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Route Optimization with Nested Correspondent Nodes
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Abstract

This document aims at assisting the problem statement of route optimization in nested mobile networks. We describe the paths packets would take using existing Mobile IPv6 and NEMO Basic Support mechanisms when one or both end nodes of a communication flow are located in a nested NEMO. One of both of the end nodes may themselves be either mobile nodes performing Mobile IPv6, or standard IPv6 nodes performing no mobility function at all. The path can

become extremely suboptimal if no optimization is provided.

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1. Introduction

This document assumes the reader is familiar with the NEMO Basic Support protocol defined in [1], and with Mobile IPv6 defined in [4]. The reader should also be familiar with the NEMO Terminology defined in [2].

The NEMO Basic Support protocol uses a bi-directional tunnel established between the mobile router and its home agents for all communications. Such communication path brings many problems such as delay, packet loss, less MTU and so on as described in [3]. The values become even more crucial under a nested mobile network, and brings the need for route optimization.

As the solutions to provide such route optimization are proposed, in this document, we try to describe some different communication models which involves a nested mobile network, and to clarify the issues for each cases. We focus on the different cases involving nested correspondent nodes, from the NEMO Basic Support perspective. A nested correspondent node is a correspondent node which itself is also a mobile network node.

In the following sections, we illustrate the path followed by packets if we assume nodes only performing Mobile IPv6 and NEMO Basic Support mechanisms. There are different cases to consider since a CN may either be located in the fixed infrastructure, in a nested NEMO, or in the same nested NEMO as the MNN. Also, we have to consider the cases where CNs and MNNs are either standard IPv6 nodes or MIPv6 nodes. As defined in [2], standard IPv6 nodes are nodes with no mobility functions whatsoever, i.e. they are not MIPv6-enabled nor NEMO-enabled (this does not only mean they cannot move around keeping open connections, but also that they can't process BUs sent by MIPv6-enabled peers).

2. CN located in the fixed infrastructure

The most typical configuration is the case where a MNN communicates with a Correspondent Node (CN) attached in the fixed infrastructure. Figure 1 below shows an example of such topology. The 3 models generally assumed for route optimization are CN as a MIPv6-enabled node, CN attached behind a Correspondent Router, or a standard IPv6 node using a bi-directional tunnel between the root-MR and its HA.

```
                   +---------+  +---------+  +---------+
                   | MR1_HA |  | MR2_HA |  | MR3_HA |
                   +---+-----+  +---+-----+  +---+-----+
                       |            |            |
                      +--------------------------+
                      |        Internet          |----+ CN
                      +--------------------------+
                              |               |
                          +---+---+       +--+------+
                root-MR   |  MR1  |       | VMN_HA |
                          +---+---+       +---------+
                              |
                          +---+---+
                 sub-MR   |  MR2  |
                          +---+---+
                              |
                          +---+---+
                 sub-MR   |  MR3  |
```

```
                                 +---+---+
                                     |
                                 ----+----
                                    MNN
```

Figure 1: CN located at the infrastructure

2.1 Case A: LFN and standard IPv6 CN

The simplest case is where both MNN and CN are fixed nodes with no mobility functions. That is, MNN is a LFN, and CN is a standard IPv6 node. Packets are encapsulated between each MR and its respective HA. As shown in Figure 2, in such case, the path between the two nodes would go through:


```
      1       2       3       4          3          2          1
MNN --- MR3 --- MR2 --- MR1 --- MR1_HA --- MR2_HA --- MR3_HA --- CN
LFN                                                          IPv6 Node
```

The digits represent the number of IPv6 headers.

Figure 2: MNN and CN are standard IPv6 nodes

Route optimization would require collaboration among the MRs. To avoid tunneling through any HA, Correspondent Routes (CRs) may be placed near CNs to handle bindings. CRs are routers enhanced which the ability to handle bindings for a mobile network, allowing a direct tunnel to the MR providing a certain level of optimization.

