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A comparative signaling cost analysis of Macro Mobility scheme in NEMO (MM-NEMO) with mobility management protocol

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Abstract. NEMO BSP is an upgraded addition to Mobile IPv6 (MIPv6). As MIPv6 and its enhancements (i.e. HMIPv6) possess some limitations like higher handoff latency, packet loss, NEMO BSP also faces all these shortcomings by inheritance. Network Mobility (NEMO) is involved to handle the movement of Mobile Router (MR) and it's Mobile Network Nodes (MNNs) during handoff. Hence it is essential to upgrade the performance of mobility management protocol to obtain continuous session connectivity with lower delay and packet loss in NEMO environment. The completion of handoff process in NEMO BSP usually takes longer period since MR needs to register its single primary care of address (CoA) with home network that may cause performance degradation of the applications running on Mobile Network Nodes. Moreover, when a change in point of attachment of the mobile network is accompanied by a sudden burst of signaling messages, "Signaling Storm" occurs which eventually results in temporary congestion, packet delays or even packet loss. This effect is particularly significant for wireless environment where a wireless link is not as steady as a wired link since bandwidth is relatively limited in wireless link. Hence, providing continuous Internet connection without any interruption through applying multihoming technique and route optimization mechanism in NEMO are becoming the center of attention to the current researchers. In this paper, we propose a handoff cost model to compare the signaling cost of MM-NEMO with NEMO Basic Support Protocol (NEMO BSP) and HMIPv6.The numerical results shows that the signaling cost for the MM-NEMO scheme is about 69.6 % less than the NEMO-BSP and HMIPv6.

Keyword: MM-NEMO; NEMO; MR; MNN; CoA;

1. Introduction

In order to achieve the continuous internet connectivity at anytime in any place, Internet Engineering Task Force (IETF) has designed solutions to overcome the inefficiency of current IP addressing to support host based mobility. However, Mobile IPv6 is not able to handle the mobility of an entire network properly, since mobile network introduces much more complex mobility scenarios than host mobility [1-4]. Hence, the NEMO Basic Support Protocol (NEMO BSP) has been proposed by the Network Mobility (NEMO) working group. Simplicity is the most important feature of this protocol since it is a logical extension of the MIPv6 operation. The main purpose of NEMO BSP is to provide seamless connectivity of the whole mobile

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network. There are mainly two major entities in NEMO which are - Mobile Routers (MRs) and Mobile Network Nodes (MNNs). For real time applications in NEMO, continuous Internet connectivity during handoff is generally expected which includes both features i.e. smooth (no or very little packet loss) as well as fast (low delay) handoff. But in accordance with NEMO Basic Support Protocol (NEMO BSP), only one primary Care of Address (CoA) of Mobile Router (MR) can be registered with HA, which affects the handoff performance resulting packet loss and delay. Moreover, there are some other mobility issues which include multi-homed mobile networks, sub optimal routing, and route optimization as well as security issues [5-10].

This paper is organized as follows: section 2 presents some background on handoff delay in NEMO environment. Section 3 presents the proposed handoff cost model. Section 4 evaluates the signaling costs of the proposed scheme with numerical analysis through comparison with NEMO BSP and HMIPv6. Conclusion is given in section 5 (shown in figure 1).
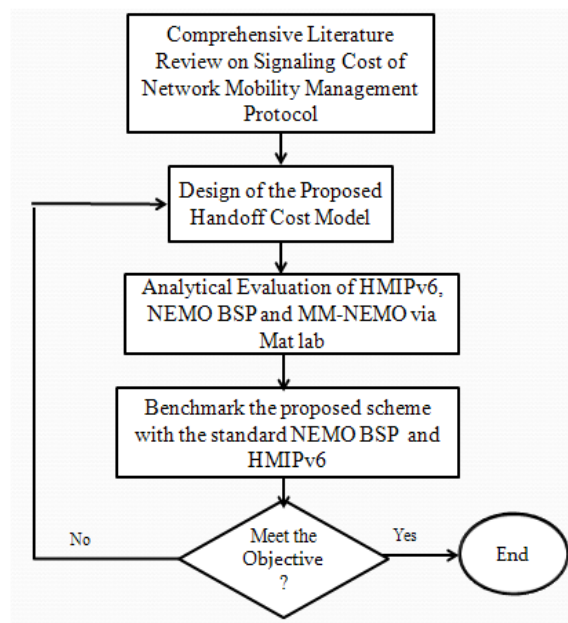

