IKEv2 Mobility and Multihoming
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Design of the MOBIKE Protocol
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Abstract

The MOBIKE (IKEv2 Mobility and Multihoming) working group is developing protocol extensions to the Internet Key Exchange Protocol version 2 (IKEv2) to enable its use in the context where there are multiple IP addresses per host or where IP addresses of an IPsec host change over time (for example, due to mobility).

This document discusses the involved network entities, and the relationship between IKEv2 signaling and information provided by other protocols and the rest of the network. Design decisions for the base MOBIKE protocol, background information and discussions within the working group are recorded.

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1. Introduction

IKEv2 is used for performing mutual authentication and establishing and maintaining IPsec security associations (SAs). IKEv2 establishes both cryptographic state (such as session keys and algorithms) as well as non-cryptographic information (such as IP addresses).

The current IKEv2 and IPsec documents explicitly say that the IPsec and IKE SAs are created implicitly between the IP address pair used during the protocol execution when establishing the IKEv2 SA. This means that there is only one IP address pair stored for the IKEv2 SA, and this single IP address pair is used as an outer endpoint address for tunnel mode IPsec SAs. After the IKE SA is created there is no way to change them.

There are scenarios where this IP address might change, even frequently. In some cases the problem could be solved by rekeying all the IPsec and IKE SAs after the IP address has changed. However, this can be problematic, as the device might be too slow to rekey the SAs that often, and other scenarios the rekeying and required IKEv2 authentication might require user interaction (SecurID cards etc). Due to these reasons, a mechanism to update the IP addresses tied to the IPsec and IKEv2 SAs is needed. MOBIKE provides solution to the problem of the updating the IP addresses stored with IKE SAs and IPsec SAs.

The charter of the MOBIKE working group requires IKEv2 [I-D.ietf-ipsec-ikev2], and as IKEv2 assumes that the RFC2401bis architecture [I-D.ietf-ipsec-rfc2401bis] is used, all protocols developed will use both IKEv2 and RFC2401bis. MOBIKE does not support IKEv1 [RFC2409] or the old RFC2401 architecture [RFC2401].

This document is structured as follows. After introducing some important terms in Section 2 we list a few scenarios in Section 3, to illustrate possible deployment environments. MOBIKE depends on information from other sources (e.g., detect an address change) which

are discussed in Section 4. Finally, Section 5 discusses design considerations effecting the MOBIKE protocol. The document concludes with security considerations in Section 6.

2. Terminology

This section introduces some useful terms for a MOBIKE protocol.

Peer:

Within this document we refer to IKEv2 endpoints as peers. A peer implements MOBIKE and therefore IKEv2.

Available address:

An address is said to be available if the following conditions are fulfilled:

* The address has been assigned to an interface of the node.
* If the address is an IPv6 address, we additionally require that (a) the address is valid in the sense of RFC 2461 [RFC2461], and that (b) the address is not tentative in the sense of RFC 2462 [RFC2462]. In other words, the address assignment is complete so that communications can be started.

  Note this explicitly allows an address to be optimistic in the sense of [I-D.ietf-ipv6-optimistic-dad] even though implementations are probably better off using other addresses as long as there is an alternative.
* The address is a global unicast or unique site-local address [I-D.ietf-ipv6-unique-local-addr]. That is, it is not an IPv6 link-local or site-local address. Where IPv4 is considered, it is not an RFC 1918 [RFC1918] address.
* The address and interface is acceptable for use according to a

local policy.
This definition is reused from
[I-D.arkko-multi6dt-failure-detection]

.

Locally Operational Address:

An available address is said to be locally operational when its use is known to be possible locally. This definition is taken from [I-D.arkko-multi6dt-failure-detection].

Operational address pair:

A pair of operational addresses are said to be an operational address pair, iff bidirectional connectivity can be shown between the two addresses. Note that sometimes it is necessary to consider a 5-tuple when connectivity between two endpoints need to be tested. This differentiation might be necessary to address load balancers, certain Network Address Translation types or

specific firewalls. This definition is taken from [I-D.arkko-multi6dt-failure-detection] and enhanced to fit the MOBIKE context. Although it is possible to further differentiate unidirectional and bidirectional operational address pairs only bidirectional connectivity is relevant for this document and unidirectional connectivity is out of scope.

Path:

The route taken by the MOBIKE and/or IPsec packets sent via the IP address of one peer to a specific destination address of the other peer. Note that the path might be effected not only by the source and destination IP addresses but also by the selected transport protocol and transport protocol identifier. Since MOBIKE and IPsec packets have a different appearance on the wire they might be routed along a different path. This definition is taken from [RFC2960] and modified to fit the MOBIKE context.

Primary Path:

The primary path is the destination and source address that will be put into a packet outbound to the peer by default. This

definition is taken from [RFC2960] and modified to fit the MOBIKE context.

Preferred Address:

An address on which a peer prefers to receive MOBIKE messages and IPsec protected data traffic. A given peer has only one active preferred address at a given point in time (ignoring the small time period where it needs to switch from the old preferred address to a new preferred address). This definition is taken from [I-D.ietf-hip-mm] and modified to fit the MOBIKE context.

Peer Address Set:

We denote the two peers in this Mobike session by peer A and peer B. A peer address set is a subset of locally operational addresses of peer A that are sent to peer B. A policy available at peer A indicates which addresses to include in the peer address set. Such a policy might be impacted by manual configuration or by interaction with other protocols that indicate new available addresses.

Terminology for different NAT types, such as Full Cone, Restricted Cone, Port Restricted Cone and Symmetric, can be found in Section 5 of [RFC3489]. For mobility related terminology, such as

Make-before-break or Break-before-make see [RFC3753].

3. Scenarios

The MOBIKE protocol can be used in different scenarios. Three of them are discussed below.