2.2 Case B: VMN and MIPv6 CN

In this second case, both end nodes are MIPv6-enabled mobile nodes, that is, MNN is a VMN. MIPv6 route optimization may thus be initiated between the two and packets wouldn't go through the HA of the VMN nor the HA of the CN (not shown in the figure). However,

packets will still be tunneled between each MR and its respective HA, in both directions. As shown in Figure 3, the path between VMN and CN would go through:

```
     1       2       3       4          3          2          1
MNN --- MR3 --- MR2 --- MR1 --- MR1_HA --- MR2_HA --- MR3_HA --- CN
VMN                                                            MIPv6
```

Figure 3: MMN and CN are MIPv6 mobile nodes

2.3 Case C: VMN and standard IPv6 CN

When the communication involves a MIPv6 node either as a MNN or as a CN, MIPv6 route optimization can not be performed because the standard IPv6 CN cannot process MIPv6 signaling. Therefore, VMN would establish a bi-directional tunnel with its HA, which causes the flow to go out the nested NEMO. Packets between MNN and CN would thus go through VMN's own HA (VMN_HA). The path would therefore be as shown on Figure 4:


```
     2       3       4       5          4          3          2
MNN --- MR3 --- MR2 --- MR1 --- MR1_HA --- MR2_HA --- MR3_HA --- VMN_HA
VMN                                                                 |
                                                                    | 1
                                                                    |
                                                                   CN
                                                               IPv6 Node
```

Figure 4: MNN is a MIPv6 mobile node and CN is a standard IPv6 node

Providing route optimization involving a MIPv6 node may require optimization among the MRs and the MIPv6 node.

3. CN located in distinct nested NEMOs

The CN may be located in another nested NEMO, different from the one MNN is attached to, as shown on Figure 5. We define such configuration as ``distinct nested NEMOs.''

The models generally assumed for route optimization are optimization

among all MRs in both NEMOs, and a bi-directional tunnel between the two root-MRs.

```
                  +---------+  +---------+  +---------+  +---------+
                  | MR2_HA |  | MR3_HA |  | MR4_HA |  | MR5_HA |
                  +-------+-+  +---+-----+  +---+-----+  +-+-------+
                          \        |            |         /
             +---------+    +--------------------------+    +---------+
             | MR1_HA |----|         Internet          |----| VMN_HA |
             +---------+    +--------------------------+    +---------+
                                |                   |
                            +---+---+           +---+---+
                 root-MR    |  MR1  |           |  MR4  |
                            +---+---+           +---+---+
                                |                   |
                            +---+---+           +---+---+
                  sub-MR    |  MR2  |           |  MR5  |
                            +---+---+           +---+---+
                                |                   |
                            +---+---+           ----+----
                  sub-MR    |  MR3  |              CN
                            +---+---+
                                |
                            ----+----
                               MNN
```

Figure 5: MNN and CN located in distinct nested NEMOs

3.1 Case D: LFN and standard IPv6 CN

Similar with Case A, we start off with the case where both end nodes do not have any mobility functions. Packets are encapsulated at every mobile router on the way out the nested NEMO, decapsulated by the HAs and then encapsulated again on its way down the nested NEMO.

```
     1       2       3       4          3          2          1
MNN --- MR3 --- MR2 --- MR1 --- MR1_HA --- MR2_HA --- MR3_HA --- MR5_HA
LFN                                                                 |
                                                                    | 2
                                                1       2       3   |
                                            CN --- MR5 --- MR4 --- MR4_HA
                                        IPv6 Node
```

Figure 6: MNN and CN are standard IPv6 nodes

3.2 Case E: VMN and MIPv6 CN

Similar with Case B, when both end nodes are MIPv6 nodes, the two nodes may initiate MIPv6 route optimization. Again, packets will not go through the HA of the VMN nor the HA of the MIPv6 CN (not shown in the figure). However, packets will still be tunneled for each MR to its HA and vise versa. Therefore, the path between MNN and CN would go through:

```
     1       2       3       4          3          2          1
MNN --- MR3 --- MR2 --- MR1 --- MR1_HA --- MR2_HA --- MR3_HA --- MR5_HA
VMN                                                                 |
                                                                    | 2
                                                1       2       3   |
                                            CN --- MR5 --- MR4 --- MR4_HA
                                           MIPv6
```

