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NSIS Protocol Operation in Mobile Environments

Abstract

Mobility of an IP-based node affects routing paths, and as a result, can have a significant effect on the protocol operation and state management. This document discusses the effects mobility can cause to the Next Steps in Signaling (NSIS) protocol suite, and shows how the NSIS protocols operate in different scenarios with mobility management protocols.

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1. Introduction

Mobility of IP-based nodes incurs route changes, usually at the edge of the network. Since IP addresses are usually part of flow identifiers, the change of IP addresses implies the change of flow identifiers (i.e., the General Internet Signaling Transport (GIST) message routing information or Message Routing Information (MRI) [RFC5971]). Local mobility usually does not cause the change of the global IP addresses, but affects the routing paths within the local access network.

The NSIS protocol suite consists of two layers: the NSIS Transport Layer Protocol (NTLP) and the NSIS Signaling Layer Protocol (NSLP). The General Internet Signaling Transport (GIST) [RFC5971] implements

the NTLP, which is a protocol that is independent of the signaling application and that transports service-related information between neighboring GIST nodes. Each specific service has its own NSLP protocol; currently there are two specified NSLP protocols, the QoS NSLP [RFC5974] and the Network Address Translator / Firewall (NAT/FW) NSLP [RFC5973].

The goals of this document are to present the effects of mobility on the NTLP/NSLPs and to provide guides on how such NSIS protocols work in basic mobility scenarios, including support for Mobile IPv4 and Mobile IPv6 scenarios. We also show how these protocols fulfill the requirements regarding mobility set forth in [RFC3726]. In general, the NSIS protocols work well in mobile environments. The Session ID (SID) used in NSIS signaling enables the separation of the signaling state and the IP addresses of the communicating hosts. This makes it possible to directly update a signaling state in the network due to mobility without being forced to first remove the old state and then re-establish a new one. This is the fundamental reason why NSIS signaling works well in mobile environments. Additional information and mobility-specific enhanced operations, e.g., operations with crossover node (CRN), are also introduced.

This document focuses on basic mobility scenarios. Key management related to handovers, multihoming, and interactions between NSIS and other mobility management protocols than Mobile IP are out of scope of this document. Also, practical implementations typically need various APIs across components within a node. API issues, e.g., APIs from GIST to the various mobility and routing schemes, are also out of scope of this work. The generic GIST API towards NSLP is flexible enough to fulfill most mobility-related needs of the NSLP layer.

2. Requirements Notation and Terminology

The terminology in this document is based on [RFC5971] and [RFC3753]. In addition, the following terms are used. Note that in this document, a generic route change caused by regular IP routing is referred to as a 'route change', and the route change caused by mobility is referred to as 'mobility'.

(1) Downstream

The direction from a data sender towards the data receiver.

(2) Upstream

The direction from a data receiver towards the data sender.

(3) Crossover Node (CRN)

A Crossover Node is a node that for a given function is a merging point of two or more paths belonging to flows of the same session along which states are installed.

In the mobility scenarios, there are two different types of merging points in the network according to the direction of signaling flows followed by data flows, where we assume that the Mobile Node (MN) is the data sender.

Upstream CRN (UCRN): the node closest to the data sender from which the state information in the direction from data receiver to data sender begins to diverge after a handover.

Downstream CRN (DCRN): the node closest to the data sender from which the state information in the direction from the data sender to the data receiver begins to converge after a handover.

In general, the DCRN and the UCRN may be different due to the asymmetric characteristics of routing, although the data receiver is the same.

(4) State Update

State Update is the procedure for the re-establishment of NSIS state on the new path, the teardown of NSIS state on the old path, and the update of NSIS state on the common path due to the mobility. The State Update procedure is used to address mobility for the affected flows.

Upstream State Update: State Update for the upstream signaling flow.

Downstream State Update: State Update for the downstream signaling flow.

3. Challenges with Mobility

This section identifies problems that are caused by mobility and affect the operations of NSIS protocol suite.

1. Change of route and possible change of the MN's IP address

Topology changes or network reconfiguration might lead to path changes for data packets sent to or from the MN and can cause an IP address change of the MN. Traditional route changes usually do not cause address changes of the flow endpoints. When an IP address

changes due to mobility, information within the path-coupled MRI is affected (the source or destination address). Consequently, this concerns GIST as well as NSLPs, e.g., the packet classifier in QoS NSLP or some rules carried in NAT/FW NSLP. So, firewall rules, NAT bindings, and QoS reservations that are already installed may become invalid because the installed states refer to a non-existent flow. If the affected nodes are also on the new path, this information must be updated accordingly.

2. Double state problem

After a handover, packets may end up getting delivered through a new path. Since the state on the old path still remains as it was after re-establishing the state along the new path, we have two separate states for the same signaling session. Although the state on the old path will be deleted automatically based on the soft state timeout, the state timer value may be quite long (e.g., 90 s as a default value). With the QoS NSLP, this problem might result in the waste of resources and lead to failure of admitting new reservations (due to lack of resources). With the NAT/FW NSLP, it is still possible to re-use this installed state although an MN roams to a new location; this means that another host can send data through a firewall without any prior NAT/FW NSLP signaling because the previous state did not yet expire.

3. End-to-end signaling and frequency of route changes

The change of route and IP addresses in mobile environments is typically much faster and more frequent than traditional route changes caused by node or link failure. This may result in a need to speed up the update procedure of NSLP states.

4. Identification of the crossover node

When a handover at the edge of a network has happened, in the typical case, only some parts of the end-to-end path used by the data packets change. In this situation, the crossover node (CRN) plays a central role in managing the establishment of the new signaling application state, and removing any useless state, while localizing the signaling to only the affected part of the network.

5. Upstream State Update vs. Downstream State Update

Due to the asymmetric nature of Internet routing, the upstream and downstream paths are likely not to be exactly the same. Therefore, state update needs to be handled independently for upstream and downstream paths.

6. Upstream signaling

If the MN is the receiver and moves to a new point of attachment, it is difficult to signal upstream towards the Correspondent Node (CN). New signaling states have to be established along the new path, but for a path-coupled Message Routing Method (MRM), this has to be initiated in downstream direction. So, NTLP signaling state in the upstream direction cannot be initiated by the MN, i.e., GIST cannot easily send a Query in the upstream direction (there is an upstream Q-mode, but this is only applicable in a limited scope). The use of additional protocols such as application-level signaling (e.g, Session Initiation Protocol (SIP)) or mobility management signaling (e.g., Mobile IP) may help to trigger NSLP and NTLP signaling from the CN side in the downstream direction though.

7. Authorization issues

The procedure of State Update may be initiated by the MN, the CN, or even nodes within the network (e.g., crossover node, Mobility Anchor Point (MAP) in Hierarchical Mobile IP (HMIP)). This State Update on behalf of the MN raises authorization issues about the entity that is allowed to make these state modifications.

8. Dead peer and invalid NSIS Receiver (NR) problem

When the MN is on the path of a signaling exchange, after handover the old Access Router (AR) cannot forward NSLP messages towards the MN. In this case, the old AR's mobility or routing protocol (or even the NSLP) may trigger an error message to indicate that the last node fails or is truncated. This error message is forwarded and may mistakenly cause the removal of the state on the existing common path, if the state is not updated before the error message is propagated through the signaling peers. This is called the 'invalid NSIS Receiver (NR) problem'.

9. IP-in-IP encapsulation

Mobility protocols may use IP-in-IP encapsulation on the segment of the end-to-end path for routing traffic from the CN to the MN, and vice versa. Encapsulation harms any attempt to identify and filter data traffic belonging to, for example, a QoS reservation. Moreover, encapsulation of data traffic may lead to changes in the routing paths since the source and the destination IP addresses of the inner header differ from those of the outer header. Mobile IP uses tunneling mechanisms to forward data packets among end hosts. Traversing through the tunnel, NSIS signaling messages are transparent on the tunneling path due to the change of flow's addresses. In case of interworking with Mobile IP tunneling, CRNs

can be discovered on the tunneling path. It enables NSIS protocols to perform the State Update procedure over the IP tunnel. In this case, GIST needs to cope with the change of Message Routing Information (MRI) for the CRN discovery on the tunnel. Also, NSLP signaling needs to determine when to remove the tunneling segment on the signaling path and/or how to tear down the old state via interworking with the IP tunneling operation. Furthermore, tunneling adds additional IP header as overhead that must be taken into account by QoS NSLP, for example, when resources must be reserved accordingly. So an NSLP must usually be aware whether tunneling or route optimization is actually used for a flow [RFC5979].

