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MM-PNEMO: a mathematical model to assess handoff delay and packet loss

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ABSTRACT

Wireless networks incorporate Mobile Nodes (MNs) that use wireless access networks to communicate. However, the communication among these MNs are not remained stable due to the poor network coverage during inter mobility. Moreover, the wireless nodes are typically small that results in resource-constrained. Thus, it is uphill to use algorithms having giant processing power or memory footprint. Accordingly, it is essential to check schemes consistently to evaluate the performance within the probable application scenario. To do so, numerical analysis could be a notable method to grasp the performance of mobility management schemes as well as the constraint of evolving mobility management solutions specifically for multi-interfaced MR in Proxy NEMO environment. This paper analyzes handoff performance by using a mathematical model of Multihoming-based scheme to support Mobility management in Proxy NEMO (MM-PNEMO) environment. Moreover, a comparative study has been made among the standard Network Mobility Basic Support Protocol (NEMO BSP), Proxy NEMO (PNEMO) and MM-PNEMO scheme respectively. The performance metrics estimated for these schemes are mainly handoff delay and packet loss. This paper also analysed the packet loss ratio and handoff gain as a function of cell radius, number of SMR and velocity respectively. It is apparent that, the MM-PNEMO scheme shows lower packet loss ratio (1%) compared to NEMO-BSP (11%) and P-NEMO (6%).

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1. INTRODUCTION

The exponential growth of the wireless access technology includes higher capacity, extended coverage with supproting seamless inter technology handoff [1-2]. However, this inter technology handoff is becoming one of the utmost significant concern in order to provide Quality of Service (QoS) for time sensitive applications (i.e. VoIP, Video) in mobile networks [3-8]. QoS can be specified as handoff delay, packet loss, packet delivery ratio, and throughput. Investigation of these performance metrics is particularly fruitful to evaluate each mobility entities performance in mobile networks [9-10].

In mobile wireless networks, mobility models are significant building blocks for numerical-based analysis. It has a substantial impact on the performance evaluation of the mobility management schemes in NEMO [11]. In order to determine the movement rate of Mobile Router (MR) or Mobile Node (MN), it is essential to select an accurate mobility model. The most familiar mobility models utilized in mobile networks nemely Random Waypoint Mobility (RWM) model, City Section Mobility (CSM) model, Manhattan Mobility (MM) model as well as Fluid-flow Mobility (FM) model [11-13].

The basis of this work is to know the functioning mechanism of the mobility management schemes and to determine which protocol provide better handoff performance. The contribution of this paper includes: (i) constructing a numerical model to compare the applicability and efficiency of the MM-PNEMO scheme with that of the standard NEMO-BSP and PNEMO respectively. (ii) Investigate and analyze the handoff performance in terms of handoff delay gain and packet loss ratio.

2. MM-PNEMO

Explaination of the MM-PNEMO scheme as shown in Figure 1 offers the location update procedure in order to separate the new attachment of the serving MR (SMR) which is termed as ‘fast registration’ process from the particular flow movement which is entitled as ‘flow-based routing’ process [6]. As soon as the New Flow-enabled MR (NFMR) identifies the new attachment of SMR on the target network, the NFMR sends Early Proxy Binding Update (EPBU) message via Handover Initiations (HI) message to the FLMA for initiating the fast registration process without enable flow-based routing information. During fast registration mechanism, the Flow-based Local Mobility Anchor Point (FLMA) accomplishes few tasks for the new attachment such as allocating a new Home Network Prefix (HNP) and Mobile Network Prefix (MNP) of the Physical Interface 2 (PI 2), building new Binding Catch Entry (BCE) for the SMR as well as creating a new tunnel among the FNMR and the FLMA. If the NFMR identifies that the SMR is connected to the new PI (i.e. PI 2), it transmits PBU message containing FMNP option to FLMA in order to initiate flow-based routing process. Once the process is completed successfully, a PBA message is directed from the FLMA to the NFMR. However, if the network entity (i.e. CFMR, NFMR or FLMA) is not informed about the HI message with encapsulated EPBU option, the SMR will initiates PNEMO handoff process.