Figure 1: Summarizes the paper steps

2. Related Work

It is possible to use Hierarchical MIPv6 (HMIPv6) and fast MIPv6 (FMIPv6) jointly as Fast Hierarchical MIPv6 (enhancement of MIPv6) to reduce signaling overhead and packet loss. Normally, the Mobility Anchor Point (MAP) is placed at a comprehensive point above the New Access Router (NAR) and Previous AR (PAR) to integrate HMIPv6 and FMIPv6. However, the forwarding of packets would be inefficient between PAR and NAR because data packets will traverse the MAP–PAR link two times before reaching at the NAR. Therefore, in HMIPv6 architecture, the MN exchanges all the signaling messages with MAP, not with PAR to establish the tunnel for the handoff. Introducing FHMIPv6 [2], [4] in IPv6 network is more convenient. However, combining FHMIPv6 with mobile network is still an open issue since it needs to take care of both MR and MNN during handoff from home network to visiting network [2]. As MIPv6 and its enhancements (i.e. FHMIPv6) possess limitations like higher handoff latency, packet loss, NEMO BSP (standard for mobile network) also faces all these shortcomings by inheritance [4]. NEMO BSP is a solution for persevering session continuity by means of bidirectional tunneling between Home Agent (HA) and a mobile network whereas NEMO Extended Support (NEMO ES) that is a result to provide the essential optimization between uninformed Mobile Networks Nodes (MNN) and correspondent Nodes (CN) [4]. NEMO BSP operates in the IP layer and inherits the benefits of Mobile IPv6 [1] by extending the binding mechanism of the ancestor.

In [2], handoff procedure of mobile router (MR) in NEMO Basic Support Protocol (BSP) is almost similar with the mobile node (MN) in MIPv6. Disruption time and packet loss ratio are the critical performance issues during handoff in NEMO network. The parameters that are used to measure the performance analysis are mainly: total handover delay which is depends on movement detection time, care of address configuration delay and registration delay. In figure 2, MR detects its movement by receiving Router Advertisement (RA). Here, RA interval is a random value between minimum router interval (MinRtrInterval) and maximum router interval (MaxRtrInterval) where Layer 2 handoff is transparent to network layer (Layer 3). For layer2 handoff, MR waits for RA to perform Layer 3 handover that is known as movement detection (MD). In [6], [1], MinRtrInterval and MaxRtrInterval are set 30 ms and 70 ms. MR configures CoA after receiving RA according to prefix acquired from RA message received. It should wait for a random time to avoid multiple MRs or MNs configured the same CoA performing duplicate address detection (DAD) at the same time. T_{RED} is the time to complete the registration between the MR and its Home Agent (HA).
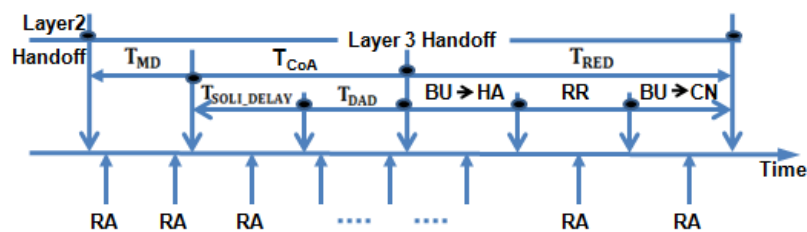

Figure 2: Handoff delay of NEMO BSP [6]

Therefore, the total handoff delay of MR in NEMO can be calculated as

$$\boldsymbol{T_{HD} = E(T_{MD}) + E(T_{DAD}) + T_{RED}} \qquad (1)$$

Therefore, NEMO handoff delay is longer than 1.5 s, which is not applicable for real time applications [6].