4. Basic Operations for Mobility Support

This section presents the basic operations of the NSIS protocol suite after mobility-related route changes. Details of the operation of Mobile IP with respect to NSIS protocols are discussed in the subsequent section.

4.1. General Functionality

The NSIS protocol suite decouples state and flow identification. A state is stored and referred by the Session ID (SID). Flows associated with a given NSLP state are defined by the Message Routing Information (MRI). GIST notices when a routing path associated with a SID changes, and provides a notification to the NSLP. It is then up to the NSLP to update the state information in the network. Thus, the effect is an update to the states, not a full new request. This decoupling also effectively solves a typical problem with certain signaling protocols, where protocol state is identified by flow endpoints, and when flow endpoint addresses change, the whole session state becomes invalid.

A further benefit of the decoupling is that if the MRI, i.e., the IP addresses associated with the data flow, remain the same after movement, the NSIS signaling will repair only the affected path of the end-to-end session. Thus, updating the session information in the network will be localized, and no end-to-end signaling will be needed. If the MRI changes, end-to-end signaling usually cannot be avoided since new information for proper data flow identification must be provided all the way between the data sender and receiver, e.g., in order to update filters, QoS profiles, or other flow-related session data.

GIST provides NSLPs with an identifier of the next signaling peer, the Source Identification Information (SII) handle. When this SII-Handle changes, the NSLP knows a routing change has happened. Yet,

the NSLP can also figure out whether it is also the crossover node for the session. Thus, CRN discovery is always done at the NSLP layer because only NSLPs have a notion of end-to-end signaling.

When a path changes, the session information on the old path needs to be removed. Normally, the information is released when the session timer is expired after a routing change. But the NSLP running on the end-host or the CRN, depending on the direction of the session, may use the SII-Handle (provided by GIST) to explicitly remove states on the old path; new session information is simultaneously set up on the new path. Both current NSLPs use sequence numbers to identify the order of messages, and this information can be used by the protocols to recover from a routing change.

Since NSIS operates on a hop-by-hop basis, any peer can perform state updates. This is possible because a chain of trust is expected between NSIS nodes. If this weren't the case (e.g., true resource reservations are not possible), one misbehaving or compromised node would effectively break everything. Thus, currently the NSIS protocols do not limit the roles of each NSIS signaling peer on a path, and any node can make updates. Yet, some updates are reflected back to the signaling endpoints, and they can decide whether or not the signaling actually succeeded.

If the signaling packets are encapsulated in a tunnel, it is necessary to perform a separate signaling exchange for the tunneled region. Furthermore, a binding is needed to tie the end-to-end and tunneled session together.

In some cases, the NSLP must be aware whether tunneling is used, since additional tunneling overhead must be taken into account, e.g., for resource reservations, etc.

4.2. QoS NSLP

Figure 1 illustrates an example of QoS NSLP signaling in a Mobile IPv6 route optimization case, for a data flow from the MN to the CN, where sender-initiated reservation is used. Once a handover event is detected in the MN, the MN needs to acquire the new Care-of Address (CoA) and update the path coupled MRI accordingly. Then, the MN issues towards the CN a QoS NSLP RESERVE message that carries the unique session ID and other identification information for the session, as well as the reservation requirements (steps (1)-(4) in Figure 1). Upon receipt of the RESERVE message, the QoS NSLP nodes (which will be discovered by the underlying NTLP) establish the corresponding QoS NSLP state, and forward the message towards the CN. When there is already an existing NSLP state with the same session ID, the state will be updated. If all the QoS NSLP nodes along the

path support the required QoS, the CN in turn responds with a RESPONSE message to confirm the reservation (steps (5)-(6) in Figure 1).

In a bidirectional tunneling case, the only difference is that the RESERVE message should be sent to the home agent (HA) instead of the CN, and the node that responds with a RESPONSE should be the HA instead of the CN, too. More details are given in Section 5.

Therefore, for the basic operation there is no fundamental difference among different operation modes of Mobile IP, and the main issue of mobility support in NSIS is to trigger NSLP signaling appropriately when a handover event is detected. Also, the destination of the NSLP signaling shall follow the Mobile IP data path using path-coupled signaling.

In this process, the obsoleted state in the old path is not explicitly released because the state can be released by timer expiration. To speed up the process, it may be possible to localize the signaling. When the RESERVE message reaches a node, depicted as CRN in this document (step (2) in Figure 1), where a state is determined for the first time to reflect the same session, the node may issue a NOTIFY message towards the MN's old CoA (step (9) in Figure 1). The QoS NSIS Entity (QNE) adjacent to the MN's old position stops the NOTIFY message (step (10) in Figure 1) and sends a RESERVE message (with Teardown bit set) towards the CN to release the obsoleted state (step (11) in Figure 1). This RESERVE with tear message is stopped by the CRN (step (12) in Figure 1). The Reservation Sequence Number (RSN) is used in the messages to distinguish the order of the signaling. More details are given in Section 4.4

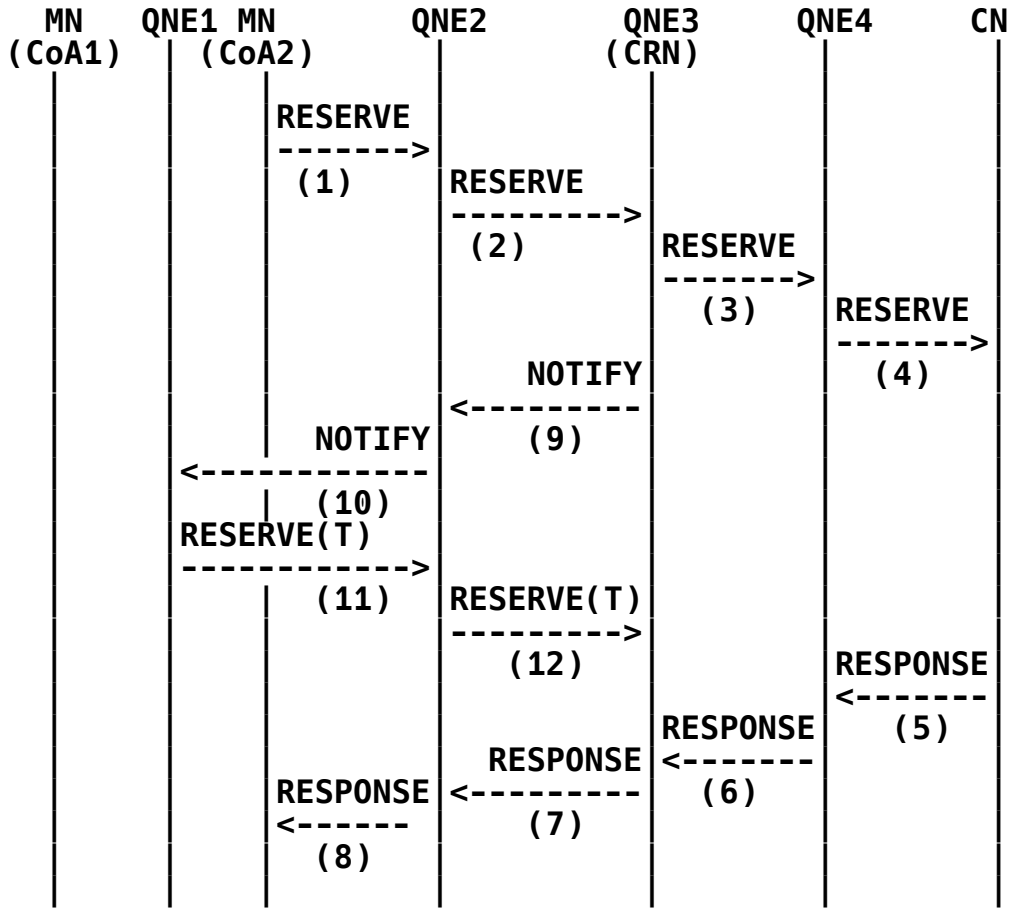


Figure 1: Example Basic Handover Signaling in the QoS NSLP

Further cases to consider are:

* receiver-initiated reservation if MN is sender

* sender-initiated reservation if MN is receiver

* receiver-initiated reservation if MN is receiver

In the first case, the MN can easily initiate a new QUERY along the new path after movement, thereby installing signaling state and eventually eliciting a new RESERVE from the CN in upstream direction. Similarly, the second and third cases require the CN to initiate a RESERVE or QUERY message respectively. The difficulty in both cases is, however, to let the CN know that the MN has moved. Because the MN is the receiver, it cannot simply use an NSLP message to do so, because upstream signaling is not possible in this case (cf. Section 3, Upstream Signaling).

