MROM Scheme to Improve Handoff Performance in Mobile Networks

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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 smart devices rapidly grows 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_Intra-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.

![Diagram of Infrastructure Optimization (Stage #1) Mechanism](http://www.i-jim.org)

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.

**Algorithm 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 | Reserved | Sequence |
|------|--------|----------|----------|
| Tree Pref. | Boot Time | Random | |
| MR Preference | Tree Depth | 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 aimed 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 bidercational 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.
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 MRCF and EMR2 act as MRNF)
exchange handoff messages “Handover Initiation (HI) and Handover Acknowledgement (HACK)” prior to 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 HI message has flow and MR’s IDs, MNP, HNP, MR ID, and (PHA or FLMA address).

Also, these gathered metrics supports for enabling MRsA 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 (EPBU), and Early Proxy Binding Acknowledgement (EPBA) are encapsulated within HI and HACK messages, respectively to perform fast registration [21-23]. Moreover, a new field option is added to EPBU and EPBA 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 relates 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].

| Symbols  | Explanation                        |
|----------|------------------------------------|
| NSMR     | Number of the SMR                  |
| \( \mu_h \) | 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) |
| \( \lambda_s \) | Average Session Length          |
| \( r \) | Radius of a cell                   |
| V        | Average speed of vehicle           |
| \( t \) | weight factors of tunnelling       |
| \( \varepsilon \) | Weight factor for the packet loss cost |

Table 1. The Parameters of the Performance Evaluation
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:

$$T_{HD}^{MROM} = T_{PR}^{MROM} + T_{SFRR}^{MROM} + T_{LS}$$  \hspace{1cm} (1)

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

$$T_{PR}^{Proposed~MROM} = (P_{wlf}H_{SMR-FMR} \left( \frac{LR_S}{B_{wl}} + t_{wl} \right)) + (L_{data}t_{wl})$$  \hspace{1cm} (2)

$$T_{SFRR}^{Proposed~MROM} = (H_{FMR-FMR} \left( \frac{L_{FS}}{B_{wd}} + t_{wd} \right) + H_{FMR-FMR} \left( \frac{L_{Ack}}{B_{wd}} + t_{wd} \right) + \tau \left( \max(H_{FMR-FMR}, H_{FLMA-FMR}) \left( \frac{L_{BU}}{B_{wd}} + t_{wd} \right) \right)$$  \hspace{1cm} (3)

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

$$T_{HD}^{NEMO~BS} = (T_{MD}^{NEMO~BS} + T_{LS}^N + T_{DAD}^{NEMO~BS} + T_{SR}^{NEMO~BS})$$  \hspace{1cm} (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, $T_{MD}^{NEMO~BS-BS}$ and $T_{SR}^{NEMO~BS}$ are calculated as:

$$T_{MD}^{NEMO~BS} = \left[ P_{wlf}H_{MR-AR} \left( \frac{LR_S}{B_{wl}} + t_{wl} \right) + \left( \frac{L_{BU}}{B_{wl}} + t_{wl} \right) \right]$$  \hspace{1cm} (5)

$$T_{SR}^{NEMO~BS} = \left[ P_{wlf}H_{MR-AR} \left( \frac{LR_B}{B_{wl}} + t_{wl} \right) + \left( \frac{L_{BA}}{B_{wl}} + t_{wl} \right) \right] + \left( H_{AR-HA} \left( \frac{L_{BU}}{B_{wd}} + t_{wd} \right) \right) + \left( H_{HA-AR} \left( \frac{L_{BA}}{B_{wd}} + t_{wd} \right) \right)$$  \hspace{1cm} (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:
From above equation 7, the time required to inform the SMR about connection to new MAG is represented as $T_{RS}$ in which, the delay time for doing location update is referred as $T_{RS}$. Hence, $T_{RS}^{P-NEMO}$, $T_{SPR}^{P-NEMO}$ are calculated as:

$$T_{RS}^{P-NEMO} = \frac{\rho_{wl}^{FM}}{\lambda_{wl}} + t_{wl}$$

(8)

$$T_{SPR}^{P-NEMO} = 2\left[\frac{H_{MAG-LMA}-PBU}{B_{wd}} + t_{wd}\right] + \max\left\{2\left[\frac{H_{MAG-LMA}-PBU}{B_{wd}} + t_{wd}\right]ight\}$$  

