MROM Scheme to Improve Handoff Performance in Mobile Networks

https://doi.org/10.3991/ijim.v14i17.16639

Ahmed Ayoob Mousa (✉), Aisha Hassan Abdalla, Huda Adibah Mohd. Ramli
International Islamic University Malaysia (IIUM), Kuala Lumpur, Malaysia
ahmedal_shehab@yahoo.com

Abstract—Mobile Router (MR) mobility supported by Network Mobility Basic Support Protocol (NEMO BS) is a Mobile IPv6 (MIPv6) extension that supports Host Mobility. Proposed Multihoming and Route Optimization for MANEMO (MROM) scheme is designed to provide Route Optimization (RO) and Multihomed in NEMO architectures. This paper proposes two novel schemes; MANEMO routing scheme and Multihoming-based scheme. These are to provide support for next generation networks. The proposed MROM scheme differs from other schemes for NEMO environment because it considers the requirements of more application flows parameters as packet lost delivery, handoff delay as well as throughput). Another difference is that not only the network infrastructure can begin the functionality of flow routing, but also an Edge Mobile Router (EMR) can do this flow for routing. Moreover, it utilizes the state of the art and presently active access network to perform the separation of each flow in mobile network. Thus, proposed MROM exhibits multihoming features and improves handoff performance by initiating flow-based fast registration process in NEMO environment. A handoff method is proposed with enhanced functionalities of the Local Mobility Anchors (LMA), Mobile Routers (MRs) and signaling messages with a view to achieve continuous connectivity through handoff in NEMO. Both analytical and simulation approaches are used. Analytical evaluation is carried out to analyze packet delivery lost and handoff delay of our proposed scheme. It was also shown that cost of signaling messages and packet delivery are contributing to total handoff cost. At the simulation part, network simulator 3 (NS 3) has been used as the tool to get performance metrics that have been considered like packet delivery ratio, handoff delay, and packet loss. Our proposed scheme (MROM) has been benchmarking to the standard NEMO BS Protocol and P-NEMO. In this paper, we discuss proposed MROM for next generation networks, providing detailed analysis with a numerical model, proposed MROM, by maximizing the handoff performance, has been justified to have better mobility support than the ordinary NEMO BS Protocol and PNEMO.

Keywords—MROM, MANEMO, RO, Multihomed, Handoff.

1 Introduction

Today, mobile technology with smarts devices rapidly growth the network traffic volumes in terms of mobile data, So the mobility support becomes an important research and attracting great considerations. Hence, the arise want for next generation networks like 5G have increased the demand for Network Mobility (NEMO). Host mobility like laptops, mobile phones and PDAs supports by Mobile IPv6 protocol. MIPv6 [1] maintains continuous connectivity between a Mobile Host (MH) and its Corresponding Node (CN) regardless of the MH current attachment location point to the Internet. Home Agent (HA) is one component of MIPv6 protocol which do sending/receiving the packets in the middle of the MH and its CN. Route Optimization (RO) in MIPv6 is called the Return Rout ability (RR) Procedure [1]. It allows an MN to send Binding Update (BU) packet to it own CN. Then, packets are directly routed between MNs and their CNs. While RR procedure in MIPV6 reduces latency of the communication and improves performances, it also introduces several issues such as modifications of end-nodes, complexity, and server overload. Furthermore, MIPv6 does not support MR mobility which called the Network Mobility support (NEMO). Therefore, the Internet Engineering Task Force (IETF) has created a “NEMO Work Group” in order to present a mobility solution regarding to the view of MIPv6 which deals with Mobile Router (MR) instead of a single mobile node [2-3]. For mobility management of the whole mobile network, NEMO Basic Support (NEMO BS) is considered with MR as main entity instead of MH.

The aim of the NEMO Basic Support is to maintain session continuity between the Mobile Network Node (MNN) and its CN while MR change its point of attachment [4]. In NEMO context, getting an optimal route is a major key to solve suboptimal routing and IP header (packet overhead) through preventing IP-in-IP tunnel between MR and its HA. Route Optimization (RO) for MIPv6 is Return Routability (RR) Procedure which gives Mobile Node (MN) the ability to send /receive packets from MN’s Home of Address (HoA) and its Care of Address (CoA). A Route Optimization solution becomes a critical need when multiple MRs connected together in Nested NEMO fashion. Hence, the Route Optimization (RO) is a critical feature for NEMO BSP because of additional issues arises which called Pinball problem [5-6]. At the Mobility Network, the IETF categorized the Multihoming of NEMO based on MR. MR becomes multihomed once a MR has Multi-prefixed addresses (Multi-Interfaced) to select among them. Furthermore, multihoming in NEMO is occurred once an MR is multihomed or multiple MRs to select one of them [7-9].

MANEMO (MANET for NEMO) is presented through integrating the localize mobility (MANET technique) with global continuing reachability features (NEMO technique). MANEMO is a layer three solution to provide Route Optimization (RO) and multihoming. MANEMO offers to MNNs/MRs to choose the best route to the edge MR at mobile network [10-11]. MANEMO solution is categorized to two types that are: NEMO to MANEMO (N2M), and MANET to MANEMO (M2M). Solutions for MANEMO have already been proposed within the IETF that is possibly related to current work in IETF such as routing protocols (i.e., OSPF), Network Mobility support (i.e., NEMO), MANET and Autoconfiguration (i.e. AUTOCON), and multi-interfaces in IPv6 (i.e., MONAMI6) [5][7].

This paper is organized as follows: In Section II, we present an overview of our proposed MROM scheme-based Route Optimization (RO). In Section III, overview of proposed MROM based Multihoming, then numerical modelling and analysis are presented in Section IV. In Section V, results and discussion of performance evaluation. Finally, in Section VI, we conclude our paper.

2 Proposed MROM Scheme Based Routing Optimization (RO)

Recently, there are many researches for new architectures to support the Routing Optimization RO in Mobile Networks that happens once the MR/MNN change among different access networks. In Nested NEMO, the sub-optimal routing issues are increased because the number of MRs and its MNNs attached to mobile networks and required to maintain connection with their home networks [12-13]. According to the proposed MROM scheme, optimal routing path can obtain by managing connectivity of the mobile networks (i.e. MNNs) with their CNs which produce (Intra - Optimization).