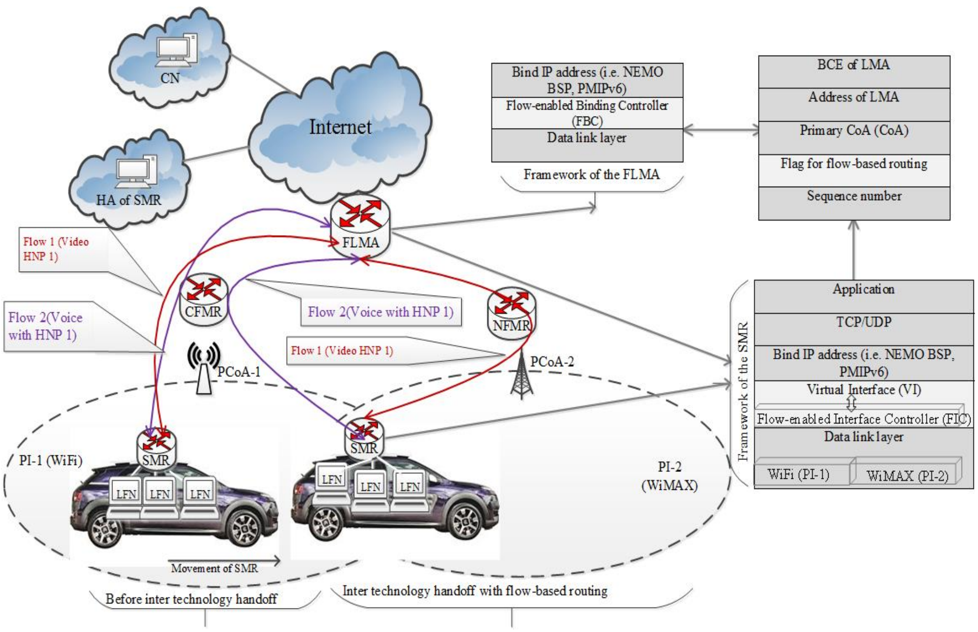

Figure 1. Basic architecture of MM-PNEMO architecture [6-7]

3. NUMERICAL ANALYSIS

In this section, a numerical model is developed to evaluate the performance of the MM-PNEMO scheme [6-7]. The MM-PNEMO scheme is then benchmarked with that of the NEMO-BSP and P-NEMO scheme [9-10], [14]. P-NEMO is compared with MM-PNEMO scheme since both schemes integrates firmly-entrenched PMIPv6 which is a network-based localized mobility protocol in NEMO to address mobility issues [15-17]. In contrast, NEMO-BSP is the standard protocol for any mobility support management aiming at NEMO network and it is also an improved version of the Mobile IPv6. The considered performance metrics to evaluate the performance of MM-PNEMO scheme are average handoff delay and its impact on packet loss. These metrics are notable since they are directly linked to the goals for the proposed model.

3.1. Assumptions and notations

To simply the comparison with NEMO-BSP and P-NEMO, it is assumed that the HA in NEMO-BSP is positioned in the similar place as Flow-enabled LMA (FLMA) in MM-PNEMO scheme and LMA in P-NEMO. Likewise, it is assumed that Access Routers (ARs) in NEMO-BSP are located at the identical place as MAGs in P-NEMO and FMRs in MM-PNEMO scheme. As the wired link is robust, it is assumed that the failure of message transmission is not anticipated over the wired link while the failure of message transmission is anticipated over the radio access link. Furthermore, it is also assumed that the SMR is connecting with one Corresponding Node (CN). Moreover, Binding Update Refreshment (BUR) cost is not considered in this analysis.

3.2. Numerical model

The City Section Mobility (CSM) model which offers a practical movement pattern for SMRs in a town or city as depicts in Figure 2 [11]. In real world situations, cars have to follow traffic guidelines as they do not have the capability to roam without any obstacles, buildings and so on. Hence, it is essential for all SMRs to monitor predefined routes as well as behaviour procedures in this movement model. The stochastic principles of CSM model have been familiarized [18]. Therefore, the MM-PNEMO, NEMO-BSP and P-NEMO scheme adopts those principles to estimate the mobility rate as well as cell residence time.

