CHAPTER 6

AVOIDING PINBALL ROUTING PROBLEM FOR NESTED NETWORK MOBILITY

6.1 NESTED NEMO

NEMO basic support protocol can support the scenarios where MR of one mobile network can maintain connectivity with its HA through another mobile network (Sabeur et al. 2006). With reference to Thubert and Molteni (2007) and Ng et al. (2007), the nested NEMO is extremely inefficient as the packet size is increased due to additional levels of encapsulation and suboptimal path. The operation of Nested NEMO is discussed in Chapter 2 (2.1.2). Vehicular communication is more complicated as the number of inter-connecting networks is potentially much higher. If the mobile network is nested, the resulting network topology will be more complex. Consider a vehicle inter-communication scenario that allows vehicles to access the Internet via the mobile network of nearby vehicles. This scenario would increase the availability of the Internet by allowing vehicles to mesh together and access the Internet indirectly via other vehicles, when they are unable to form their direct Internet connection. This scenario would result in many mobile networks connecting with each other and could therefore be expected to generate nested NEMO that are several layers depth, further exacerbating the inefficiencies of the NEMO model. In case of nested NEMO network, several tunneling occurs and this leads to some intricacies. One of the serious problems regarding the nested NEMO is the pinball routing problem.
6.2 PINBALL ROUTING

Dattani et al. (2004) quotes that both inbound and outbound packets will flow through all the HA and the MR. This increases the latency, packet loss, bandwidth wastage and less resilience. When a mobile node sends a message to a distant corresponding node in nested NEMO, the data has to be processed with several encapsulations. On reaching each MR, a tunnel has to be established with the respective HA. Thus, for a single data transmission, the packet has to roam through various MR and their corresponding HA. When the mobile network performs handoff, the new CoA has to be updated to the respective HA. This BU and BA has to go through several MR-HA tunnels like regular data transfer. Such routing of packets, commonly termed as pinball routing, is considered a serious performance limitation and its adverse effect is maximum during intra nest communication. Another issue concerned with nested mobile networks is loop formation and race condition between two competing MR.

Pinball routing can be well described by considering a situation, where three mobile networks are considered MN1, MN2, and MN3. These are managed by the routers MR, oMR (old mobile router) and nMR (new Mobile Router) respectively. MN1 is directly connected to the Internet through the AR. MN2 and MN3 access the Internet through MN1. This forms two level nested mobile network. The packets transferred to these networks will undergo tunneling process. Figure 6.1 illustrates the pinball routing problem.
Assume that an MN visits mobile network; its called as VMN to that network. When VMN initiates a data transfer to its HA, the packets are sent to its NMR, then the packets are forwarded to the MR. The packets are forwarded to HA1 (home agent of MR) after next level of encapsulation at MR. HA1 will decapsulate the packet once and forward it to HA2 (home agent of NMR). Finally HA2 will send the data packets to HA of the mobile node (HA3). Thus, when the router in the network receives a data packet, it is first forwarded to its HA and to the destination node. Such kind of routing the packets between multiple nodes will create the pinball routing problem. As per Miska et al. (2004) and Ying et al. (2009) observation, the various problems that occur due to pinball routing are as follows.

- Processing delay increase
- More packet fragmentation.
- Susceptibility to link failure
- Increased Packet Size
6.3 NESTED NEMO WITHOUT PBR

In pinball routing the data packets pass through several MR-HA tunnel resulting in latency. When the mobile network starts moving, BU is delayed and the HA of mobile network is unaware of the new location. Hence it transfers the data packet to the previous location. The motivation behind this proposal is to reduce the BU and BA delay that occurs during the handoff. The proposed mechanism states that when a mobile network moves to a new location, the former mobile router sends a HI to the new mobile router. This HI message passes through several MR-HA tunnels (Thubert et al. 2007). The message must pass through the HA of old mobile router then the HA of new mobile router. When HI message reaches the HA of new MR, a binding update is sent to the HA of the mobile network. Than the HI message reaches the new MR and it replies with a HAck message that passes through several MR-HA tunnels.