Once the Exit Mobile Router (EMR) in hierarchical structure is selected, Neighbour Discovery Protocol is used by sending a Tree Information Message (TIO) for all other MRs in Mobile Networks [10]. EMR works logically as controller of sending / receiving packets to mobile networks through optimal route. The proposed MROM scheme-based Route Optimization (RO) consists of three phases as shown in figure 1 below:

1. **IF** (MRs//MNNs) are communicated with (HAs//CNs) **Then**
1.1 Call _Infrastructure Optimisation// Stage 1
2. Else IF (MRs//MNNs) are communicated with (MRs//MNNs) at the same domain
2.1 **Then** Call_ Intra-NEMO optimisation // Stage 2
3. Else (MRs//MNNs) are communicated with (MRs//MNNs) at different IP subnet domain
3.1 Call_Inter-NEMO optimisation // Stage 3 (combination 1,2)
End Else
End Else IF
End IF

Fig. 1. Mechanism of Entire proposed MROM Scheme

As shown from *Pseudo* code in figure 1, the optimal path for our proposed scheme divided into the three stages:

2.1 Infrastructure optimization (Stage #1)

This stage focuses on infrastructure optimisation by utilising new functionality of a home agent of the Exit Mobile Router as a centralize HA namely; Proxy HA to handle inefficient routing matters which include redundant tunnelling packet overhead (extra IP header), packet delivery lost and scalability. The main goal of using a Proxy HA is to get an optimal routing method matching with all entities of MIPv6 and NEMO BSP**.** The Home Agent (HA) of the Exit MR (EMR) acts as PHA.

The major key solution of our proposed (MROM) is HAs exchange information (metrics) about MRs that can be reached and the MNNs behind each MR. Hence, hop distance between the end points is decreased**.** Additionally, has notify the same network prefixes gathered from various network domains by using anycast routing [4][11]. Likewise, has sharing metrics about their associations with MRs.

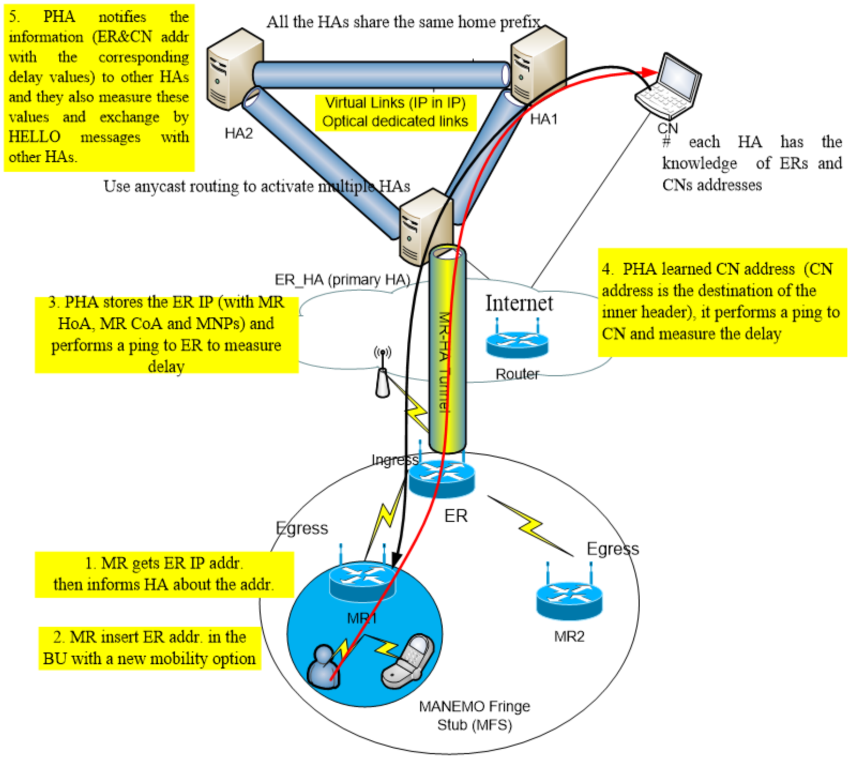

Fig. 2. Infrastructure Optimization (Stage #1) Mechanism

2.2 Intra NEMO optimization (Stage #2)

This stage involves Intra-NEMO optimisation that supports local connectivity among MNs/MRs in the same mobile network, in order to address HA dependency, bottleneck, traffic congestion and selection of ER. MANEMO forms a free network loop for each subnet [13-15]. MANEMO arranges a tree structure towards the Internet by using Tree Discovery Protocol. NINA exposes the MNPs up to the tree (out of MR's E) after tree is formed. Network in Node Option (NINO) carries the MNP in the Neighbour Advertisement (NA) message. By exchanging the NINO options through NA messages up to the tree, an MR learns the Mobile Network prefix (MNP) of all other MRs down its tree [11][14]. Binding Cache table of the Exit router (BC_ER) is extended to preserve the addresses of MNNs/MRs within mobile network. At the Intra-NEMO stage, various Internet Gateways (EMR) are improved. These improvements are achieved by using ER mechanism through extending the functionalities of MR and expanding MR's cache table. This Binding Cache (BC) makes the mapping with HoA, CoA, and PHA linked with MRs. Each MR keeps the prefixes of all MRs at the MFS. Furthermore, the CoAs and HoAs for the lower MRs are kept.

Algorithem 1: Select the ER

- ER_count = 0
- Do
- IF MR has direct Internet connection Then
- MR acts as (IGW/ ER)
- ER_count = ER_count +1
- Else MR has Indirect Internet connection (through other MRs)
- Select the best route to ER
- End Else
- While ∀ MRs test their connectivity status
- End Do
- End IF
- Do
- Case "ER selection" of
- $((TD_{ER1} > TD_{ER2})$ && $(LD_{ER1} > LD_{ER2}))$: select ER2 as the best route to Internet
- $((TD_{ER1} > TD_{ER2})$ && $(Q_{ER1} >> Q_{ER2}))$: select ER2 as the best route to Internet
- $(LD_{ER1} > LD_{ER2})$ && $(Q_{ER1} >> Q_{ER2}))$: select ER2 as the best route to Internet
- Default
- Select ER1 as the best route to get Internet connection
- End case
- While MFS has > 1 ER
- End Do
- Halt

Fig. 3. Extension of Selecting Exit Router (ER) Mechanism - NEMO Multihomed

Figure 4 shows the format of Tree Information Option (TIO) message where "P" letter is specifying as a bit represent when an HA operates as Proxy HA, and "G" flag is specifying as another bit when an MR operates as EMR. Also, a sub option field is allocated to uniform path metrics which carries network of measurements as lowest path, link's time delay, throughput, and bandwidth [16-17]. lastly, Exit MR advertises its address (HoA and CoA) for all MRs/MNNs within mobile network by TIO.

Type	Length |G|H|P|	Reserved	Sequence
Tree Pref.	Boot Time Random		
MR Preference		Tree Depth (L)	Tree Delay
Path Digest			
Tree ID			
Newly Sub-options: 1. Internet Connectivity 2. RTT between (ER-PHA) and between (PHA-CN) 3. Packet Queuing			
ER_CoA			
ER_HoA			

Fig. 4. New Metrics Carried by Tree Information Option (TIO) message

2.3 Inter NEMO Optimization (Stage #3)

This stage is aim to discard route sub-optimal concerns by integrating with the Infrastructure optimization (stage #1) and Intra-NEMO optimization (stage #2) which produces one-way tunnel between the terminals as shown in figure 5.

