

Research Article

Analytical Evaluation of Intra Domain Mobility Approach in NEMO Environment

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Abstract: Network Mobility Basic Support Protocol (NEMO BSP) is considered as the most widespread network mobility protocol at the present time which is a logical extension of the MIPv6 operation. Hence, Location Update (LU) procedure of NEMO BSP is almost similar to MIPv6 registration apart from setting of the MR flag and sending of prefix in the Binding Update (BU). However, in NEMO network, providing an uninterrupted Internet connectivity during handoff (seamless handoff) is still an open issue for the current researchers in terms of handoff delay, packet loss, service disruption time and signaling overhead respectively. To concentrate on these issues, in this study, an Intra Domain Mobility scheme in NEMO (IDM-NEMO) is proposed that aims to reduce signaling overhead by incorporating an improved version of Fast HMIPv6 scheme with NEMO network to attain continuous Internet connectivity at the time of movement from one subnet to another. Additionally, in order to analyze the location update cost, a mathematical model has been developed and compared with the standard NEMO BSP. The analytical result demonstrates that the proposed scheme reduced location update cost by 52% than that of NEMO-BSP.

Keywords: FHMIPv6, IDM-NEMO, LU, micro mobility, NEMO BSP, seamless handoff, SMR

INTRODUCTION

Nowadays, the key concern for the industries is the support of network mobility for the whole network; this is due to the existing Internet connection for the period of handoff. The main reason behind this is because existing Internet connectivity is presently not designed to trace mobility due to the IP location-based addressing method as IP addresses are joined to the geographical areas. It becomes crucial to obtain a new IP address in host based mobility, especially when a host needs to move among different subnets. This makes the communication unsuccessful while retaining reach ability and continuousness attribution of the session. As a result, authors (Johnson *et al.*, 2004) in recent time Internet Engineering Task Force (IETF) has come up with a solution (e.g. MIPv6) to resolve the shortcomings of existing IP addressing to sustain the host mobility. However, this solution appears to have other complications to handle the mobility of the whole network accurately. Therefore, the IETF has observed the shortcomings of previous solution and proposed a Network Mobility Basic Support Protocol (NEMO BSP) (Devarapalli *et al.*, 2005). The principle function of NEMO BSP is to deliver seamless Internet

connectivity over the entire mobile network during movement of Mobile Router (MR) from one subnet to another, which includes Mobile Network Nodes (MNNs) and Mobile Routers (MRs), as depicted in Fig. 1.

In NEMO, MR executes the whole task on behalf of MNNs during handoff, which creates a bi-directional tunnel between the serving Mobile Router (MR) with its Home Agent (HA) and then carries out the handoff after implementing the layer 2 switching, thus defining the basic inspiration of NEMO BSP (Devarapalli *et al.*, 2005). Therefore, it ought to limit frequent registrations of Mobile Network Nodes (MNNs) with their Home Agents (HA). Binding Update (BU) message should be only sent by the serving MR with network prefix by providing Internet connectivity to all nodes inside its network. Nevertheless, generating a bi-directional tunnel between MR and its HA for all communications makes sub optimal quandary in which all the packets are encapsulated and tunneled via HA of serving MR (MR). This amplifies the handoff delay, disconnections probability and packet loss. In order to triumph over these handoff related conundrum, the Fast Hierarchical Mobile IPv6 (FHMIPv6) (Jung *et al.*, 2005) and PMIPv6 (Bernardos and Calderon, 2012),

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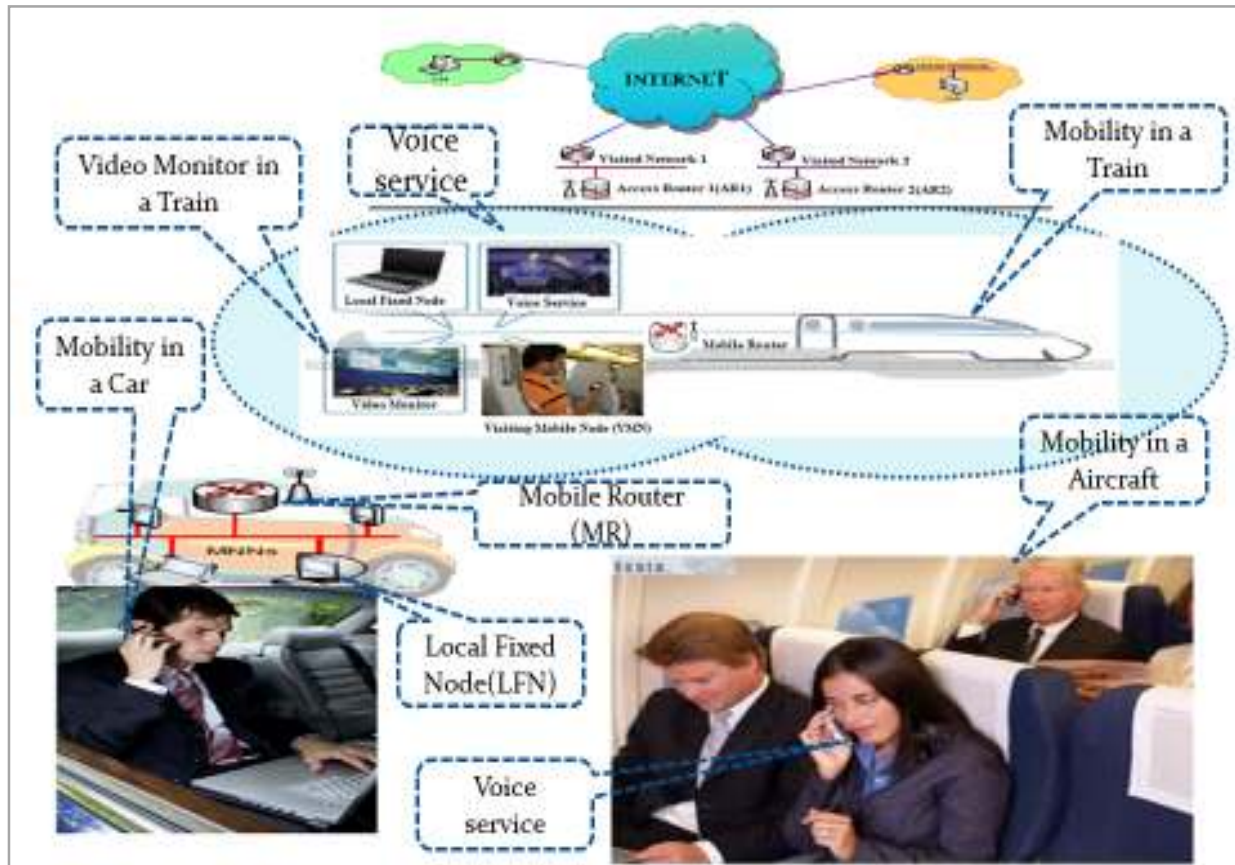


