              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.

Status of This Memo

Table of Contents

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

```
        MN    QNE1 MN        QNE2        QNE3      QNE4      CN
      (CoA1)  | (CoA2)        |         (CRN)      |         |
        |     |    |          |           |        |         |
        |     |    |RESERVE   |           |        |         |
        |     |    |------->  |           |        |         |
        |     |    |  (1)     |RESERVE    |        |         |
        |     |    |          |--------> |         |         |
        |     |    |          |  (2)     |RESERVE  |         |
        |     |    |          |          |------->|          |
        |     |    |          |          |  (3)    |RESERVE  |
        |     |    |          |          |         |------->  |
        |     |    |          |          |         |  (4)     |
        |     |    |          |   NOTIFY |         |         |
        |     |    |          |<---------|         |         |
        |     |    |  NOTIFY  |   (9)    |         |         |
        |     |<------------  |          |         |         |
        |     |    |  (10)    |          |         |         |
        |  RESERVE(T)  |      |          |         |         |
        |     |------------>  |          |         |         |
        |     |    |  (11)    |RESERVE(T)|         |         |
        |     |    |          |--------> |         |         |
        |     |    |          |  (12)    |         |RESPONSE |
        |     |    |          |          |         |<------- |
        |     |    |          |          |RESPONSE |   (5)   |
        |     |    |          | RESPONSE |<------- |         |
        |     |  RESPONSE|<---------|   (6)    |         |
        |     |<------ |     (7)    |         |         |
        |     |    |  (8)     |          |         |         |
        |     |    |          |          |         |         |
```
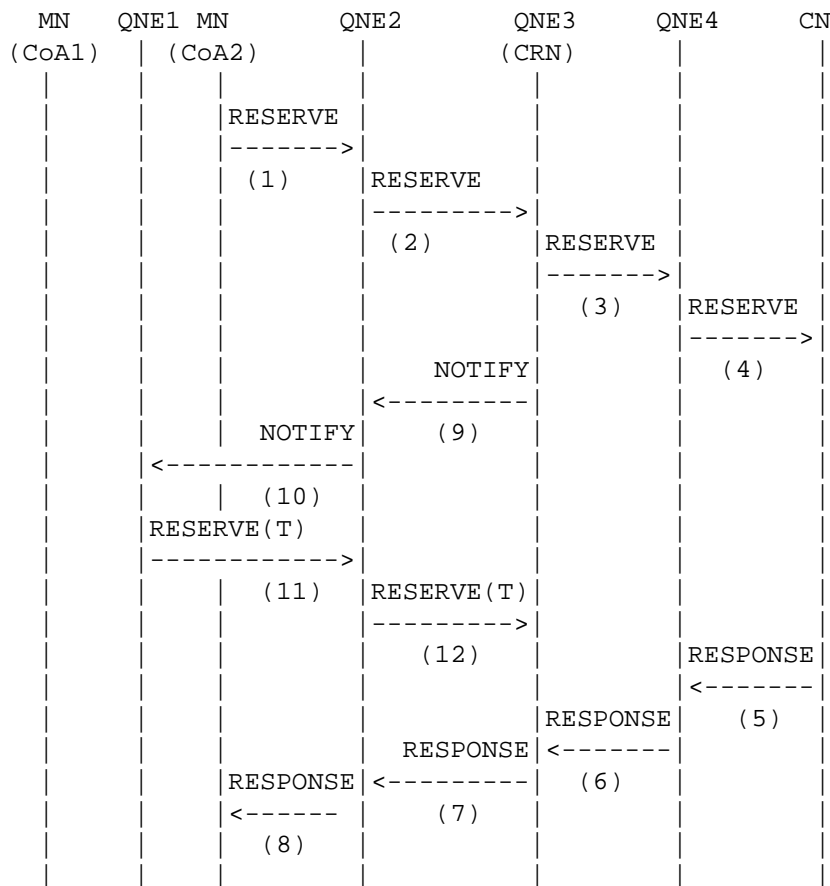
                Figure 1: Example Basic Handover Signaling in the QoS NSLP