3. Proposed Handoff Cost Model

Usually, NEMO network is considered as mobility in a car or vehicular network. Hence, for this type of network, advance preparation mechanism work very well. Therefore, the main idea of the proposed handoff cost model is to apply the fast handoff mechanism for the Serving MR (SMR) with its Local Fixed Node (LFN) in NEMO network to acquire seamless handoff. This method is performed in layer 3 by taking the information from layer 2. For simplicity, the following assumption has been made in the proposed cost model [13].

a) It is assumed that under the Serving MR (SMR) the local nodes are fixed.

b) In addition, during handoff signaling message for Local Fixed Nodes (LFNs) is completely handled by the Serving MR.

c) The Serving MR does not need to register with the Home Agent of Mobile Router (HAMR) until it moves from the current Mobility Anchor Point (CMAP) to New MAP (NMAP) as it is assumed that HMIPv6 is supported by network. Hence, the Serving MR only needs to update current location to CMAP through Current Mobile Router (CMR) during local movement.

d) Moreover, Serving MR is communicating with one Corresponding Node (CN). Additionally, Binding Update (BU) refreshment cost is not considered.

In the proposed system model, it is assumed that the hop distances of A, B, F, G are one where as E,C,D,H,I (as shown in figure 3) are considered as five hops because of Internet link connection [11-12]. According to fast handoff procedure in MM-NEMO scheme, after Layer 2 trigger the Current Mobility Anchor Point (CMAP) create New Regional Care of Address (NRCoA) with New Link Care of Address (NLCoA) instead of the Serving MR. This is based on the Mobile Network Prefix (MNP) of the new link. A temporary bi-directional tunnel is established between the Current MAP (CMAP) and the New MR (NMR) as well. This tunnel allows the CMAP to transfer the data packets to the Serving MR's new address as well as buffer these data packets at the new location of the Serving MR. By applying this mechanism, it is possible to minimize packet loss and delay in NEMO network. For performance analysis in NEMO network, a widely known simple mobility model i.e. random waypoint model [13] has been used to find out the residence time of the SMR. In random-based mobility model, the Serving MR (SMR) move liberally on a random basis where destination, speed, and direction all these factors are selected autonomously and independently of other routers. Different values for system parameters are used in our proposed model for numerical analysis are listed in Table 1 [11-13].
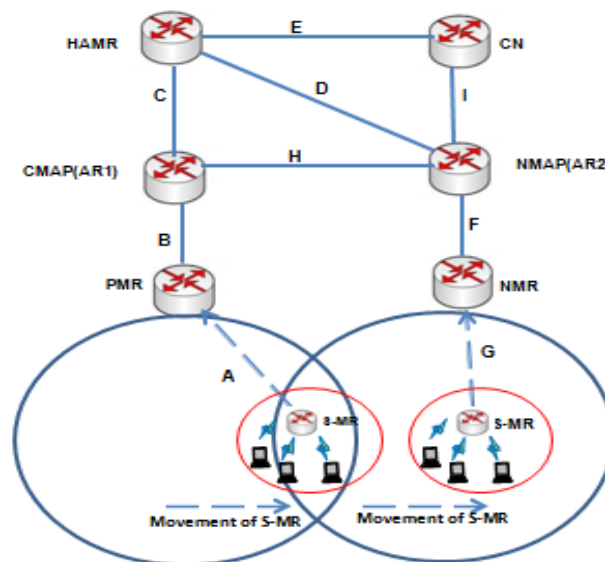