3.1 Mobility Scenario

Figure 1 shows a break-before-make mobility scenario where a mobile

node attaches to, for example a wireless LAN, to obtain connectivity to some security gateway. This security gateway might connect the mobile node to a corporate network, to a 3G network or to some other network. The initial IKEv2 exchange takes place along the path labeled as 'old path' from the MN using its old IP address via the old access router (OAR) towards the security gateway (GW). The IPsec tunnel mode terminates there but the decapsulated data packet will typically address another destination. Since only MOBIKE communication from the MN to the gateway is relevant for this discussion the end-to-end communication between the MN and some destination is not shown in Figure 1.

When the MN moves to a new network and obtains a new IP address from a new access router (NAR) it is the responsibility of MOBIKE to avoid restarting the IKEv2 exchange from scratch. As a result, a protocol exchange, denoted by 'MOBIKE Address Update' , will perform the necessary state update.

Note that in a break-before-make mobility scenario the MN obtains a new IP address after reachability to the old IP address has been lost. MOBIKE is also assumed to work in scenarios where the mobile node is able to establish connectivity with the new IP address while still being reachable at the old IP address.

(Initial IKEv2 Exchange)

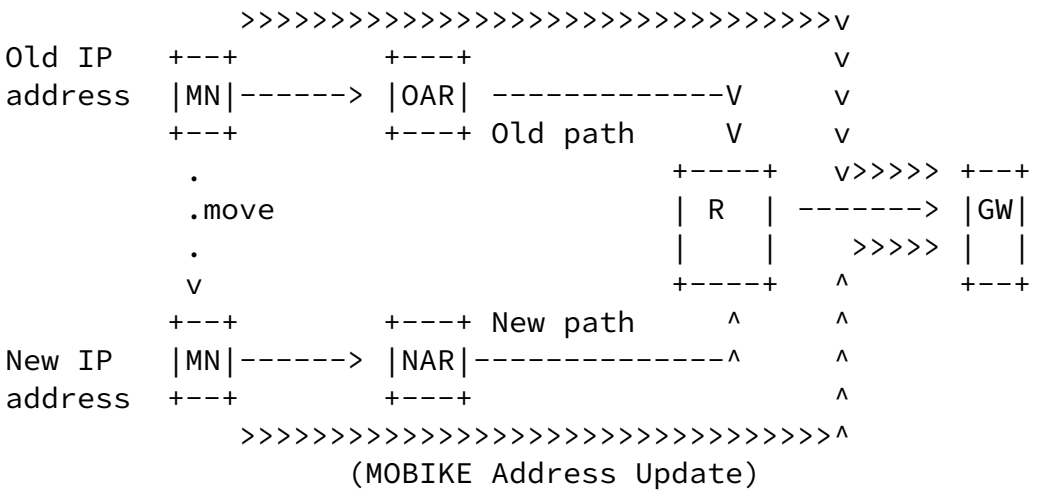


Figure 1: Mobility Scenario

3.2 Multihoming Scenario

Another scenario where MOBIKE might be used is between two peers equipped with multiple interfaces (and multiple IP addresses). Figure 2 shows two such multi-homed peers. Peer A has two interface cards with two IP addresses IP_A1 and IP_A2. Additionally, Peer B also has two IP addresses, IP_B1 and IP_B2. Each peer selects one of its IP addresses as the preferred address which will subsequently be used for communication. Various reasons, such as problems with the interface card, might require a peer to switch from one IP address to the other one.

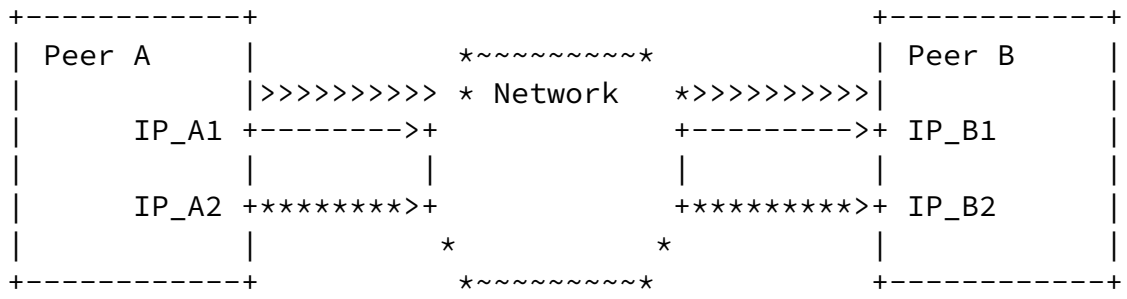


Figure 2: Multihoming Scenario

Note that MOBIKE does not support load balancing between multiple IP addresses. That is, each peer uses only one of the available IP addresses at a given point in time.

3.3 Multihomed Laptop Scenario

In the multihomed laptop scenario we consider a laptop, which has multiple interface cards and therefore several ways to connect to a network. It might for example have a fixed Ethernet, WLAN, GPRS, Bluetooth or USB hardware in order to send IP packets. A number of interfaces might connected to a network over time depending on a number of reasons (e.g., cost, availability of certain link layer technologies, user convenience). Note that a policy for selecting a network interface based on cost, etc. is out of scope for MOBIKE. For example, the user can disconnect himself from the fixed Ethernet, use the office WLAN, and then later leave the office and start using GPRS during the trip home. At home he might use WLAN. At a certain point in time multiple interfaces might be connected. As such, the laptop is a multihomed device. In any case, the IP address of the individual interfaces are subject to change.

The user desires to keep the established IKE-SA and IPsec SAs alive all the time without the need to re-run the initial IKEv2 exchange which could require user interaction as part of the authentication process. Furthermore, even if IP addresses change due to interface switching or mobility, the IP source and destination address obtained via the configuration payloads within IKEv2 and used inside the IPsec tunnel remains unaffected, i.e., applications might not detect any change at all.