Fig. 1: Different application scenarios in NEMO infrastructure

enhancements of MIPv6 works effectively as a host mobility solution (Soliman *et al.*, 2008). Though in NEMO environment, applying FHMIPv6 mechanism is a challenging task, since consideration has to be given to both MR and its MNNs as well. Therefore, in order to setup an uninterrupted Internet connection during intra domain mobility, a modification is required to be made to adapt an improved version of FHMIPv6 scheme in NEMO environment (Shayla *et al.*, 2012; Chang and Chou, 2009).

The conception of this study is to explore the present handoff solution in NEMO network. Subsequently, based on the present NEMO solution, a handoff scheme is proposed with the aim of minimizing signaling message for fast handoff in mobile network as well. The performance of the proposed scheme has been evaluated with numerical analysis.

ARCHITECTURE OF NEMO

Network Mobility Basic Support Protocol (NEMO BSP) has been developed to give an uninterrupted access to the Internet when there comes a change in MR or MN, based on its point attachment. In NEMO BSP architecture, as it's shown in Fig. 2, there might be a presence of more than one router, known as Mobile

Router (MR), functions as gateways in favor of the Mobile Network Nodes (MNNs) (Devarapalli *et al.*, 2005). Mainly, there are three types of MNNs: Local Fixed Node (LFN) that do not move with respect to the mobile network, Local Mobile Node (LMN) usually reside in the mobile network but can move to other networks, Visiting Mobile Node (VMN) belong to another network but is currently attached to the mobile network and MR. MNNs can perform as MR due to establishing a nested mobile network. The network through which a mobile network is linked is known as the home network. Home Agent (HA) refers to when MR is registered with a router in its own network. A node which communicates with MNNs is called Correspondent Node (CN), which is seldom also considered to be MNN. Due to use by its MNNs, the home network assigns one or more prefixes to the Top Level Mobile Router (TLMR) in NEMO BSP. TLMR has a Home Address (HoA) through which it is reachable in its own network. When the TLMR shifts to a foreign network, it acquires a Care-of-Address (CoA) from the foreign network. After that it registers the CoA with its HA through passing a Binding Update (BU). The BU comprises of a MR flag specifying that TLMR is functioning as a router. Besides that, HA of TLMR sends a positive Binding Acknowledgement (BA) to

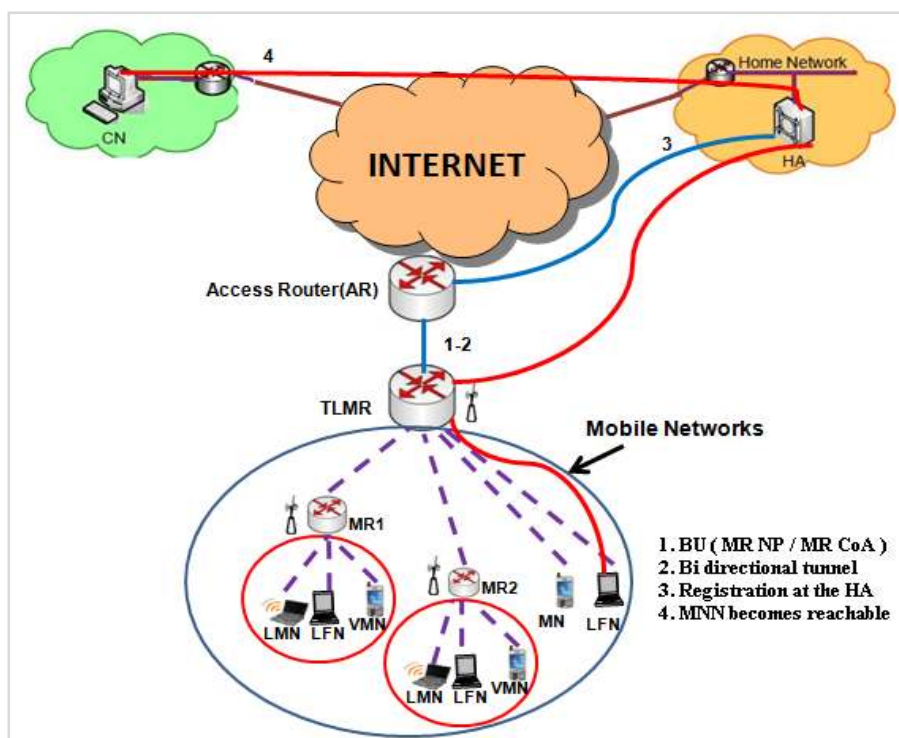


Fig. 2: General architecture of NEMO BSP (Shayla *et al.*, 2012)