(9)

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

$$G_{HD1} = \frac{T_{NEMO BS}^{HD}}{T_{MROM}^{HD}}$$

(10)

$$G_{HD2} = \frac{T_{P-NEMO}^{HD}}{T_{MROM}^{HD}}$$

(11)

$$G_{HD3} = \frac{T_{NEMO BS}^{P-NEMO}}{T_{P-NEMO}^{MROM}}$$

(12)

4.2 Packet Loss (PL) analysis

From figure 7, the multi-interfaced SMR is capable of supporting Flow based Fast Registration (SFR) 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 MRNF once it received the EPBU message from MRNF 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:

$$T_{PL}^{MROM} = \lambda_{s}H_{N_{SMR}}T_{LS}H_{PMR-FMR}\left[\frac{L_{HI}}{B_{wd}} + t_{wd}\right] + \left[\frac{L_{ACK}}{B_{wd}} + t_{wd}\right]$$

(13)

Where $\lambda_{s}$ 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:

$$T_{PL}^{MROM} = \frac{T_{PL}^{MROM}}{T_{cell}} \times 100$$

(14)

Where:

$$T_{cell} = \frac{2\tau}{v}$$

(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 summation of total (SC) and total (PDC). So, (THC) of proposed MROM ($\psi^{MROM}_{THC}$), NEMO BS ($\psi^{NEMO-BS}_{THC}$) and P-NEMO ($\psi^{P-NEMO}_{THC}$) will be:

$$\psi^{MROM}_{THC} = \psi^{MROM}_{SC} + \psi^{MROM}_{PDC} \quad (16)$$

$$\psi^{NEMO-BS}_{THC} = \psi^{NEMO-BS}_{SC} + \psi^{PDC}_{PDC} \quad (17)$$

$$\psi^{P-NEMO}_{THC} = \psi^{P-NEMO}_{SC} + \psi^{PDC}_{PDC} \quad (18)$$

Where $\psi^{MROM}$, $\psi^{MM-PNEMO}$, $\psi^{SC-PDC}$, $\psi^{NEMO-BS}$, $\psi^{PDC}$, and $\psi^{P-NEMO}$ 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 (EPBu and EPBa) sends via (Ht and Hbak) messages, respectively in order to support the seamless handoff for an SMR. But at PNEMO scheme, signaling registration messages EPBu and EPBa between Support Flow enabled Fast Registration (SFFR) is taken in our analytical. Hence, the SC of our proposed MROM does not need multiple LU. The SC can be expressed as:

$$\psi^{MROM}_{SC} = \frac{1}{E(T_{SMR})}N_{SMR}\pi_{FLMA}^{MROM} + C_{SFFR}^{MROM} + C_{SFFR}^{MROM} \quad (19)$$

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

$$C_{SFFR}^{MROM} = H_{FMRFMR} \left[\frac{IL_{PU}}{T_{PD}} + T_{PD} \right] + H_{FMRFMR} \left[\frac{IL_{PU}}{T_{PD}} + T_{PD} \right] +$$

$$H_{FMR-FMR} \left[\frac{IL_{PU}}{T_{PD}} + T_{PD} \right] + H_{FMR-FMR} \left[\frac{IL_{PU}}{T_{PD}} + T_{PD} \right] +$$

$$H_{FMR-FMR} \left[\frac{IL_{PU}}{T_{PD}} + T_{PD} \right] + H_{FMR-FMR} \left[\frac{IL_{PU}}{T_{PD}} + T_{PD} \right] \quad \text{(20)}$$
\[ C_{\text{MROM}}^{\text{SPR}} = \left( \frac{P_{\text{wif}} H_{\text{SMR}-\text{FMN}}}{1-P_{\text{wif}}} \left( \frac{L_{RS}}{B_{wl}} + t_{wl} \right) \right) \]  

