Scalability Analysis of Cost Essence for a HA entity in Diff-FH NEMO Scheme

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Summary
Network Mobility Basic Support (NEMO BS) protocol has been accredited and approved by Internet Engineering Task Force (IETF) working group for mobility of sub-networks. Trains, aircrafts and buses are three examples of typical applications for this protocol. The NEMO BS protocol was designed to offer Internet access for a group of passengers in a roaming vehicle in an adequate fashion. Furthermore, in NEMO BS protocol, specific gateways referred to Mobile Routers (MRs) are responsible for carrying out the mobility management operations. Unfortunately, the main limitations of this basic solution are pinball suboptimal routing, excessive signaling cost, scalability, packet delivery overhead and handoff latency. In order to tackle shortcomings of triangular routing and Quality of Service (QoS) deterioration, the proposed scheme (Diff-FH NEMO) has previously evolved for end-users in moving network. In this sense, the article focuses on an exhaustive analytic evaluation at Home Agent (HA) entity of the proposed solutions. An investigation has been conducted on the signaling costs to assess the performance of the proposed scheme (Diff-FH NEMO) in comparison with the standard NEMO BS protocol and MIPv6 based Route Optimization (MIRON) scheme. The obtained results demonstrate that, the proposed scheme (Diff-FH NEMO) significantly improves the signaling cost at the HA entity in terms of the subnet residence time, number of mobile nodes, the number of DMRs, the number of LFNs and the number of CNs.

Keywords:
QoS; Diff-FH NEMO; Network Mobility; MIRON.

1. Introduction

Due to the exponential growth of Internet usage, a variety of network technologies have emerged in recent years, including WiMAX, 4G, 5G, and 6G. User behavior and expectations have changed as wireless technology has become more widely available. The users anticipate being able to access their normal network applications or services when on the go. Across heterogeneous networks, a universal mobility management architecture is necessary to provide improved QoS to end-users. Nevertheless, layer L3 movement need the end-users to alter their IP addresses in order to prevent routing problems. Such IP address alterations might disrupt current connection without special assistance. Therefore, the IETF working group has proposed Mobile IPv4, Mobile IPv6, Fast Mobile IPv6, Hierarchical Mobile IPv6 and Fast Hierarchical Mobile IPv6 as the main protocols for supporting IP mobility to a single host or mobile node [1-5]. However, when the need for mobility is not confined to a single host, the issue becomes even greater.

Moving vehicles (such as automobiles, buses, and trains) are increasingly in need of Internet connectivity in the mobile era. The Network Mobility Basic Support protocol (NEMO BS) was introduced by the IETF working group to provide Internet access for a group of users in a moving vehicle [6]. It inherits the drawbacks from both the host-based and the centralized mobility management protocol such as sub-optimal routing, excessive signaling cost and scalability issues. Therefore, studying and analyzing the impact of scalability on the signaling cost is crucial as far as cost of network mobility is concerned. This article examines the signaling cost for Home Agent (HA) as entity-wise since a complete or partial communication within with the mobile network occur through it. These signaling related to binding update cost, session continuity cost, pre-registration kick-off cost and packet delivery cost. Then, the performance of formal proposed scheme (Diff-FH NEMO) [7], [8] compared to the standard NEMO BS protocol and MIPv6 based Route Optimization (MIRON) scheme [9], [10] for benchmarking.

The composition of this article is as follows. Section 2, briefly describes a background information about NEMO BS protocol and its recent related works. Section 3 discusses the signaling cost analysis for the proposed scheme (Diff-FH NEMO), NEMO BS and MIRON in details. Section 4 covers the mathematical outcomes for the performance evaluation of the mobility management techniques. Finally, Section 5 concludes this article.

2. Related Works

The NEMO BS protocol (RFC 3963) is an extension lead of Mobile IPv6. It is the mobility of a network where a set of nodes such as laptops, I-Pad, mobiles, and PCs, move as a single unit. There is a gateway known as Mobile Router (MR) handles the point of attachment in favor of all numbers of nodes on the Internet as shown in Figure 1. When the MR is registered with its HA, it receives a unique home address known as the Mobile Network Prefix (MNP).

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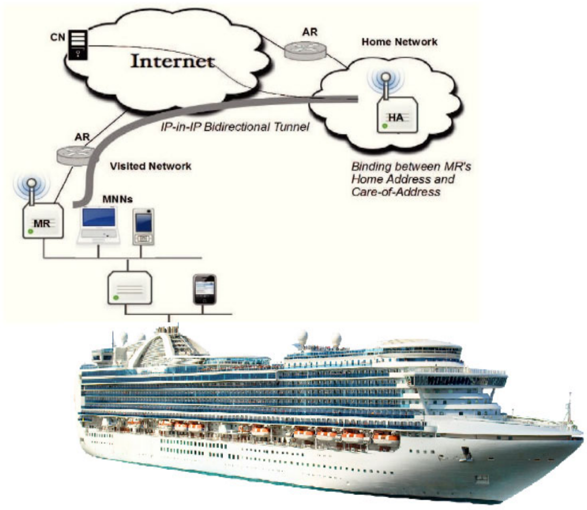

Fig. 1 NEMO Basic Support Protocol.