   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.

```
          MN      NI MN            NF1         NF2      NF3      CN
         (CoA1)   | (CoA2)          |          (CRN)     |        |
          |       | |               |           |        |        |
          |       | |               |           |        |        |
          |       | |CREATE         |           |        |        |
          |       | |------->|      |           |        |        |
          |       | |  (1)   |CREATE|           |        |        |
          |       | |        |--------->|       |        |        |
          |       | |        |  (2)  |CREATE    |        |        |
          |       | |        |       |------->| |        |        |
          |       | |        |       |   (3)  |CREATE    |        |
          |       | |        |       |        |------->| |        |
          |       | |        |       |  NOTIFY|    (4)   |        |
          |       | |        |       |<---------|        |        |
          |       | |  NOTIFY|       |   (9)    |        |        |
          |       |<------------|    |          |        |        |
          |       | |  (10)  |       |          |        |        |
          |       |CREATE(CoA2)       |          |        |        |
          |       |------------>|     |          |        |        |
          |       | |  (11)  |CREATE(CoA2)       |        |        |
          |       | |        |--------->|        |        |        |
          |       | |        |  (12)   |         |RESPONSE|        |
          |       | |        |         |         |<-------|        |
          |       | |        |         |RESPONSE |   (5)  |        |
          |       | |        | RESPONSE|<-------|          |        |
          |       | |RESPONSE|<---------|   (6)  |          |        |
          |       | |<------ |    (7)  |         |          |        |
          |       | |  (8)   |         |         |          |        |
          |       | |        |         |         |          |        |
          |       | |        |         |         |          |        |
```
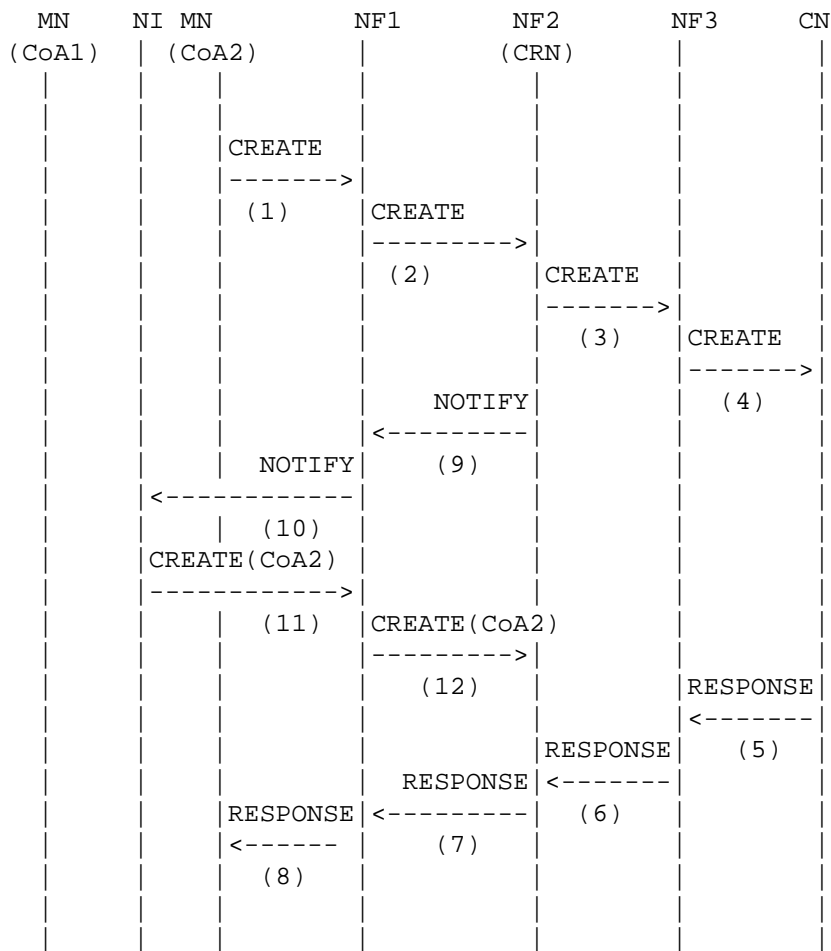
                  Figure 2: Example of NATFW NSLP Operation