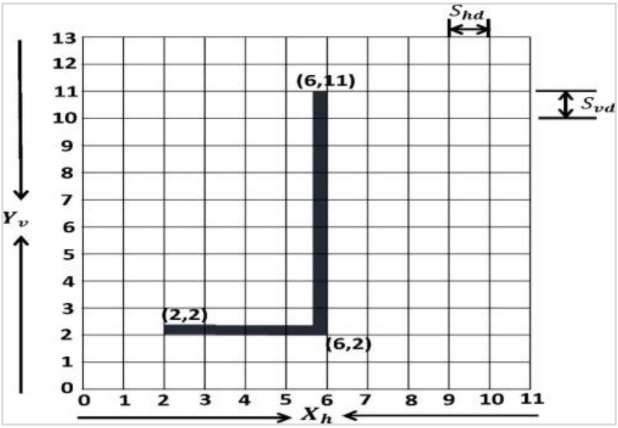

Figure 2. Structure of a road in CSM model [7, 11]

According to CSM model, the speed limit is set for each street and the area is symbolised via a grid of lanes starting an individual sector of an urban. Each SMR begins at a defined crossing on two lanes. After that, it randomly selects an end point. Once reaching at the destination, the SMR pauses for a random time. After that, it randomly selects a new destination. Thus, the same process is repetitive and each movement is named as an epoch. The main aim of this section is to analyse the cell residence time and the mobility rate of SMR in a cell. Therefore, cell residence time of the SMR (T_{SMR}) can be calculated:

$$T_{SMR} = \frac{E(t)+E(p)}{E(c)} \tag{1}$$

where, the estimated number of SMR's epoch time and pause time is represented as $E(t)$ and $E(p)$ respectively. Estimated number of SMR's cell crossings in an epoch can be symbolized as E (c). It is anticipated that the moving speed of the SMR is v. Then, $E(t)$ can be expressed as:

$$E(t) = \left(\frac{X_h \times \left(N_{VR}+1\right)}{3 \times N_{VR}} + \frac{Y_v \times \left(N_{HR}+1\right)}{3 \times N_{HR}} \right) \times \frac{1}{v} \tag{2}$$

In (2), the number of horizontal and vertical road can be represented as N_{HR} and N_{VR} respectively whereas horizontal and vertical length of dissection area is indicated as X_h and Yv respectively. Thus, N_{HR} and N_{VR} can be expressed as:

$$N_{HR} = \frac{Xh}{Shd} + 1 \quad (3)$$

$$N_{VR} = \frac{Yv}{Svd} + 1 \quad (4)$$

In (3) and (4), distance of horizontal and vertical road is symbolized as S_{hd} and S_{vd} correspondingly. Since the random pause time exists in between 0 to Umax to evade collisions at each road intersection, hence E (p) can be expressed as:

$$E(p) = \frac{1}{2} \times U_{\max} \quad (5)$$

It is considered that, each Access Point (AP) coverage area is circular with radius r and $r > S_{hd}$ and $r > S_{vd}$. It is also assumed that, 2 x r=K1 x S_{hd}=$K2$ x S_{vd}. For all the movement towards horizontal and vertical direction (i.e. K1 x S_{hd} to 2K1 x S_{hd}), there should be at most two APs crossings .Therefore, E (c) can be represented as:

$$E(c)= \left[\frac{1}{6\times N_{VR}^{2}}\left\{\begin{matrix}\left(m^{2}+m\right)\times K1\times \\ \left(6N_{VR}-4m\times K1+K1+3\right)\end{matrix}\right\}\right]+ \left[\frac{1}{6\times N_{HR}^{2}}\left\{\begin{matrix}\left(n^{2}+n\right)\times K2\times \\ \left(6N_{HR}-4n\times K2+K2+3\right)\end{matrix}\right\}\right] \quad (6)$$

It is noted that, the expected number of APs crossings reduces with the higher numbers of K1, K2 (i.e., 2r/Shd and 2r/Svd). Greater numbers of K1, K2 indicate larger coverage zone for APs, following in smaller number of AP crossings. On the contrary, expected number of APs crossings rises with the larger values of N_{HR} and N_{VR}. Larger values of N_{HR} and N_{VR} indicate smaller coverage zone for APs, following in greater number of AP crossings.

