNG and hash functions are RECOMMENDED.
- The peer that generated the QCR token, should be able to immediately verify it, provided that the IKE SPIs are given, and that the IKE SA has not expired or been otherwise deleted.

5.1. A Stateful Method of Token Generation

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This describes a stateful method of generating a token:

- Before sending the QCR token, 32 random octets are generated using a secure random number generator or a PRNG.
- Those 32 bytes are used as the TOKEN_SECRET_DATA field, and stored as part of the IKE SA.
- For verification, the IKE implementation simply retrieves the IKE SA, and compares the TOKEN_SECRET_DATA field from the notification to the TOKEN_SECRET_DATA field stored with the SA.

5.2. A Stateless Method of Token Generation

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This describes a stateless method of generating a token.

- At startup, the IKE implementation generates a 32-octet random buffer using a cryptographically secure PRNG. This buffer is called the QCR_SECRET.
- For each QCR token, the TOKEN_SECRET_DATA field is generated by calculating a SHA-256 hash over a concatenation of the QCR_SECRET and the IKE SPI as follows:

```
TOKEN_SECRET_DATA = HASH(QCR_SECRET | SPI-I | SPI-R)
```

- Verification uses the same calculation, and works even if the IKE SA has been deleted. Still, if the IKE SA is no longer valid, the notification MUST NOT be acknowledged, as this could be used in an attempt to guess the QCR_SECRET.

5.3. Token Lifetime

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The token is associated with a single IKE SA, and SHOULD be deleted when the SA is deleted or expires. More formally, the token is associated with the pair (SPI-I, SPI-R).

6. Alternative Solutions

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6.1. Why not Save the Entire IKE SA

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IKEv2 does not assume the existence of a persistent storage module. If we are adding such a module, why not use it to save the entire IKE SA across reboots, nullifying the need for a crash recovery procedure?

There are several reasons why we believe that this is not a good idea:

1. A token is only 16-256 octets, and is much more compact than all the data needed to store an IKE SA.
2. A token is valid for the life of an IKE SA. An IKE SA state is updated whenever a message is sent, becuase of the requirement to keep the sequence of message IDs. It may not be acceptable to update the persistent storage whenever an IKE message is sent.
3. A reboot is usually an unpredictable event, and as such, we cannot know how long it will last. By the time the machine has rebooted, the peer may have attempted some type of protected exchange (liveness check, create-child-SA or delete), timed out, and deleted the SA. It is far better to reboot without SAs and with only a token for quick recovery.

6.2. Initiating a new IKE SA

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Instead of sending a QCR token, we could have the rebooted implementation start an Initial exchange with the peer, including the INITIAL_CONTACT notification. This would have the same effect, instructing the peer to erase the old IKE SA, as well as establishing a new IKE SA with fewer rounds.

The disadvantage here, is that in IKEv2 an authentication exchange MUST have a piggy-backed Child SA set up. Since our use case is such that the rebooted implementation does not have traffic flowing to the peer, there are no good selectors for such a child SA.

Additionally, when authentication is assymetric, such as when EAP is used, it is not possible for the rebooted implementation to initiate IKE.

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7. Operational Considerations

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To support this standard, an implementation needs to have access to a persistent storage module. This could be an internal hard disk, a local or remote database application, or any other method that persists across reboots. This storage module and the data links between the storage module and the IKE module must meet the performance requirements of the IKE module. The storage module MUST support insertion and deletion rates equal to peek IKE SA setup rates and it SHOULD support query rates that are fast enough.

See **Section 8 (Security Considerations)** for security considerations for this storage mechanism.

In order to limit the effects of DoS attacks, an implementation SHOULD limit the rate of queries into the token storage so as not to overload it. If excessive amounts of IKE requests protected with unknown IKE SPIs arrive, the IKE module SHOULD revert to the behavior described in section 2.21 of **[RFC4306] (Kaufman, C., "Internet Key Exchange (IKEv2) Protocol," December 2005.)** and either send an INVALID_IKE_SPI notification, or ignore it entirely.

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8. Security Considerations

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Tokens MUST be hard to guess. This is critical, because if an attacker can guess the token associated with the IKE SA, she can tear down the IKE SA and associated tunnels at will. When the token is delivered in the IKE_AUTH exchange, it is encrypted. When it is sent back in an informational exchange it is not encrypted, but that is the last use of that token.

An aggregation of some tokens generated by one peer together with the related IKE SPIs MUST NOT give an attacker the ability to guess other tokens. Specifically, if one peer does not properly secure the QCR tokens and an attacker gains access to them, this attacker MUST NOT be able to guess other tokens generated by the same peer. This is the reason that the QCR_SECRET in **Section 5.2 (A Stateless Method of Token Generation)** needs to be long.

The persistent storage MUST be protected from access by other parties. Anyone gaining access to the contents of the storage will be able to delete all the IKE SAs described in it.

The tokens associated with expired and deleted IKE SAs MUST be deleted from the storage, so that a future compromise of the storage does not reveal enough tokens to facilitate an attack against the QCR tokens.

The QCR token is sent by the rebooted peer in an unprotected message. A message like that is subject to modification, deletion and replay by an attacker. However, these attacks will not compromise the security of either side. Modification is meaningless because a modified token is simply an invalid token. Deletion will only cause the protocol not to work, resulting in a delay in tunnel re-establishment as described in **Section 2 (RFC 4306 Crash Recovery)**. Replay is also meaningless, because the IKE SA has been deleted after the first transmission.

9. IANA Considerations

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IANA is requested to assign a notify message type from the error types range (43-8191) of the "IKEv2 Notify Message Types" registry with name "QUICK_CRASH_RECOVERY".

10. Normative References

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[RFC2119] **Bradner, S.**, "**Key words for use in RFCs to Indicate Requirement Levels**," BCP 14, RFC 2119, March 1997 (**TXT**, **HTML**, **XML**).

[RFC4306] Kaufman, C., "**Internet Key Exchange (IKEv2) Protocol**," RFC 4306, December 2005 (**TXT**, **HTML**, **XML**).

[RFC4718] Eronen, P. and P. Hoffman, "**IKEv2 Clarifications and Implementation Guidelines**," RFC 4718, October 2006 (**TXT**, **HTML**, **XML**).

[resumption] Sheffer, Y., Tschofenig,H., Dondeti, L., and V. Narayanan, "**IPsec Gateway Failover Protocol**," draft-sheffer-ipsec-failover-02 (work in progress), November 2007.

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