(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 \( \pi_{\text{nemo}}^{\text{BS}} \) refers to cost of HA’s processing at NEMO BS Protocol, and \( \pi_{\text{LMA}}^{\text{P-NEMO}} \) refers to the cost of LMA’s processing at PNEMO. The \( C_{\text{MD+DAD}}, C_{\text{REG}}, C_{\text{RS}}^{\text{P-NEMO}}, \) and \( C_{\text{REG}}^{\text{P-NEMO}} \) 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:

\[ u_{\text{SC}}^{\text{NEMO BS}} = \frac{1}{E(T_{\text{MR}})} N_{\text{MR}} (P_{\text{HA}}^{\text{NEMO BS}} + C_{\text{MD+DAD}}^{\text{NEMO BS}} + C_{\text{REG}}^{\text{NEMO BS}}) \]  

(22)

\[ u_{\text{SC}}^{\text{P-NEMO}} = \frac{1}{E(T_{\text{MR}})} N_{\text{MR}} (P_{\text{LMA}}^{\text{P-NEMO}} + C_{\text{RS}}^{\text{P-NEMO}} + C_{\text{REG}}^{\text{P-NEMO}}) \]  

(23)

Where

\[ C_{\text{MD+DAD}}^{\text{NEMO BS}} = \frac{P_{\text{wif}} H_{\text{MR}-\text{AR}}}{1-P_{\text{wif}}} \left( \left( \frac{L_{RS}}{B_{wl}} + t_{wl} \right) + \left( \frac{L_{BA}}{B_{wl}} + t_{wl} \right) + \left( \frac{L_{NS}}{B_{wl}} + t_{wl} \right) \right) \]  

(24)

\[ C_{\text{REG}}^{\text{NEMO BS}} = \frac{P_{\text{wif}} H_{\text{MR}-\text{AR}}}{1-P_{\text{wif}}} \left( \left( \frac{L_{BU}}{B_{wl}} + t_{wl} \right) + \left( \frac{L_{BA}}{B_{wl}} + t_{wl} \right) + d_{HA-AR} \left( \frac{L_{NS}}{B_{wl}} + t_{wl} \right) \right) + H_{HA-AR} \left( \frac{L_{NS}}{B_{wl}} + t_{wl} \right) \]  

(25)

\[ C_{\text{REG}}^{\text{P-NEMO}} = 2 \left( H_{\text{LMA-EMR}} \left( \frac{L_{PBG}}{B_{wd}} + t_{wd} \right) + H_{LMA-EMR} \left( \frac{L_{PBG}}{B_{wd}} + t_{wd} \right) \right) \]  

(26)

\[ C_{\text{REG}}^{\text{P-NEMO}} = \frac{P_{\text{wif}} H_{\text{MR}-\text{AR}}}{1-P_{\text{wif}}} \left( \frac{L_{RS}}{B_{wl}} + t_{wl} \right) \]  

(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), delay of Link Switching (LS), delay of obtaining 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 summation of the packet transmission 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 $E_{PB}$ from MR NF by wired link, FLMA starts forwarding
data packets to MR which is not including any buffering.

For the duration of $(T_{SJR})$, if PHA does not receive the $E_{PB}$ message, all the
packets forwarding to Serving MR will be tunnelled such as P-NEMO. $(\psi^{MROM}_{PDC})$
refers to the PDC of the proposed MROM and it’s calculated as “$TC + LU$”.