4.3. NATFW NSLP

Figure 2 illustrates an example of NATFW NSLP signaling in a Mobile IPv6 route optimization case, for a data flow from the MN to the CN. The difference to the QoS NSLP is that for the NATFW NSLP only the NSIS initiator (NI) can update the signaling session, in any case. Once a handover event is detected in the MN, the MN must get to know the new Care-of Address and update the path coupled MRI accordingly. Then the MN issues a NATFW NSLP CREATE message towards the CN, that carries the unique session ID and other identification information for the session (steps (1)-(4) in Figure 2). Upon receipt of the CREATE message, the NATFW NSLP nodes (which will be discovered by the underlying NTLP) establish the corresponding NATFW NSLP state, and forward the message towards the CN. When there is already an existing NSLP state with the same session ID, the state will be updated. If all the NATFW NSLP nodes along the path accept the required NAT/firewall configuration, the CN in turn responds with a RESPONSE message, to confirm the configuration (steps (5)-(8) in Figure 2).

In a bidirectional tunneling case, the only difference is that the CREATE message should be sent to the HA instead of the CN, and the node that responds with a RESPONSE should be the HA instead of the CN too.

Therefore, for the basic operation there is no fundamental difference among different operation modes of Mobile IP, and the main issue of mobility support in NSIS is to trigger NSLP signaling appropriately when a handover event is detected, and the destination of the NSLP signaling shall follow the Mobile IP data path as being path-coupled signaling.

In this process, the obsoleted state in the old path is not explicitly released because the state can be released by timer expiration. To speed up the process, when the CREATE message reaches a node, depicted as CRN in this document (step (2) in Figure 2), where a state is determined for the first time to reflect the same session, the node may issue a NOTIFY message towards the MN's old CoA (steps (9)-(10) in Figure 2). When the NI notices this, it sends a CREATE message towards the CN to release the obsoleted state (steps (11)-(12)) in Figure 2).

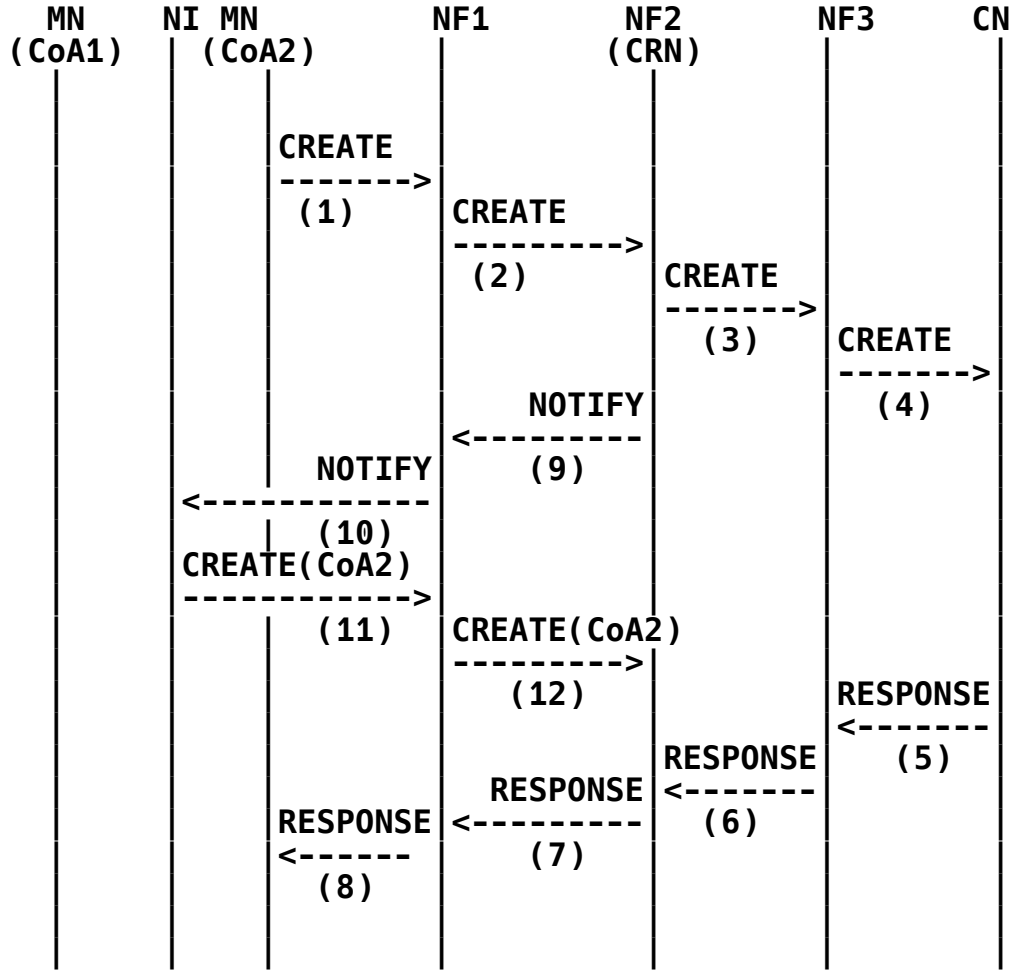
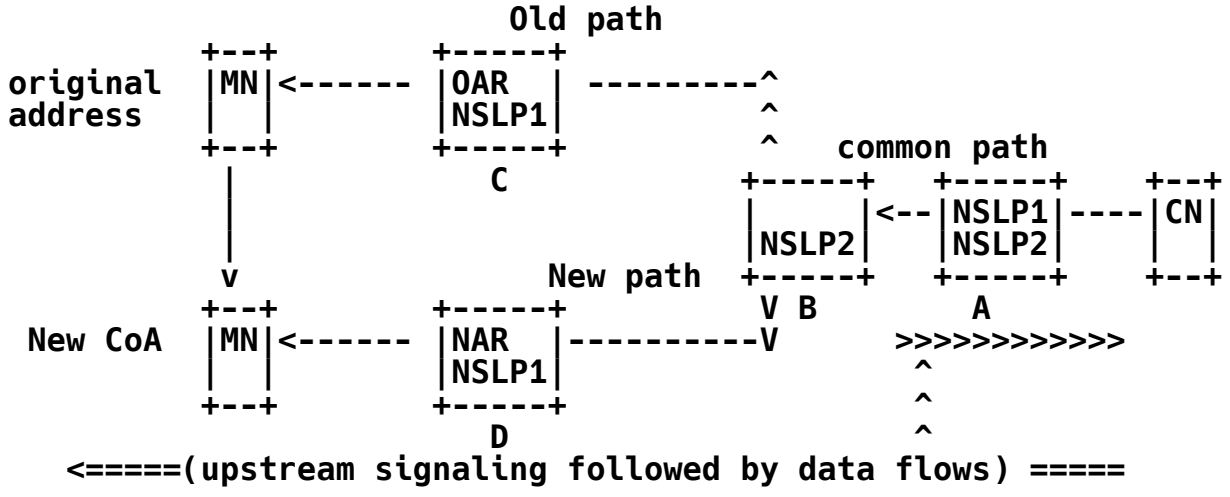


Figure 2: Example of NATFW NSLP Operation

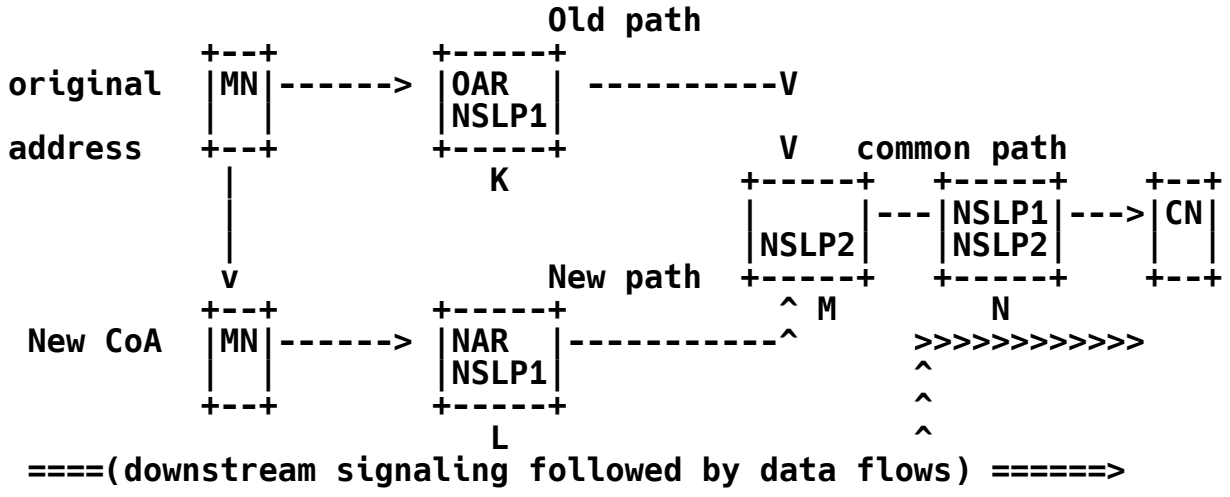
4.4. Localized Signaling in Mobile Scenarios

This section describes detailed CRN operations. As described in previous sections, CRN operations are informational.