point out that forwarding to TLMR is set and launches a binding cache entry that maps the TLMR's HoA and prefixes to the CoA of the TLMR. Therefore, it ascertains a bi-directional tunnel between TLMR and TLMR HA. For this reason, it can be mentioned that registration process is almost parallel to MIPv6 registration (Johnson *et al.*, 2004) apart from setting of the MR flag and sending of prefix to the BU. However, it is essential to apply some mechanism to support handoff in NEMO to accomplish uninterrupted Internet connection during intra domain movement of MR. Moreover, route optimization needs to be focused and multihoming technique as NEMO BSP is not considered as these mechanisms due to security reasons (Johnson *et al.*, 2004; Shayla *et al.*, 2012).

LITERATURE REVIEW

In order to classify the movement patterns of the Mobile Router (MR) as well as to present hierarchical fast handoff scenarios in NEMO environment, the authors (Yoo *et al.* 2009) presents a study of high-speed handoff means for hierarchical NEMO environment. According to this mechanism, MR movement scenarios in NEMO environment are classified into intra micro network mobility, AR network mobility and macro network mobility respectively. Handoff abeyancy along with packet delivery cost is examined as well. According to analytical approach, if handoff fails then the least packet delivery cost is needed for intra AR

network Mobility, as higher packet delivery price is essential for inter MAP Mobility. However, it is needed to design and implement NEMO test bed in order to install this fast handoff mechanism as well as to improve the real quality of service during handoff.

The authors (Long-Sheng *et al.*, 2010) has proposed an efficient fast hierarchical handoff scheme in NEMO environment. In nested NEMO environment, it is not possible for the Mobile Router (MR) to know the information of the Mobile Router (MR) under different domain. Hence there is a possibility to fail the fast handoff scheme. To overcome this problem, this scheme includes the Router Information Table (RIT) in MR and MAP along with new option within the Router Advertisement (RA) message. Thus MR gets the precise knowledge of neighbored MR and possible to decrease the handoff failure rate. Additionally, in order to determine the best access router, the previous MR (PMR) uses the RIT. However, for better analysis should implement the analytical and simulation approach respectively.

The authors (Chang and Chou, 2009), describes the Hierarchical Care of Prefix (HCoP) with Binding Update Tree (BUT) scheme because of localizing handoff signaling and optimizing routing of the nested NEMO by integrating the MAP (Mobility Anchor Point) of the hierarchical approach. The MAP in HCoP extends the CoP (Care-of Prefix) allotment to the nested NEMO, maintaining the binding cache for all MRs/MNNs and accomplishing optimal routing from

the CN to the MNN in the nested NEMO via itself. HCoP has two noticeable problems. Firstly, the value of the handoff latency increases as the layer of the nested NEMO develops. Secondly it still suffers from the binding update storm problem. Therefore, to resolve these two problems, the HCoP with a novel Binding Update Tree (BUT) is integrated, i.e., HCoP-B scheme. The main advantage of this scheme is it achieves the shortest handoff latency, the lowest number of duplicate binding update messages conveyed over the Internet. Additionally, the smallest amount of consumed Internet and local wireless network bandwidth for session initialization and route optimization of all connecting CNs at the expense of a small amount of extra binding caches in the BUT are the positive side. Consequently, HCoP-B achieves CNs route optimization and resolves the associated binding update storm problem simultaneously for the nested mobile network. However, it should focus on how the HIP signaling delegation process can be integrated with HCoP-B to achieve a mutual trust between CNs and the MAP. Consequently, it does not provide seamless handoff mechanisms.

An flexible NEMO support protocol is explained by the authors (Pack *et al.*, 2009), which formulates the utilization of HMIPv6 and NEMO basic support protocols. Depending on the Session to Mobility Ratio (SMR) in the adaptive NEMO support protocol, the adaptive BU strategy is utilized. This is the major feature for differentiating a mobile network. When the SMR is low it is essential to decrease the number of BUs which is the main reason to use the adaptive BU where as when the SMR is high then the number of tunnelling is reduced. By implementing the adaptive mechanism, it is exposed that the adaptive NEMO support protocol is scalable and works well for different mobile environments, thus improving the performance because of low SMR. Therefore, this technique is most noteworthy for the NEMO network. Yet, further research is required to diminish away the implementation overhead for SMR measurement with security concern.

A seamless multi-interfaced handoff mechanism in NEMO network are studied by the authors (Chen *et al.*, 2010). To find out the most excellent path under current network conditions, a proposal of a path selection algorithm is made. Because of using multiple interfaces there is no packet loss and it is possible to use different bi-directional tunnel simultaneously. As this scheme uses multiple Care of Address (MCoA) mechanism, hence binding update mechanisms are pre-processed inside the MCoA. Through analysis it is indicated that multiple interfaced MR is capable to increase the performance of MR movement across different network. However, need to concentrate on

implementation cost since to use multiple interfaces along with security issues.

With the purpose of reducing handoff delay and packet loss, the authors (Prakash *et al.*, 2010) has offered a Cross layer Seamless Handoff Scheme (CSHS) in IEEE 802.11p based Vehicular Networks. The principal aim of this scheme is to create new address in advance before starting the actual handoff. Additionally CSHS uses redirect technique in order to flow the traffic of the vehicles via one another during handoff with the aim of minimizing packet loss. In CSHS, it is observed that as number of hops is increased to send packet from Home Agent (HA) to the Mobile Router (MR), the handoff completion time is increased with packet loss. According to this scheme, the handoff latency is 30 % lower than NEMO BSP and the packet loss is minimized through using cross layer information. However further investigation is required in order to provide complete seamless connectivity during handoff in NEMO network.