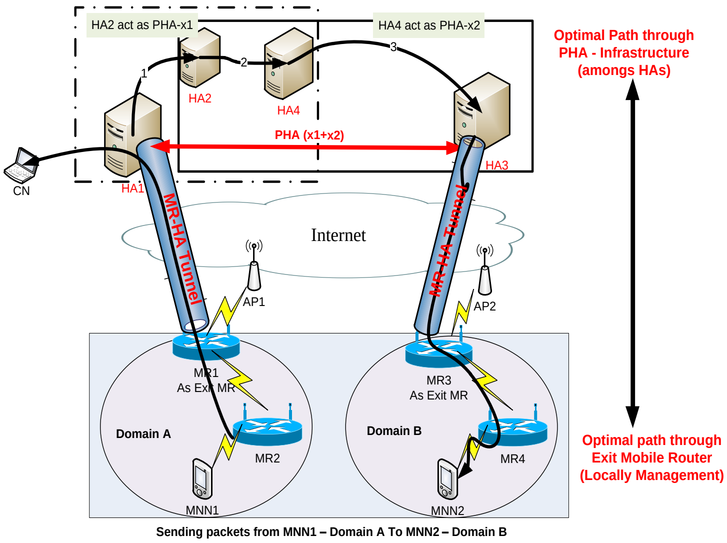

Fig. 5. Inter –Optimization based on proposed MROM

The Exit MR continuously collects the connectivity information from all the MRs in mobile networks and learns the network topology. Each MR maintains a route to the Exit MR to receive connectivity information [18]. The global view of the network has information regarding the number of MRs in the mobile network and the connectivity between the MRs. Algorithm 1 shows the mechanism of selecting Exit MR. The selection of Exit MR among other MRs in NEMO is a type of NEMO Multihoming as IETF classification [4]. At Intra NEMO, the proposed MROM is designed for maintaining route to Exit MR, learning network topology, and sending network routes. Therefore, Exit MR serves the direct connection between two MNN/MRs at same domain.

On another hand, the proposed MORM scheme deployed the infrastructure optimization through choosing a Proxy Home Agent (PHA) from multiple HAs that connected previously with them [19]. PHA collects information from the other HAs to control the packets received or sends from/to Exit MR. Hence, the optimal path between MNN and its CN in Nested NEMO can be obtained without any bidirectional tunneling between MRs and their HAs, just one biderical tional tunnel generated between Exit MR and Proxy HA. While the CN needs to communicate with MNN, its collect flow path information from previous communication (binding cache of ER) and sending packets to it MNN without any IP tunnels.

3 Proposed MROM Based Multihoming

In our proposed MROM configuration, each MR has three interfaces: Egress (E), Ingress (I) and Virtual (V) Interfaces as shown in figure 6. Therefore, these Multiple interfaces of MR can achieve NEMO multihoming features; as like improved availability and balanced traffic load with flow distribution through corresponding connectivity through inter technology Handoff [14-18]. Hence, handoff delay time is reduced.

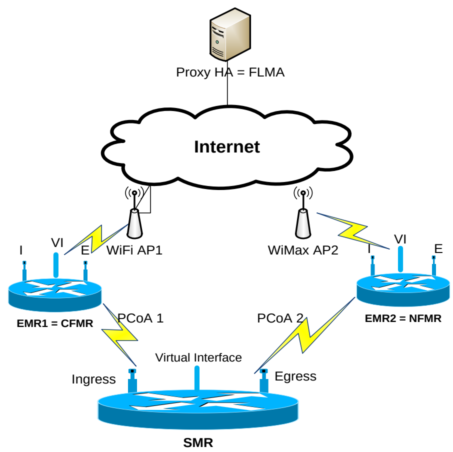

Fig. 6. Multi-Interface for SMR in Proposed MROM

This section gives a brief overview of our PROPOSED MROM to support mobility management within NEMO style. Regarding to our proposed MROM scheme, the Flow Based Local Mobility Anchor (FLMA), and Serving Mobile Router (SMR) operates as an LMA and MR in P-NEMO style respectively [15]. Also, MROM assumes that old Exit Mobile Router (EMR1) and the new Exit Mobile Router (EMR2) act as Current Flow – enabled MR (MRCF), and the New Flow – enabled MR (MRNF), respectively. Both MRCF and MRNF devices are utilized for learning the changing of SMR across different wireless access routers [19][20][21]. Moreover, MRCF and MRNF are responsible to the Mobile and Home Network Prefix (MNP and HNP) respectively, from the Acknowledgement (Ack) that is forwarded directly by the Proxy-HA (as FLMA). Finally, both devices (MRCF and MRNF) are exchanging the metrics of MNN/SMR through Layer 2 process of triggering. Figure 7 is shown a framework of the network components [14].

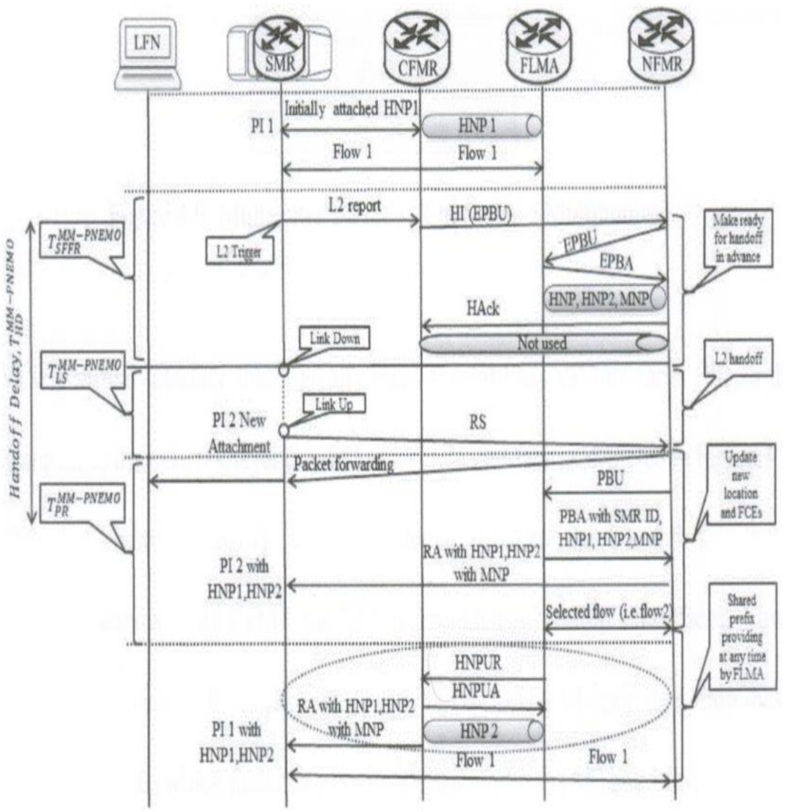

Fig. 7. A Reference Timing Diagram during Handoff (H/O) procedure of the proposed MROM

Additionally, the proposed MROM support Fast-Handoff procedure. In our proposed scheme (MROM), the (EMR1 act as MR_{CF} and EMR2 act as MR_{NF})

exchange handoff messages "Handover Initiation (H_I) and Handover Acknowledgement (H_{Ack})" prior of layer two handover [14][15][16]. This exchanging operation is to support flow-based routing of SMR efficiently within P-NEMO style. The collected metrics of SMR which H_I message has flow and MR's IDs, MNP, HNP, MR ID, and (PHA or FLMA address).