There are numerous types of nodes, including Mobile Network Nodes (MNNs), Visiting Mobile Nodes (VMNs), and Local Fixed Nodes (LFNs). At any given moment, the mobile router can function as both a mobile host and a mobile router. If the mobile router is attempting to behave as a mobile host, a mobile router flag (R) will be set to zero in the BU message. The HA then does not retain any MNP-related data but maintains a binding cache registration associated with the MR's HoA. On the other hands, if the mobile router pursues to behave as a Mobile Router and delivers node connectivity in NEMO, this is will be indicated to the Home Agent by activating a flag (R) with one value at the Binding Update. NEMO binding update message is slightly different from that in MIPv6. It extends two fields M and R, as illustrated in Figure 2. The MH Type field must set with the value 5 to indicate that BU message is being carried in the Mobility Header. Unlike mobile IPv6, the mobile nodes in NEMO will not send binding update to the HA when they change their point of attachment, instead the Mobile router will send BU along with MNP to the HA [6].

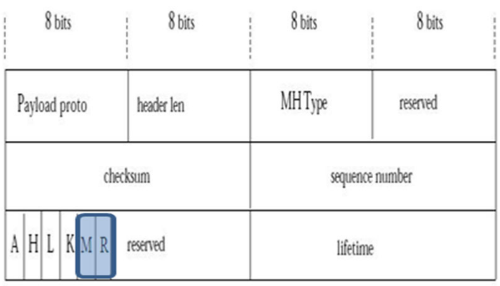

Fig. 2 NEMO binding update message format.

The MR communicates with the Home Agent in two ways in order to ascertain which prefixes belong to the Mobile Router as depicted in Figure 3. The Mobile Router Flag (R) will be set to one in both modes. These modes can be presented as follows:-

- Explicit mode:

In this mode, one or more Mobile Network Prefix Options are included in the Binding Update for Mobile Router. These options contain information about the MNP(es) configured on the Mobile Network.

- Implicit mode:

In this mode, the MR excludes a MNP Option in the Binding Update. The Home Agent can employ any methods to identify the Mobile Network Prefix(s) possessed by the Mobile Router and set up the Mobile Network forwarding.

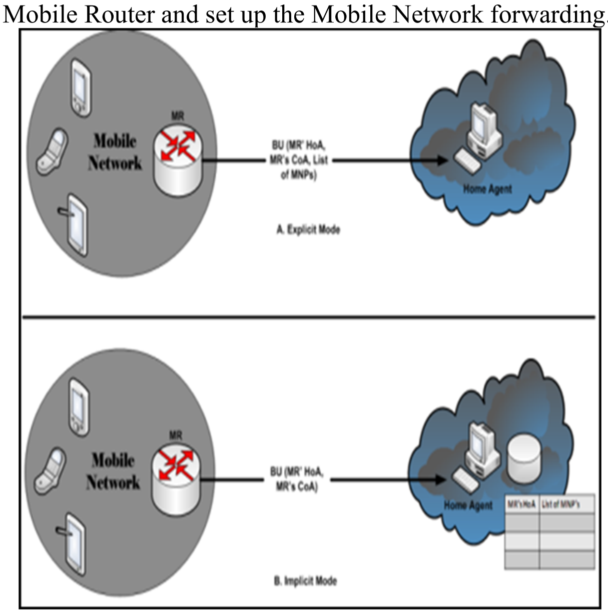

Fig. 3 NEMO Explicit and Implicit Modes.

Movement detection (MD) is one of the crucial events that affect the performance of handover. Yet, it is not easy to do it quickly and reliably for many reasons. Firstly, the MD at IP layer is based on detecting the movement at lower/link layer. In wireless technologies, a link may be lost and regained, which does not mean movement. Another reason is that a router can utilize the identical local-link address on various interfaces but promote distinct prefixes. Therefore, the MR performs movement detection to discover a new access router by exchanging Router Solicitation /Advertisement Router (RS/RA) messages. The MR enrolls with the HA once the mobile network is connected to the Home Network and obtains a Home Address (HoA) for home network reachability. The minute, mobile network travels to a foreign network from its home network, the MR acquires from the external network a fresh address termed Care-of-Address (CoA) and sends a Binding Update (BU) to its HA immediately enlightening the new

CoA. The MR must also enlighten it's HA with the Mobile Network Prefix (MNP), as it frequently designates one or more address prefixes within its network for use by MNNs. In exchange, the HA sends a positive Binding Acknowledgement (BA) indicating that transmission to the MR is set and generates a binding cache entry mapping the HoA and MR prefixes to the MR's CoA. Once the binding process is completed, a bi-directional (IPv6-in-IPv6) tunnel is established between the HA and the MR to maintain session continuity of the nodes within its mobile network. The communication between Correspondent Node (CN) and Mobile Network Node (MNN) is illustrated in Figure 4.