As shown in Figure 3, mobility generally causes the signaling path to either converge or diverge depending on the direction of each signaling flow.



(a) The topology for upstream NSIS signaling flow due to mobility (in the case that the MN is a data sender)



(b) The topology for downstream NSIS signaling flow due to mobility (in the case that the MN is a data sender)

Note: OAR - old access router
NAR - new access router

Figure 3: The Topology for NSIS Signaling Caused by Mobility

These topological changes due to mobility cause the NSIS state established in the old path to be useless. Such state may be removed as soon as possible. In addition, NSIS state needs to be established along the new path and be updated along the common path. The re-

establishment of NSIS signaling may be localized when route changes (including mobility) occur; this is to minimize the impact on the service and to avoid unnecessary signaling overhead. This localized signaling procedure is referred to as State Update (refer to the terminology section). In mobile environments, for example, the NSLP/NTLP needs to limit the scope of signaling information to only the affected portion of the signaling path because the signaling path in the wireless access network usually changes only partially.

4.4.1. CRN Discovery

The CRN is discovered at the NSLP layer. In case of QoS NSLP, when a RESERVE message with an existing SESSION_ID is received and its SII and MRI are changed, the QNE knows its upstream or downstream peer has changed by the handover, for sender-oriented and receiver-oriented reservations, respectively. Also, the QNE realizes it is implicitly the CRN.

4.4.2. Localized State Update

In the downstream State Update, the MN initiates the RESERVE with a new RSN for state setup toward a CN, and also the implicit DCRN discovery is performed by the procedure of signaling as described in Section 4.4.1. The MRI from the DCRN to the CN (i.e., common path) is updated by the RESERVE message. The DCRN may also send a NOTIFY with "Route Change" (0x02) to the previous upstream peer. The NOTIFY is forwarded hop-by-hop and reaches the edge QNE (i.e., QNE1 in Figure 1). After the QNE is aware that the MN as QNI has disappeared (how this can be noticed is out of scope for NSIS, yet, e.g., GIST will eventually know this through undelivered messages), the QNE sends a tearing RESERVE towards downstream. When the tearing RESERVE reaches the DCRN, it stops forwarding and drops it. Note that, however, it is not necessary for GIST state to be explicitly removed because of the inexpensiveness of the state maintenance at the GIST layer [RFC5971]. Note that the sender-initiated approach leads to faster setup than the receiver-initiated approach as in RSVP [RFC2205].

In the scenario of an upstream State Update, there are two possible methods for state update. One is the CN (or the HA, Gateway Foreign Agent (GFA), or MAP) sends the refreshing RESERVE message toward the MN to perform State Update upon receiving the trigger (e.g., Mobile IP (MIP) binding update). The UCRN is discovered implicitly by the CN-initiated signaling along the common path as described in Section 4.4.1. When the refreshing RESERVE reaches to the adjacent QNE of UCRN, the QNE sends back a RESPONSE saying "Reduced refreshes not supported; full QSPEC required" (0x03). Then, the UCRN sends the RESERVE with full QSPEC towards the MN to set up a new reservation.

The UCRN may also send a tearing RESERVE to the previous downstream peer. The tearing RESERVE is forwarded hop-by-hop and reaches the edge QNE. After the QNE is aware that the MN as QNI has disappeared, the QNE drops the tearing peer. Another method is: if a GIST hop is already established on the new path (e.g., by QUERY from the CN, or the HA, GFA, or MAP) when MN gets a hint from GIST that routing has changed, the MN sends a NOTIFY upstream saying "Route Change" (0x02). When the NOTIFY hits the UCRN, the UCRN is aware that the NOTIFY is for a known session and comes from a new SII-Handle. Then, the UCRN sends towards the MN a RESERVE with a new RSN and an RII. By receiving the RESERVE, the MN replies with a RESPONSE. The UCRN may also send tearing RESERVE to previous downstream peer. The tearing RESERVE is forwarded hop-by-hop and reaches to the edge QNE. After the QNE is aware that the MN as QNI has disappeared, the QNE drops the tearing peer.

The State Update on the common path to reflect the changed MRI brings issues on the end-to-end signaling addressed in Section 3. Although the State Update over the common path does not give rise to re-processing of AAA and admission control, it may lead to increased signaling overhead and latency.

One of the goals of the State Update is to avoid the double reservation on the common path as described in Section 3. The double reservation problem on the common path can be solved by establishing a signaling association using a unique SID and by updating the packet classifier / MRI. In this case, even though the flows on the common path have different MRIs, they refer to the same NSLP state.

5. Interaction with Mobile IPv4/v6

Mobility management solutions like Mobile IP try to hide mobility effects from applications by providing stable addresses and avoiding address changes. On the other hand, the MRI [RFC5971] contains flow addresses and will change if the CoA changes. This makes an impact on some NSLPs such as QoS NSLP and NAT/FW NSLP.

QoS NSLP must be mobility-aware because it needs to care about the resources on the actual current path, and sending a new RESERVE or QUERY for the new path. Applications on top of Mobile IP communicate along logical flows that use home addresses, whereas QoS NSLP has to be aware of the actual flow path, e.g., whether the flow is currently tunneled or route-optimized, etc. QoS NSLP may have to obtain current link properties; especially there may be additional overhead due to mobility header extensions that must be taken into account in QSPEC (e.g., the m parameter in the traffic model (TMOD); see [RFC5975]). Therefore, NSLPs must interact with mobility management implementations in order to request information about the current

flow address (CoAs), source addresses, tunneling, or overhead. Furthermore, an implementation must select proper interface addresses in the natural language interface (NLI) in order to ensure that a corresponding Messaging Association is established along the same path as the flow in the MRI. Moreover, the home agent needs to perform additional actions (e.g., reservations) for the tunnel. If the home agent lacks support of a mobility-aware QoS NSLP, a missing tunnel reservation is usually the result. Practical problems may occur in situations where a home agent needs to send a GIST query (with S-flag=1) towards the MN's home address and the query is not tunneled due to route optimization between HA and MN: the query will be wrongly intercepted by QNEs within the tunnel.

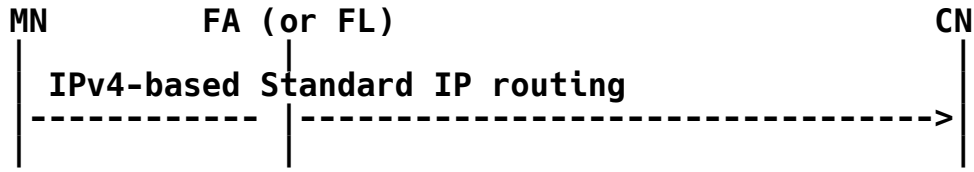
NAT/FW box needs to be configured before MIP signaling, hence NAT/FW signaling will have to be performed to allow Return Routability Test (RRT) and Binding Update (BU) / Binding Acknowledgement (BA) messages to traverse the NAT/FWs in the path. After RRT and BU/BA messages are completed, more NAT/FW signaling needs to be performed for passing the data. Optimized version can include a combined NAT/FW message to cover both RRT and BU/BA messages pattern. However, this may require NAT/FW NSLP to do a slight update to support carrying multiple NAT/FW rules in one signaling round trip.

This section analyzes NSIS operation with the tunneled route case especially for QoS NSLP.

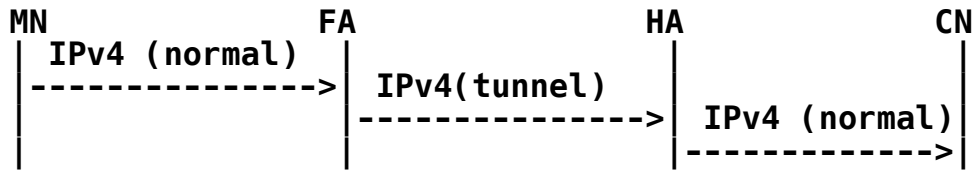
5.1. Interaction with Mobile IPv4

In Mobile IPv4 [RFC5944], the data flows are forwarded based on triangular routing, and an MN retains a new CoA from the Foreign Agent (FA) (or an external method such as DHCP) in the visited access network. When the MN acts as a data sender, the data and signaling flows sent from the MN are directly transferred to the CN, not necessarily through the HA or indirectly through the HA using the reverse tunneling. On the other hand, when the MN acts as a data receiver, the data and signaling flows sent from the CN are routed through the IP tunneling between the HA and the FA (or the HA and the MN in the case of the co-located CoA). With this approach, routing is dependent on the HA, and therefore the NSIS protocols interact with the IP tunneling procedure of Mobile IP for signaling.