For simplicity, it is also assumed that an access gateway area is equal to an AP area. Hence, the SMR handoff rate (µh) can be estimated as follows:

$$\mu_h = \frac{1}{T_{SMR}} \quad (7)$$

The numerical model for performance investigation of the MM-PNEMO scheme is illustrated in Figure 3, presenting communication paths among related nodes and routers.

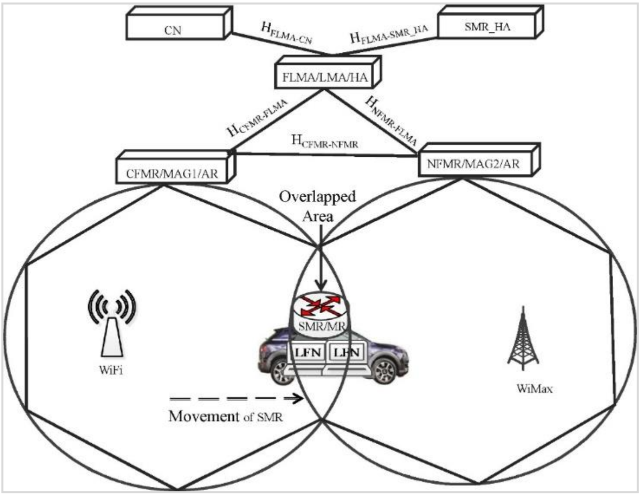

Figure 3. Numerical framework [7]

4. RESULTS AND ANALYSIS

The parameters are detailed in Table 1 [7-10], [19-23]. This section, the results of study is clarified and at the same time, a comprehensive discussion is also given.

Table 1. Parameters used for numerical analysis

Parameter	Value
NSMR	1-20
TLS	[50-300] ms
Bwl	54 Mb/s
Bwd	1000 Mb/s
twl	2 ms
twd	.5 ms
HSMR-FMR=HMR-AR=HMR-MAG	1
HFLMA-FMR=HHA-AR=HLMA-MAG	5
HCN-FLMA=HCN-HA=HCN-LMA	5
HCFMR-NFMR=HAR-AR=HMAG1-MAG2	1
LRS=LRA	52 Bytes
LBA=LPBA	52 Bytes
LBU=LPBU	72 Bytes
LHI=LHAck	52 Bytes
LRA	92 Bytes
E(TSMR)	[10-100] second

4.1. Impact of tunnelling weight factor on handoff delay (HD)

The Handoff Delays (HD) of MM-PNEMO scheme, NEMO-BSP and P-NEMO are investigated in Figure 4 as a function of tunneling weight factor (τ). It shows that, the delays for all schemes are increasing with changing the τ. τ indicate the amount of traffic density over the link among the FMRs in the proposed scheme. When road traffic is high, the number of SMRs moving between the same FMRs increase. Therefore, τ can imply road traffic characteristics. Since, the delay over wireless link rises, the handoff delay rises in MM-PNEMO scheme (182.8 millisecond) and P-NEMO (543.1 millisecond). However, these delays are not critical as in NEMO-BSP (1034 millisecond). From the observation in Figure 4, it is confirmed that the MM-PNEMO scheme and P-NEMO show frequent handoff compared to NEMO-BSP. This is because, the LU over the wireless link is avoided and no tunnelled packets are conveyed over the wireless link. Moreover, the DAD mechanism in NEMO-BSP counts for a huge portion of handoff delay. Hence, it is essential to reduce this DAD delay to improve handoff performance. Subsequently, MM-PNEMO also outperforms P-NEMO by taking the advantage of previous knowledge about the network conditions and its flows during flow-enabled fast registration phase.