4. Framework

The working group will develop a MOBIKE protocol which needs to perform the following functionality:

- Ability to inform the other peer about the peer address set
- Ability to inform the other peer about the preferred address
- Ability to test connectivity along a path and thereby to detect an outage situation
- Ability to change the preferred address
- Ability to change the peer address set
- Ability to deal with Network Address Translation devices

The technical details of these functions are discussed below. Although the interaction with other protocols is important for MOBIKE to operate correctly the working group is chartered to leave this aspect outside the scope.

When a MOBIKE peer initiates a protocol exchange with its MOBIKE peer it needs to define a peer address set based on the available addresses. It might want to make this peer address set available to the other peer. The Initiator does not need to explicitly indicate its preferred address since it is already using its preferred address. The outgoing IKEv2 and MOBIKE messages use this preferred address as the source IP address and the MOBIKE peer expects incoming signaling messages to be sent to this address. Interaction with other protocols at the MOBIKE host is required to build the peer address set and the preferred address. In some cases the peer address set is available before the initial protocol exchange and does not change during the lifetime of the IKE-SA. The preferred address might change due to policy reasons. Section 3 describes three scenarios in which the peer address set is modified (by adding or deleting addresses). In these scenarios the preferred address needs to be changed as well.

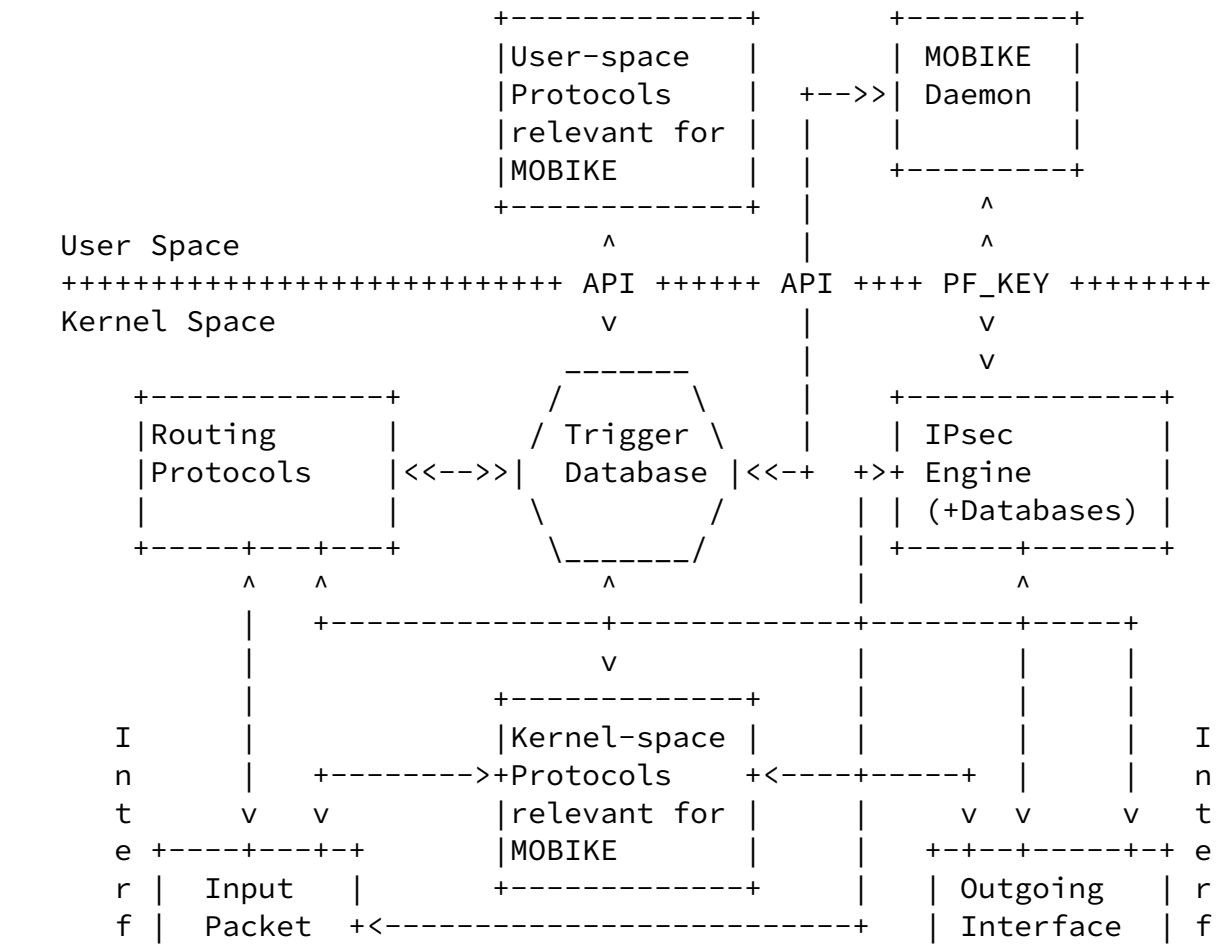
Modifying the peer address set or changing the preferred address is effected by the host's local policy and by the interaction with other protocols (such as DHCP or IPv6 Neighbor Discovery).

Figure 3 shows an example protocol interaction at a MOBIKE peer.

MOBIKE interacts with the IPsec engine using the PF_KEY interface [RFC2367] to create entries in the Security Association and Security Policy Databases. The IPsec engine might also interact with IKEv2 and MOBIKE. Established state at the IPsec databases has an impact on the incoming and outgoing data traffic. MOBIKE receives information from other protocols running in both kernel-mode and user-mode, as previously mentioned. Information relevant for MOBIKE is stored in a database, referred as Trigger database, that guides MOBIKE in its decisions regarding the available addresses, peer

address set, and the preferred address. Policies might affect the selection process.