With the intention of performing mobility as well as traffic management, a router-proxy is introduced as a central gateway inside the NEMO Network in the study (Slimane *et al.*, 2010). In this scheme, unidirectional tunnel is used from Home Agent (HA) to Mobile Router (MR) instead of bi-directional tunnel in order to reduce transmission delay. This scheme provides transparent and uninterrupted Internet connectivity in terms of handoff delay with packet loss and optimizes the route. However it is still needed to focus on implementation overhead as well as security issue.

The authors Lee and Ernst (2011) have introduced a network-based mobility management protocolin which lightweight mechanism for mobile networks is integrated with Proxy Mobile IPv6 (PMIPv6). The authors claim that through making longer the mobility service provisioning entities, NEMO is attained in a given PMIPv6 domain. The positive part of this study is that it is not essential for an MR to generate its own mobility signaling in order to update location information during handoff. Additionally, the overall performance is improved through omitting the duplicate address detection (DAD) mechanism for each handoff. However, an experimental test bed is recommended to include for validating the measurement and evaluation of the proposed scheme performance.

With the aim of reducing higher handoff latency and traffic load, the authors (Lee *et al.*, 2012) has introduced fast P-NEMO (FP-NEMO) which is an extension of PMIPv6-based NEMO (P-NEMO), with the intention of improving handover performance. As the advanced handoff preparation mechanism is applied, FP-NEMO reduces packet loss and delay during handoff in intra Mobility environment. Nevertheless, packet overhead, security and service disruption still open issues for NEMO environment.

INTRA DOMAIN MOBILITY SCHEME IN NEMO ENVIRONMENT

It is crucial to reduce the handoff delay as much as possible in NEMO network with the aspiration of providing seamless Internet connectivity. The proposed Intra Domain Mobility scheme in NEMO environment can be identified also as IDM-NEMO scheme for additional reduction of handoff delay. In case of the proposed scheme, if the serving MR (MR) travels within the same MAP domain it needs only to register its new LCoA with its CMAP. The requirement of Global registration is not necessary in this case i.e., the RCoA is not altered. The proposed IDM-NEMO procedure is shown in Fig. 3 and accordingly explained in details:

- Initially, serving MR sends Improved RtSolPr (IRtSolPr) message (with the I bit set as shown in Fig. 4) to the Mobility Anchor Point (MAP) via the Current MR (CMR) to allow the support of IDM-NEMO.
- MAP will formulate a new LCoA and RCoA on behalf of the serving MR as the I bit is set. However, if I bit is not situated then the serving MR will follow NEMO BSP handoff mechanism.
- After putting together the new LCoA, the MAP sends the IPrRtAdv message to the serving MR and also the Handover Initiation (HI) message to the New MR (NMR) that contains New LCOA (NLCOA). It can be seen that the serving MR does not require to send the FBU to the CMAP. Rather it

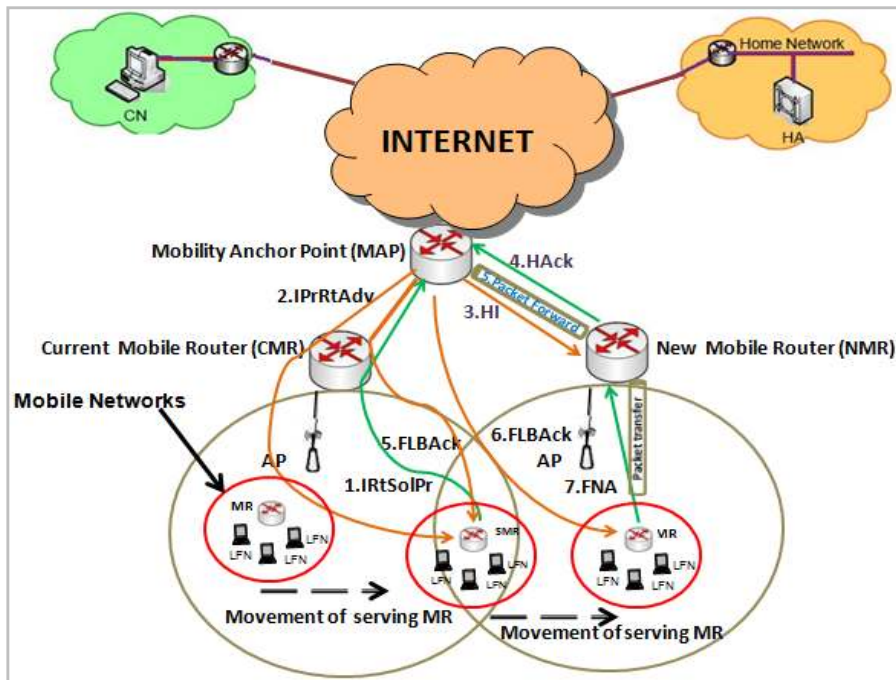


Fig. 3: Proposed intra domain mobility of the serving MR Movement in NEMO environment

0		8		16		24		31	
Type		Code		Checksum					
Subtype		Reserved		I		Identifier			
						Sequence number			
A	H	L	K	M	R	Lifetime			
Mobility Option									

Fig. 4: Router solicitation proxy message with FBU option (Shayla *et al.*, 2012)

just needs to wait for the Fast Local Binding Acknowledgement (FLBAck) message. The message format for IRtSolPr with FBU option is shown in Fig. 4.