Figure 3: Proposed MM-NEMO Cost Model in NEMO

3.1 Analysis of Location Update Cost
In this section, a signaling cost model is developed to analyze the performance of the MM-NEMO, NEMO BSP, and HMIPv6. In MM-NEMO, extra signaling cost is needed to decrease the packet loss during handoff. When a MR with local fixed node enters into a NMAP domain, the total signaling cost can be calculated as:

$$C_{SIGNALING\ DATA} = C_{SIGNALING\_BASIC} + C_{SIGNALING\_FNA} + C_{SIGNALING\_LBU/LBAck} + C_{SIGNALING\_BA\_SMR\_HA}$$
(2)

In equation (2), $C_{SIGNALING\_BASIC}$ is a signaling cost incurred during the time $T_{SIGNALING\_BASIC}$, $C_{SIGNALING\_FNA}$ is a signaling cost incurred during the time $T_{SIGNALING\_FNA}$, $C_{SIGNALING\_LBU/LBAck}$ is a signaling cost incurred during the time $T_{SIGNALING\_LBU/LBAck}$ and $C_{SIGNALING\_BA\_SMR\_HA}$ is a signaling cost incurred during the time $T_{SIGNALING\_BA\_SMR\_HA}$ (shown in figure 4). In the proposed cost model, it is assumed that, HA of SMR send the data packets at a mean rate α as well as the SMR moves from one subnet to another at a mean rate β.
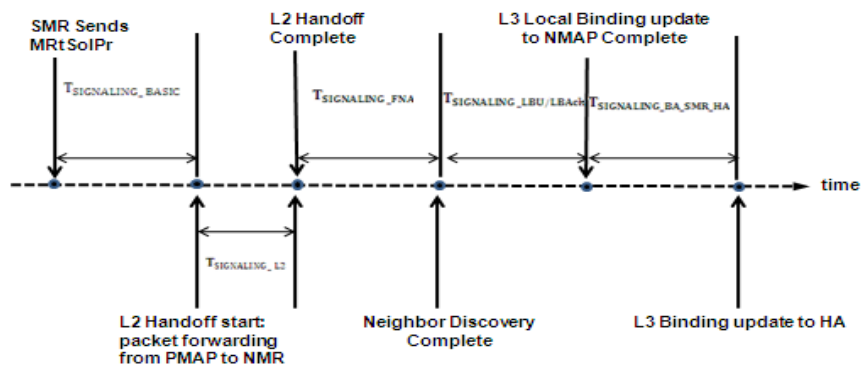
Figure 4: Timing diagram of the MM-NEMO scheme

3.2 *The Cost for Transmitting Data Packets*

Packet delivery cost $C_{DATA\ PAChET}$ is caused when a HA_SMR send packets to a SMR. Therefore, Packet delivery cost is defined as the total of the packet tunneling cost (C_{tunnel}) and the packet loss cost (C_{LOSS}). So, the packet delivery cost is calculated as follows:

$$C_{DATA\ PAChET}= \quad P_{SUCCESS}.C_{TUNNEL} + \lambda.P_{FAIL}.C_{LOSS} \qquad\qquad (3)$$

Where, $P_{SUCCESS}$ is the probability for MR to perform fast handover successfully in Predictive mode and P_{FAIL} is the probability of failure. λ represent the increasing rate while HA_SMR retransmits the packets to SMR. $P_{SUCCESS}.C_{TUNNEL}$ is a packet delivery cost when the handover is success, $P_{FAIL}.C_{LOSS}$ is a Packet delivery cost when the handover is fail. C_{Tunnel} is the packet tunneling cost for the SMR_HA to send packets through the tunnel between CMAP and NMR.