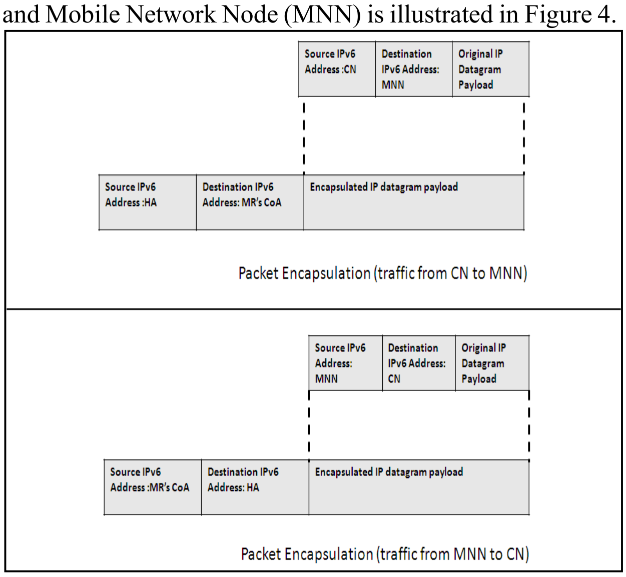

Fig. 4 The encapsulation between the CN and MNN in NEMO.

The CN transmits an IP datagram destined for MNN. This datagram bears as IPv6 destination address of MNN, which belongs to the MNP of the NEMO. This IP datagram is transferred to the home network of the NEMO, where it is intercepted and encapsulated inside a new IP datagram by Home Agent (HA). The fresh datagram will be sent to the mobile router's CoA, with the HA's IPv6 address by means of source address. The encapsulation helps to maintain transparency of movement. In particular, while preserving established Internet connectivity to MNN, both the MNN and corresponding node are fully ignorant of the mobility inside NEMO. The mobile router gets the embedded IP datagram and subsequently wraps the tunnel with the external IPv6 header removed. It is then submitted to the MNN of the NEMO subnet with the original datagram. The procedure is comparable in the opposite sense. The MR wraps MNN's IP datagrams to its Home Agent, which subsequently encapsulates and transfers the original datagram to the CN. Although NEMO guarantees continuation of the session for each mobile node, it introduces a large number of overhead headers and constructs tunnels on suboptimal paths. This duplicated path is wasting network assets and increasing communication delays.

There has been a lot of effort done in the past to study the signaling cost in order to improve mobility management protocols.

Pack et al. performed a cost analysis for an adaptive NEMO support scheme depended on hierarchical mobile IPv6 (HMIPv6) to mitigate tunneling overhead [11]. Using the adaptive BU approach, the proposed protocol optimizes both binding update (BU) traffic and tunneling overhead, based on the session-to-mobility ratio (SMR). The obtained numerical results revealed that the adaptive NEMO protocol support delivers considerable improvement for low SMR performance and is similar to NEMO's basic support protocol for high SMR performance. Moreover, it performs well and is scalable in many mobile situations. However, the suggested protocol should take account of the reduction of overhead and solve security problems.

Zong et al. developed fast NEMO (FNEMO) scheme in IEEE 802.16e networks [12]. When the MR is switched on, the MR sends a quick binding update (FBU) message to its HA for tunnel setup using the NAR to exchange the HI and HAck acknowledgement (HAck). Therefore, by tunneling the packet straight to the NAR, FNEMO reduce the round trip time as well as the additional encapsulation of the PAR. However, it did not state how packets delivered from the PAR might be sent to the NAR in the transfer to escape the loss of packets.

In [13], the authors designed an analytical model fitting each HIP based NEMO solution. They intended to give insight into an efficient signal overhead definition.

In order to evaluate the overall cost of several NEMO BSP mobility management entities, authors in [14] established a mathematical model including all conceivable costs affecting their functions. Total costs for different entities are shown to grow over a smaller session time when signal traffic increases compared with data traffic. This paper's cost analysis will assist network engineers assess the real needs of resources.

Ing-Chau Chang et al. presented mathematical analytical model for the cost analysis of handover latency, total buffer size, packet loss time and playback interruption time of reactive FHCoP-B [15]. This work the handover prediction concept of the fast mobile IPv6 in order to develop a cross-layer architecture. With the lowest handover latencies, the smaller number of packet losses, the least interruption time during transfer, with little buffer space available even with error-prone wireless links to the NEMO nesting, the FHCoP-B outperforms HCoP-B and the other two famous NEMO schemes. Nevertheless, inter-MAP handover with the proactive FHCoP-B mode need to be investigated more to improve the proposed scheme performance.