Building and maintaining a peer address set and selecting or changing a preferred address based on locally available information is, however, insufficient. This information needs to be available to the other peer and in order to address various failure cases it is necessary to test connectivity along a path. A number of address pairs might be available for connectivity tests but most important are the source and the destination IP address of the primary path since these addresses are selected for sending and receiving MOBIKE signaling messages and for sending and receiving IPsec protected data traffic. If a problem along this primary path is detected (e.g., due to a router failure) it is necessary to switch to the new primary path. Optionally, periodic testing of other paths might be useful to determine when a disconnected path becomes operational.


User-space
Protocols
relevant for
MOBIKE
MOBIKE
Daemon
User Space
API
API
PF_KEY
Kernel Space
Routing
Protocols
Trigger
Database
IPsec
Engine
(+Databases)
Kernel-space
Protocols
relevant for
MOBIKE
Input
Packet
Outgoing
Interface
Internet

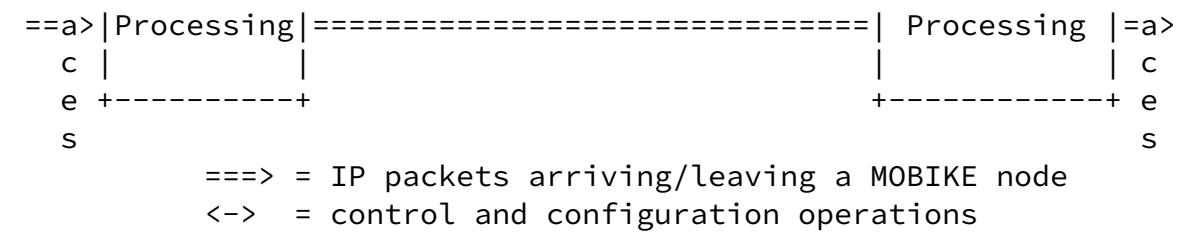


Figure 3: Framework

Please note that Figure 3 is only one way of implementing MOBIKE. Hence, it serves illustrative purposes only.

Extensions of the PF_KEY interface required by MOBIKE are also within the scope of the working group. Finally, optimizations in wireless environment will also be covered.

5. Design Considerations

This section discusses aspects affecting the design of the MOBIKE protocol.

5.1 Indicating Support for MOBIKE

In order for MOBIKE to function correctly, both peers must implement this extension. We propose extensions to IKEv2 described below for MOBIKE support. If only one peer supports MOBIKE, then the peers will just run IKEv2. Specifically, a node needs to be able to guarantee that its address change messages are understood by its corresponding peer. Otherwise an address change may render the connection useless, and it is important that both sides realize this as early as possible.

Ensuring that the messages are understood can in be arranged either by marking some IKEv2 payloads critical so that they are either

processed or an error message is returned, by using Vendor ID payloads or via a Notify.

The first solution approach is to use Vendor ID payloads during the initial IKEv2 exchange using a specific string denoting MOBIKE to signal the support of the MOBIKE protocol. This ensures that in all cases a MOBIKE capable node knows whether its peer supports MOBIKE or not.

The second solution approach uses the Notify payload which is also used for NAT detection (via NAT_DETECTION_SOURCE_IP and NAT_DETECTION_DESTINATION_IP).

Both a Vendor ID and a Notify payload might be used to indicate the support of certain extensions.

Note that the node could also attempt MOBIKE opportunistically with the critical bit set when an address change has occurred. The drawback of this approach is, however, that the an unnecessary MOBIKE message exchange is introduced.

Although Vendor ID payloads and Notifications are technically equivalent Notifications are already used in IKEv2 as a capability negotiation mechanism and is therefore the preferred mechanism.

5.2 Changing a Preferred Address and Multihoming Support

From MOBIKE's point of view multihoming support is integrated by supporting a peer address set rather than a single address and protocol mechanisms to change to use a new preferred IP address.

From a protocol point of view each peer needs to learn the preferred address and the peer address set either implicitly or explicitly.

5.2.1 Storing a single or multiple addresses

One design decision is whether an IKE-SA should store a single IP address or multiple IP addresses as part of the peer address set. One option is that the other end can provide a list of addresses which can be used as destination addresses. MOBIKE does not support load balancing, i.e., only one IP address is set to a preferred address at a time and changing the preferred address typically

requires some MOBIKE signaling.

Another option is to only communicate one address to the other peer and both peers only use that address when communicating. If this preferred address cannot be used anymore then an address update is sent to the other peer changing the preferred address.

If peer A provides a peer address set with multiple IP addresses then peer B can recover from a failure of the preferred address on its own, meaning that when it detects that the primary path does not work anymore it can either switch to a new preferred address locally (i.e., causing the source IP address of outgoing MOBIKE messages to have a non-preferred address) or try an IP address from A's peer address set. If peer B only received a single IP address as the A's peer address set then peer B can only change its own preferred address. The other end has to wait for an address update from peer A with a new IP address in order to fix the problem. The main advantage about using a single IP address for the remote host is that it makes retransmission easy, and it also simplifies the recovery procedure. The peer, whose IP address changed, must start the recovery process and send the new IP address to the other peer. Failures along the path are not well covered with advertising a single IP address.

The single IP address approach will not work if both peers happen to loose their IP address at the same time (due to, say, the failure of one of the links that both nodes are connected to). It may also require the IKEv2 window size to be larger than 1, especially if only direct indications are used. This is because the host needs to be able to send the IP address change notifications before it can switch to another address, and depending on the return routability checks, retransmissions policies etc, it might be hard to make the protocol such that it works with window size of 1 too. Furthermore, the single IP address approach does not really benefit much from indirect indications as the peer receiving these indications might not be able to fix the situation by itself (e.g., even if a peer receives an ICMP host unreachable message for the old IP address, it cannot try other

IP addresses, since they are unknown).