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.
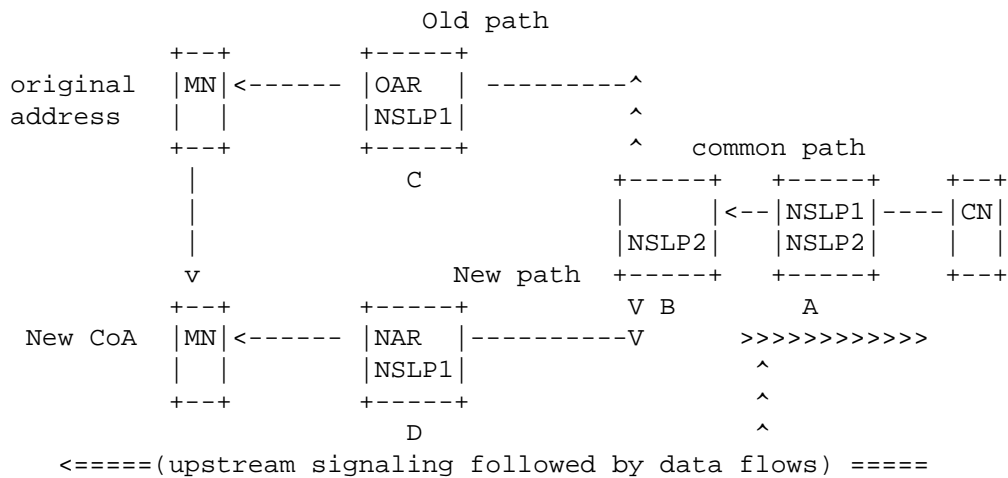
```
                              Old path
                 +--+         +-----+
    original     |MN|<------  |OAR  | ---------^
    address      |  |         |NSLP1|          ^
                 +--+         +-----+          ^    common path
                  |              C          +-----+   +-----+    +--+
                  |                         |     |<--|NSLP1|----|CN|
                  |                         |NSLP2|   |NSLP2|    |  |
                  v            New path     +-----+   +-----+    +--+
                 +--+         +-----+       V B           A
    New CoA      |MN|<------  |NAR  |----------V     >>>>>>>>>>>>
                 |  |         |NSLP1|                     ^
                 +--+         +-----+                     ^
                                D                         ^
              <=====(upstream signaling followed by data flows) =====

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


                              Old path
                 +--+         +-----+
    original     |MN|------>  |OAR  | ----------V
                 |  |         |NSLP1|
    address      +--+         +-----+           V   common path
                  |              K           +-----+   +-----+    +--+
                  |                          |     |---|NSLP1|--->|CN|
                  |                          |NSLP2|   |NSLP2|    |  |
                  v            New path      +-----+   +-----+    +--+
                 +--+         +-----+        ^ M           N
    New CoA      |MN|------>  |NAR  |----------^     >>>>>>>>>>>>
                 |  |         |NSLP1|                     ^
                 +--+         +-----+                     ^
                                L                         ^
            ====(downstream signaling followed by data flows) ======>

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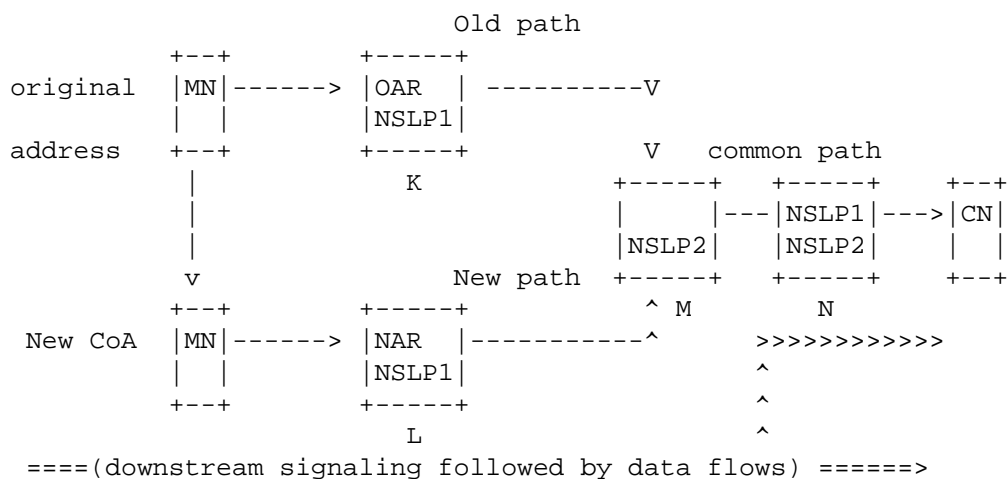
   These topological changes due to mobility cause the NSIS state
   established in the old path to be useless. Such state may be removed
   as soon as possible. In addition, NSIS state needs to be established
   along the new path and be updated along the common path. The re-

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.
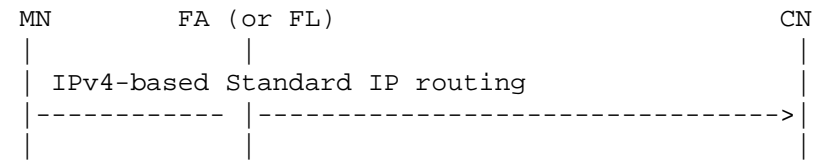
```
       MN          FA (or FL)                              CN
        |           |                                       |
        | IPv4-based Standard IP routing                    |
        |----------- |------------------------------------->|
        |           |                                       |

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


       MN                FA                HA                CN
        | IPv4 (normal)  |                 |                 |
        |--------------->| IPv4(tunnel)    |                 |
        |                |---------------->| IPv4 (normal)   |
        |                |                 |-------------->|

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


       MN               (FL)               HA                CN
        |                |                 |                 |
        |          IPv4(tunnel)            |                 |
        |------------------------------->|IPv4 (normal)    |
        |                |                 |-------------->|

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


       CN               HA                FA                MN
        |IPv4 (normal)  |                 |                 |
        |-------------->|                 |                 |
        |               | MIPv4 (tunnel)  |                 |
        |               |---------------->| IPv4 (normal)   |
        |               |                 |-------------->|

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


       CN               HA               (FL)               MN
        |IPv4(normal )  |                 |                 |
        |-------------->|                 |                 |
        |               | MIPv4 (tunnel)  |                 |
        |               |------------------------------->|
        |               |                 |                 |

          (e) MIPv4: CN-->MN with co-located CoA
```
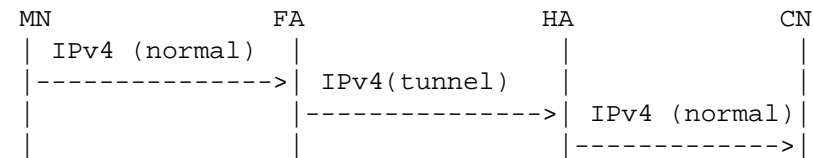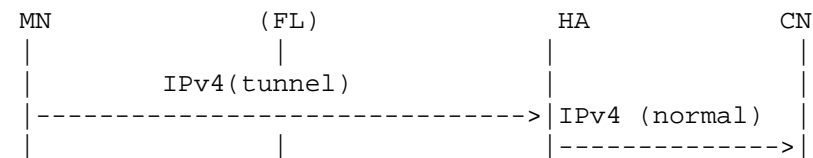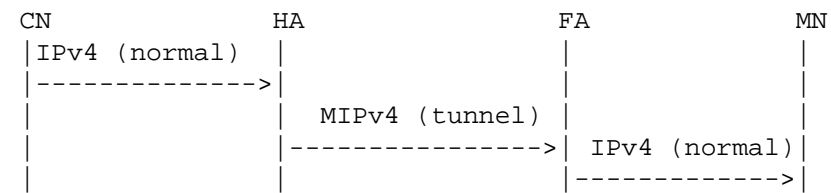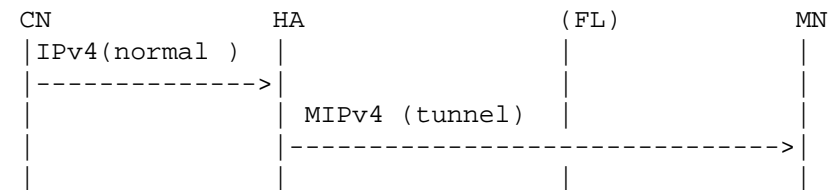
   Figure 4: NSIS Signaling Flows under Different Mobile IPv4 Scenarios

   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].