Figure 7: MNN and CN are MIPv6 mobile nodes

3.3 Case F: VMN and standard IPv6 CN

Similar to Case C, when the communication involves a MIPv6 node either as a MNN or as a CN, MIPv6 route optimization can not be performed because the standard IPv6 CN cannot process MIPv6 signaling. VMN would therefore establish a bi-directional tunnel with its HA. Packets between MNN and CN would thus go through VMN's own HA as shown on figure Figure 8:

```
         2       3       4       5          4          3          2
   MNN --- MR3 --- MR2 --- MR1 --- MR1_HA --- MR2_HA --- MR3_HA --- VMN_HA
   VMN                                                                 |
                                                                       | 1
                                             1       2       3          2    |
                                          CN --- MR5 --- MR4 --- MR4_HA  --- MR5_HA
                                       IPv6 Node
```

Figure 8: MNN is a MIPv6 mobile node and CN a standard IPv6 node

4. CN and MNN located in the same nested NEMO

Figure 9 below shows the case where the two communicating nodes are connected behind a different MR, but the MRs are connected in the same nested NEMO, and thus behind the same root-MR. Route optimization can avoid packets being tunneled outside the nested NEMO.

```
              +---------+ +---------+ +---------+ +---------+
              | MR2_HA  | | MR3_HA  | | MR4_HA  | | MR5_HA  |
              +-------+-+ +---+-----+ +---+-----+ +-+-------+
                      \       |           |        /
     +---------+    +--------------------------+    +---------+
     | MR1_HA  |----|         Internet         |----| VMN_HA  |
     +---------+    +--------------------------+    +---------+
                                |
                            +---+---+
               root-MR      |  MR1  |
                            +-------+
                             |     |
                        +--------+  +--------+
            sub-MR      |  MR2   |  |  MR4   |
                        +---+----+  +---+----+
                            |           |
                        +---+----+  +---+----+
            sub-MR      |  MR3   |  |  MR5   |
                        +---+----+  +---+----+
                            |           |
                        ----+----   ----+----
                           MNN         CN
```

Figure 9: CN and MNN located in the same nested NEMO

4.1 Case G: LFN and standard IPv6 CN

Again, we start off with the case where both end nodes do not have any mobility functions. Packets are encapsulated at every mobile router on the way out the nested NEMO via the root-MR, decapsulated and encapsulated by the HAs and then make their way back to the nested NEMO through the same root-MR. Therefore, the path between MNN and CN would go through:


```
    1       2       3       4          3          2          1
MNN --- MR3 --- MR2 --- MR1 --- MR1_HA --- MR2_HA --- MR3_HA --- MR5_HA
LFN                                                                 |
                                                                    | 2
                          1       2       3       4          3      |
                       CN --- MR5 --- MR4 --- MR1 --- MR1_HA --- MR4_HA
                    IPv6 Node
```

Figure 10: MNN and CN are standard IPv6 nodes

4.2 Case H: VMN and MIPv6 CN

Similar with Case B and E, when both end nodes are MIPv6 nodes, the two nodes may initiate MIPv6 route optimization which will avoid the packets to go through the HA of the VMN nor the HA of the MIPv6 CN (not shown in the figure). However, packets will still be tunneled between each MR and its respective HA in both directions. Therefore, the path would be the same with Case G and go through:

```
    1       2       3       4          3          2          1
MNN --- MR3 --- MR2 --- MR1 --- MR1_HA --- MR2_HA --- MR3_HA --- MR5_HA
VMN                                                                 |
                                                                    | 2
                          1       2       3       4          3      |
                       CN --- MR5 --- MR4 --- MR1 --- MR1_HA --- MR4_HA
                   MIPv6 Node
```