The problems with IP address lists are mostly in its complexity. Notification and recovery processes are more complex. Both ends can

recover from the IP address changes. However, both peers should not attempt to recover at the same time or nearly the same time as it could cause them to lose connectivity. The MOBIKE protocol is required to prevent this.

The previous discussion is independent of the question of how many addresses to send in a single MOBIKE message. A MOBIKE message might be able to carry more than one IP address (with the IP address list approach) or a single address only. The latter approach has the advantage of dealing with NAT traversal in a proper fashion. A NAT cannot change addresses carried inside the MOBIKE message but it can change IP address (and transport layer addresses) in the IP header and Transport Protocol header (if NAT traversal is enabled). Furthermore, a MOBIKE message carrying the peer address set could be idempotent (i.e., always resending the full address list) or the protocol may allow add/delete operations to be specified. [I-D.dupont-ikev2-addrmgmt], for example, offers an approach which defines add/delete operations. The same is true for the dynamic address reconfiguration extension for SCTP [I-D.ietf-tsvwg-addip-sctp].

5.2.2 Indirect or Direct Indication

An indication to change the preferred IP address might be either direct or indirect.

Direct indication:

A direct indication means that the other peer will send an message with the address change. Such a message can, for example, accomplished by having MOBIKE sending an authenticated address update notification with a different preferred address.

Indirect indication:

An indirect indication to change the preferred address can be obtained by observing the environment. An indirect indication might, for example, be be the receipt of an ICMP message or information of a link failure. This information should be seen as a hint and might not directly cause any changes to the preferred address. Depending on the local policy MOBIKE might decide to perform a dead-peer detection exchange for the preferred address pair (or another address pair from the peer address set). When a peer detects that the other end started to use a different source

IP address than before, it might want to authorize the new preferred address (if not already authorized). A peer might also start a connectivity test of this particular address. If a bidirectionally operational address pair is selected then MOBIKE needs to communicate this new preferred address to its remote peer.

MOBIKE will utilize both mechanisms, direct and indirect indications, to make a more intelligent decision which address pair to select as the preferred address. The more information will be available to MOBIKE the faster a new primary path can be selected among the available candiates.

5.2.3 Connectivity Tests using IKEv2 Dead-Peer Detection

This section discusses the suitability of the IKEv2 dead-peer detection (DPD) mechanism for connectivity tests between address pairs. The basic IKEv2 DPD mechanism is not modified by MOBIKE but it needs to be investigated whether it can be used for MOBIKE purposes as well.

The IKEv2 DPD mechanism is done by sending an empty informational exchange packet to the other peer, in which case the other end will respond with an acknowledgement. If no acknowledgement is received after a certain timeout (and after couple of retransmissions), the other peer is considered to be not reachable. Note that the receipt of IPsec protected data traffic is also a guarantee that the other peer is alive.

When reusing dead-peer detection in MOBIKE for connectivity tests it seems to be reasonable to try other IP addresses (if they are available) in case of an unsuccessful connectivity test for a given address pair. Dead-peer detection messages using a different address pair should use the same message-id as the original dead-peer detection message (i.e. they are simply retransmissions of the dead-peer detection packet using different destination IP address). If different message-id is used then it violates constraints placed by the IKEv2 specification on the DPD message with regard to the mandatory ACK for each message-id, causing the IKEv2 SA to be deleted.

If MOBIKE strictly follows the guidelines of the dead-peer detection mechanism in IKEv2 then an IKE-SA should be marked as dead and deleted if the connectivity test for all address pairs fails. Note that this is not in-line with the approach used, for example, in SCTP where a failed connectivity test for an address does not lead to (a) the IP address or IP address pair to be marked as dead and (b) delete

state. Connectivity tests will be continued for the address pairs in

hope that the problem will recover soon.

Note that as IKEv2 implementations might have window size of 1, which prevents it from initiating a dead-peer detection exchange while doing another exchange. As a result, all other exchanges experience the identical retransmission policy as used for the dead-peer detection.

The dead-peer detection for the other IP address pairs can also be executed simultaneously (with a window size larger than 1), meaning that after the initial timeout of the preferred address expires, we send packets simultaneously to all other address pairs. It is necessary to differentiate individual acknowledgement messages in order to determine which address pair is operational. Therefore the source IP address of the acknowledgement should match the destination IP towards the message that was previously sent.

Also the other peer is most likely going to reply only to the first packet it receives, and that first packet might not be the best (by whatever criteria) address pair. The reason the other peer is only responding to the first packet it receives is that implementations should not send retransmissions if they have just sent out an identical response message. This is to protect the packet multiplication problem, which can happen if some node in the network queues up packets and then sends them to the destination. If the destination were to reply to all of them then the other end will again see multiple packets, and will reply to all of them, etc.

The protocol should also be nice to the network, meaning, that when some core router link goes down, and a large number of MOBIKE clients notice it, they should not start sending a large number of messages while trying to recover from the problem. This might be especially bad because packets are dropped because of the congested network. If MOBIKE clients simultaneously try to test all possible address pairs by executing connectivity tests then the congestion problem only gets worse.

Also note that the IKEv2 dead-peer detection is not sufficient for the return routability check. See Section 5.6 for more information.

5.3 Simultaneous Movements

MOBIKE does not aim to provide a full mobility solution which allows simultaneous movements. Instead, the MOBIKE working group focuses on selected scenarios as described in Section 3. Some of the scenarios assume that one peer has a fixed set of addresses (from which some subset might be in use). Thus it cannot move to the address unknown to the other peer. Situations in which both peers move and the

movement notifications cannot reach the other peer are outside the scope of the MOBIKE WG. MOBIKE has not being chartered to deal with the rendezvous problem, or with the introduction of any new entities in the network.