```
    MN (Sender)    FA (Tentry)        Tmid        HA (Texit)  CN (Receiver)

        |             |               |             |             |
        |  RESERVE    |               |             |             |
        +------------>|               |             |             |
        |             |        RESERVE |             |             |
        |             +----------------------------->|             |
        |             |               |             |  RESERVE    |
        |             |               |             +------------>|
        |             |               |             |  RESPONSE   |
        |             |               |             |<------------+
        |             |        RESPONSE|             |             |
        |             |<-----------------------------+             |
        |  RESPONSE   |               |             |             |
        |<------------+               |             |             |
        |             |               |             |             |
```
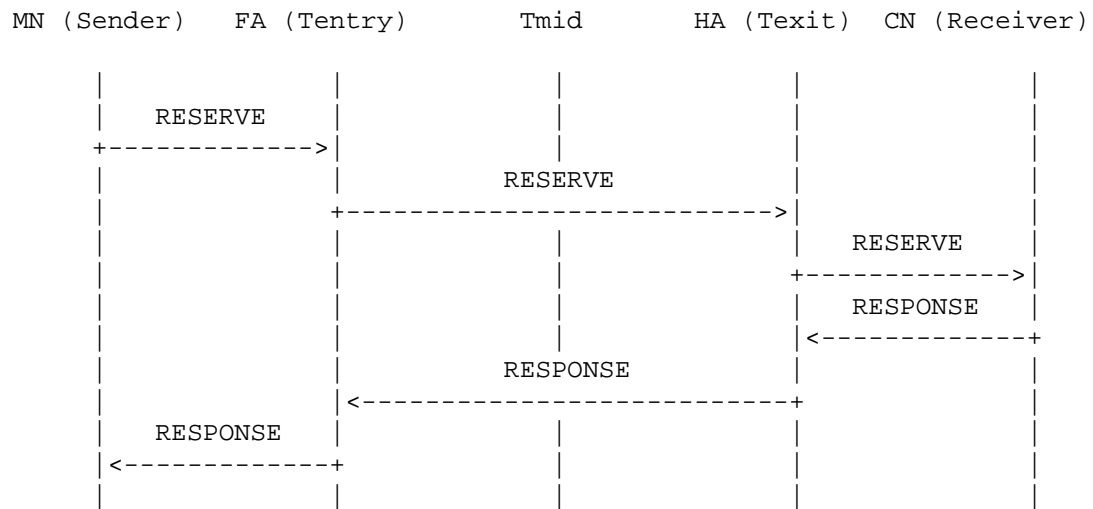
            Figure 5: Sender-Initiated QoS NSLP over Tunnel with Preconfigured
                              QoS Sessions

```
    MN (Sender)    FA (Tentry)        Tmid        HA (Texit)  CN (Receiver)