By assuming “$\tau$” 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 $\omega_{Success} \times \tau \times C_{TC}^{MROM}$, and $\omega_{Failure} \times \sigma \times C_{PL}^{MROM}$. So $\psi^{PDC}_{PDC}$, $T_{TC}^{MROM}$, and $T_{PL}^{MROM}$ are expressed as:

$$\psi^{MROM}_{PDC} = N_{CN} N_{SMR} \lambda^H_{MR} \left\{ (\omega_{Success} \times \tau \times C_{TC}^{MROM}) + (\omega_{Failure} \times \sigma \times C_{PL}^{MROM}) \right\} \quad (28)$$

$$C_{TC}^{MROM} = \left( H_{FLMA-\overrightarrow{MR}} (2L^T) + \min(\max(H_{FLMA-\overrightarrow{MR}} t_{wd} -
H_{FLMA-\overrightarrow{MR}} t_{wd}^t), 0), (2T_{LS} H_{FLMA-\overrightarrow{MR}} t_{wd}) \right) \quad (29)$$

$$C_{PL}^{MROM} = \left( H_{FLMA-\overrightarrow{MR}} L_{TTH} (T_{LS} + (H_{FLMA-\overrightarrow{MR}} t_{wd})) \right) \quad (30)$$

In NEMO BS, sending/receiving packets from MR and its HA are encapsulated via
bidirectional tunnel which leads to increase tunneling overhead cost. Additionally,
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:

$$\psi^{NEMO BS}_{PDC} = N_{MR} \lambda^H_{MR} \left\{ C_{TC}^{NEMO BS} + \sigma C_{PL}^{NEMO BS} \right\} \quad (31)$$

$$C_{TC}^{NEMO BS} = \left\{ t_{win} H_{AR-\overrightarrow{MR}}, 1 - \rho_{win} \right\} + (H_{AR-\overrightarrow{MR}} L_{TTH}) \quad (32)$$

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

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 entities, 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:

$$\psi^{P-NEMO}_{PDC} = N_{MR} \lambda^H_{MR} \left\{ C_{TC}^{P-NEMO} + \sigma C_{PL}^{P-NEMO} \right\} \quad (34)$$

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

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

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:
\[
Gain_{THC} = \frac{\text{NEMO BS}}{\text{MROM}} \quad (37)
\]
\[
Gain_{THC} = \frac{\text{P-NEMO}}{\text{MROM}} \quad (38)
\]
\[
Gain_{THC} = \frac{\text{NEMO BS}}{\text{P-NEMO}} \quad (39)
\]

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](image)

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 its location frequently, the SMR will notify its HA in NEMO BS. Thus, the signaling of NEMO BS $\psi_{NEMO-BS}^{SC}$ 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](http://www.i-jim.org)

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 $\psi_{PDC}^{MROM}$, and P-NEMO $\psi_{PDC}^{P-NEMO}$ schemes.

NEMO BS

http://www.i-jim.org
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 (λₛ=10)](image1)

![Fig. 11. Packet Delivery Costs (PDC) vs. Cell Residence Time with Different NSMR](image2)

Nowadays, Mobile Networks in our real-life are rapidly increased, some of Network 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 remotely 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.

| Preferences                  | (NEMO BS) | (P-NEMO) | (Proposed MROM) |
|------------------------------|-----------|----------|-----------------|
| Handoff Time Delay (millisecond) | 1034      | 543.1    | 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.

| Preferences                  | (NEMO BS) | (P-NEMO) | (Proposed MROM) |
|------------------------------|-----------|----------|-----------------|
| Handoff Time Delay (millisecond) | 1034      | 543.1    | 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.