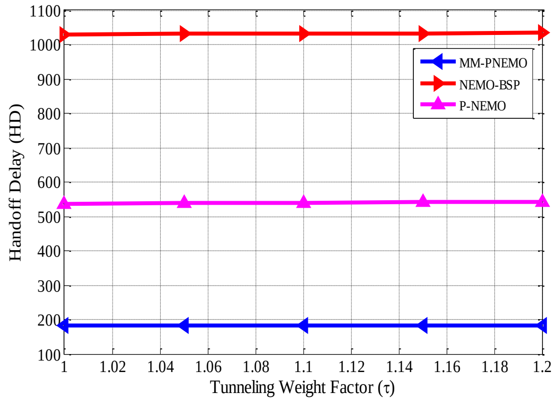

Figure 4. Handoff delay vs tunnelling weight factor [7]

4.2. Impact of tunneling weight factor on HD gain

The influence of tunneling weight factor (τ) on handoff delay gain is illustrated in Figure 5. It is noticed that, the overall gain of P-NEMO decreases as τ increases, whereas that of MM-PNEMO remains almost the same, regardless of the increasing τ. This is due to the tunnelling burden of P-NEMO that effects in disruption of session continuity. Accordingly, P-NEMO and MM-PNEMO outperform NEMO-BSP. Therefore, it can be summed up from Figure 5 that, the MM-PNEMO scheme can vastly improve the handoff performance compared to NEMO-BSP and P-NEMO regardless of increasing τ. This is because, SMR is capable to split the application flow burden among multiple access technology during inter technology handoff.

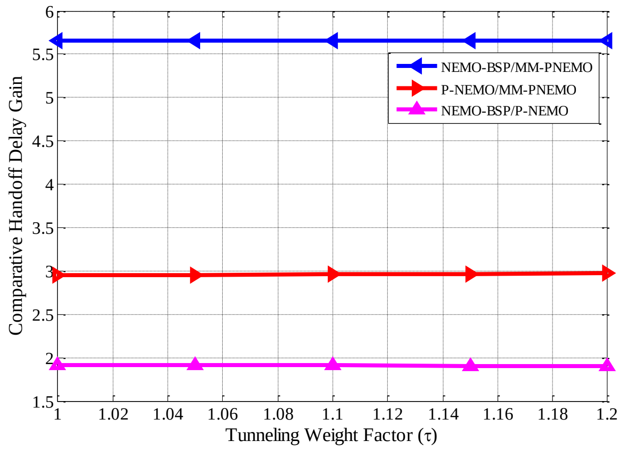

Figure 5. Handoff delay gain vs tunneling weight factor

4.3. Impact of number of SMR on packet loss (PL)

In Figure 6, the amount of packet loss during inters technology handoff for each scheme is depicted for varying the number of SMRs and different cell residence time (TSMR). It is observed from Figure 5 that, the total packet loss of each scheme increases for changing the number of SMRs with setting lower residence times (i.e. TSMR=20 sec). If the TSMR is varying from 20 to 100 sec, the SMR is most likely to stay in a cell and rarely moves to another position. Thus, the packet loss during handoff is very small as depicts in Figure 5. Basically, packet loss is proportional to the handoff disruption time. Therefore, the cases of the handoff mode for MM-PNEMO shows lower packet loss compared to P-NEMO and NEMO-BSP.

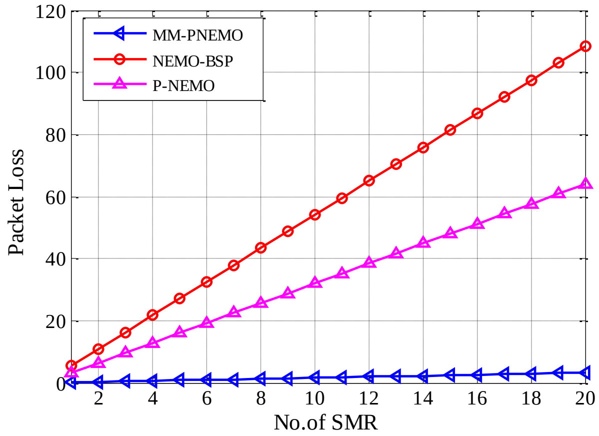

Figure 6. Packet loss vs number of SMR (TSMR=80sec) [7]

4.4. Impact of mobility rate and average session length on packet loss (PL)

In Figures 7 and 8, the amount of packet loss for each scheme is depicted for varying mobility rate (μh) and different session length (λs). Typically, total packet loss decreases with lower μh of SMR. When μh increases, the SMR moves frequently and changes subnet recurrently because of its high mobility. Thus, includes a number of SMR handoffs which leads to increase packet loss as shown in Figure 7.