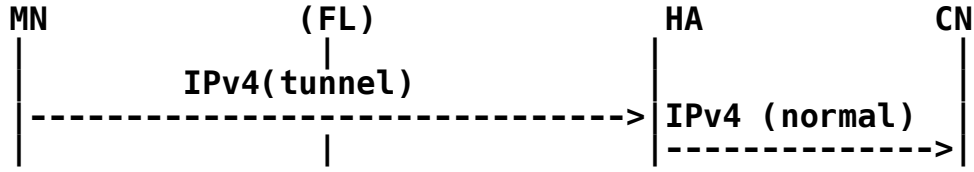
Figure 4 (a) to (e) show how the NSIS signaling flows depend on the direction of the data flows and the routing methods.



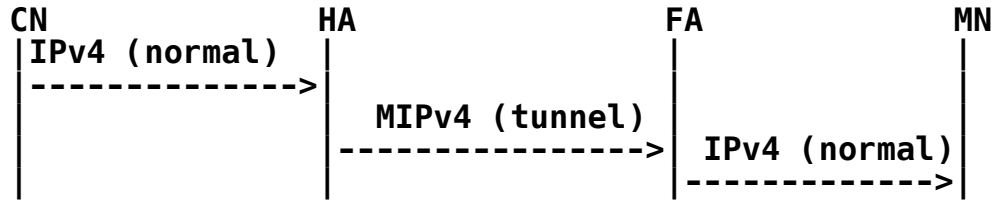
(a) MIPv4: MN-->CN, no reverse tunnel



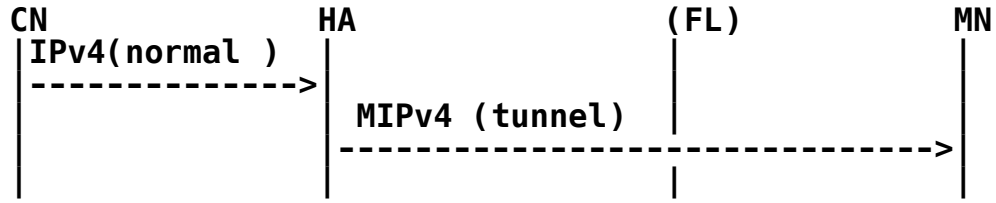
(b) MIPv4: MN-->CN, the reverse tunnel with FA CoA



(c) MIPv4: MN-->CN, the reverse tunnel with co-located CoA



(d) MIPv4: CN-->MN, Foreign agent CoA



(e) MIPv4: CN-->MN with co-located CoA

Figure 4: NSIS Signaling Flows under Different Mobile IPv4 Scenarios

When an MN (as a signaling sender) arrives at a new FA and the corresponding binding process is completed (Figure 4 (a), (b), and (c)), the MN performs the CRN discovery (DCRN) and the State Update toward the CN (as described in Section 4) to establish the NSIS state

along the new path between the MN and the CN. In case the reverse tunnel is not used (Figure 4 (a)), a new NSIS state is established on the direct path from the MN to the CN. If the reverse tunnel and FA CoA are used (Figure 4 (b)), a new NSIS state is established along a tunneling path from the FA to the HA separately from the end-to-end path. CRN discovery and State Update in tunneling path is also separately performed if necessary. If the reverse tunnel and co-located CoA are used (Figure 4 (c)), the NSIS signaling for the DCRN discovery and for the State Update is the same as the case of using the FA CoA above, except for the use of the reverse tunneling path from the MN to the HA. That is, in this case, one of the tunnel endpoints is the MN, not the FA.

When an MN (as a signaling receiver) arrives at a new FA and the corresponding binding process is completed (Figure 4 (d) and (e)), the MN sends a NOTIFY message to the signaling sender, i.e., the CN. In case the FA CoA is used (Figure 4 (d)), the CN initiates an NSIS signaling to update an existing state between the CN and the HA, and afterwards the NSIS signaling messages are forwarded to the FA and reach the MN. A new NSIS state is established along the tunneling path from the HA to the FA separately from end-to-end path. During this operation, a UCRN is discovered on the tunneling path, and a new MRI for the State Update on the tunnel may need to be created. CRN discovery and State Update in the tunneling path is also separately performed if necessary. In case co-located CoA is used (Figure 4 (d)), the NSIS signaling for the UCRN discovery and for the State Update is also the same as the case of using the FA CoA, above except for the endpoint of the tunneling path from the HA to the MN.

Note that Mobile IPv4 optionally supports route optimization. In the case route optimization is supported, the signaling operation will be the same as Mobile IPv6 route optimization.

5.2. Interaction with Mobile IPv6

Unlike Mobile IPv4, with Mobile IPv6 [RFC3775], the FA is not required on the data path. If an MN moves to a visited network, a CoA at the network is allocated like co-located CoA in Mobile IPv4. In addition, the route optimization process between the MN and CN can be used to avoid the triangular routing in the Mobile IPv4 scenarios.

If the route optimization is not used, data flow routing and NSIS signaling procedures (including the CRN discovery and the State Update) will be similar to the case of using Mobile IPv4 with the co-located CoA. However, if route optimization is used, signaling messages are sent directly from the MN to the CN, or from the CN to the MN. Therefore, route change procedures described in Section 4 are applicable to this case.

5.3. Interaction with Mobile IP Tunneling

In this section, we assume that the MN acts as an NI and the CN acts as an NR in interworking between Mobile IP and NSIS signaling.

Scenarios for interaction with Mobile IP tunneling vary depending on:

- Whether a tunneling entry point (Tentry) is an MN or other node. For a Mobile IPv4 co-located CoA or Mobile IPv6 CoA, Tentry is an MN. For a Mobile IPv4 FA CoA, Tentry is an FA. In both cases, an HA is the tunneling exit point (Texit).

- Whether the mode of QoS NSLP signaling is sender-initiated or receiver-initiated.

- Whether the operation mode over the tunnel is with preconfigured QoS sessions or with dynamically created QoS sessions as described in [RFC5979].

The following subsections describe sender-initiated and receiver-initiated reservations with Mobile IP tunneling, as well as CRN discovery and State Updates with Mobile IP tunneling.

5.3.1. Sender-Initiated Reservation with Mobile IP Tunnel

The following scenario assumes that an FA is a Tentry. However, the procedure is the same when an MN is a Tentry if the MN and the FA are considered the same node.

- When an MN moves into a new network attachment point, QoS NSLP in the MN initiates the RESERVE (end-to-end) message to start the State Update procedure. The GIST below the QoS NSLP adds the GIST header and then sends the encapsulated RESERVE message to peer GIST node with the corresponding QoS NSLP. In this case, the peer GIST node is an FA if the FA is an NSIS-aware node. The FA is one of the endpoints of Mobile IP tunneling: Tentry. For proper NSIS tunneling operation, a Mobile IP endpoint is required to be NSIS tunneling aware. In case of interaction with tunnel signaling originated from the FA, there can be two scenarios depending on whether or not the tunnel already has preconfigured QoS sessions. In the former case, the FA map end-to-end QoS signaling requests directly to existing tunnel sessions. In the latter case, the FA dynamically initiates and maintains tunnel QoS sessions that are then associated with the corresponding end-to-end QoS sessions. [RFC5979].

- Figure 5 shows the typical NSIS operation over tunnels with preconfigured QoS sessions. Both the FA and the HA are configured with information about the Flow ID of the tunnel QoS session. Upon receiving a RESERVE message from the MN, the FA checks tunnel QoS configuration, and determines whether and how this end-to-end session can be mapped to a preconfigured tunnel session. The FA then tunnels the RESERVE message to the HA. The CN replies with a RESPONSE message which arrives at the HA, the FA, and the MN.