7 References

[1] Johnson D., Perkins C., and Arkko J. (2004). “Mobility Support in IPv6”, RFC 3775.
[2] Devarapalli, Wakikawa R., Petrescu A., and Thubert P. (2005). “Network Mobility (NEMO) Basic Support Protocol”, RFC 3963. https://doi.org/10.17487/rfc3963
[3] Lach., Ernst T. and H.Y. (2014). "Network Mobility Support Terminology”. RFC 4885.
[4] Ahmed A. Mosa, Aisha Hassan Abdalla, Rashid A. Saed, and Othman O. Khalifa (2011). “Investigation of Route Optimization for Mobile Ad hoc NEMO (MANEMO) Based Proposals”. Australian Journal of Basic and Applied Sciences, 5(6): 814-838, ISSN 1991-8178.
[5] Sharma, Yatendra Mohan, Pawan Kumar Saini, and Pramendra Kumar. (2018). “ORSM: An Optimized Routing Scheme for MANETs”. Proceedings of the Second International Conference on Inventive Systems and Control (ICISC 2018). https://doi.org/10.1109/icisc.2018.8398863
[6] Subhrananda Goswami, and Chandan Bikash Das. (2016). “A Survey on Various Route Optimization Techniques in Network Mobility”. Journal of Uncertain Systems. 91-107.
[7] Kuntz, R., Montavont, J., and Noel, T. (2013). “Multihoming in IPv6 Mobile Networks: Progress, Challenges, and Solutions”. Communications Magazine, IEEE, 51(1), 128-135. https://doi.org/10.1109/mcom.2013.6400449
[8] Ibrahim S.Alsukati, Edwards, and Christopher. (2015). "Multihomed Mobile Network Architecture." ISBN 978-3-901882-68-5 © 2015 IFIP.
[9] Islam, S., Abdalla, A. H., and Hasan, M. K. (2017). “Novel Multihoming-based Flow mobility Scheme for Proxy NEMO Environment: A Numerical Approach to Analyse Handoff Performance”. SCIENCEASIA, 43, 27-34. https://doi.org/10.2306/scienceasia1513-1874.2017.43s.027
[10] Hajime Tazaki, Rodney V. M., Ryuji W. and Thirapon W. (2010). “MANEMO Routing in Practice: Protocol Selection, Expected, Performance, and Experimentation Evaluation”. IEICE Trans. Commun., E93-B (8). https://doi.org/10.1587/transcom.e93.b.3004
[11] Ahmed A. Mousa, Aisha Hassan Abdalla, Khalid Al khateeb, Othman Khalifa, Huda Adibah, (2014).” design a New Proposed Route Optimization Scheme based NEMO-Centric MANEMO (NCM)”. 3rd ICACSAT. https://doi.org/10.1109/acsat.2014.37
[12] Wakikawa, R., Devarapalli, V., Tsirtsis, G., Ernst, T., & Nagami, K. (2009). “Multiple care- of addresses registration”, RFC 5648. https://doi.org/10.17487/rfc5648
[13] Calderon, M., Bernardos, C., & Soto, I. (2012). “PMIPv6 and Network Mobility Problem Statement”.
[14] M. Ahmed, Hashim, A. A., Khalifa, O. O., Alkali, A. H., Midi, N. B., & Rahman, F. A. (2019). Evaluating Mobility Management Models for Content Forwarding in Named Data Networking Environments. 47-60. https://doi.org/10.3991/ijim.v13i04.10519
[15] Muhammed Zaharadeen Ahmed, Aisha Hassan Abdallah Hashim, Othman Omran Khalifa, and Momoh JE Salami. “Border Gateway Protocol to provide failover in multihoming environment.” International Journal of Information Technology 9, no. 1 (2017): 33-39. https://doi.org/10.1007/s41870-017-0003-1
[16] Muhammed Zaharadeen Ahmed, Othman Omran Khalifa, Aisha Hassan, Abdallah Hashim, Momoh JE Salami, and Muhanad Babikier. “Queueing Theory Approach for Evaluating Rate of Transmission in Wireless Network Using Network Coding.” International Journal of Future Generation Communication and Networking 10, no. 6 (2017): 1-11. https://doi.org/10.14257/ijfgcn.2017.10.6.01
[17] Shayma, and Aisha Hassan A. Hashim. (2017). “Hierarchical Route Optimization Scheme Using Advanced Binding Update List (BUL+) for Nested Mobile Networks”. International Journal of Future Generation Communication and Networking. 55-64. https://doi.org/10.1007/s41870-017-0003-1
[18] Petro P. Ernest, Olabisi E. Falowo, and H.Anthony Chan. (2015). “Design and Performance Evaluation of Distributed Mobility Management Schemes for Network Mobility”. Journal of Network and Computer Applications. https://doi.org/10.1016/j.jnca.2014.09.017
[19] Peer A.Sah, Halabi B. Hashullah, Ibrahim A. Lawal, Abubakar A. Mu’azu, and Low T. Jung. (2014). “A TOTP-Based Enhanced Route Optimization Procedure for Mobile IPv6 to Reduce Handover Delay and Signalling Overhead”. The Scientific World Journal. https://doi.org/10.1155/2014/506028
[20] Mohammed, Altaya A., Murtada K. Elbashir, Awadallah M. Ahmed, and Muslim M. Ali. (2017). “Enhancement of Seamless Mobility in Nested Network Mobility”. International Conference on Communication, Control, Computing and Electronics Engineering (ICCCCCEE). https://doi.org/10.1109/iccccee.2017.7867675
[21] Mohammed Balfaqih, Mahamod Ismail, Rosdiadee Nordin, Abd Alrazak Rahem, and Zain Balfaqih. (2016). “Fast Handover Solution for Network-based Distributed Mobility Management in Intelligent Transportation Systems”. Telecommunication System. https://doi.org/10.1007/s11235-016-0178-y
[22] Yan, Z., Zhou, H., & You, I. (2010). “N-NEMO: A Comprehensive Network Mobility Solution in Proxy Mobile IPv6 Network”. Journal of Wireless Mobile Networks, Ubiquitous Computing, and Dependable Applications, 1(2/3), 52-70.
[23] Mohammed Babiker Ali, and Aisha Hassan A.Hashim. (2015). “Improving Message Delay, Handoff latency and Binding Update in High level Nested Network Mobility”. IJCSNS International Journal of Computer Science and Network Security.
[24] Md. Humayun Kabir, Mohammad Mukhtaruzzaman, Mohammed Atiquzzaman. (2013). “Efficient Route Optimization Scheme for Nested-NEMO”. Journal of Network and Computer Applications 36 | 3 | 1039-1049. https://doi.org/10.1016/j.jnca.2012.12.026
[25] M. Babiker, Khalifa, O. O., Hashim, A. H. A., Salami, M. J., & Ahmed, M. Z. (2017). Performance of Turbo Code in CDMA under AWGN Channel. International Journal of Future Generation Communication and Networking, 10(5), 18-28. https://doi.org/10.14257/ijfgcn.2017.10.5.02
[26] M. Babiker, Khalifa, O. O., Hitike, K. K., Hassan, A., & Zaharadeen, M. (2017, November). Automated daily human activity recognition for video surveillance using neural network. In