Also, theses gathered metrics supports for enabling MR_{NF} to forward (BU and BA) binding registration messages which containing MNP's MR option to Flow Local Mobility Anchor (FLMA) in order to complete the processing of Location Update (LU). Two binding registration messages namely, Early Proxy Binding Update (EP_{BU}), and Early Proxy Binding Acknowledgement (EP_{BA}) are encapsulated within H_I and H_{Ack} messages, respectively to perform fast registration [21-23]. Moreover, a new field option is added to EP_{BU} and EP_{BA} that contains Flow Based Mobile Network Prefix (FMNP). FMNP also advise the interfaces current status and ask for implementing the flow routing via inter technology handoff.

4 Performance Analysis of the Proposed MROM

Typically, this section related with the numerical framework which is done in order to evaluate the performance analysis of our proposed MROM scheme. This performance of the proposed MROM is compared with standard protocol NEMO BSP and with P-NEMO scheme. PNEMO is selected as comparative scheme with proposed MROM because both schemes depended on the concepts of PMIPv6, that is a network based and support local management mobility at NEMO environment to solve NEMO drawbacks [22]. On another hand, NEMO-BS Protocol is designed to work with local and global mobility management in NEMO environment [23]. The performance metrics that considered in Our proposed MROM are; costs of signaling message and packet delivery, handoff time delay, and packet loss. Table 1 shows the notation symbols which are used to evaluate analytical performance of our proposed MROM scheme. With the assumption that PHA in NEMO BS protocol is at a similar level as FLMA in proposed MROM and LMA in P-NEMO [14].

Table 1. The Parameters of the Performance Evaluation

Symbols	Explanation
N_{SMR}	Number of the SMR
μh	SMR mobility rate
T_{SMR}	Cell residence time
Pwlr	Probability of wireless link failure
B_{w1}	Bandwidth of the wireless link
B_{wd}	Bandwidth of the wired link
Hx-y	Hop distances between (x) and (y)
λs	Average Session Length
r	Radius of a cell
V	Average speed of vehicle
τ	weight factors of tunnelling
ε	weight factor for the packet loss cost

4.1 Handoff Delay (HD) analysis

When MR is moving from one mobile subnet to another, handoff process is occurred. So, the HD of the moving MR (Exit MR) is equal to the total time required to complete tasks as getting CoA, MR's movement tracking, Link Switching (LS) process including current location update of SMR[24] [32]. The HD of the proposed MROM can be expressed as:

$$T_{HD}^{\mathrm{MROM}} = T_{PR}^{\mathrm{MROM}} + T_{SFFR}^{\mathrm{MROM}} + T_{LS} \quad (1)$$

Where T_{PR}^{MROM} and T_{SFFR}^{MROM} are the handoff delays that support Flow based Fast Registeration through inter technology handoff in the proposed MROM scheme, T_{LS} refers to the link switching delay. Hence, T_{PR}^{MROM} and T_{SFFR}^{MROM} are:

$$T_{PR}^{\text{Proposed MROM}} = \left[\left\{\frac{P_{wlf}H_{SMR-FMR}}{1-P_{wlf}}\left(\frac{L_{RS}}{B_{wl}} + t_{wl}\right)\right\} + (L_{data}t_{wl})\right] \quad (2)$$

$$T_{SFFR}^{\text{Poposed MROM}} = \left[H_{FMR-FMR}\left(\frac{L_{HI}}{B_{wd}} + t_{wd}\right) + H_{FMR-FMR}\left(\frac{L_{HAck}}{B_{wd}} + t_{wd}\right) + \tau\left\{max\,(H_{FMR-FMR}, H_{FLMA-FMR})\left(\frac{L_{EPBU}}{B_{wd}} + t_{wd}\right)\right\}\right] \quad (3)$$

The hop distances between the Exit MRs (EMR) plus Proxy HA (i.e. FLMA) and EMR are representive as $H_{ER\text{-}ER}$ and $H_{FLMA\text{-}ER}$ respectively. Hence, the HD of NEMO BS protocol is:

$$T_{HD}^{NEMO\ BS} = (T_{MD}^{NEMO\ BS} + T_{Ls} + T_{DAD}^{NEMO\ BS} + T_{SR}^{NEMO\ BS}) \quad (4)$$

Where $T_{MD}^{NEMO\ BS}$ represents the delay of Movement Detection (MD) and it's implemented during mapping the messages (RS and RA) between previous, and current access networks. Also, $T_{DAD}^{NEMO\ BS}$ is replaced as Retrans Timer in [23] where its supposed there is no CoA that used at each MN in the access link. Likewise, $T_{SR}^{NEMO\ BS}$ referred to the total registration delay in which SMR (Exit MR) and it's HA (Proxy HA) are exchanged messages of (BU) and (BA) in order to update MR's present location. Thus, $T_{MD}^{NEMO-BS}$ and $T_{SR}^{NEMO\ BS}$ are calculated as:

$$T_{MD}^{NEMO\ BS} = \left[\frac{P_{wlf}H_{MR-AR}}{1-P_{wlf}}\left\{\left(\frac{L_{RS}}{B_{wl}} + t_{wl}\right) + \left(\frac{L_{RA}}{B_{wl}} + t_{wl}\right)\right\}\right] \quad (5)$$

$$T_{SR}^{NEMO\ BS} = \left[\frac{P_{wlf}H_{MR-AR}}{1-P_{wlf}}\left\{\left(\frac{L_{BU}}{B_{wl}} + t_{wl}\right) + \left(\frac{L_{BA}}{B_{wl}} + t_{wl}\right)\right\} + \left\{H_{AR-HA}\left(\frac{L_{BU}}{B_{wd}} + t_{wd}\right) + H_{HA-AR}\left(\frac{L_{BA}}{B_{wd}} + t_{wd}\right)\right\}\right] \quad (6)$$