On the other hand, the packet delivery cost of HMIPv6 based NEMO environment can be expressed as:

$$\frac{C_{LOSS}}{C_{ORIGINAL\_PACKET}}= \lambda*P_{FAIL}* \alpha*C_{CMAP\_LOSS} *(T_{L2} + T_{IP}+\frac{T_{SIGNALING\_LBU}}{L_{BAck}}{}_k +T_{SIGNALING\_BU\_SMR\_HA}) \ (4)$$

4. Numerical Analysis

The system parameters for numerical analysis are shown in table 1. Numerical results are obtained using MATLAB 7.0.4. The following observations are made: In figure 5 and figure 6, the variation of location update cost with average cell residence time and velocity are illustrated. Here, the longer an S-MR remains in a current cell, the lower the location update cost. It shows that, location update cost for the proposed scheme is about 69.6 % less than that of the NEMO-BSP. It is observed that the location update cost increases with velocity since cell residence time is inversely proportional to velocity. In this case, it results same amount of cost reduction from NEMO-BSP when the number of S-MR is 4. The variation of total cost of MM-NEMO, NEMO BSP, and HMIPV6 with cell residence time is illustrated in figure 7. Since the cell residence time increases, both the total cost of MM-NEMO scheme and NEMO-BSP decrease while HMIPV6 increases linearly. When the time is less than 5 second the total cost of NEMO-BSP is higher than that of HMIPV6 while for MM-NEMO scheme, it is minimized to 2 seconds which is explained in figure 8. In figure 9, it is observed that the cost ratio of NEMO-BSP and HMIPV6 is higher than that of the MM-NEMO and HMIPV6 schemes. When the cell residence time approaches to 2 seconds the cost ratio for the MM-NEMO scheme goes below unity at the same time this ratio is obtained in 5 seconds for NEMO-BSP.

Table 1. System Parameters

Parameter	Value
$T_{SIGNALING\_BASIC}$	43.253 msec
T_{L2}	55 msec
T_{FNA}	5.726 msec
$T_{LBU/LBAck}$	11.452 msec
T_{BU_HA}	25.018 msec
T_{RR}	38.584 msec
T_{BU_CN}	25.018 msec
$c\ d\ f\ g$	1 hop
e	2 hop
h $i\ j\ k\ l$	5 hop

The influence of the number of Serving Mobile Router (S-MR) on packet delivery cost is rising exponentially which is represented in figure 10. By analyzing the figure 9, it is summarized that when the number of S-MR is below 8, the cost ratio is decreasing which shows better performance for MM-NEMO. Furthermore, the proposed MM-NEMO scheme reduces the total cost by 72% over NEMO-BSP when the number of S-MR is 4.The significance of this figure is that if the time is set at 16 seconds the cost for proposed MM-NEMo will be reduce by 83% over the NEMO-BSP at any number of S-MR.
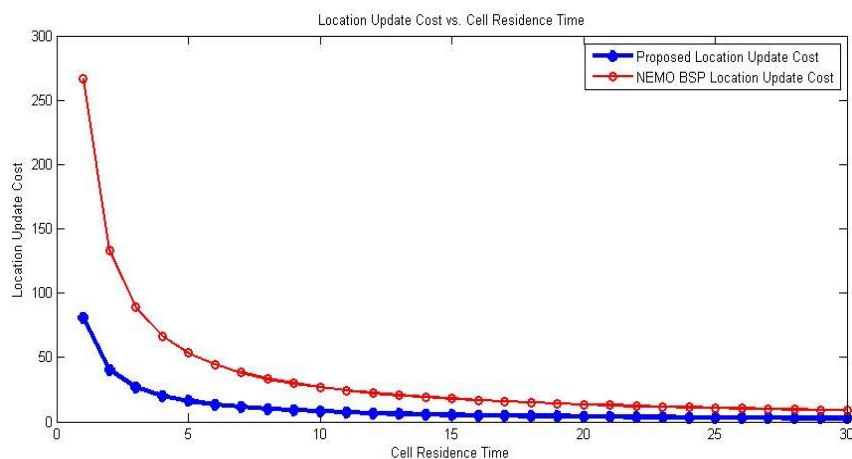