        |             |               |             |             |
        | RESERVE     |               |             |             |
        +------------>|               |             |             |
        |             | RESERVE'      |             |             |
        |             +=============>|             |             |
        |             |               | RESERVE'    |             |
        |             |               +=============>|             |
        |             |        RESERVE |             |             |
        |             +----------------------------->|             |
        |             |               | RESPONSE'   |             |
        |             |               |<============+             |
        |             | RESPONSE'      |             |             |
        |             |<============+               |             |
        |             |               |             |  RESERVE    |
        |             |               |             +------------>|
        |             |               |             |  RESPONSE   |
        |             |               |             |<------------+
        |             |        RESPONSE|             |             |
        |             |<-----------------------------+             |
        | RESPONSE    |               |             |             |
        |<------------+               |             |             |
        |             |               |             |             |
```
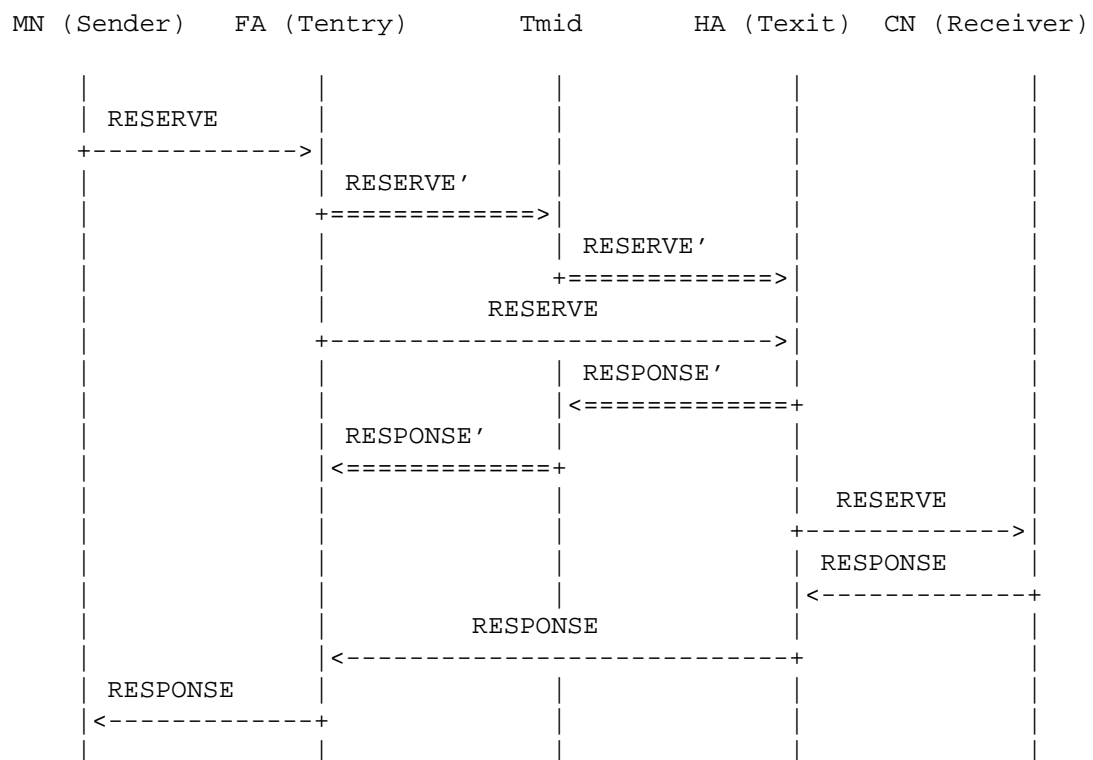
            Figure 6: Sender-Initiated QoS NSLP over Tunnel with Dynamically
                               Created QoS Sessions

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.

```
   MN (Sender)    FA (Tentry)        Tmid        HA (Texit)  CN (Receiver)

        |              |              |              |              |
        |    QUERY     |              |              |              |
        +------------->|              |              |              |
        |              |            QUERY            |              |
        |              +---------------------------->|              |
        |              |              |              |    QUERY     |
        |              |              |              +------------->|
        |              |              |              |   RESERVE    |
        |              |              |              |<-------------+
        |              |           RESERVE           |              |
        |              |<----------------------------+              |
        |   RESERVE    |              |              |              |
        |<-------------+              |              |              |
        |   RESPONSE   |              |              |              |
        +------------->|              |              |              |
        |              |           RESPONSE          |              |
        |              +---------------------------->|              |
        |              |              |              |   RESPONSE   |
        |              |              |              +------------->|
        |              |              |              |              |
```

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