Kuo and Ji, introduced an enhanced hierarchical NEMO protocol [16] known as HRO+. The authors

attempted to enhance inter-domain and intra-domain routing packet latency. Conversely, the HRO+ fails to take account of inter-domain handoff and might continue to suffer from the intra-domain routing sub-optimal issue.
X Chen et al. studied the Internet connectivity of mobile router (MR) equipped with multi-interfaced such as WLAN, CDMA and GPRS [17]. Not only allows wide-run movement over heterogeneous MR networks, the multi-interfaced method also offers for a seamless transmission without packet loss and low service disturbance time.

3. The Signal Cost Analysis

By definition, mobility has an impact mutually on the control and data planes of a communication system. As soon as a Mobile Node (MN) relocates, new signaling is presented and alter within the directing way is required in arrange to transport data packets to the MN's new position. Furthermore, tunneling is included as an intrinsic method in mobility management protocols to provide the user with smooth mobility. This analytical model is an extension of our previous work [7] and [8] that has been developed to afford QoS with mobility management for end-users in roaming network. The former proposed scheme (Diff-FH NEMO) correspondingly improves network mobility's route optimization (RO) to allow straight connection between any type of MNN and CN on the Internet. For the purpose of quantitative analysis, we compare the proposed scheme (Diff-FH NEMO) with the existing proposals including the standard NEMO BS protocol [6] and MIPv6 based Route Optimization (MIRON) scheme [9], [10]. Different parameters have been used for an exhaustive analytic such as the subnet residence time, number of mobile nodes, the number of DMRs, the number of LFNs and the number of CNs.

Figure 5. shows a reference topology for performance analysis. It is believed that the CN creates data packets with a mean rate (λ_p) destined for a Mobile Network Node (i.e. LFNs, LMNs, and VMNs). The DMR travels from one (Access Router or subnet) to another at mean rate (μ) whereas the MNN is either immobile or transports at the same prior mean rate. This article is focused on the HA entity-wise evaluation since partial or all communications within the mobile network schemes ensued via it.

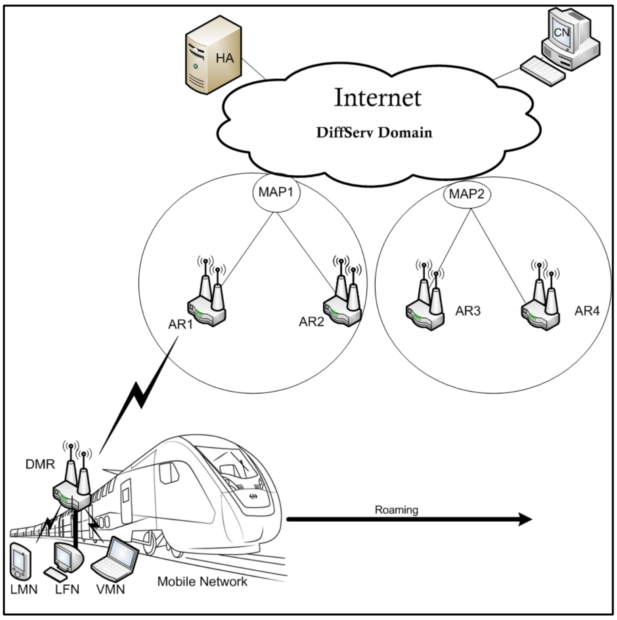

Fig. 5 The system topology employed for the investigation.

The overall signaling cost for NEMO BS protocol is the sum of the costs of location update, packet delivery, and pre-registration kick-off.

$C_{total} = C_{LU} + C_{PD} + C_{PK}$ (1)

Location update signaling is classified into two categories. The first arises when a DMN traverses a subnet, and the second arises when the binding is about to expire. The former relates to the Binding Update (BU) message, whereas the latter relates to the Binding Refresh (BR) message. In the proposed architecture, the location update cost for BU messages might occur at HA, MAP, or CN. As a result, the location update cost is calculated as follows:

$C_{LU} = C_{BU}^{HA,MAP} + C_{SC}^{CN}$ (2)

C_{BU} is involved the cost of BU message at HA and/or MAP plus binding refresh cost C_{BR} for MAP and HA. Hence, binding update cost is given by:

$C_{BU}^{MAP,HA} = C_{BU}^{MAP,HA} f_U + C_{BR}^{MAP,HA} f_R$ (3)

C_{SC} It made up of the cost of session continuity for BU messages at CN as well as the binding refresh cost C_{BR} for CN. As a result, the cost of session continuation is as follows:

$C_{SC}^{CN} = C_{SC}^{CN} f_U + C_{BR}^{CN} f_R$ (4)

Consequently, the overall signaling cost C_{total} might be recast as the addition of the binding update cost C_{BU}, C_{SC} session continuity cost and packet delivery cost C_{PD}. Equation (1) can so be represented as follows:

$C_{total} = C_{BU}^{HA,MAP} + C_{SC}^{CN} + C_{PD}$ (5)

The singling cost is denoted by X and Y to indicate the scheme and the type of cost, respectively. X will be substituted by N, M and D for NEMO BSP, MIRON, Diff-FH NEMO, respectively. Y will be substituted by BU, SC, PD and T for binding update, session continuity, packet delivery and total signaling costs, respectively.