- Once the Handover Initiation (HI) message is sent to the NMR, the NMR carries out Duplicate Address Detection (DAD) mechanism to authenticate whether the new NLCOA is unique or not.
- If the address is not duplicated, the NMR sends the Handover Acknowledgement (HAck) message to the CMAP. After receiving the HAck message, the CMAP sends FLBAck message to the serving MR to acknowledge the availability of the address. Simultaneously, bi-directional tunnel is established between CMAP and NMR (which starts to buffer the packets sent to the SMR).
- After that, layer 2 handover starts and layer 3 connections will be cut.
- Once the serving MR arrives at NMR, it propels Fast Neighbor Advertisement (FNA) message to NMR. Subsequently, NMR transfers the buffered packet to the Serving MR.
- After getting buffered packets from NMR; the SMR sends the Local Binding Update (LBU) message to CMAP.

ANALYTICAL EVALUATION

During handoff of the serving MR, the mathematical evaluation of handoff process is carried out mainly based on location update cost. The location update cost does not deem the number of Local Fixed Nodes (LFNs) since LFNs do not perform any registration for location update. Once the serving MR with LFNs enters into a NMAP domain extra signalling cost is required to drop off the packet loss during handoff.

Location Update Cost ($LUC_{IDM-NEMO}$) in IDM-NEMO scheme: Signaling is required during the movement of the serving MR (MR) from one subnet to another in order to update the location. Signaling is one of the most significant factors since to measure the performance of the protocol. With the purpose of maintaining the reach ability, the serving MR need to send Local Binding Update/Global Binding Update (LBU/GBU) messages to its Home Agent(HA) to notify the current location during Intra/Inter domainmobility handoff. Hence, resources are consumed with these LBU/GBU messages that eventually include location update cost.As an expansion to FHMIPv6, the concept of MAP is applied in IDM-NEMO scheme. The serving MR performs two types of movements i.e., intra and inter. The earlier one is a sort of movement inside a MAP domain where as the later one is a movement between two MAPs. Therefore, two location update procedures are included in the signaling cost. Usually, transmission over wired link is not expensive compared

Table 1: System parameters for the numerical analysis

Parameters	Value
Number of the serving mobile router (N_{MR})	20
Number of Correspondents node (N_{CN})	1
The cell residence time of the serving MR (T_{MR})	120 sec.
Number of message via wireless in micro mobility (x)	7
Number of message via Wired in micro mobility (y)	11
d_{MR-CMR} , $d_{CMR-CMAP}$, $d_{NMR-NMAP}$, d_{MR-NMR} ,	1 hop
$d_{HAMR-CN}$, $d_{HAMR-CMAP}$, $d_{HAMR-NMAP}$, $d_{CMAP-NMAP}$, $d_{NMAP-CN}$	6 hops
$d_{CMR-NMR}$	2 (j)
Number of message via wireless in macro mobility (X)	2
Number of message via wired in macro mobility (Y)	2
Signaling cost of each message via wireless link (β)	2
Signaling cost of each message via wired link (γ)	1

to that over a wireless link (Shayla *et al.*, 2012). It is assumed that β and γ signifies the unit transmission cost for a wireless and wired connection (Shayla *et al.*, 2012; Reaz *et al.*, 2006; Zhang and Pierre, 2008; Akyildiz and Wang, 2002). During the entrance of SMR with Local Fixed Node into a NMAP domain, the total signaling message is calculated as below:

$$SINTRA_{IDM-NEMO} = (x \times \beta) + (y \times (\gamma \times d_{CMR-CMAP} + d_{CMAP-NMAP})) \quad (1)$$

$$SINTER_{IDM-NEMO} = SINTRA_{IDM-NEMO} + (X \times \beta) + (Y \times \gamma \times d_{NMAP-HAMR}) \quad (2)$$

According to the equation no.1, x refers to the number of exchanged messages (where x = 7) via wireless link and y refers to the numbered of exchanged messages via wired link (where y=11) during intra handoff of the serving MR. Additionally, d refers the hop distance between different domains. The same strategy has been applied in equation 2 (inter domainmobility environment) where Binding Update and Binding Acknowledgement (BU/BA) messages are exchanged between the serving MR and HAMR via NMAP (Zhang and Pierre, 2008). X and Y are the number of wireless and wired message in macro mobility environment respectively where X = Y = 2. Based on the above calculation (Eq. 1 and 2), the Location Update Cost ($LUC_{IDM-NEMO}$) for the serving MR by using random-walk model (Shayla *et al.*, 2012; Reaz *et al.*, 2006; Zhang and Pierre, 2008; Akyildiz and Wang, 2002) can be calculated as:

$$LUC_{IDM-NEMO} = N_{MR} \times \frac{P_M \times SINTER_{IDM-NEMO} + (1-P_M) \times SINTRA_{IDM-NEMO}}{E(T_{SMR})} \quad (3)$$

where, N_{MR} is the number of the serving MR (MR), $E(T_{MR})$ is the average cell residence time of the serving MR with the purpose of staying in a cell and P_M denotes the probability of the serving MR to perform the inter domainmobility location updates.