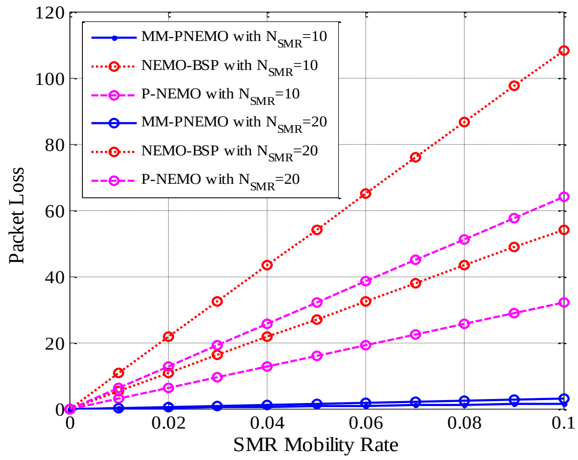

Figure 7. Packet loss vs SMR mobility rate [7]

Correspondingly, the packet loss is proportional to λs. In Figure 8, it is apparent that packet loss increases proportionally with the λs for all schemes. Network-based localized schemes (i.e., MM-PNEMO and P-NEMO) outperform NEMO-BSP. This is because due to the elimination of mobility signalling over the wireless link (when λs increases). Besides, the proposed MM-PNEMO consumes less packet loss compared to NEMO-BSP and P-NEMO due to the support of inter technology handoff in P-NEMO. This means that MM-PNEMO is better suited for real time applications where periodic packets are sent at higher rates.

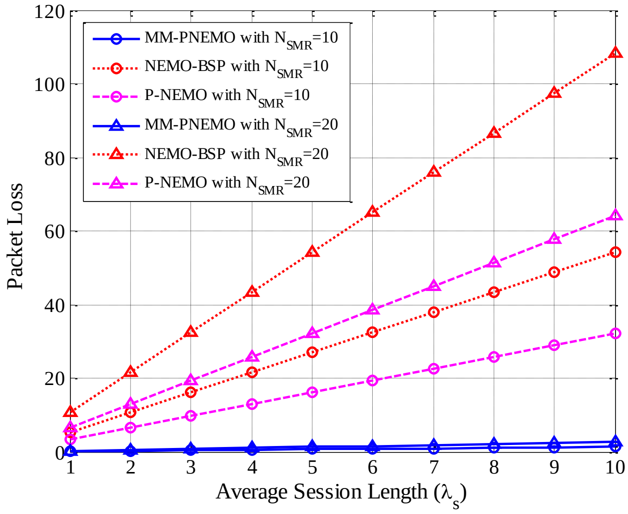

Figure 8. Packet loss vs average session length (packets/flow) [7]

4.5. Impact of radius, no. of SMR and speed on packet loss ratio

Figure 9 to 11 illustrate packet loss ratio as a function of cell radius, number of SMR and velocity respectively. In Figure 10 and 11, the the number of SMR and cell radius is varied; whereas the speed and the residence time are kept constant (i.e. speed=60 meter/second and T_{SMR}=20 second). It is apparent from both figures that, the packet loss ratio fluctuates among 1% to 12%. Correspondingly, the moving speed is set from 1 to 80 meter/second (like that of usual moving bus or car) as depicts in Figure 11. It is apparent from Figures 9 to 11 that, the packet loss ratio increases with changing the velocity of the SMR. This is because, higher velocity results in smaller residence time which leads to increase number of handoffs. As a result, MM-PNEMO and P-NEMO scheme shows lower packet loss ratio compared to NEMO-BSP. In contrast, MM-PNEMO shows lower packet loss ratio (1%) compared to NEMO-BSP (11%) and P-NEMO (6%) as shown in Figure 9.