Note that if only a single address is stored in the peer address set (instead of an address list) we might end up in the case where it seems that both peers changed their addresses at the same time. This is something that the protocol must deal with.

Three cases can be differentiated:

- Two mobile nodes obtain a new address at the same time, and then being unable to tell each other where they are (in a break-before-make scenario). This problem is called the rendezvous problem, and is traditionally solved by introducing another third entity, for example, the home agents (in Mobile IPv4/IPv6) or forwarding agents (in Host Identity Protocol). Essentially, solving this problem requires the existence of a stable infrastructure node somewhere.

- Simultaneous changes to addresses such that at least one of the new addresses is known to the other peer before the change occurred.

- No simultaneous changes at all.

5.4 NAT Traversal

IKEv2 has support of legacy NAT traversal built-in. This feature is known as NAT-T which allows IKEv2 to work even if a NAT along the path between the Initiator and the Responder modified the source and possibly the destination IP address. With NAPT even the transport

protocol identifiers are modified (which then requires UDP encapsulation for subsequent IPsec protected data traffic). Therefore, the required IP address information is taken from the IP header (if a NAT was detected who rewrote IP header information) rather than from the protected payload. This problem is not new and was discovered during the design of mobility protocol where the only valuable information is IP address information.

One of the goals in the MOBIKE protocol is to securely exchange one or more addresses of the peer address set and to securely set the primary address. If no other protocol is used to securely retrieve the IP address and port information allocated by the NAT then it is not possible to tackle all attacks against MOBIKE. Various solution approaches have been presented:

- Securely retrieving IP address and port information allocated by the NAT using a protocol different from MOBIKE. This approach is outside the scope of the MOBIKE working group since other working groups, such as MIDCOM and NSIS, already deal with this problem. The MOBIKE protocol can benefit from the interaction with these protocols.

- Design a protocol in such a way that NAT boxes are able to inspect (or even participate) in the protocol exchange. This approach was taken with HIP but is not an option for IKEv2 and MOBIKE.

- Disable NAT-T support by indicating the desire never to use information from the (unauthenticated) header. While this approach prevents some problems it effectively disallows the protocol to work in certain environments.

There is no way to distinguish the cases where there is NAT along the path that modifies the header information in packets or whether an adversary mounts an attack. If NAT is detected in the IKE SA creation, that should automatically disable the MOBIKE extensions and use NAT-T.

A design question is whether NAT detection capabilities should be enabled only during the initial exchange or even at subsequent message exchanges. If MOBIKE is executed with no NAT along the path when the IKE SA was created, then a NAT which appears after moving to

a new network cannot be dealt with if NAT detection is enabled only during the initial exchange. Hence, it might be desirable to also support a scenario where a MOBIKE peer moves from a network which does not deploy a NAT to a network which uses a private address space.

A NAT prevention mechanism can be used to make sure that no adversary can interact with the protocol if no NAT is expected between the Initiator and the Responder.

The support for NAT traversal is certainly one of the most important design decisions with an impact on other protocol aspects.

5.5 Changing addresses or changing the paths

A design decision is whether it is enough for the MOBIKE protocol to detect dead address, or does it need to detect also dead paths. Dead address detection means that we only detect that we cannot get packets through to that remote address by using the local IP address given by the local IP-stack (i.e., local address selected normally by the routing information). Dead path detection means that we need to try all possible local interfaces/IP addresses for each remote

addresses, i.e., find all possible paths between the hosts and try them all to see which of them work (or at least find one working path).

While performing just an address change is simpler, the existence of locally operational addresses are not, however, a guarantee that communications can be established with the peer. A failure in the routing infrastructure can prevent the sent packets from reaching their destination. Or a failure of an interface on one side can be related to the failure of an interface on the other side, making it necessary to change more than one address at a time.

5.6 Return Routability Tests

Setting a new preferred address which is subsequently used for communication is associated with an authorization decision: Is a peer allowed to use this address? Does this peer own this address? Two mechanisms have been proposed in the past to allow a peer to determine the answer to this question:

- The addresses a peer is using are part of a certificate. [RFC3554] introduced this approach. If the other peer is, for example, a security gateway with a limited set of fixed IP addresses, then the security gateway may have a certificate with all the IP addresses in the certificate.

- A return routability check is performed before the address is used to ensure that the peer is reachable at the indicated address.

Without performing an authorization decision a malicious peer can redirect traffic towards a third party or a blackhole.

An IP address should not be used as a primary address without computing the authorization decision. If the addresses are part of the certificate then it is not necessary to execute the weaker return routability test. If multiple addresses are communicated to another peer as part of the peer address set then some of these addresses might be already verified even if the primary address is still operational.

Another option is to use the [I-D.dupont-mipv6-3bombing] approach which suggests to do a return routability test only if you have to send an address update from some other address than the indicated preferred address.

Finally it would be possible not to execute return routability checks at all. In case of indirect change notifications then we only move to the new preferred address after successful dead-peer detection on

the new address, which is already a return routability check. With a direct notifications the authenticated peer may have provided an authenticated IP address, thus we could simply trust the other end. There is no way external attacker can cause any attacks, but we are not protected from the internal attacker, i.e. the authenticated peer forwarding its traffic to the new address. On the other hand we do know the identity of the peer in that case.

As such, it seems that there it is also a policy issue when to schedule a return routability test.

The basic format of the return routability check could be similar to

dead-peer detection, but the problem is that if that fails then the IKEv2 specification requires the IKE SA to be deleted. Because of this we might need to do some kind of other exchange.

There are potential attacks if a return routability check does not include some kind of nonce. In this attack the valid end point sends address update notification for the third party, trying to get all the traffic to be sent there, causing a denial of service attack. If the return routability checks does not contain any cookies or other random information not known by the other end, then that valid node could reply to the return routability checks even when it cannot see the request. This might cause the other end to turn the traffic to there, even when the true original recipient cannot be reached at this address.