In P-NEMO scheme [14], the new MAG sends a Proxy BU message to LMA (i.e. Exit MR) to support SMR for the handoff registration. The Proxy BU message could not send by the wireless links as whole signaling message is processed at the network infrastructure [25-27]. Therefore, Handoff Delay of the P -NEMO T_{HD}^{P-NEMO} can be expressed as:

$$T_{HD}^{PNEMO} = (T_{RS}^{PNEMO} + T_{Ls} + T_{SPR}^{PNEMO}) \quad (7)$$

From above equation 7, the time required to inform the SMR about connection to new MAG is represented as T_{RS}^{P-NEMO} in which, the delay time for doing location update is referred as T_{REG}^{P-NEMO}. Hence, T_{RS}^{P-NEMO} , T_{SPR}^{P-NEMO} are calculated as:

$$T_{RS}^{P-NEMO} = \left\{\frac{P_{wlf}H_{MR-MAG}}{1-P_{wlf}}\left(\frac{L_{RS}}{B_{wl}} + t_{wl}\right)\right\} \quad (8)$$

$$T_{SPR}^{P-NEMO} = \left[2\left(\frac{H_{MAG-LMA}L_{PBU}}{B_{wd}} + t_{wd}\right) + max\left\{2\left(\frac{H_{MAG-LMA}L_{PBU}}{B_{wd}} + t_{wd}\right), T_{RS}^{P-NEMO} + 2\tau\left(\frac{H_{MAG-LMA}L_{PBU}}{B_{wd}} + t_{wd}\right)\right\}\right] \quad (9)$$

Hence, the relative Handover Delay gains (G_{HD}) of our Proposed MROM to the NEMO BS protocol, and PNEMO are calculated as below:

$$G_{HD1} = \frac{T_{HD}^{NEMO\ BS}}{T_{HD}^{\mathrm{MROM}}} \quad (10)$$

$$G_{HD2} = \frac{T_{HD}^{P-NEMO}}{T_{HD}^{\mathrm{MROM}}} \quad (11)$$

$$G_{HD3} = \frac{T_{HD}^{NEMO\ BS}}{T_{HD}^{P-NEMO}} \quad (12)$$

4.2 Packet Loss (PL) analysis

From figure 7, the multi-interfaced SMR is capable of supporting Flow based Fast Registeration (SFFR) procedure in the proposed MROM scheme. Thus, it is possible to prevent the PL during handoff as mentioned in equation 11. According to the proposed scheme, the FLMA sends packets to the MR_{NF} once it received the EP_{BU} message from MR_{NF} through wired links. Since the number of PL is proportionate to the total HD, hence, the total PL for the proposed MROM is expressed as:

$$T_{PL}^{\mathrm{MROM}} = \lambda_s \mu_h N_{SMR}\left\{T_{LS}H_{FMR-FMR}\left[\left(\frac{L_{Hi}}{B_{wd}} + t_{wd}\right) + \left(\frac{L_{HAck}}{B_{wd}} + t_{wd}\right)\right]\right\} \quad (13)$$

Where λ_s denotes average session length. In addition to that, the Number of SMR (N_{SMR}) plays an important role. This is because the PL is directly equivalent to the rate of handoffs it is exposed to, within a particular time [9][28]. Consequently, the Packet Loss Ratio (PLR) of the proposed MROM scheme can be expressed as:

$$T_{PLR}^{\mathrm{MROM}} = \frac{T_{PL}^{\mathrm{MROM}}}{T_{cell}} \times 100 \quad (14)$$

Where:

$$T_{cell} = \frac{2r}{v} \quad (15)$$

4.3 Total Handoff Cost (THC) analysis

This subsection formulates mathematical terms of Signaling Cost (SC) and Packet Delivery Cost (PD). In order to evaluate the analytical performance of our proposed MROM scheme, then to compare it with NEMO BSP and PNEMO. Total Handoff Cost (THC) is presented as sumuation of total (SC) and total (PDC). So, (THC) of proposed MROM ($\Psi_{THC}^{\mathrm{MROM}}$), NEMO BS ($\Psi_{THC}^{NEMO\ BS}$) and P-NEMO ($\Psi_{THC}^{P-NEMO}$) will be:

$$\Psi_{THC}^{\mathrm{MROM}} = \Psi_{SC}^{\mathrm{MROM}} + \Psi_{PDC}^{\mathrm{MROM}} \tag{16}$$

$$\Psi_{THC}^{NEMO-BS} = \Psi_{SC}^{NEMO-BS} + \Psi_{PDC}^{NEMO-BS} \tag{17}$$

$$\Psi_{THC}^{P-NEMO} = \Psi_{SC}^{P-NEMO} + \Psi_{PDC}^{P-NEMO} \tag{18}$$

Where $\Psi_{SC}^{\mathrm{MROM}}$,$\Psi_{PDC}^{MM-PNEMO}$, $\Psi_{SC}^{NEMO-BS} + \Psi_{PDC}^{NEMO\ BS}$, and $\Psi_{SC}^{P-NEMO} + \Psi_{PDC}^{P-NEMO}$ are Signalling Cost (SC) and the Packet Delivery Cost (PDC) of our Proposed MROM, NEMO BS, and PNEMO.

4.4 Signaling Cost (SC) analysis

The cost of message signaling is proportional to handoff rate, while handoff rate is an inverse proportional to residence time for each cell. Thus, SC of Location Update (LU) is equal to the multiplication of the message length of signaling with count of hop distance [16]. Signaling Cost also contains the processing cost of mobile network components. At our proposed MROM, The (LU) is done in the PHA (FLMA). Besides, P - NEMO scheme does not need to send Binding Update (BU) message across wireless links which have greater delay than the wired link, since PNEMO scheme depends on the PMIPv6 subent within NEMO environment [5] [14]. In our proposed MROM scheme, signaling messages (EP_{BU} and EP_{BA}) sends via (H_I and H_{Ack}) messages, respectively in order to support the seamless handoff for an SMR. But at PNEMO scheme, signaling registration messages EP_{BU} and EP_{BA}) between Support Flow enabled Fast Registeration (SFFR) is taken in our analytical. Hence, the SC of our proposed MROM does not need multiple LU. The SC can be expressed as:

$$\Psi_{SC}^{\mathrm{MROM}} = \frac{1}{E(T_{SMR})} N_{SMR} \pi_{FLMA}^{\mathrm{MROM}} + C_{SFFR}^{\mathrm{MROM}} + C_{SPR}^{\mathrm{MROM}} \tag{19}$$