- Figure 6 shows the typical NSIS operation over tunnels with dynamically created QoS sessions. When the FA receives an end-to-end RESERVE message from the MN, the FA chooses the tunnel Flow ID, creates the tunnel session, and associates the end-to-end session with the tunnel session. The FA then sends a tunnel RESERVE' message (matching the request of the end-to-end session) towards the HA to reserve tunnel resources. The tunnel RESERVE' message is processed hop-by-hop inside the tunnel for the flow identified by the chosen tunnel Flow ID, while the end-to-end RESERVE message passes through the tunnel intermediate nodes (Tmid). When these two messages arrive at the HA, the HA creates the reservation state for the tunnel session, and sends a tunnel RESPONSE' message to the FA. At the same time, the HA updates the end-to-end RESERVE message based on the result of the tunnel session reservation and forwards the end-to-end RESERVE message along the path towards the CN. When the CN receives the end-to-end RESERVE message, it sends an end-to-end RESPONSE message back to the MN.

More detailed operations are specified in [RFC5979].

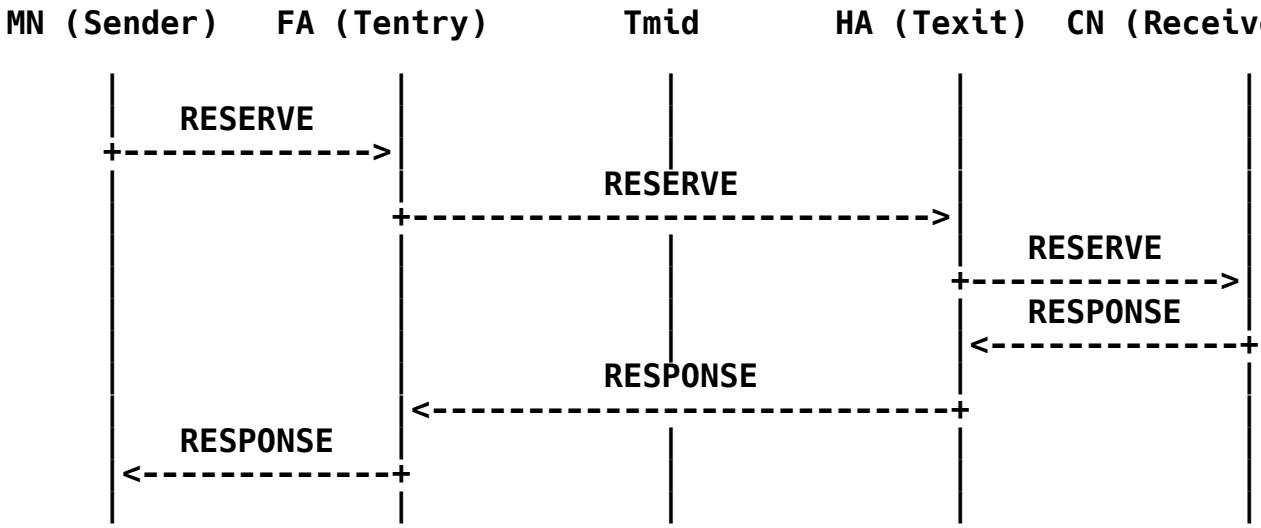


Figure 5: Sender-Initiated QoS NSLP over Tunnel with Preconfigured QoS Sessions

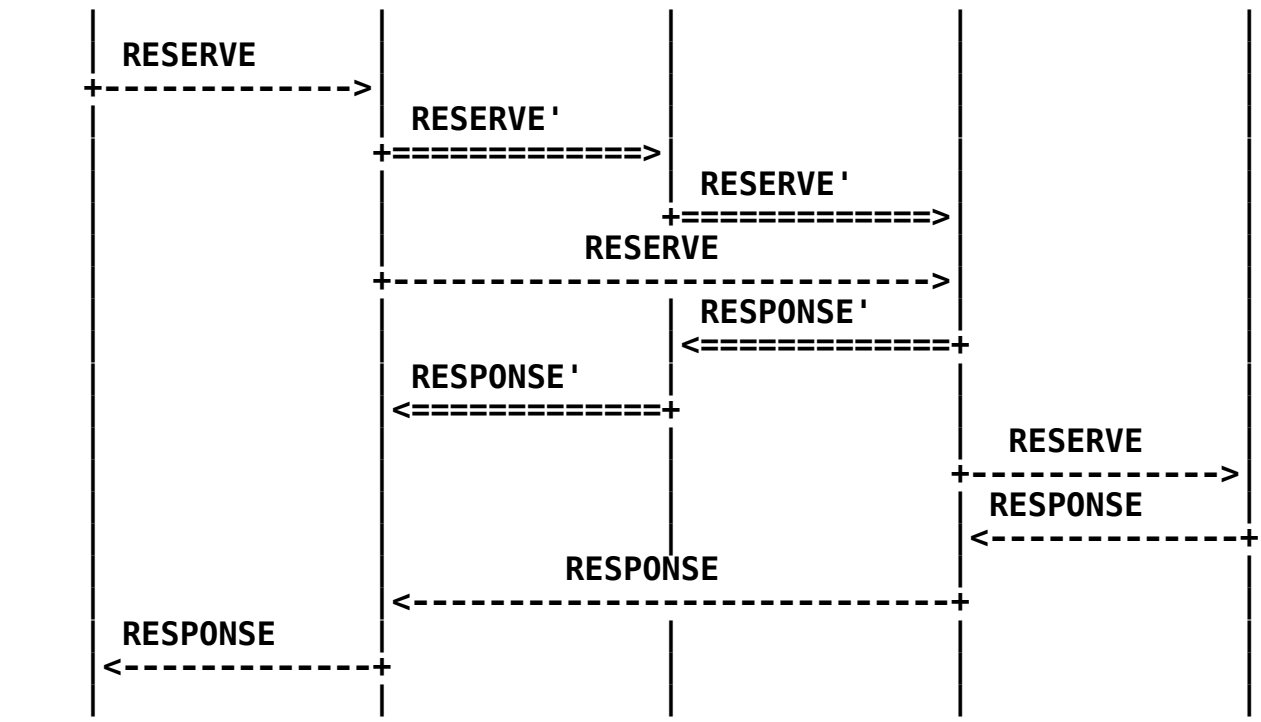


Figure 6: Sender-Initiated QoS NSLP over Tunnel with Dynamically Created QoS Sessions

5.3.2. Receiver-Initiated Reservation with Mobile IP Tunnel

Figures 7 and 8 show examples of receiver-initiated operation over Mobile IP tunnel with preconfigured and dynamically created QoS sessions, respectively. The Basic Operation is the same as the sender-initiated case.

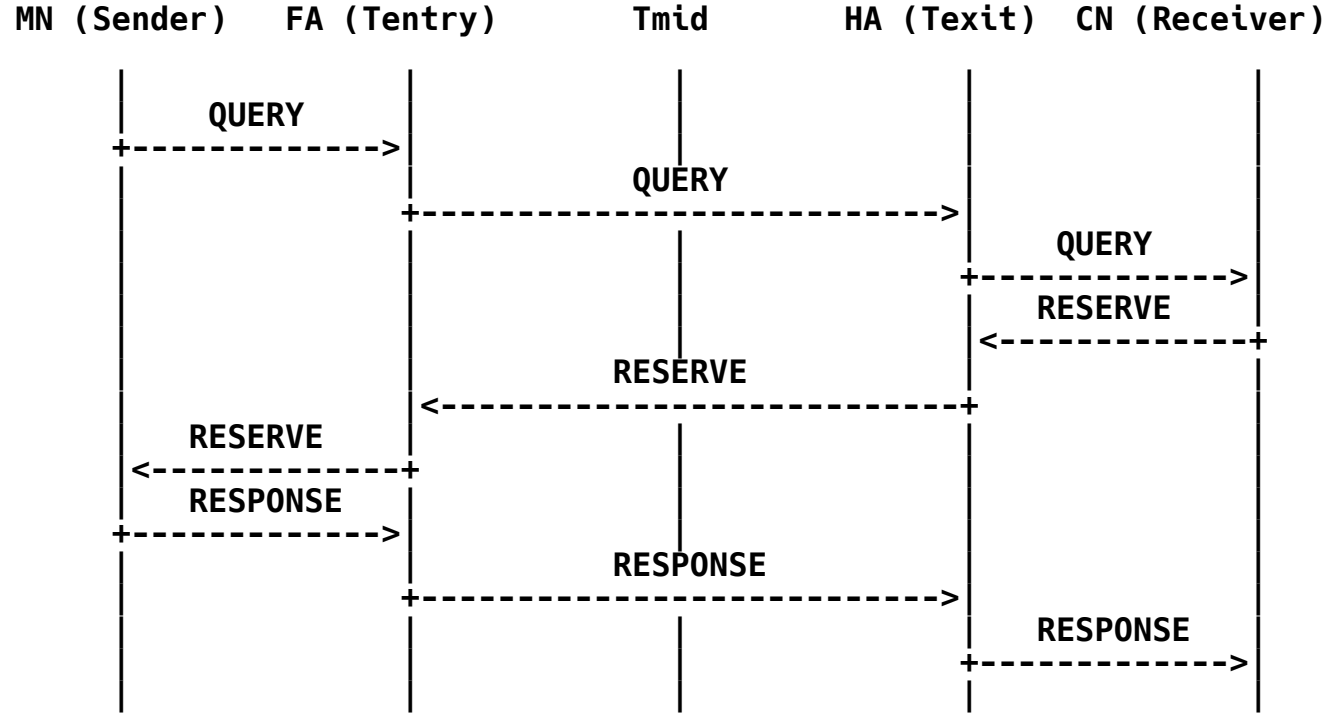


Figure 7: Receiver-Initiated QoS NSLP over Tunnel with Preconfigured QoS Sessions