The IKEv2 NAT-T mechanism does not perform any return routability checks. It simply uses the last seen source IP address used by the other peer as the destination address to send response packets. An adversary can change those IP addresses, and can cause the response packets to be sent to wrong IP address. The situation is self-fixing when the adversary is no longer able to modify packets and the first packet with true IP address reaches the other peer. In a certain sense mobility handling makes this attack difficult for an adversary since it needs to be located somewhere along the path where the individual paths ({CoA1, ..., CoAn} towards the destination IP address) have a shared path or if the adversary is located near the MOBIKE client then it needs to follow the users mobility patterns. With IKEv2 NAT-T, the genuine client can cause third party bombing by redirecting all the traffic pointed to him to third party. As the MOBIKE protocol tries to provide equal or better security than IKEv2 NAT-T the MOBIKE protocol should protect against these attacks.

There might be also return routability information available from the other parts of the system too (as shown in Figure 3), but the checks done might have a different quality. There are multiple levels for return routability checks:

- None, no tests
- A party willing to answer is on the path to the claimed address. This is the basic form of return routability test.
- There is an answer from the tested address, and that answer was authenticated (including the address) to be from our peer.

- o There was an authenticated answer from the peer, but it is not guaranteed to be from the tested address or path to it (because the peer can construct a response without seeing the request).

The basic return routability checks do not protect against 3rd party bombing if the attacker is along the path, as the attacker can forward the return routability checks to the real peer (even if those packets are cryptographically authenticated).

If the address to be tested is inside the MOBIKE packet too, then the adversary cannot forward packets, thus it prevents 3rd party bombings.

If the reply packet can be constructed without seeing the request packet (for example, if there is no nonce, challenge or similar mechanism to show liveness), then the genuine peer can cause 3rd party bombing, by replying to those requests without seeing them at all.

Other levels might only provide information that there is someone at the IP address which replied to the request. There might not be an indication that the reply was freshly generated or repeated, or the request might have been transmitted from a different source address.

Requirements for a MOBIKE protocol for the return routability test might be able to verify that there is the same (cryptographically) authenticated node at the other peer and it can now receive packets from the IP address it claims to have.

5.7 Employing MOBIKE results in other protocols

If MOBIKE has learned about new locations or verified the validity of an address through a return routability test, can this information be useful for other protocols?

When considering the basic MOBIKE VPN scenario, the answer is no. Transport and application layer protocols running inside the VPN tunnel have no consideration about the outer addresses or their status.

Similarly, IP layer tunnel termination at a gateway rather than a host endpoint limits the benefits for "other protocols" that could be

informed -- all application protocols at the other side are running in a node that is unaware of IPsec, IKE, or MOBIKE.

However, it is conceivable that future uses or extensions of the MOBIKE protocol make such information distribution useful. For instance, if transport mode MOBIKE and SCTP were made to work together, it would likely be useful for SCTP to learn about the new addresses at the same time as MOBIKE learns them. Similarly, various IP layer mechanisms might make use of the fact that a return routability test of a specific type has already been performed. However, in all of these cases careful consideration should be applied. This consideration should answer to questions such as whether other alternative sources exist for the information, whether dependencies are created between parts that prior to this had no dependencies, and what the impacts in terms of number of messages or latency are.

[I-D.crocker-celp] discussed the use of common locator information pools in IPv6 multihoming context; it assumed that both transport and IP layer solutions would be used for providing multihoming, and that it would be beneficial for different protocols to coordinate their results in some manner, for instance by sharing experienced throughput information for address pairs. This may apply to MOBIKE as well, assuming it co-exists with non-IPsec protocols that are faced with the same multiaddressing choices.

Nevertheless, all of this is outside the scope of current MOBIKE base protocol design and may be addressed in future work.

5.8 Scope of SA changes

Most sections of this document discuss design considerations for updating and maintaining addresses for the IKE-SA. However, changing the preferred address also has an impact for IPsec SAs. The outer tunnel header addresses (source IP and destination IP addresses) need to be modified according to the primary path to allow the IPsec protected data traffic to travel along the same path as the MOBIKE packets (if we only consider the IP header information).

The basic question is then how the IPsec SAs are changed to use the new address pair (the same address pair as the MOBIKE signaling traffic -- the primary path). One option is that when the IKE SA address is changed then automatically all IPsec SAs associated with it are moved along with it to new address pair. Another option is to have a separate exchange to move the IPsec SAs separately.

If IPsec SAs should be updated separately then a more efficient format than notification payload is needed. A notification payload

can only store one SPI per payload. A separate payload which would have list of IPsec SA SPIs and new preferred address. If there are large number of IPsec SAs, those payloads can be quite large unless ranges of SPI values are supported. If we automatically move all IPsec SAs when the IKE SA moves, then we only need to keep track which IKE SA was used to create the IPsec SA, and fetch the IP addresses. Note that IKEv2 [I-D.ietf-ipsec-ikev2] already requires implementations to keep track which IPsec SAs are created using which IKE SA.

If we do allow each IPsec SAs address set to be updated separately, then we can support scenarios, where the machine has fast and/or cheap connections and slow and/or expensive connections, and it wants to allow moving some of the SAs to the slower and/or more expensive connection, and prevent the move, for example, of the news video stream from the WLAN to the GPRS link.

On the other hand, even if we tie the IKE SA update to the IPsec SA update, then we can create separate IKE SAs for this scenario, e.g., we create one IKE SA which have both links as endpoints, and it is used for important traffic, and then we create another IKE SA which have only the fast and/or cheap connection, which is then used for that kind of bulk traffic.