http://www.i-jim.org
2017 IEEE 4th International Conference on Smart Instrumentation, Measurement and Application (ICSIMA) (pp. 1-5). IEEE. https://doi.org/10.1109/icsima.2017.8312024

[27] Md. Shohrab H., Abu Zafar M. S., Mohammed A., and William I. (2010). “Scalability Analysis of NEMO Prefix Delegation-based Schemes”. IEEE 978-1-4244-6971-0/10.

[28] Do-hyung Kim, Jong-hwan Kim, Yu-sung Kim, Hyun-soo Yoon, Ijyun Yeom. (2014). “End-to-End Mobility Support in Content Centric Networks”. https://doi.org/10.1002/dac.2752

[29] Mathi, Senthilkumar, M. Lavavya, and R. Priyanka. (2015). “Integrating Dynamic Architecture with Distributed Mobility Management to Optimize Route in Next Generation Internet Protocol Mobility”. Indian Journal of Science and Technology. 963-974. https://doi.org/10.17485/ijst/2015/v8i10/58213

[30] Koa, Haneul, Sangheon Packa, Jong-Hyouk Leeb, and Alexandru Petrescuc. (2016). “DLM: Delayed location management in network mobility (NEMO)-based public transportation systems”. Journal of Network and Computer Applications. https://doi.org/10.1016/j.jnca.2016.12.010