The major advantage of the NEMO without PBR mechanism is that the burden of sending BU and receiving BAck by MN is done by the HA of new MR. Hence the time taken for handoff registration is reduced and the continuous data transaction is possible. Let us consider a scenario where a mobile network moves from old mobile router to a new mobile router. The HI message is sent from previous mobile router to the following mobile router. During this process the message reaches the HA of the next mobile router before reaching it. Here the HA of the next mobile router registers the new location of the mobile node to the mobile node’s HA. This information about the new location of the mobile node is sent along with the hand-off initiation message. The HI message sent by previous mobile router is received by next mobile router. Now, next mobile router sends an acknowledgement message to the previous mobile router. So when the mobile network reaches the new MR, the mobile network is already registered with its HA and the handoff latency is significantly reduced. Ming et al. (2011) has proposed a
domain based architecture and routing scheme for Pinball routing problem. Domain based network architecture can be created and domain based routing can also be incorporated to handle the Pinball routing problem. Domain based routing also improves the intra-domain handoff performance. The sequence diagram (Figure 6.2) shows the sequence of events that occur during the HI and HAcK.

**Figure 6.2 Sequence Diagram of Nested NEMO without PBR Architecture**

The overall process that occurs during handoff registration can be depicted in the form of block diagram in Figure 6.3.
The NEMO without PBR system gives an effective mechanism to reduce the handoff latency in the pinball routing problem. The various merits concerning the NEMO without PBR system are as follows.

- Handoff latency is greatly reduced. The burden of BU and BA is taken care by the HA of new MR and when MN reaches a new network, it is already updated to HA.

- The packet loss percentage in the NEMO without PBR mechanism is greatly reduced. This is because the latency that occurs during handoff is reduced and so the ongoing data sessions remain uninterrupted.

Figure 6.3 Block Diagram of Nested NEMO without PBR Architecture
6.4 PERFORMANCE ANALYSIS

The NEMO without PBR system and the existing mechanism are simulated using NS2 tool under linux environment. To evaluate the effectiveness of the system handoff latency and packet loss are considered.

6.4.1 Handoff Latency

Xinyi and Gang (2009) observed that the mechanism that provides lower latency value will be considered as an efficient mechanism. The average handoff delay values are generated during simulation and given in Table 6.1. The graph depicting the handoff latency is shown in Figure 6.4 and 6.5.

Table 6.1 Comparision of Handoff Latency

<table>
<thead>
<tr>
<th>System</th>
<th>Hand-off latency (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEMO in PBR</td>
<td>3.87</td>
</tr>
<tr>
<td>NEMO without PBR System</td>
<td>2.64</td>
</tr>
</tbody>
</table>

Figure 6.4 Handoff Latency of Nested NEMO - PBR
6.4.2 Packet Loss

An efficient mechanism must reduce the packet loss. The packet loss count for existing and NEMO without PBR system is illustrated as data in Figures 6.6 and 6.7. The NEMO with PBR has more packet loss whereas the NEMO without PBR system has fewer as shown in the Table 6.2.

Table 6.2 Packet Loss Percentage Comparison

<table>
<thead>
<tr>
<th>System</th>
<th>Total Packet Transferred</th>
<th>Total Packet Loss</th>
<th>Packet loss percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEMO - PBR</td>
<td>2049</td>
<td>57</td>
<td>2.78</td>
</tr>
<tr>
<td>NEMO without PBR System</td>
<td>2548</td>
<td>48</td>
<td>1.88</td>
</tr>
</tbody>
</table>
Figure 6.6 Packet Loss of Nested NEMO - PBR

Figure 6.7 Packet Loss of NEMO without PBR

The bar graph in Figure 6.8 displays overall comparative results of Packet loss and Hand-off Latency in both systems.
When there is a data transfer while the MN is on the move in nested NEMO environment, the packets are routed between access routers of visited network. This routing of packets leads to pinball routing. A mechanism is proposed to avoid PBR in NEMO to reduce the handoff latency and packet loss. The nested NEMO and proposed system are compared in the simulation environment. The data transfer between CN and MN was implemented in both the protocols approximately for 6 seconds. It took 3.87 seconds for handoff in nested NEMO due to PBR, whereas NEMO without PBR took only 2.64 seconds for handoff. The handoff latency will lead to packet loss, 57 packets are lost in nested NEMO out of 2049 packets due to PBR. Only 48 packets are lost in NEMO without PBR system out of 2548 packets. The results are derived as graph from the trace files of simulation. The lesser packet loss improves the performance of the NEMO protocol.
6.5 SUMMARY

One of the major concerns in NEMO is providing seamless data transfer for mobile users. This seamless connectivity is very much affected by pinball problem and handoff delays that occur in the mobile networks. The solution proposed is effective in reducing the handoff delays in the nested NEMO environment. The packet loss in the system also shows a significant difference when compared to NEMO.

The routing mechanism in the Nested NEMO must also be optimized in order to increase the performance. In the next chapter a mechanism to improve the performance metrics of the nested NEMO is proposed.