$жc_{Y}^{X}$ = Cost of type Y incurred at HA for scheme X (6)

Since all BU/BAs go through the HA, the local/global binding update signalling cost for NEMO BS protocol at HA is expressed by:

$C_{NEMO}^{l} = C_{NEMO}^{g} = N_r \{2[C_{MR,AR} + C_{AR,HA} + PC_{AR}] + PC_{HA}\}$ (7)

In addition to the cost mentioned above, we need to consider registering the BU at HA binding cache (i.e. include transmission and processing cost) in order to come up with the binding update cost. Also, after BU is been sent by MR, the binding refresh BR goes through established tunnel which is incurred additional look up cost. The processing look-up cost can be computed as:

C_{LK}=Щ $\log_2 [N_r+N_m]$ (8)

Where, Щ is the cost of the look up per operation. As result the binding refresh signaling cost for the standard NEMO BS protocol at HA is expressed by:

$C_{BR}^{NEMO} = [N_r+N_m]\ [\ C_{MR,AR}^{BR} + C_{MR,AR}^{BR\,tun} + PC_{MR}^{BR\,tun} + C_{AR,HA}^{BR} + C_{AR,HA}^{BR\,tun} + C_{LK} + PC_{HA}^{BR\,tun}]$ (9)

By using equation (3),(7), (9), the total binding update signaling cost for the standard NEMO BS protocol at HA is expressed by:

$жc_{BU}^{N} = C_{BU}^{HA} = [E\ (N_{l,g})\ C_{NEMO}^{l,g}\ ]\ f_U + \frac{1}{\mu l,g}\ C_{BR}^{NEMO}\ f_R$ (10)

Since all BU/BAs go through the HA, the local/global binding update signalling cost for MIRON scheme at HA is expressed by:

$C_{\text{MIRON}}^{l} = C_{\text{MIRON}}^{g} = [N_r+N_m]\ 4\{C_{MNN,AR} + C_{MR,AR}\} + 8[C_{AR,HA} + PC_{AR}] + 4\ PC_{HA}$ (11)

The binding refresh signaling cost for MIRON scheme at HA is expressed by:

$C_{BR}^{\text{MIRON}} = [N_r+N_m][\ C_{MNN,AR}^{BR} + C_{MR,AR}^{BR} + C_{MR,AR}^{BR\,tun} + PC_{MR}^{BR\,tun} + C_{AR,HA}^{BR} + C_{AR,HA}^{BR\,tun} + C_{LK} + PC_{HA}^{BR\,tun}]$ (12)

By using equation (3), (11) and (12), the total binding update signaling cost for MIRON scheme at HA is expressed by:

$жc_{BU}^{M} = C_{BU}^{HA} = [E\ (N_{l,g})\ C_{\text{MIRON}}^{l,g}\ ]\ f_U + \frac{1}{\mu l,g}\ C_{BR}^{\text{MIRON}} f_R$ (13)

Since all BU/BAs go through the HA, the global binding update signalling cost for the proposed scheme (Diff-FH NEMO) at HA is expressed by:

$C_{\text{Diff-FH NEMO}}^{g} = C_{HA}^{\text{g}} = 2N_r\ [C_{DMR,NAR} + C_{NAR,HA} + PC_{NAR}] + PC_{HA}$ (14)

The binding refresh signaling cost for the proposed scheme (Diff-FH NEMO) at HA is expressed by:

$C_{BR}^{\text{Diff-FH NEMO}} = C_{BR}^{\text{HA}} = [N_r]\ [\ C_{DMR,AR}^{BR} + C_{DMR,AR}^{BR\,tun} + PC_{DMR}^{BR\,tun} + C_{AR,MAP}^{BR} + C_{AR,MAP}^{BR\,tun} + C_{MAP,HA}^{BR} + C_{LK} + PC_{MAP}^{BR\,tun}]$ (15)

By using equation (3),(14), (15), the total binding update signaling cost for the proposed scheme (Diff-FH NEMO) at HA is expressed by: $жc_{BU}^{D} = C_{BU}^{HA} = [E\ (N_g)\ C_{\text{Diff-FH NEMO}}^{g}\ ]\ f_U + \frac{1}{\mu g}\ C_{BR}^{\text{Diff-FH NEMO}}\ f_R$ (16)

Since all BU/BAs go through the HA, the session continuity signalling cost for global binding update in NEMO BS protocol at HA is expressed by:

$C_{NEMO}^{g} = 0$ (17)