5.9 Zero Address Set

One of the features which might be useful would be for the peer to announce the other end that it will now disconnect for some time, i.e., it will not be reachable at all. For instance, a laptop might go to suspend mode. In this case the peer could send address notification with zero new addresses, which means that it will not have any valid addresses anymore. The responder of that kind of notification would then acknowledge that, and could then temporarily disable all SAs. If any of the SAs gets any packets they are simply dropped. This could also include some kind of ACK spoofing to keep the TCP/IP sessions alive (or simply set the TCP/IP keepalives and timeouts large enough not to cause problems), or it could simply be left to the applications, e.g., allow TCP/IP sessions to notice the link is broken.

The local policy could then decide how long the peer would allow other peers to be disconnected, e.g., whether this is only allowed for few minutes, or do they allow users to disconnect Friday evening

and reconnect Monday morning (consuming resources during weekend too, but on the other hand not more than is normally used during week days, but we do not need lots of extra resources on the Monday morning to support all those people connecting back to network).

From a technical point of view this feature addresses two aspects:

- There is no need to transmit IPsec data traffic. IPsec protected data needs to be dropped which saves bandwidth. This does not provide a functional benefit i.e, nothing breaks if this feature is not provided.

- MOBIKE signaling messages are also ignored and need to be suspended. The IKE-SA must not be deleted and the suspend functionality (realized with the zero address set) might require the IKE-SA to be tagged with a lifetime value since the IKE-SA will not be kept in memory an arbitrary amount of time. Note that the IKE-SA has no lifetime associated with it. In order to prevent the IKE-SA to be deleted the dead-peer detection mechanism needs to be suspended as well.

Due to the enhanced complexity of this extension a first version of the MOBIKE protocol will not provide this feature.

5.10 IPsec Tunnel or Transport Mode

Current MOBIKE design is focused only on the VPN type usage and tunnel mode. Transport mode behaviour would also be useful, but will be discussed in future documents.

5.11 Message Representation

The basic IP address change notifications can be sent either via an informational exchange already specified in the IKEv2, or via a MOBIKE specific message exchange. Using informational exchange has the main advantage that it is already specified in the IKEv2 and implementations incorporated the functionality already.

Another question is the basic format of the address update notifications. The address update notifications can include multiple addresses, which some can be IPv4 and some IPv6 addresses. The

number of addresses is most likely going to be quite small (less than 10). The format might need to indicate a preference value for each address. Furthermore, one of the addresses in the peer address set must be labeled as the preferred address. The format could either contain the preference number, giving out the relative order of the addresses, or it could simply be ordered list of IP addresses in the order of the most preferred first. While two addresses can have the same preference value an ordered list avoids this problem.

Even if load balancing is currently outside the scope of MOBIKE, there might be future work to include this feature. The format selected needs to be flexible enough to include additional

information (e.g., to enable load balancing). This might be something like one reserved field, which can later be used to store additional information. As there is other potential information which might have to be tied to the address in the future, a reserved field seems like a prudent design in any case.

There are two basic formats for putting IP address list in to the exchange, we can include each IP address as separate payload (where the payload order indicates the preference value, or the payload itself might include the preference value), or we can put the IP address list as one payload to the exchange, and that one payload will then have internal format which includes the list of IP addresses.

Having multiple payloads each having one IP address makes the protocol probably easier to parse, as we can already use the normal IKEv2 payload parsing procedures to get the list out. It also offers easy way for the extensions, as the payload probably contains only the type of the IP address (or the type is encoded to the payload type), and the IP address itself, and as each payload already has length associated to it, we can detect if there is any extra data after the IP address. Some implementations might have problems parsing too long of a list of IKEv2 payloads, but if the sender sends them in the most preferred first, the other end can simply only take the first addresses and use them.

Having all IP addresses in one big MOBIKE specified internal format provides more compact encoding, and keeps the MOBIKE implementation more concentrated to one module.

The next choice is which type of payloads to use. IKEv2 already specifies a notify payload. It includes some extra fields (SPI size, SPI, protocol etc), which gives 4 bytes of the extra overhead, and there is the notify data field, which could include the MOBIKE specific data.

Another option would be to have a custom payload type, which then includes the information needed for the MOBIKE protocol.

MOBIKE might send the full peer address list once one of the IP addresses changes (either addresses are added, removed, the order changes or the preferred address is updated) or an incremental update. Sending incremental updates provides more compact packets (meaning we can support more IP addresses), but on the other hand have more problems in the synchronization and packet reordering cases, i.e., the incremental updates must be processed in order, but for full updates we can simply use the most recent one, and ignore old ones, even if they arrive after the most recent one (IKEv2

packets have message id which is incremented for each packet, thus we know the sending order easily).

Note that each peer needs to communicate its peer address set to the other peer.

6. Security Considerations

As all the messages are already authenticated by the IKEv2 there is no problem that any attackers would modify the actual contents of the packets. The IP addresses in IP header of the packets are not authenticated, thus the protocol defined must take care that they are only used as an indication that something might be different, they should not cause any direct actions.

Attacker can also spoof ICMP error messages in an effort to confuse the peers about which addresses are not working. At worst this causes denial of service and/or the use of non-preferred addresses, so it is not that serious.

One type of attack that needs to be taken care of in the MOBIKE

protocol is also various flooding attacks. See [I-D.ietf-mip6-ro-sec] and [Aur02] for more information about flooding attacks.

[EDITOR's NOTE: This section needs more work.]

7. IANA Considerations

This document does not introduce any IANA considerations.

8. Acknowledgments

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9. Open Issues

This document is not yet complete, the following open issues need to be addressed in a future version:

- Section 4 needs an example to better illustrate the functionality of MOBIKE
- Section 6 requires a more detailed discussion about the potential security vulnerabilities and their solution.
- Some text is need to address the implications of unidirectional connectivity aspect for MOBIKE (see also issue #19).
- A discussion about the scalability aspects of connectivity tests would be benefical.
- More details are necessary to describe the implications of NAT traversal for MOBIKE.

A complete list of issues is available at TBD.

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