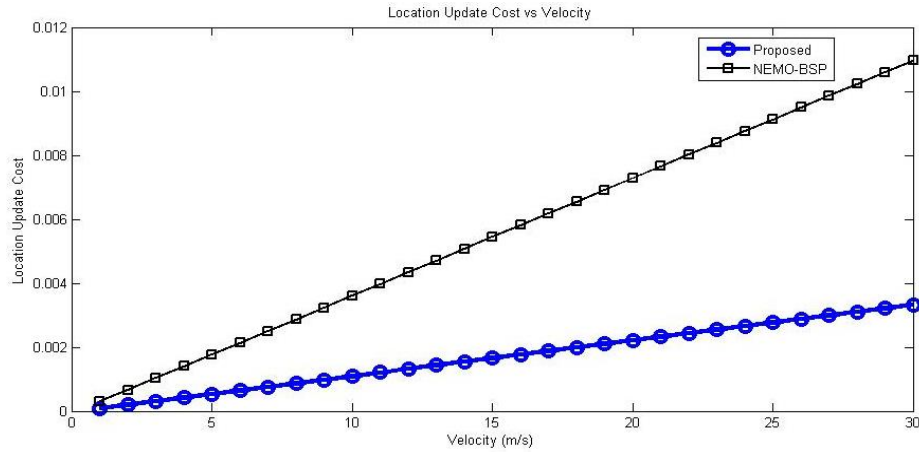Figure 5: Location Update Cost vs. Cell Residence Time
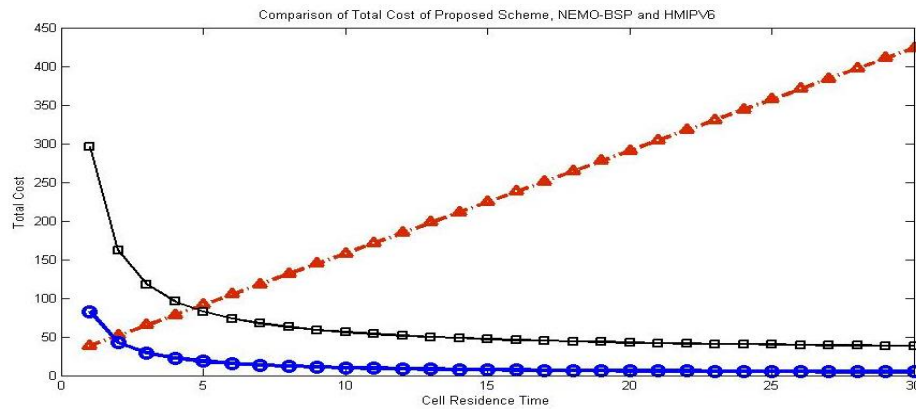
Figure 6: Location Update Cost vs. Velocity

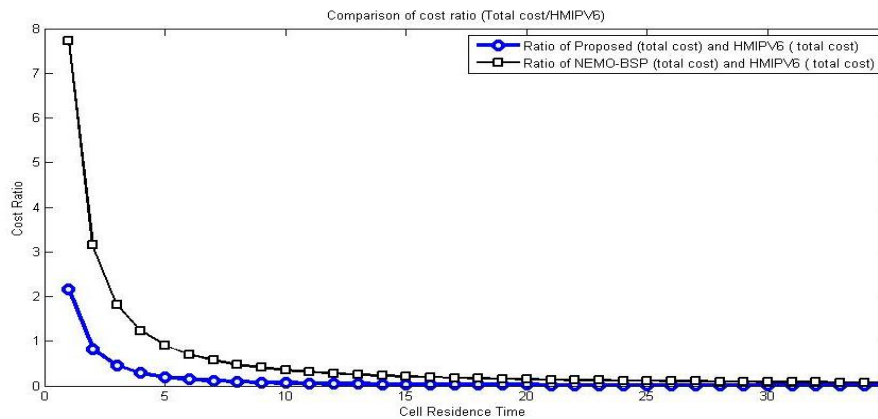Figure 7: Comparison of Total Cost (MM-NEMO, NEMO BSP, and HMIPV6)