The binding refresh signaling cost for the standard NEMO BS protocol at HA is expressed by:

$C_{BR}^{NEMO} = N_{CN}\ [N_r+N_m]\ [\ C_{MR,AR}^{BR} + C_{MR,AR}^{BR\,tun} + PC_{MR}^{BR\,tun} + C_{AR,HA}^{BR} + C_{AR,HA}^{BR\,tun} + C_{LK} + PC_{HA}^{BR\,tun}]$ (18)

By using equation (4), (17), (18), the total session continuity signaling cost for the standard NEMO BS protocol at HA is expressed by:

$жc_{SC}^{N} = C_{BU}^{CN} = [E\ (N_g)\ C_{NEMO}^{g}]\ f_U + \frac{1}{\mu g}\ C_{BR}^{NEMO} f_R$ (19)

Since all BU/BAs go through the CN, the session continuity signalling cost for global binding update in MIRON scheme at HA is expressed by:

$C_{\text{MIRON}}^{g} = 0$ (20)

The binding refresh signaling cost for MIRON scheme at HA is expressed by:

$C_{BR}^{\text{MIRON}} = 0$ (21)

By using equation (4),(20), (21), the total session continuity signaling cost for MIRON scheme at HA is expressed by:

$жc_{SC}^{M} = C_{BU}^{HA} = [E\ (N_g)\ C_{\text{MIRON}}^{g}\ ]\ f_U + \frac{1}{\mu g}\ C_{BR}^{\text{MIRON}} f_R$ (22)

Since all BU/BAs go through the CN, the session continuity signalling cost for global binding update in the proposed scheme (Diff-FH NEMO) at HA is expressed by:

$C_{\text{Diff-FH NEMO}}^{g} = C_{HA}^{\text{g}} = 0$ (23)

The binding refresh signaling cost for the proposed scheme (Diff-FH NEMO) at HA is expressed by:

$C_{BR}^{\text{Diff-FH NEMO}} = C_{BR}^{\text{HA}} = 0$ (24)

By using equation (4), (23), (24), the total session continuity signaling cost for the proposed scheme (Diff-FH NEMO) at HA is expressed by:

$$ж_{SC}^{D} = C_{BU}^{HA} = [E\ (N_g)\ C_{\text{Diff-FH NEMO}}^{g}\ ]\ f_U + \frac{1}{\mu g}\ C_{BR}^{\text{Diff-FH NEMO}} f_R \quad (25)$$

The cost of data packet delivery is incurred as a result of a combination of data packet transport, processing, tunneling, and look up. Furthermore, it might be re-formed as the linear sum of packet tunneling cost (C_{tun}) and packet loss cost (C_{loss}). Assume α and β are weighting variables that accentuate tunneling and dropping effects (where α + β = 1). Therefore, the overall packet delivery cost is specified by:

$$C_{PD} = \alpha C_{tun} + \beta C_{loss} \quad (26)$$

Initially, $C_{PD,tun}^{NENO}$ is equal to zero in the standard NEMO BS protocol. Hence, the packet loss cost only determines the cost of the packet delivery and it can be calculated at HA, as follows:

$$C_{PD,loss}^{NENO} = \lambda_p\ C_{cm}^{f}\ (t_{L2} + t_{IP} + t_U) \quad (27)$$

Where,

$$C_{CM}^{f} = \eta\ (N_m+N_f)\ [\ C_{MNN,MR}^{Pkt} + C_{MR,OAR}^{Pkt} + C_{MR,OAR}^{Pkt\ tun} + PC_{MR}^{Pkt\ tun} + C_{OAR,HA}^{Pkt} + C_{OAR,HA}^{Pkt\ tun} + C_{LK} + PC_{HA}^{Pkt\ tun} \quad (28)$$

The following equations represent the process of how to calculate the packet tunnelling cost at HA, in the standard NEMO BS protocol.

$$C_{PD,tun}^{NENO} = \lambda_p\ C_{cm}^{s}\ (t_{L2} + t_{IP} + t_U) \quad (29)$$

Where,

$$C_{CM}^{s} = \eta\ (N_m+N_f)\ [\ C_{MNN,MR}^{Pkt} + C_{MR,NAR}^{Pkt} + C_{MR,NAR}^{Pkt\ tun} + PC_{MR}^{Pkt\ tun} + C_{NAR,HA}^{Pkt} + C_{NAR,HA}^{Pkt\ tun} + C_{LK} + PC_{HA}^{Pkt\ tun}\ ] \quad (30)$$

By summing up all of equations (27), (28), (29), (30), in (26), the packet delivery cost for NEMO BS protocol at HA, can be found respectively as follows:

$$ж_{PD}^{N} = C_{PD,HA}^{NEMO} = \alpha C_{tun}^{NEMO} + \beta C_{loss}^{NEMO} \quad (31)$$