Where $\pi_{FLMA}^{\mathrm{MROM}}$ refers to cost of processing for FLMA, and $E(T_{SMR})$ refers to the estimated cell residence time, and C_{SFFR}^{MROM}, C_{SPR}^{MROM} are cost signaling message for (fast and post registerations) for each Serving MR, respectively. C_{SFFR}^{MROM} , C_{SPR}^{MROM} are calculated as:

$$C_{SFFR}^{\mathrm{MROM}} = H_{FMR-FMR}\left(\frac{L_{Hi}}{B_{wd}} + t_{wd}\right) + H_{FMR-FMR}\left(\frac{L_{HAck}}{B_{wd}} + t_{wd}\right) + H_{FLMA-FMR}\left(\frac{L_{EPBU}}{B_{wd}} + t_{wd}\right) + H_{FLMA-FMR}\left(\frac{L_{PBU}}{B_{wd}} + t_{wd}\right) \tag{20}$$

$$C_{SPR}^{\text{MROM}} = \left\{\frac{P_{wlf}H_{SMR-FMR}}{1-p_{wlf}}\left(\frac{L_{RS}}{B_{wl}} + t_{wl}\right)\right\} \quad (21)$$

In both schemes, our proposed MROM and P-NEMO, the process of MR's Location Update (LU) is done within network infrastructure entities (MAGs= EMR, and LMA= PHA). In spite of that, P-NEMO is needed two LU messages. On another hand, the LU configuration of NEMO BS Protocol is processed within the HA's of MR. Consequently, whenever the MR does any movement, its' HA should be notified. In the equations below (22-28), the $\pi_{HA}^{NEMO\ BS}$ refers to cost of HA's processing at NEMO BS Protocol, and π_{LMA}^{P-NEMO} refers to the cost of LMA's processing at PNEMO. The $C_{MD+DAD}^{NEMO\ BS}$, $C_{REG}^{NEMO\ BS}$, C_{RS}^{P-NEMO} , and C_{REG}^{P-NEMO} are assumed as the LU's Cost for NEMO BS Protocol and PNEMO. As a result, the SC of both NEMO BS and PNEMO are expressed:

$$\Psi_{SC}^{NEMO\ BS} = \frac{1}{E(T_{MR})} N_{MR}(\pi_{HA}^{NEMO\ BS} + C_{MD+DAD}^{NEMO\ BS} + C_{REG}^{NEMO\ BS}) \quad (22)$$

$$\Psi_{SC}^{P-NEMO} = \frac{1}{E(T_{MR})} N_{MR}(\pi_{LMA}^{P-NEMO} + C_{RS}^{P-NEMO} + C_{REG}^{P-NEMO}) \quad (23)$$

Where

$$C_{MD+DAD}^{NEMO\ BS} = \frac{P_{wlf}H_{MR-AR}}{1-P_{wlf}}\left\{\left(\frac{L_{RS}}{B_{wl}} + t_{wl}\right) + \left(\frac{L_{RA}}{B_{wl}} + t_{wl}\right) + \left(\frac{L_{NS}}{B_{wl}} + t_{wl}\right)\right\} \quad (24)$$

$$C_{REG}^{NEMO\ BS} = \frac{P_{wlf}H_{MR-AR}}{1-P_{wlf}}\left\{\left(\frac{L_{BU}}{B_{wl}} + t_{wl}\right) + \left(\frac{L_{BA}}{B_{wl}} + t_{wl}\right) + d_{HA-AR}\left(\frac{L_{NS}}{B_{wl}} + t_{wl}\right) + H_{HA-AR}\left(\frac{L_{NS}}{B_{wl}} + t_{wl}\right)\right\} \quad (25)$$

$$C_{REG}^{P-NEMO} = 2\left\{H_{MAG-LMA}\left(\frac{L_{PBU}}{B_{wd}} + t_{wd}\right) + H_{LMA-MAG}\left(\frac{L_{PBA}}{B_{wd}} + t_{wd}\right)\right\} \quad (26)$$

$$C_{RS}^{P-NEMO} = \left\{\frac{P_{wlf}H_{MR-MAG}}{1-P_{wlf}}\left(\frac{L_{RS}}{B_{wl}} + t_{wl}\right)\right\} \quad (27)$$

4.5 Packet Delivery Cost (PDC)

As discussed earlier of the section that handoff delay is classified into four modules of delay mainly are; delay of Movement Detection (MD), dely of Link Switching (LS), delay of obtining CoA as well as delay of registration process [28]. CoA configuration delay focuses on how swiftly IP data packets are sent by the SMR after layer 2 handoff. LU delay can be termed as the delay of forwarding IP data packets to the SMR's new IP address. The packet Delivery Cost (PDC) is equal to sumuation of the packet transmision and processing cost [28]. Therefore, the total PDC is also referred as the linear association of Tunneling Cost (TC), and packet Lost Cost (LC) [29].

At P-NEMO environment, both proposed MROM scheme, and P-NEMO scheme use support Flow enabled Fast Registration (SFFR). As a result, the FLMA preserves the Binding Cache Entity (BCE) same as HA of MR at NEMO BS. FLMA firstly intercepts any packet that sent by CN to MR. After that, FLMA establishes a Bi-directional tunnel between FLMA and MR through access router. Once the (FLMA=PHA) received the EP_{BU} from MR_{NF} by wired link, FLMA starts forwarding data packets to MR_{NF} which is not including any buffering.

For the duration of (T_{SER}^{MROM}), if PHA does not receive the EP_{BU} message, all the packets forwarding to Serving MR will be tunnelled such as P-NEMO. (Ψ_{PDC}^{MROM}) refers to the PDC of the proposed MROM and it's calculated as "TC + LU".

By assuming "τ" as the tunneling overhead factor whereas the CN forwarding data to MR. the PDC for both handoff status (successful and failure) are calculated and referred as $\omega_{Success} \times \tau \times C_{TC}^{\text{MROM}}$, and $\omega_{Failure} \times \sigma \times C_{PLOSS}^{\text{MROM}}$ So Ψ_{PDC}^{MROM}, T_{TC}^{MROM}, and T_{PLOSS}^{MROM} are expressed as:

$$\Psi_{PDC}^{\text{MROM}} = N_{CN} N_{SMR} \lambda_S \mu_H \{(\omega_{Success} \times \tau \times C_{TC}^{\text{MROM}}) + (\omega_{Failure} \times \sigma \times C_{PLOSS}^{\text{MROM}})\} \quad (28)$$

$$C_{TC}^{\text{MROM}} = \{H_{FMR-FMR}(2L_{THD}) \times min[max(H_{FLMA-FMR}t_{wd} - H_{FMR-FMR}t_{wd}, 0), (2T_{LS}H_{FLMA-FMR}t_{wd})]\} \quad (29)$$

$$C_{PLOSS}^{\text{MROM}} = \{H_{FLMA-FMR}L_{THD}[T_{LS} + (H_{FLMA-FMR}t_{wd})]\} \quad (30)$$