Performance analysis: The cost is presented as a function of the number of the serving MR (MR) and the subnet residence time by using the expressions developed in a simplified format in the analytical

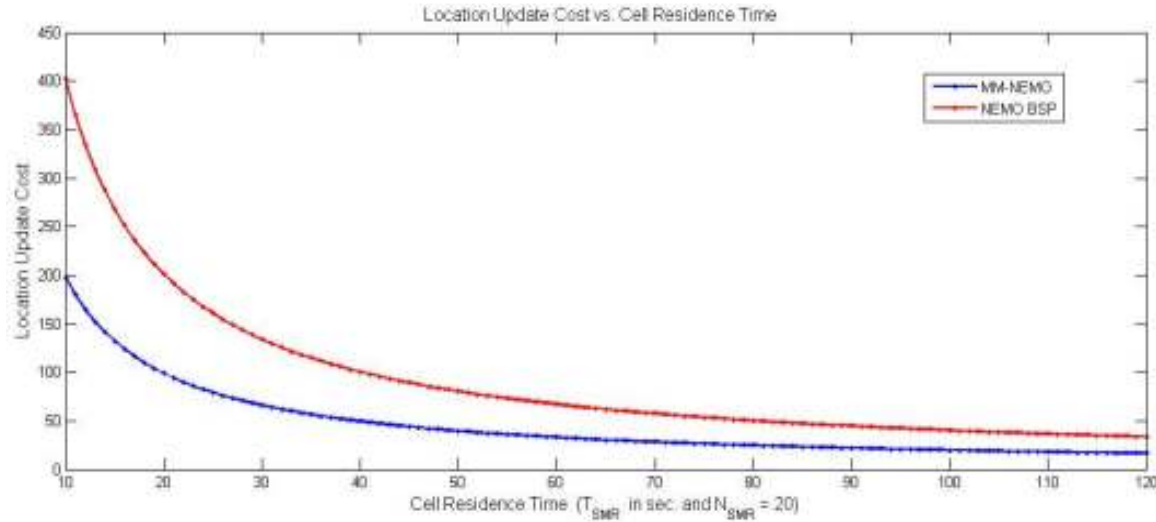


Fig. 5: Location update cost vs. cell residence time

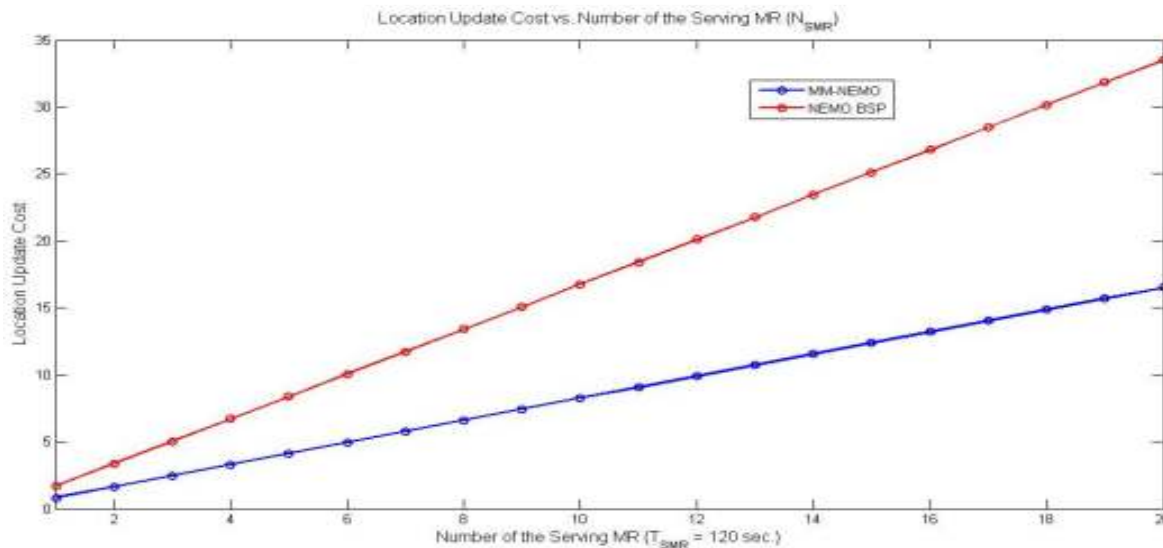


Fig. 6: Location update cost vs. number of the serving MR

evaluation section. The values for system parameters are listed in Table 1 (Shayla *et al.*, 2012; Reaz *et al.*, 2006; Zhang and Pierre, 2008; Akyildiz and Wang, 2002).

- Location update cost for different cell residence time:** By the implementation of Eq. (1), (2) and (3), the variation of location update cost is illustrated as a function of average cell residence time for different number of the serving MR (MR). The cell residence time has been found to have an effect on location update cost for both NEMO BSP and IDM-NEMO scheme as depict in Fig. 5. The time period, for which the serving MR stays at the current cell, the location update cost remains lower. Thus the location update cost for the proposed

scheme is much lower than that of the NEMO-BSP. For IDM-NEMO scheme, with the decrease of cell residence time, the location update cost has not been increased much in proportion compared to NEMO BSP. So the signaling cost for the proposed scheme is not high as it is in NEMO BSP. Additionally, in case of the proposed scheme, it is noticeable from the graph that the locations update cost has been escalating gradually with the decrease of cell residence time. Usually, in NEMO BSP, if cell residence time reduces then handoff occurs frequently. So, with the frequent movement of the SMR, it becomes essential for it to notify its Home Agent and that augments the signaling cost. Besides that, MAP concept of the proposed scheme, along with fast handoff procedure, are