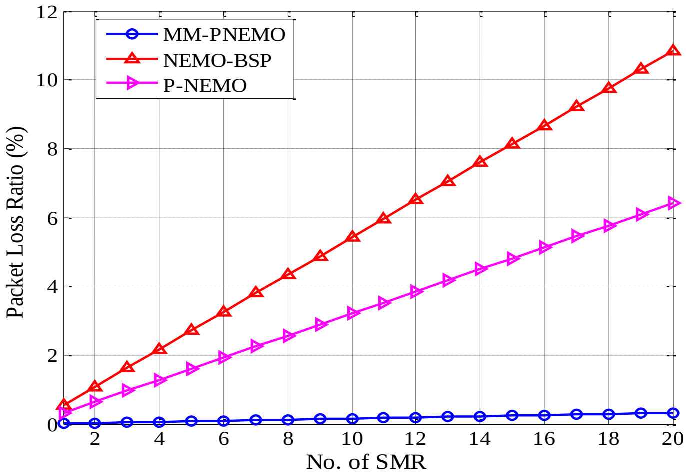

Figure 9. Packet loss ratio vs number of SMR (TSMR=20 sec)

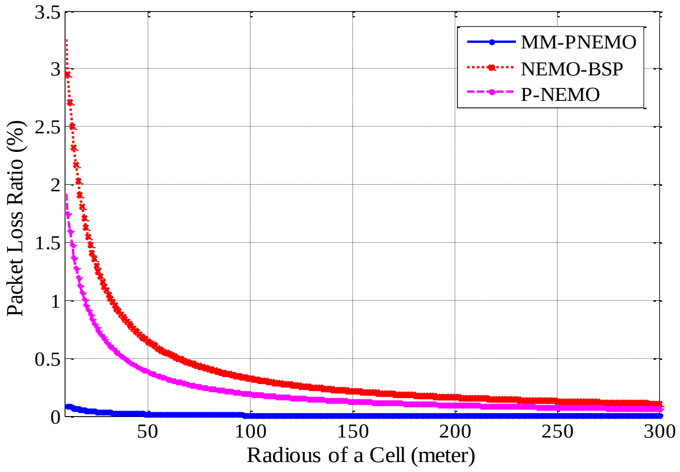

Figure 10. Packet loss ratio vs cell radius (T_{SMR}=20 sec)

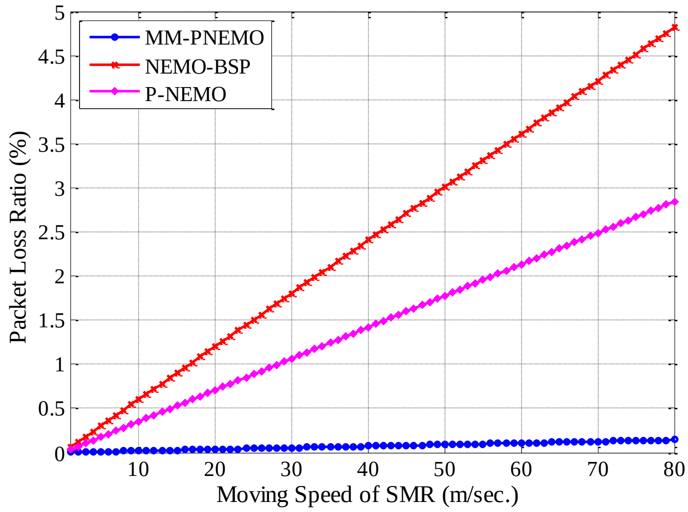

Figure 11. Packet loss ratio vs speed (TSMR=60 sec)

5. CONCLUSION

NEMO-BSP is the basic standard protocol that is enahanced from the MIPV6. However, the study suggests that the NEMO-BSP take over the llimitations of MIPV6 especially for ineffective routing path, single point of failure, higher handoff delays as well as high packet loss. Hence, to cope handoff issues, this paper evaluates handoff performance by using a mathematical model of Multihoming-based scheme to support Mobility management in Proxy NEMO (MM-PNEMO) environment. As of the study, the MM-PNEMO is paralleled with the standard NEMO-BSP and P-NEMO for benchmarking. The mathematical results demostrated that, the MM-PNEMO significantly maximizes the packet delivery ratio upto 99% in compare with NEMO BSP and P-NEMO respectively.

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