In NEMO BS, sending/receiving packets from MR and its HA are encapsulated via bidirectional tunnel which leads to increase tunneling overhead cost. Additionaly, during handoff; all packets transmitted from CN to MNN/LFN via access router by using wireless [16][25]. Therefore, packet loss cost is added with tunneling overhead cost. The $C_{TC}^{NEMO\ BS}$, and $C_{PL}^{NEMO\ BS}$ are referred to the tunneling cost and packets lost cost. So, the PDC for NEMO BS Protocol is calculated as;

$$\Psi_{PDC}^{NEMO\ BS} = N_{MR}\lambda_S \mu_H \{\tau C_{TC}^{NEMO\ BS} + \sigma C_{PL}^{NEMO\ BS}\} \quad (31)$$

$$C_{TC}^{NEMO\ BS} = \left\{\left(\frac{P_{wlf}H_{AR-MR}}{1-P_{wlf}}\right) + (H_{AR-MR}L_{THD})\right\} \quad (32)$$

$$C_{PL}^{NEMO\ BS} = (H_{CN-HA} + H_{AR-MR}L_{THD})\left(T_{HD}^{NEMO\ BS} - \frac{T_{REG}}{2}\right) \quad (33)$$

In P-NEMO, packets send/receive via the bidirectional tunnel that established between the new MAG and LMA. Because of LMA and MAG2 are infrastructure network enities, all data send/receive through bidirectional tunnel via wired links. The C_{TC}^{P-NEMO}, C_{PL}^{P-NEMO} are referred to tunneling cost and packet loss cost. So, PDC for P -NEMO is:

$$\Psi_{PDC}^{P-NEMO} = N_{MR}\lambda_S \mu_H \{\tau C_{TC}^{P-NEMO} + \sigma C_{PL}^{P-NEMO}\} \quad (34)$$

$$C_{TC}^{P-NEMO} = (H_{LMA-MAG}L_{THD}) \quad (35)$$

$$C_{PL}^{P-NEMO} = \{2H_{LMA-MAG}L_{THD}(T_{LS} + t_{wl} + (2H_{LMA-MAG}t_{wd}))\} \quad (36)$$

The proposed MROM scheme is compared to that of NEMO BS Protocol and P-NEMO scheme in terms of the HD. Hence, the relative handoff cost is:

$$Gain_{THC} = \frac{T_{THC}^{NEMO\ BS}}{T_{THC}^{\text{MROM}}} \quad (37)$$

$$Gain_{THC} = \frac{T_{THC}^{P-NEMO}}{T_{THC}^{\text{MROM}}} \quad (38)$$

$$Gain_{THC} = \frac{T_{THC}^{NEMO\ BS}}{T_{THC}^{P-NEMO}} \quad (39)$$

5 Results and Discussion of Performance Evaluation

5.1 Effects of different no. of SMR, link and cell residence time on signaling cost

Figures 8 and 9 represent the impact of SC regarding to No. of MRs, and the time of cell residence. From Figure 8, when the No. of MRs increases, the Signaling Cost (SC) for proposed MROM, NEMO BS Protocol, and PNEMO increases linearly. The SC of proposed MROM and PNEMO schemes is lower than NEMO BS Protocol because of the eradication of signaling message transmitted wirelessly.

The localized movement of MR in our proposed MROM and P-NEMO is managed without notifying its HA. Therefore, the signaling cost is reduced to our proposed MROM, and PNEMO. But our Proposed MROM scheme presents small amount of LU cost than P-NEMO. This enables many users to get the Internet features all together in wireless vehicle networks.

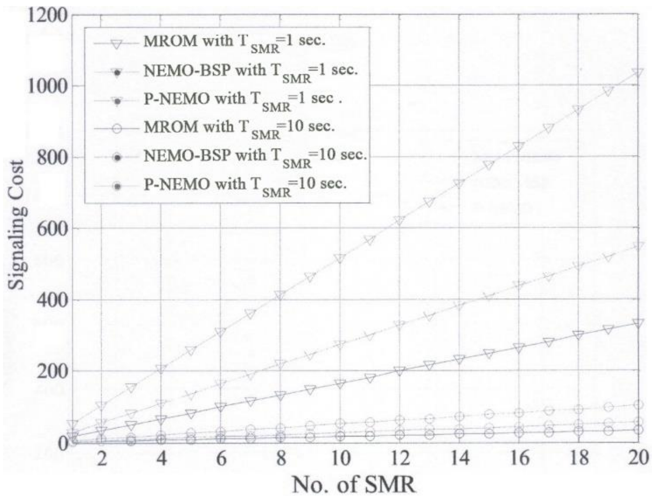

Fig. 8. Signaling Cost (SC) vs. Different No. of MRs

Figure 9 indicates the relationship between the signaling cost and time of cell residence for our Proposed MROM scheme, P- NEMO, and NEMO BS. The cell residence time is varied from 1 to 100 second while the NSMR is set to 20. The

Handoff occurs frequently when the cell residence time decreases. Consequently, if the SMR changes it location frequently, the SMR will notify its HA in NEMO BS. Thus, the signaling of NEMO BS $\Psi_{SC}^{NEMO-BS}$ is increased.

In contrast, our Proposed MROM and P-NEMO scheme, if the SMR changes its location (moves away), it is not required to notify or send LU to its own HA. This is because, an LMA concept is applied in the network. This significantly reduces the location update cost. Hence, with the increase of cell residence time, the obvious outcome indicates that the proposed MROM and P- NEMO require a smaller amount of signaling cost regarding to standard NEMO BS. However, proposed MROM shows a lower signaling cost compared to P-NEMO due to the elimination of double location update as appeared in figure 9.

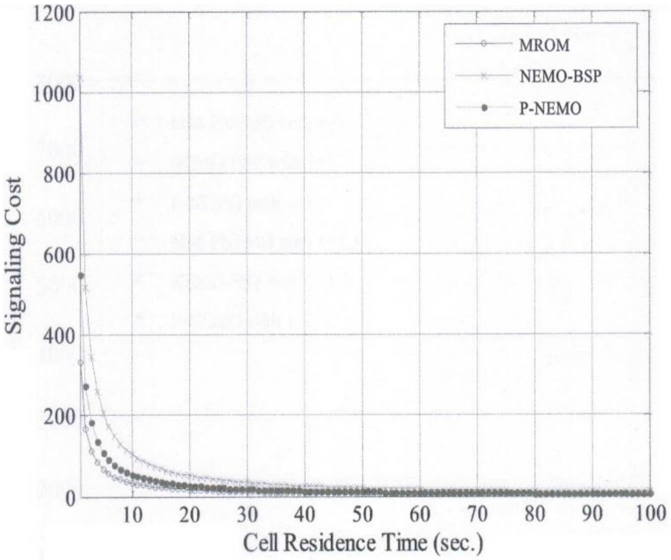

Fig. 9. Signaling Cost vs. Cell Residence Time

5.2 Effects of different no. of SMRs (N_{SMR}) and cell residence time on Packet Delivery Cost (PDC)

Figures 10 and 11 represent the effect of No. of SMR (N_{SMR}) with time cell residence on Packet Delivery Cost (PDC). The (N_{SMR}) is set as 10 and 20 that results of changing the cell residence time.