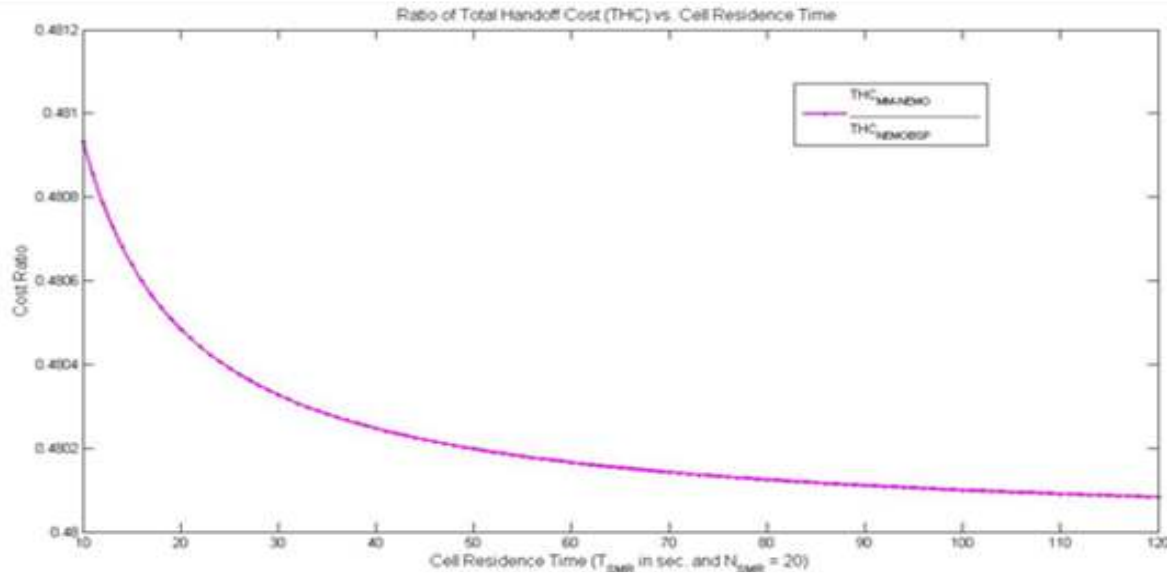


Fig. 7: Cost ratio of MM-NEMO scheme against NEMO-BSP

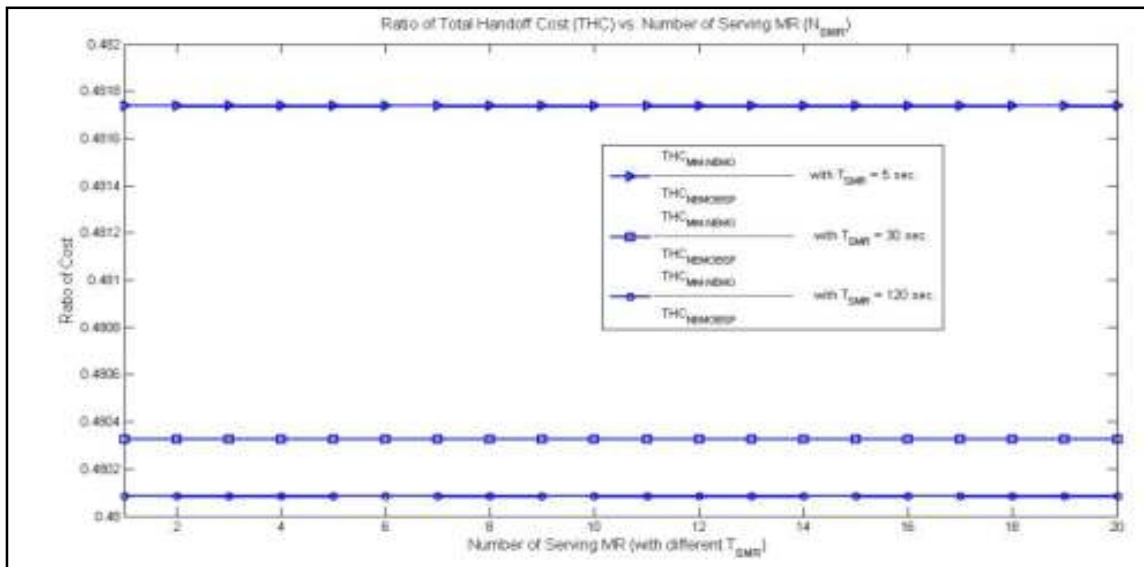


Fig. 8: Cost ratio of MM-NEMO scheme against NEMO BSP

being applied in the network. However, it becomes redundant for the serving MR to notify its home agent for each single movement. This significantly reduces the packet loss and delay. As the average cell residence time is increased, it is required less location update. For both the proposed scheme and NEMO BSP, if serving MR is static then no need to inform it's HA and CN frequently which effects directly on the total handoff cost. On the other hand, cell residence time decrement has led the location update cost to rise abruptly for NEMO BSP which in turn increases the signaling cost significantly as shown in Fig. 5. From the obtained results, it is evident that the proposed scheme is cost effective than that of NEMO BSP.

- Location update cost for number of the Serving MR:** The impact of the number of serving MR for average subnet residence time on location update cost of MM-NEMO and NEMO BSP is shown in Fig. 6. The location update cost for both IDM-NEMO and NEMO BSP increases linearly by increasing the number of the serving MR along with cell residence time. However, the cost of IDM-NEMO scheme is much lower than that of NEMO BSP since no need to notify the Home Agent (HA) for intra domain movement of the serving MR unlike NEMO BSP. This ultimately reduces the location update cost for MM-NEMO scheme.