[31] Mohanad Babiker, Othman O. Khalifa, Kyaw Kyaw Htike, Aisha Hassan, and Muhamed Zaharadeen. “Harris corner detector and blob analysis features in human activity recognition.” In 2017 IEEE 4th International Conference on Smart Instrumentation, Measurement and Application (ICSIMA), pp. 1-5. IEEE, 2017. https://doi.org/10.1109/icsima.2017.8312025

[32] Hossain, M. S., Atiquzzaman, M., and Ivancic, W. (2012). “Performance Evaluation of Multihomed NEMO”. IEEE International Conference on the Communications (ICC). https://doi.org/10.1109/icc.2012.6364465

[33] Hsieh, R. Hossain, M. S. & Atiquzzaman, M. (2011). “Cost and Scalability Analysis of Mobility”. http://mobqos.ee.unsw.edu.au/robert/opcomum/

[34] Hasan, Samer Sami, Rosilah Hassan, and Hussam Ali. (2013). “Resource Consumption in NEMO Route Optimization using Correspondent Router”. Journal of Theoretical and Applied Information Technology ISSN: 1992-8645.

[35] Giust, Fabio, Carlos J. Bernardos, and Antonio de la Oliva. (2014). “HDMM: Deploying Client and Network-Based Distributed Mobility Management, A hybrid approach”. Telecommun Syst. https://doi.org/10.1007/s11235-014-9959-3

[36] Ernest, Petro P., Olabisi E. Falowo, and H. Anthony Chan. (2015). "Design and Performance Evaluation of Distributed Mobility Management Schemes for Network Mobility". Journal of network and Computer Applications. https://doi.org/10.1016/j.jnca.2015.09.012

[37] Makaya, C. and Pierre, S. (2008). “An Analytical Framework for Performance Evaluation of IPv6-Based Mobility Management Protocols”. IEEE Transactions on Wireless Communications, 7, 972-983. https://doi.org/10.1109/twc.2008.060725

[38] J-H Lee, T Ernst, and N Chilamkurti (2011);“Performance Analysis of PMIPv6-Based NEwork MObility for Intelligent Transportation Systems”. IEEE Transactions on Vehicular Technology. Volume: 61, Issue: 1. https://doi.org/10.1109/tvt.2011.2157949

[39] Muhammed Zaharadeen Ahmed, Aisha Hassan Abdalla Hashim, Huda Adibah Bt Mohd Ramli, Kaloma Usman Majikurna. "Evaluating Average Throughput for Quantity of Data Stream In an Ndn Rendezvous Server". International Journal of Advanced Science and Technology Vol. 29, No. 6, (2020), pp. 125-134 125 ISSN: 2005-4238 IJAST Copyright © 2020 SERSC

[40] Muhammed Zaharadeen Ahmed, Aisha Hassan Abdalla Hashim, Othman O. Khalifa, Abdulkadir H. Alkali, Sarah Yasmin BtMohd, Malik Arman Morshidi “Throughput
Analysis for the Mobility of a Consumer and an Anchorless Producer in NDN.” (2019). Journal of Advanced Research in Dynamical & Control Systems, Vol. 11, No. 1, 2019.

[41] Sherine Akkara, Mallikarjuna Sastry Mallampalli, Venkata Surya Seshagiri Anumula. (2020). Improving Second Language Speaking and Pronunciation through Smartphones. International Journal of Interactive Mobile Technologies. 14(11), 280-287. https://doi.org/10.3991/ijim.v14i11.13891

[42] Thipsuda Wongkhamdi, Nagul Cooharojananone, Jintavee Khlaisan. (2020). E-Commerce Competence Assessment Mobile Application Development for SMEs in Thailand. International Journal of Interactive Mobile Technologies, 14(11), 48-75. https://doi.org/10.3991/ijim.v14i11.11358

[43] Muralidhar Kurni, Madhavi K (2020). Approaches to Address the Operational Limitations of MANETs through Ad Hoc Mobile Cloud Computing Paradigm. International Journal of Interactive Mobile Technologies. 14(9), 153-165. https://doi.org/10.3991/ijim.v14i09.14103

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.

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