```
MN (Sender)   FA (Tentry)        Tmid        HA (Texit)  CN (Receiver)
    | QUERY         |              |             |            |
    +------------->|              |             |            |
    |              | QUERY'       |             |            |
    |              +============>|              |            |
    |              |              | QUERY'      |            |
    |              |              +===========>|             |
    |              |              | RESPONSE'   |            |
    |              |              |<===========+            |
    |              | RESPONSE'    |             |            |
    |              |<===========+              |            |
    |              |              QUERY         |            |
    |              +--------------------------->|            |
    |              |              |             |  QUERY     |
    |              |              |             +----------->|
    |              |              |             | RESERVE    |
    |              |              |             |<-----------+
    |              |              | RESERVE'    |            |
    |              |              |<===========+            |
    |              | RESERVE'     |             |            |
    |              |<===========+              |            |
    |              |            RESERVE         |            |
    |              |<---------------------------+            |
    |              | RESPONSE'    |             |            |
    |              +============>|              |            |
    |              |              | RESPONSE'   |            |
    |              |              +===========>|             |
    | RESERVE      |              |             |            |
    |<------------+              |             |            |
    | RESPONSE     |              |             |            |
    +------------->|              |             |            |
    |              |           RESPONSE          |            |
    |              +--------------------------->|            |
    |              |              |             | RESPONSE   |
    |              |              |             +----------->|
    |              |              |             |            |
```
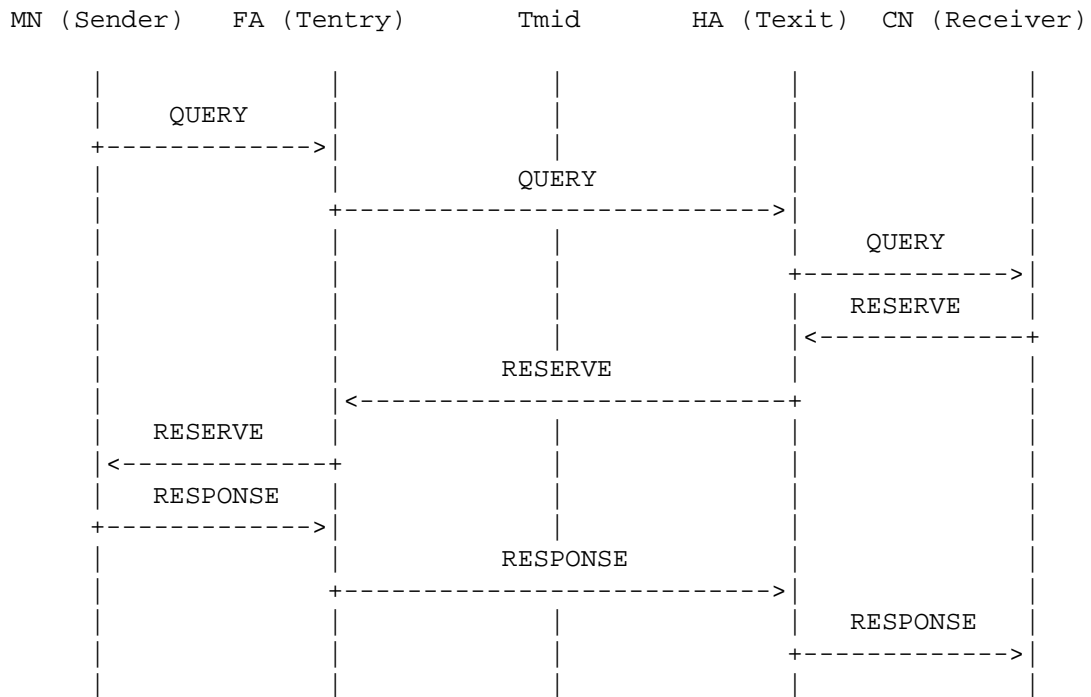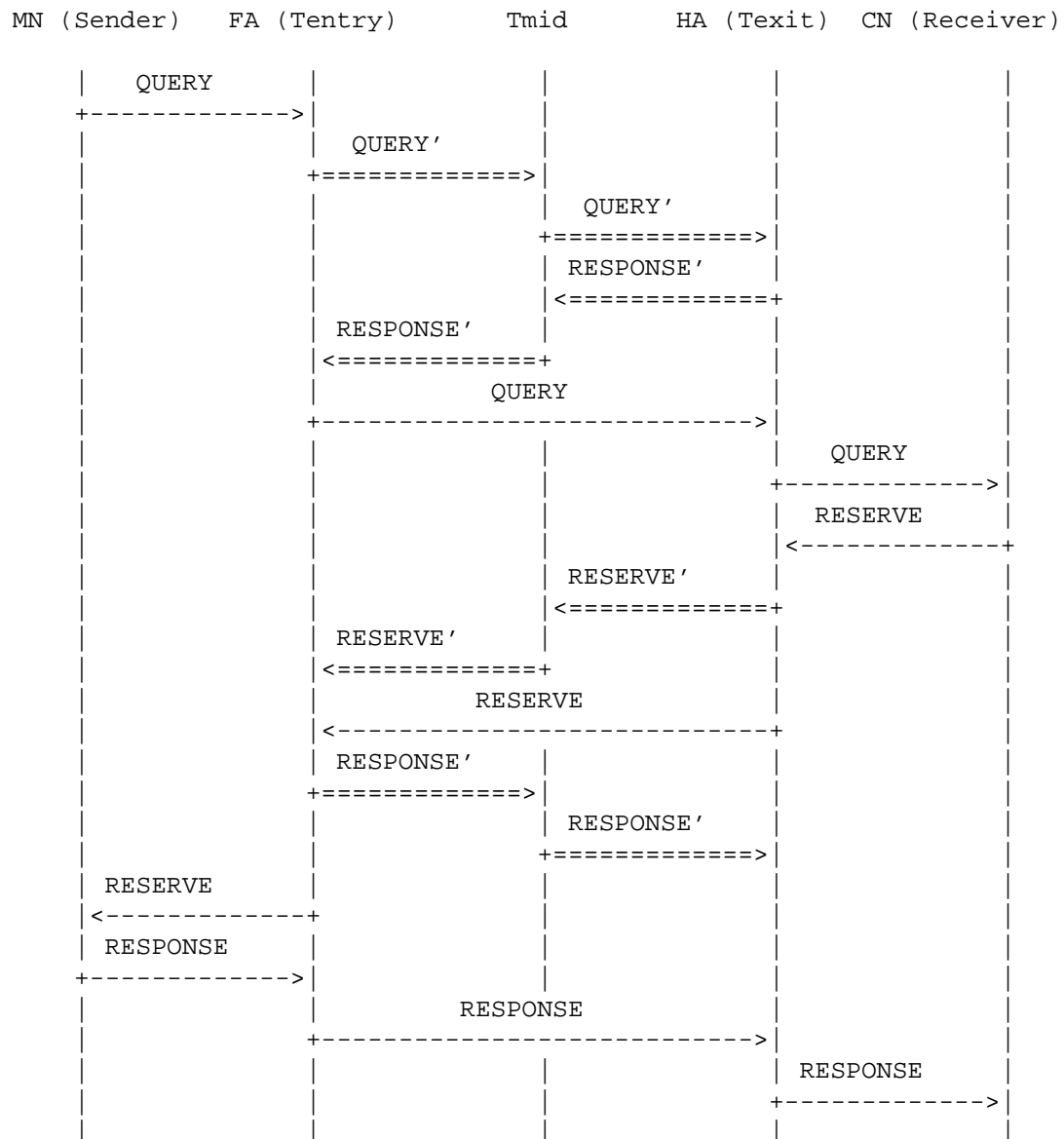
Figure 8: Receiver-Initiated QoS NSLP over Tunnel with Dynamically
                        Created QoS Session

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
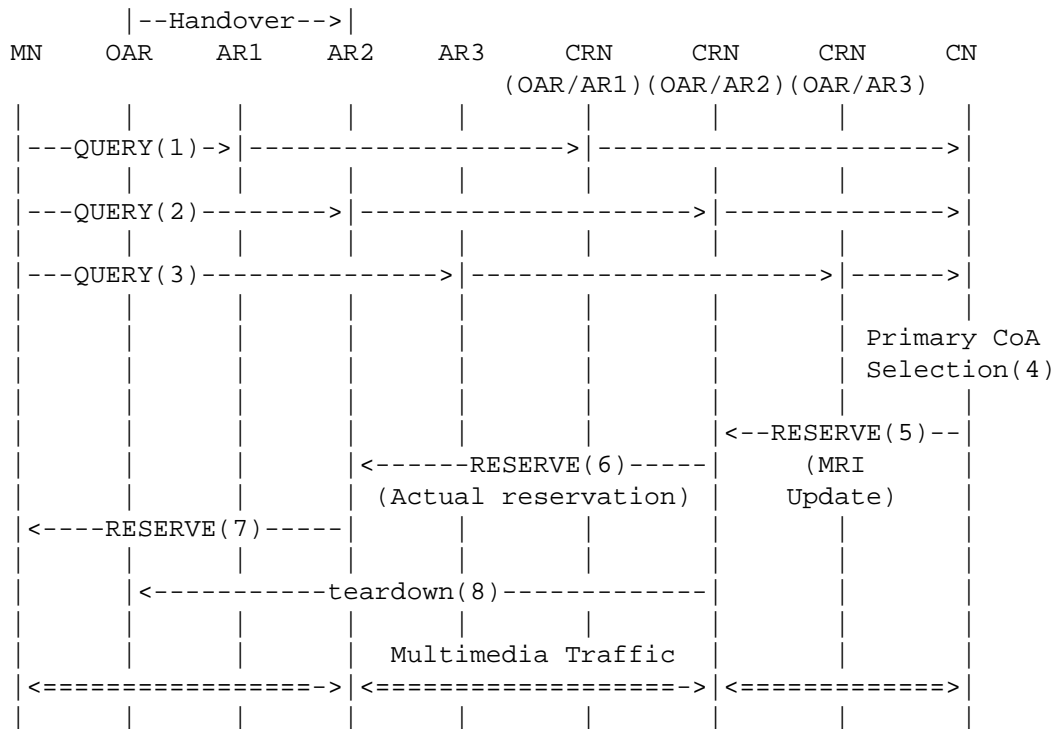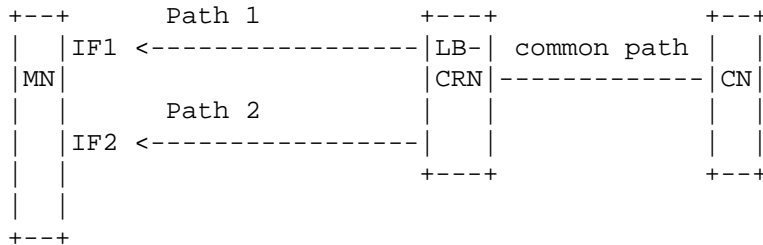   the QUERY message.