Since our proposed MROM scheme supports NEMO infrastructure entities, MROM effects by the number of active sessions and also by subnet range of FLMA. When (N_{SMR}) increases with lower cell residence time, the routing cost and packet processing cost increase in FLMA. So, the PDC is also increased as a result.

Figures 10 and 11 present higher Packet Delivery Cost of NEMO BS $\Psi_{PDC}^{NEMO\ BS}$ than our Proposed MROM Ψ_{PDC}^{MROM}, and P- NEMO Ψ_{PDC}^{P-NEMO} schemes. NEMO BS

Protocol shows higher PDC because multiple bidirectional tunnels are established between MR and its HA when the CN is communicated with SMR.

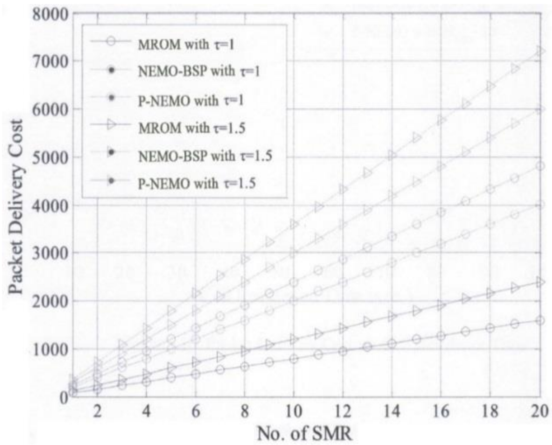

Fig. 10. Total Packet Delivery Cost vs. No. of SMR (λ_s=10)

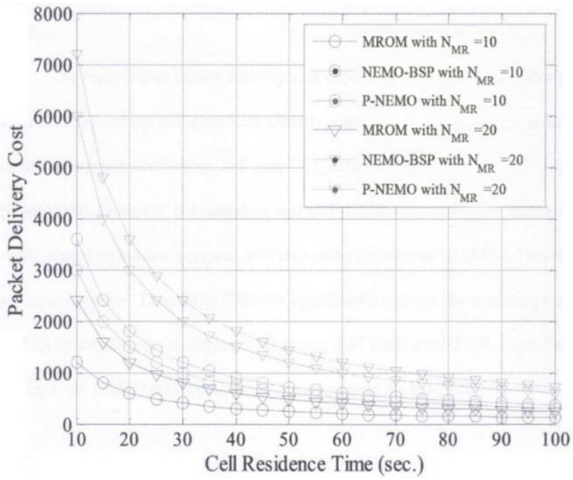

Fig. 11. Packet Delivery Costs (PDC) vs. Cell Residence Time with Different NSMR

Nowadays, Mobile Networks in our real-life are rapidly increased, some of Netwok Mobility applications are; Wireless Sensor Networks (WSN) in Vehicular Networks for both communications (Vehicles to Vehicles and Vehicles to Internet), Personal Area Networks PANs (Monitoring and remotly control), and Emergency Network (Post- Disaster recovery). Features of mobile networks embrace wide accessibility in cities and roads. So, Intelligent Transportation System (ITS) is one best example of Network Mobility. By using either 4G or 5G mobile networks through the utilization of onboard and road-side sensors, then ITS applications can transmit information. Traffic congestion, and automation can be avoided for the driver through using ITS.

For Safety, Japan's Smart-way and the United States' IntelliDrive are two examples of ITS communications systems which are designed to help vehicles to avoid the accident.

6 Conclusion

In this work, a NEMO BS successor is presented and supported with a detailed numerical model analysis; where, the presented proposed MROM, by maximizing the handoff performance, has been justified to have better mobility support than the ordinary NEMO BS Protocol and P-NEMO scheme. At the performance analytical, we discussed the Signaling Cost (SC) (i.e. Location Update LU cost) in terms of total handoff costs, packet loss cost, and Packet Delivery Cost (PDC) (as tunneling overhead cost).

The Analytical part shows that our proposed MROM scheme significantly reduces handoff cost by an average of 64% compared to P- NEMO and NEMO BS Protocol because of proposed MROM is enhanced the flow binding that is used in P- NEMO for supporting the fast registration process.

Hence, using the Exit MR (MRCF, MRNF) reduced the bidirectional tunnels (tunneling cost) for multi-interfaced of SMR during inter technology handoff and also reduces the effect probability of tunnel failure. Analytically, Table 2 shows the comparison of the three scenarios.

Table 2. Performance Analytical Results

Preferences	(NEMO BS)	(P-NEMO)	(Proposed MROM)
Handoff Time Delay (millisecond)	1034	543.l	182.8
Average packet loss	54	32	3
Packet loss ratio (%)	11	6	1
Total handoff cost	7304	6059	2433

In simulation part, performance of the proposed MROM scheme is evaluated via using NS-3 simulator. Table 3 is shown the metrics which are selected in simulation part such as average packet loss, handoff time delay, packet delivery cost ratio, as well as throughput.

Table 3. Simulation Analysis Results

Preferences	(NEMO BS)	(P-NEMO)	(Proposed MROM)
Handoff Time Delay (millisecond)	1034	543.l	182.8
Average packet loss	54	32	3
Packet loss ratio (%)	11	6	1
Total handoff cost	7304	6059	2433

The research work undertaken here has emphasized on achieving a seamless handoff solution that provides less packet loss along with lower handoff delay, during

SMR movement within different access networks. For IoT applications such as driverless cars or mobile phones, some possible extensions to this work are recommended:

- The other types of Mobile Network Node (MNNs); Local and Visiting Mobile Nodes (LMN and VMN) should be considered under the SMR since nodes are regarded as static in the proposed scheme. Considering Mobile Nodes such as mobile phones and self-driving cars is sometimes required in IoT applications.
- Experimental testbed is recommended to include as a future work for more precise evaluation on end-to-end delay of the proposed MROM scheme.
- For handling more set of wireless access technologies for the next generation networks (i.e. LTE, 5G), the integrated schemes or mechanisms are required for link selection.

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8 Authors

Ahmed Ayoob Mousa, Faculty of Engineering, Department of Electrical and Computer Engineering, International Islamic University Malaysia (IIUM), Kuala Lumpur, Malaysia, ahmedal_shehab@yahoo.com.

Aisha Hassan Abdalla, Faculty of Engineering, Department of Electrical and Computer Engineering, International Islamic University Malaysia (IIUM), Kuala Lumpur, Malaysia, aisha@iium.edu.my.

Huda Adibah Mohd Ramli, Faculty of Engineering, Department of Electrical and Computer Engineering, International Islamic University Malaysia (IIUM), Kuala Lumpur, Malaysia, hadibah@iium.edu.my.

Article submitted 2020-06-26. Resubmitted 2020-07-27. Final acceptance 2020-07-28. Final version published as submitted by the authors.