Figure 11: MNN and CN are MIPv6 mobile nodes

4.3 Case I: VMN and standard IPv6 CN

As for Case C and Case F, when the communication involves a MIPv6 node either as a MNN or as a CN, MIPv6 route optimization can not be performed. Therefore, VMN will establish a bi-directional tunnel with its HA. Packets between MNN and CN would thus go through VMN's own HA. The path would therefore be as shown on Figure 12:


```
     2       3       4       5          4          3          2
MNN --- MR3 --- MR2 --- MR1 --- MR1_HA --- MR2_HA --- MR3_HA --- VMN_HA
VMN                                                                 |
                                                                    | 1
           1       2       3       4          3          2          |
      CN --- MR5 --- MR4 --- MR1 --- MR1_HA --- MR4_HA --- MR5_HA
     IPv6 Node
```

Figure 12: MNN is a MIPv6 mobile node and CN a standard IPv6 node

5. CN located behind the same nested MR

Figure 13 below shows the case where the two communicating nodes are connected behind the same nested MR. The optimization is required when the communication involves MIPv6-enabled nodes.

```
              +---------+  +---------+  +---------+  +---------+
              | MR2_HA  |  | MR3_HA  |  | MR4_HA  |  | MR5_HA  |
              +-------+-+  +---+-----+  +---+-----+  +-+-------+
                       \       |            |        /
         +---------+    +--------------------------+    +---------+
         | MR1_HA  |----|         Internet         |----| VMN_HA  |
         +---------+    +--------------------------+    +---------+
                                     |
```

```
                       +---+---+
          root-MR      |  MR1  |
                       +---+---+
                           |
                       +-------+
           sub-MR      |  MR2  |
                       +---+---+
                           |
                       +---+---+
           sub-MR      |  MR3  |
                       +---+---+
                           |
                       -+--+--+-
                       MNN    CN
```

Figure 13: MNN and CN located behind the same nested MR

5.1 Case H: LFN and standard IPv6 CN

If both end nodes are LFNs, no special function is necessary for optimization of their communication. The path between the two nodes would go through:


```
                     1
                 MNN --- CN
                 LFN    IPv6 Node
```

Figure 14: MNN and CN are standard IPv6 nodes

5.2 Case I: VMN and MIPv6 CN

Similar with Case H, when both end nodes are MIPv6 nodes, the two nodes may initiate MIPv6 route optimization. Although few packets would go out the nested NEMO for the Return Routability initialization, however, unlike Case B and Case E, packets will not get tunneled outside the nested NEMO. Therefore, packets between MNN and CN would eventually go through:

```
                   1
                MNN --- CN
                VMN   MIPv6 Node
```

Figure 15: MNN and CN are MIPv6 mobile nodes

If the root-MR is disconnected while the nodes exchange keys for the RR procedure, they may not communicate even though they are connected on the same link.

5.3 Case I: VMN and standard IPv6 CN

When the communication involves a MIPv6 node either as a MNN or as a CN, MIPv6 route optimization can not be performed. Therefore, even though the two nodes are on the same link, VMN will establish a bi-directional tunnel with it's HA, which causes the flow to go out the nested NEMO. Path between MNN and CN would require another HA (HA4) to go through for this MIPv6 node:


```
        2       3       4       5          4          3          2
```

```
MNN --- MR3 --- MR2 --- MR1 --- MR1_HA --- MR2_HA --- MR3_HA --- VMN_HA
VMN                                                                  |
                                                                     | 1
                                                                     |
                                                                    CN
                                                                IPv6 Node
```

Figure 16: MNN is a MIPv6 mobile node and CN is a standard IPv6 node

6. Conclusion

This document described the paths packets would take using existing Mobile IPv6 and NEMO Basic Support mechanisms when one or both end nodes of a communication flow are located in a nested NEMO. One of both of the end nodes may themselves be either mobile nodes performing Mobile IPv6, or standard IPv6 nodes performing no mobility function at all.

This draft aims at helping the definition of the problem statement for route optimization when one or both end nodes are located in a nested NEMO. As emphasized on our figures, the path can become extremely un-optimal if no optimization is provided besides the sole opetation of existing Mobile IPv6 by some end nodes and NEMO Basic Support by the MR. The generic solution to come up should cover all cases, providing certain level of optimization for each case.

7 References

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