```
           |--Handover-->|
      MN    OAR    AR1    AR2    AR3    CRN     CRN     CRN     CN
                                       (OAR/AR1)(OAR/AR2)(OAR/AR3)
      |      |      |      |      |      |       |       |      |
      |---QUERY(1)->|--------------------->|---------------------->|
      |      |      |      |      |      |       |       |      |
      |---QUERY(2)-------->|--------------------->|-------------->|
      |      |      |      |      |      |       |       |      |
      |---QUERY(3)--------------->|---------------------->|------>|
      |      |      |      |      |      |       |       |      |
      |      |      |      |      |      |       |       | Primary CoA
      |      |      |      |      |      |       |       | Selection(4)
      |      |      |      |      |      |       |       |      |
      |      |      |      |      |      |      |<--RESERVE(5)--|
      |      |      |      |<------RESERVE(6)-----|   (MRI      |
      |      |      |      | (Actual reservation) |   Update)   |
      |<----RESERVE(7)-----|      |      |       |       |      |
      |      |      |      |      |      |       |       |      |
      |      |<-----------teardown(8)-------------|       |      |
      |      |      |      |      |      |       |       |      |
      |      |      |      | Multimedia Traffic  |       |      |
      |<=================>|<===================>|<=============>|
      |      |      |      |      |      |       |       |      |
```

Figure 9: Receiver-Initiated Reservation in the Multihomed
Environment

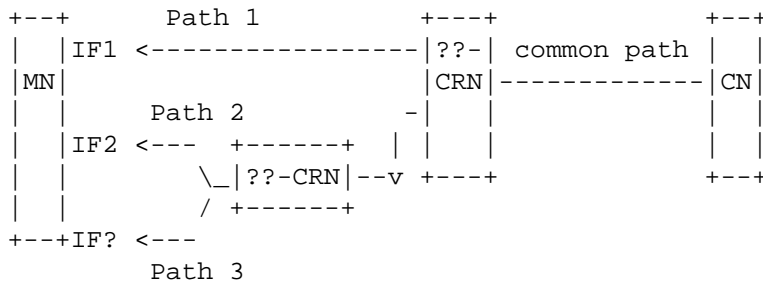6.1.2. Differentiation of Two Types of CRNs

   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.