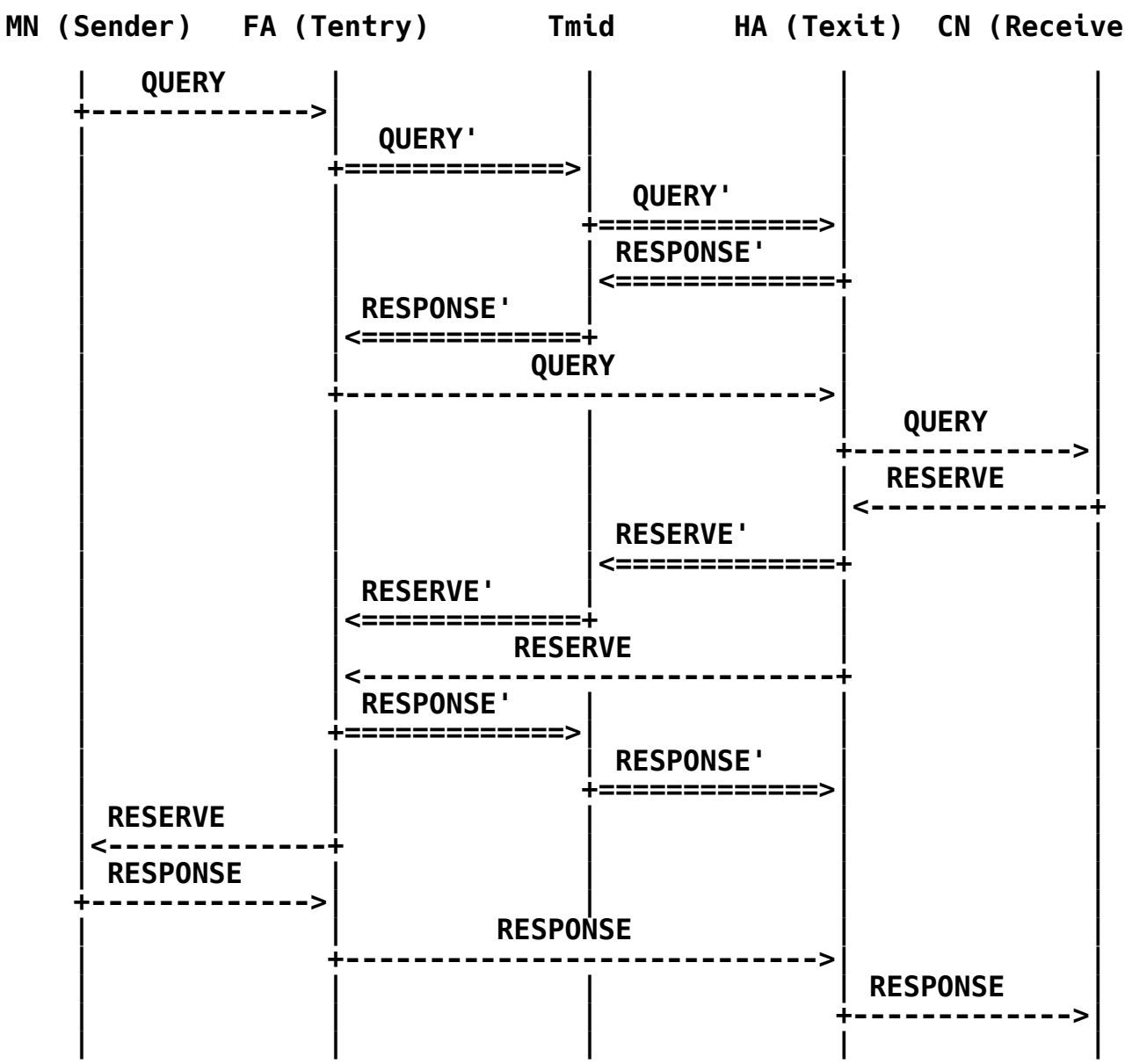


Figure 8: Receiver-Initiated QoS NSLP over Tunnel with Dynamically Created QoS Session

5.3.3. CRN Discovery and State Update with Mobile IP Tunneling

If a tunnel is in the mode of using dynamically created QoS sessions, the Mobile IP tunneling scenario can include two types of CRNs, i.e., a CRN on an end-to-end path and a CRN on a tunneling path. If a

tunnel is in the mode of using preconfigured QoS sessions, it can only have CRNs on end-to-end paths. CRN discovery and State Update for these two paths are operated independently.

CRN discovery for an end-to-end path is initiated by the MN by sending a RESERVE (sender-initiated case) or QUERY (receiver-initiated case) message. As the MN uses HoA as the source address even after handover, a CRN is found by normal route change process (i.e., the same SID and Flow ID, but a different SII-Handle). If an HA is QoS NSLP aware, the HA is found as the CRN. The CRN initiates the tearing-down process on the old path as described in [RFC5974].

CRN discovery for the tunneling path is initiated by Tentry by sending a RESERVE' (sender-initiated case) or QUERY' (receiver-initiated case) message. The route change procedures described in Section 4 are applicable to this case.

The end-to-end state inside the tunnel should not be torn down until all states inside the tunnel have been torn from the implementation perspective. However, detailed discussions are out of scope for this document.

6. Further Studies

All sections above dealt with basic issues on NSIS mobility support. This section introduces potential issues and possible approaches for complicated scenarios in the mobile environment, i.e., peer failure scenarios, multihomed scenarios, and interworking with other mobility protocols, which may need to be resolved in the future. Topics in this section are out of scope for this document. Detailed operations in this section are just for future reference.

6.1. NSIS Operation in the Multihomed Mobile Environment

In multihomed mobile environments, multiple interfaces and addresses (i.e., CoAs and HoAs) are available, so two major issues can be considered. One is how to select or acquire the most appropriate interface(s) and/or address(es) from the end-to-end QoS point of view. The other is, when multiple paths are simultaneously used for load-balancing purposes, how to differentiate and manage two types of CRNs, i.e., the CRN between two ongoing paths (LB-CRN: Load Balancing CRN) and the CRN between the old and new paths caused by the MN's handover (HO-CRN: Handover CRN). This section introduces possible approaches for these issues.

6.1.1. Selecting the Best Interface(s) or CoA(s)

In the MIPv6 route optimization case, if registrations of multiple CoAs are provided [RFC5648], the contents of QUERYs sent by candidate CoAs can be used to select the best interface(s) or CoA(s).

Assume that an MN is a data sender and has multiple interfaces. Now the MN moves to a new location and acquires CoA(s) for multiple interfaces. After the MN performs the BU/BA procedure, it sends QUERY messages toward the CN through the interface(s) associated with the CoA(s). On receiving the QUERY messages, the CN or gateway, determines the best (primary) CoA(s) by checking the 'QoS Available' object in the QUERY messages. Then, a RESERVE message is sent toward the MN to reserve resources along the path that the primary CoA takes. If the reservation is not successful, the CN transmits another RESERVE message using the CoA with the next highest priority. The CRN may initiate a teardown (RESERVE with the TEAR flag set) message toward old access router (OAR) to release the reserved resources on the old path.

For a sender-initiated reservation, a similar approach is possible. That is, the QUERY and RESERVE messages are initiated by an MN, and the MN selects the primary CoA based on the information delivered by the QUERY message.