- **Ratio of total cost for different cell residence time:** In fact, the total cost ratio of NEMO BSP is increased due to frequent movement of the serving MR. It is observed from Fig. 7 that, the cost ratio changes when the range of cell residence time is between 20 to 80 second with different number of the serving MR. While the cost ratio is wrapping into the value 0.48, it can be considered that the IDM-NEMO has saved the cost by 52%.
- **Ratio of total cost for different cell residence time:** Moreover, the total scenario of the dependency of number of the serving MR is plotted for different cell residence time as depicted Fig. 8. Handoff rate keeps increasing with lower subnet residence time that leads to increase the total handoff cost. Figure 8 indicates the performance of the prospective lay out in comparison to NEMO-BSP in terms of cell residence time and the quantity of the serving MR respectively. In this Figure, for IDM-NEMO scheme, the total handoff cost ratio changes with different cell residence time considering the fact that data packet transmission cost is not incurred by the local location update procedure. In addition, by analyzing Fig. 8, it is apparent that the cost ratio is analogous with various number of the serving MR and it shows better performance as well.

CONCLUSION

In this study, the existing handoff solution has been explored and a handoff method (IDM-NEMO) is proposed that integrates the improved FHMIPv6 mobility management protocol in NEMO network with a view to achieve seamless handoff from one subnet to another. The proposed scheme is developed to enhance the mobility management protocol in NEMO network. The contribution of this study is proposing a Intra Domain Mobility scheme in NEMO (IDM-NEMO) that aims to reduce signaling message for fast handoff in mobile network. The performance of the proposed scheme is evaluated with numerical analysis. According to the proposed scheme, one Round Trip Time (RTT) between the serving MR and the MAP can be diminished in order to reduce the signaling messages exchanging period during fast handoff operation. This mitigated time which is a significant issue in NEMO network and can result in a huge improvement of the total location update cost (52% reduced than NEMO BSP).

REFERENCES

Akyildiz, I.F. and W. Wang, 2002. A dynamic location management scheme for next-generation multiuser PCS systems. *IEEE T. Wirel. Commun.*, 1(1): 178-189, Doi: 10.1109/7693.975456002E.

Bernardos, C.J. and M. Calderon, 2012. PMIPv6 and Network Mobility Problem Statement. Information Engineering Task Force. Reviewed from: draft-bernardos-netext-pmipv6-nemo-ps-02.

Chang, I. and C. Chou, 2009. HCoP-B: A hierarchical care-of prefix with BUT scheme for nested mobile networks. *IEEE T. Veh. Technol.*, 58(6): 2942-2965.

Chen, X., H. Zhang, Y. Chang and H. Chao, 2010. Experimentation and performance analysis of multi-interfaced mobile router scheme. *Simul. Model. Pract. Th.*, 18: 407-415.

Devarapalli, V., R. Wakikawa, A. Petrescu and P. Thubert, 2005. Network Mobility (NEMO) basic Support Protocol. RFC 3963.

Johnson, D., C. Perkins and J. Arkko, 2004. Mobility support in IPv6. Information Engineering Task Force (IETF), RFC 3775.

Jung, H., H. Soliman, S. Koh and J. Lee, 2005. Fast Handover for Hierarchical MIPv6 (FHMIPv6). Information Engineering Task Force, Reviewed from: draft-jung-mobopts-fhmipv6-00.txt.

Lee, J. and T. Ernst, 2011. Lightweight network mobility within PMIPv6 for transportation systems. *IEEE Syst. J.*, 5(3), Doi: 10.1109/JSYST.2011.2158681

Lee, J., N. Chilamkurti and T. Ernst, 2012. Performance analysis of PMIPv6-based network mobility for intelligent transportation systems. *IEEE T. Veh. Technol.*, 61(1), Doi: 10.1109/TVT.2011.2157949.

Long-Sheng, L., T. Yao-Hui and L. Ping-Cheng, 2010. An efficient fast handoff scheme in hierarchical mobile IPv6 for NEMO. *Proceeding of International Symposium on Computer, Communication, Control and Automation*, 2: 90-945, Doi: 10.1109/3CA.2010.5533787.

Pack, S., T. Kwon, Y. Choi and E.K. Paik, 2009. An adaptive network mobility support protocol in hierarchical mobile IPv6 networks. *IEEE T. Veh. Technol.*, 58(7): 3627-3639.

Prakash, A., S. Tripathi, R. Verma, N. Tyagi, R. Rajeev and K. Naik, 2010. A cross layer seamless handover scheme in IEEE 802.11p based vehicular networks. *Contemp. Comput.*, 95(2): 84-95.

Reaz, A., M. Atiquzzaman and W. Ivancic, 2006. Signaling cost analysis of SINEMO: Seamless end-to-end network mobility. *Proceeding of the ACM/IEEE International Workshop on Mobility in the Evolving Internet Architecture (MobiArc'06)*, pp: 37-42, Doi: 10.1145/1186699.1186712.

Shayla, I., H. Aisha-Hassan, M.K. Hasan, O. Khalifa and S. Rashid, 2012. Micro mobility scheme in NEMO to support seamless handoff. *Proceeding of the International Conference on Computer and Communication Engineering (ICCCE2012)*, pp: 212-215, Doi: 10.1109/ICCCE.2012.6271182.

- Slimane, Z., M. Feham and A. Abdelmalek, 2010. A seamless and transparent MN-Proxy based mobility support for (n, n, 1) multihomed NEMO model. *Int. J. Comput. Sci. Netw. Secur.*, 10(4).
- Soliman, H., C. Castelluccia, K. El Malki and L. Bellier, 2008. Hierarchical Mobile IPV6 Mobility Management (HMIPV6). RFC 5380, IETF.
- Yoo, S., S. Choi and D. Su, 2009. Analysis of fast handover mechanisms for hierarchical mobile IPv6 network mobility. *Wireless Pers. Commun.*, 48: 215-238.
- Zhang, L. and S. Pierre, 2008. Evaluating the performance of fast handover for hierarchical MIPv6 in cellular networks. *J. Netw.*, 3(6).