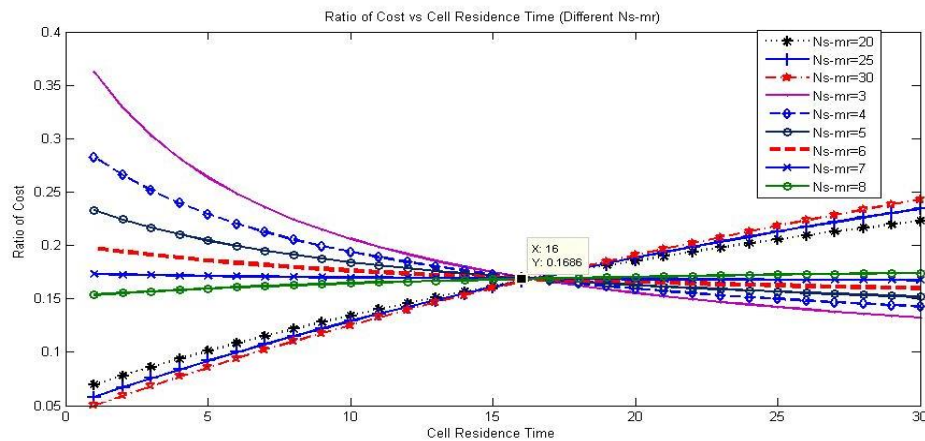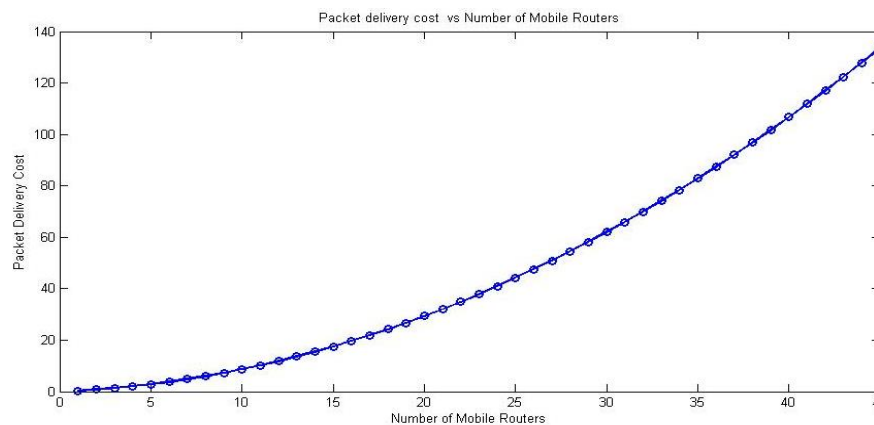Figure 8: Ratio Comparison of MM-NEMO and NEMO-BSP with HMIPV6

Figure 9: Ratio of Cost vs Cell Residence Time (different N_{S-MR})

Figure 10: Packet Delivery cost vs. Number of S-MR

5. Conclusion

In this paper, we propose the macro mobility architecture that supports fast handover between the MAP domains by adopting the FHMIPv6 (fast HMIPv6) to improve handover between MAP domains in NEMO environment. Thus, the proposed macro mobility scheme can reduce the signaling cost almost 69.6 % less than NEMO BSP as well as the handoff delay which is incurred when the serving MR (S-MR) with fixed nodes moves between the MAP domains. We observe that the proposed scheme can provide better performance than NEMO BSP that is essential for seamless/uninterrupted handoff. However in order to more precise evaluation, need to consider visiting and local mobile node in the proposed scheme is another requirement as a future work.

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