```
   +--+        Path 1             +---+              +--+
   |  |IF1 <----------------|LB-|  common path |  |
   |MN|                         |CRN|-------------|CN|
   |  |        Path 2           |   |              |  |
   |  |IF2 <----------------|   |              |  |
   |  |                         +---+              +--+
   |  |
   +--+


       (a) NSIS Path classification in multihomed environments


   +--+        Path 1             +---+              +--+
   |  |IF1 <----------------|??-|  common path |  |
   |MN|                         |CRN|-------------|CN|
   |  |        Path 2        -|   |              |  |
   |  |IF2 <---  +------+  | |   |              |  |
   |  |          \_|??-CRN|--v +---+              +--+
   |  |          / +------+
   +--+IF? <---
           Path 3


       (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

   Mendes, Robert Hancock, Roland Bless, Shivanajay Marwaha, and Martin
   Stiemerling. Separating authors into two groups was done without
   treating any one of them better (or worse) than others.

9. Acknowledgements

   The authors would like to thank Byoung-Joon Lee, Charles Q. Shen,
   Cornelia Kappler, Henning Schulzrinne, and Jongho Bang for
   significant contributions in early drafts of this document. The
   authors would also like to thank Robert Hancock, Andrew Mcdonald,
   John Loughney, Rudiger Geib, Cheng Hong, Elena Scialpi, Pratic Bose,
   Martin Stiemerling, and Luis Cordeiro for their useful comments and
   suggestions.

10. References

10.1. Normative References

   [RFC3775] Johnson, D., "Mobility Support in IPv6", RFC3775 ,
              June 2004.

   [RFC5971] Schulzrinne, H. and R. Hancock, "GIST: General Internet
              Signalling Transport", RFC 5971, October 2010.

   [RFC5973] Stiemerling, M., Tschofenig, H., Aoun, C., and E. Davies,
              "NAT/Firewall NSIS Signaling Layer Protocol (NSLP)",
              RFC 5973, October 2010.

   [RFC5974] Manner, J., Karagiannis, G., and A. McDonald, "NSIS
              Signaling Layer Protocol (NSLP) for Quality-of-Service
              Signaling", RFC 5974, October 2010.

   [RFC5944] Perkins, C., Ed., "IP Mobility Support for IPv4, Revised",
              RFC 5944, November 2010.

10.2. Informative References

   [RFC2205] Braden, B., "Resource ReSerVation Protocol (RSVP) --
              Version 1 Functional Specification", RFC2205 ,
              September 1997.

   [RFC3726] Brunner, (Ed), M., "Requirements for Signaling Protocols",
              RFC3726 , June 2004.

   [RFC3753] Manner, J., "Mobility Related Terminology", RFC3753 ,
              June 2004.

   [RFC4066] Liebsch, M., "Candidate Access Router Discovery (CARD)",
              RFC4066 , July 2005.

   [RFC4067] Loughney, J., "Context Transfer Protocol (CXTP)",
              RFC4067 , July 2005.

   [RFC5648] Wakikawa, R., "Multiple Care-of-Address Registration",
              RFC5648 , October 2009.

   [RFC5975] Ash, G., Bader, A., Kappler, C., and D. Oran, "QSPEC
              Template for the Quality-of-Service NSIS Signaling Layer
              Protocol (NSLP)", RFC 5975, October 2010.

   [RFC5979] Shen, C., Schulzrinne, H., Lee, S., and J. Bang, "NSIS
              Operation over IP Tunnels", RFC 5979, March 2011.

Authors' Addresses

   Takako Sanda (editor)
   Panasonic Corporation
   600 Saedo-cho, Tsuzuki-ku, Yokohama
   Kanagawa 224-8539
   Japan

   Phone: +81 45 938 3056
   EMail: sanda.takako@jp.panasonic.com

   Xiaoming Fu
   University of Goettingen
   Computer Networks Group
   Goldschmidtstr. 7
   Goettingen 37077
   Germany

   Phone: +49 551 39 172023
   EMail: fu@cs.uni-goettingen.de

   Seong-Ho Jeong
   Hankuk University of FS
   Dept. of Information and Communications Engineering
   89 Wangsan, Mohyun, Cheoin-gu
   Yongin-si, Gyeonggi-do 449-791
   Korea

   Phone: +82 31 330 4642
   EMail: shjeong@hufs.ac.kr

Jukka Manner
Aalto University
Department of Communications and Networking (Comnet)
P.O. Box 13000
FIN-00076 Aalto
Finland

Phone: +358 9 470 22481
EMail: jukka.manner@tkk.fi
URI: http://www.netlab.tkk.fi/~jmanner/

Hannes Tschofenig
Nokia Siemens Networks
Linnoitustie 6
Espoo
02600
Finland

Phone: +358 50 4871445
EMail: Hannes.Tschofenig@nsn.com