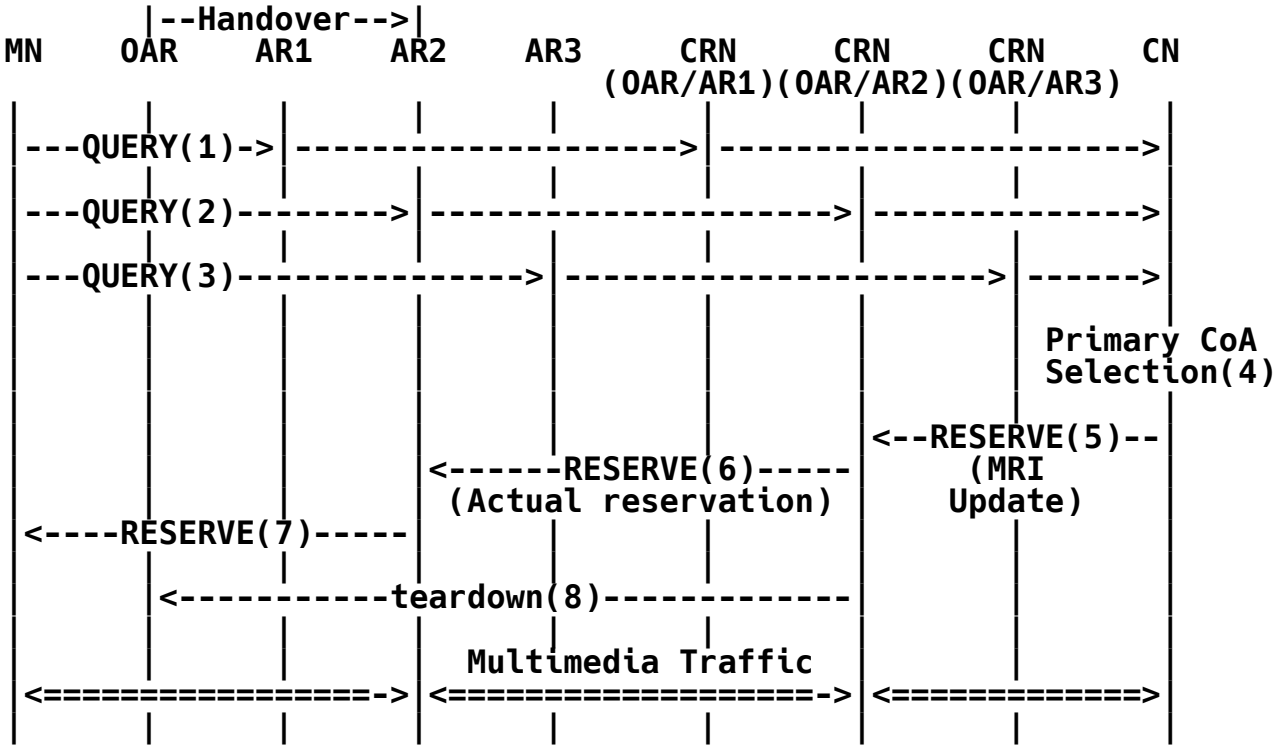


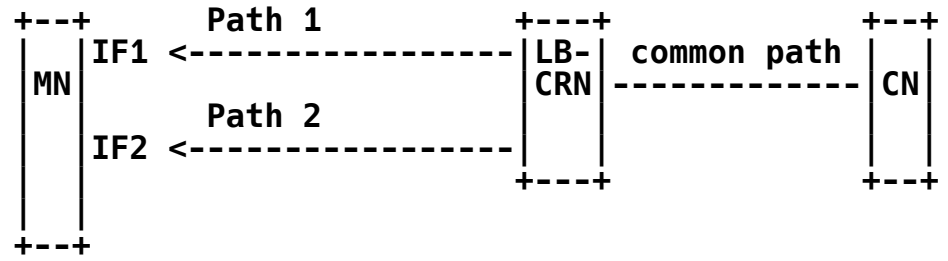
Figure 9: Receiver-Initiated Reservation in the Multihomed Environment

6.1.2. Differentiation of Two Types of CRNs

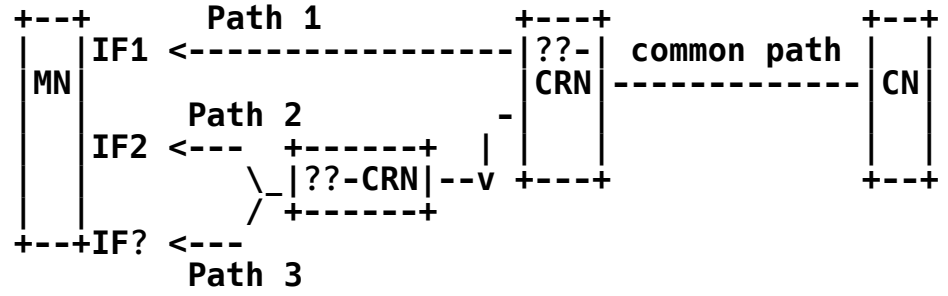
When multiple interfaces of the MN are simultaneously used for load-balancing purposes, a possible approach for distinguishing the LB-CRN and HO-CRN will introduce an identifier to determine the relationship between interfaces and paths.

An MN uses interface 1 and interface 2 for the same session, where the paths (say path 1 and path 2) have the same SID but different Flow IDs as shown in (a) of Figure 10. Then, one of the interfaces of the MN performs a handover and obtains a new CoA, and the MN will try to establish a new path (say Path 3) with the new Flow ID, as shown in (b) of Figure 10. In this case, the CRN between path 2 and path 3 cannot determine if it is LB-CRN or HO-CRN since for both cases, the SID is the same but the Flow IDs are different. Hence, the CRN will not know if State Update is required. One possible solution to solve this issue is to introduce a path classification identifier, which shows the relationship between interfaces and paths. For example, signaling messages and QNEs that belong to paths from interface 1 and interface 2 carry the identifiers '00' and '02', respectively. By having this identifier, the CRN between path 2 and

path 3 will be able to determine whether it is an LB-CRN or HO-CRN. For example, if path 3 carries '00', the CRN is an LB-CRN, and if '01', the CRN is an HO-CRN.



(a) NSIS Path classification in multihomed environments



(b) NSIS Path classification after handover

Figure 10: The Topology for NSIS Signaling in Multihomed Mobile Environments

6.2. Interworking with Other Mobility Protocols

In mobility scenarios, the end-to-end signaling problem by the State Update (unlike the problem of generic route changes) gives rise to the degradation of network performance, e.g., increased signaling overhead, service blackout, and so on. To reduce signaling latency in the Mobile-IP-based scenarios, the NSIS protocol suite may need to interwork with localized mobility management (LMM). If the GIST/NSLP (QoS NSLP or NAT/FW NSLP) protocols interact with Hierarchical Mobile IPv6 and the CRN is discovered between an MN and an MAP, the State Update can be localized by address mapping. However, how the State Update is performed with scoped signaling messages within the access network under the MAP is for future study.

In the interdomain handover, a possible way to mitigate the latency penalty is to use the multihomed MN. It is also possible to allow the NSIS protocols to interact with mobility protocols such as Seamoby protocols (e.g., Candidate Access Router Discovery (CARD) [RFC4066] and the Context Transfer Protocol (CXTP) [RFC4067]) and Fast Mobile IP (FMIP). Another scenario is to use a peering agreement that allows aggregation authorization to be performed for aggregate reservation on an interdomain link without authorizing each individual session. How these approaches can be used in NSIS signaling is for further study.

6.3. Intermediate Node Becomes a Dead Peer

The failure of a (potential) NSIS CRN may result in incomplete state re-establishment on the new path and incomplete teardown on the old path after handover. In this case, a new CRN should be rediscovered immediately by the CRN discovery procedure.

The failure of an AR may make the interactions with Seamoby protocols (such as CARD and CXTP) impossible. In this case, the neighboring peer closest to the dead AR may need to interact with such protocols. A more detailed analysis of interactions with Seamoby protocols is left for future work.

In Mobile-IP-based scenarios, the failures of NSIS functions at an FA and an HA may result in incomplete interaction with IP tunneling. In this case, recovery for NSIS functions needs to be performed immediately. In addition, a more detailed analysis of interactions with IP tunneling is left for future work.

7. Security Considerations

This document does not introduce new security concerns. The security considerations pertaining to the NSIS protocol specifications, especially [RFC5971], [RFC5973], and [RFC5974], remain relevant. When deployed in service provider networks, it is mandatory to ensure that only authorized entities are permitted to initiate re-establishment and removal of NSIS states in mobile environments, including the use of NSIS proxies and CRNs.

8. Contributors

Sung-Hyuck Lee was the editor of early drafts of this document. Since draft version 06, Takako Sanda has taken the editorship.

Many individuals have contributed to this document. Since it was not possible to list them all in the authors section, this section was created to have a sincere respect for those who contributed: Paulo

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