In same way, the signalling cost for the packet delivery for MIRON scheme can be obtained. The packet loss cost from the CN to MNN via ONAR is given as follows, for HA:

$$C_{PD,loss}^{\text{MIRON}} = \lambda_p\ C_{cm}^{F}\ \{\ t_{PANA/DHCPv6} + t_{rr} + 2(t_{MR/MNN,HA} + t_{MR/MNN,CN})\} \quad (32)$$

where,

$$C_{CM}^{F} = \eta\ (N_m+N_f)\ [\ C_{MNN,MR}^{Pkt} + C_{MR,OAR}^{Pkt} + C_{MR,OAR}^{Pkt\ tun} + PC_{MR}^{Pkt\ tun} + C_{OAR,HA}^{Pkt} + C_{OAR,HA}^{Pkt\ tun} + C_{LK} + PC_{HA}^{Pkt\ tun}] \quad (33)$$

Also, the packet tunnelling cost for MIRON scheme from the CN to MNN via New Access Router (NAR) is obtained as follows, for HA:

$$C_{PD,tun}^{\text{MIRON}} = \lambda_p\ C_{cm}^{s}\{\ t_{PANA/DHCPv6} + t_{rr} + 2(t_{MR/MNN,HA} + t_{MR/MNN,CN})\} \quad (34)$$

Where,

$$C_{CM}^{s} = 0 \quad (35)$$

By summing up all of equations (32), (33), (34), (35) in (26), the packet delivery cost for MIRON scheme is provided at HA, as follows:

$$ж_{PD}^{M} = C_{PD,HA}^{\text{MIRON}} = \beta C_{loss}^{\text{MIRON}} \quad (36)$$

The packet loss cost in reactive mode of the proposed scheme Diff-FH NEMO (from the CN to MNN via ONAR) is given as follows, for the HA:

$$C_{PD,loss}^{\text{Diff-FH NEMO}} = C_{PD,loss}^{R} = \lambda_p\ C_{cm}^{R}\ \{t_{L2} + t_{IP} + t_{RR} + 2(t_{DMR,HA} + t_{DMR,MAP} + t_{DMR,CN})\} \quad (37)$$

Where,

$$C_{CM}^{R} = \eta\ (N_m+N_f)\ [\ C_{MNND,MR}^{Pkt} + C_{DMR,OAR}^{Pkt} + C_{DMR,OAR}^{Pkt\ tun} + PC_{DMR}^{Pkt\ tun} + C_{OAR,MAP}^{Pkt} + C_{OAR,MAP}^{Pkt\ tun} + PC_{MAP}^{Pkt\ tun} + C_{MAP,HA}^{Pkt} + C_{LK} + PC_{ER}^{pkt}] \quad (38)$$

Moreover, the packet tunnelling cost for the proposed scheme (Diff-FH NEMO) in prediction mode from the CN to MNN via New Access Router (NAR) is achieved as follows, for the HA:

$$C_{PD,tun}^{\text{Diff-FH NEMO}} = C_{PD,tun}^{P} = \lambda_p\ C_{cm}^{P}\ \{t_{L2} + t_{IP} + t_{RR} + 2(t_{DMR,HA} + t_{DMR,MAP} + t_{DMR,CN})\} \quad (39)$$

Where,

$$C_{CM}^{P} = 0 \quad (40)$$

By summing up all of equations (37), (38), (39), (40) in (26) the packet delivery cost for the proposed scheme (Diff-FH NEMO) is expressed as follows for the HA:

$$ж_{PD}^{D} = C_{PD,HA}^{\text{Diff-FH NEMO}} = \beta\ [1-P_S]\ C_{PD,loss}^{\text{Diff-FH NEMO}} \quad (41)$$

3.1 The Total Signaling Cost for NEMO BS, MIRON, Diff-FH NEMO Models

Conferring to investigation that have been arranged to examine all of the binding update cost, session continuity cost, and packet delivery cost, the performance of Diff-FH NEMO, MIRON, and regular NEMO BS protocols may be simply taught and resolved. Using equations in (5), (10), (19), and (31) respectively, the total signalling cost of NEMO BS protocol incurred at the HA is as follows:

$$ж_T^N = ж_{BU}^N + ж_{SC}^N + ж_{PD}^N \quad (42)$$

Similarly, referring to equations in (5), (13), (22), and (36), the total signalling cost MIRON scheme incurred at the HA is representing as follows:

$$ж_T^M = ж_{BU}^M + ж_{SC}^M + ж_{PD}^M \quad (43)$$

Ultimately, referring to equations in (5), (16), (25) and (41), the total signalling cost the proposed Diff-FH NEMO scheme incurred at the HA can be calculated as follows:

$$ж_T^D = ж_{BU}^D + ж_{SC}^D + ж_{PD}^D = ж_{BU}^D + ж_{PD}^D \quad (44)$$

4. The Numerical Results of Signaling Cost

This section grants the performance assessment of the proposed scheme (Diff-FH NEMO) that provides QoS way out in mobile network environments and the numerical results of signaling cost. To produce arithmetic results from calculations derived above, the typical default values of the system parameters are get and set from details works [14], [18], [19], and [20]. Referring to Figure 5. the expanse in the analytical system topology is defined as the number of steps between several entities. The network media are presumed to be full duplex in terms of volume and delay. In addition, supplementary parameters consumed by the signaling cost computation are defined as follows: Transmission cost for tunnel header C^{tun}=0.5, $\tau = 1$, $\alpha = 0.3$, $\beta = 0.7$, PC_{MR}=20, PC_{DMR}=25, $\kappa = 10$, PC_{AR}=3, PC_{ER}=7, PC_{MAP}=13, PC_{HA}=25 and PC_{CN}=10. It is assumed that the processing cost is fixed for those entities to deal with any kind of processing either for tunneling, home address destination option, routing header type 2, BU message or other remaining control messages.

4.1 Impact of Nm, N_f, N_r, N_c and T_r on the Entire Signaling Cost at HA

This scenario studies the impact of increasing the number of mobile nodes, the number of DMR/MRs, the number of LFNs, the number of CNs and the subnet residence time, on the entire cost incurred at the HA. Comparison results based on the proposed scheme Diff-FH NEMO, MIRON scheme and the standard NEMO BS protocol are imparted in Figure 6-10. The entire signaling cost at HA constitutes the cost of both binding update and packet delivery as well. Like the earliest scenario, for every network expansion, the entire signaling cost at HA increases noticeable expect with the number of DMR/MRs and the subnet residence time. In addition, it can be deduced that the entire signaling cost at HA for LFN is increased gradually lesser than the cost of number of mobile nodes for the standard NEMO BS protocol as depicted in Figure 8.
On the other hand, the entire signaling cost at HA for the proposed scheme Diff-FH NEMO and MIRON scheme is occurred to be almost zero because of their route optimization mechanism which facilitates the communications (between the MNNs and CN) and omits signaling cost overhead by the intermediate nodes (i.e. HA). Yet it will be negligible cost due to the packet loss at the beginning of first session.

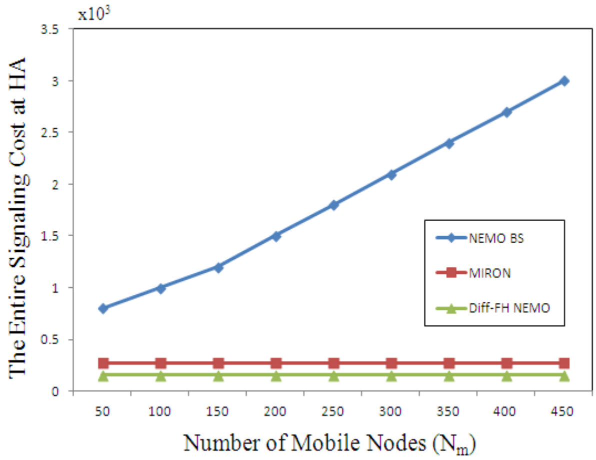

Fig.6 N_m versus the entire signaling cost at HA.

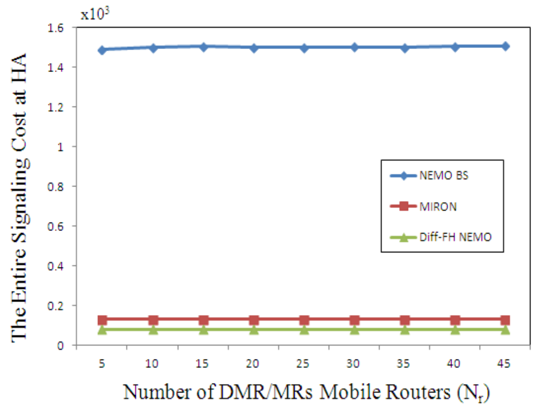

Fig.7 N_r versus the entire signaling cost at HA.

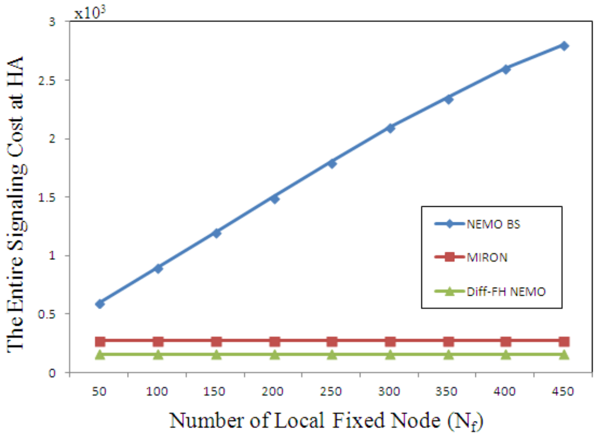

Fig.8 N_f versus the entire signaling cost at HA.

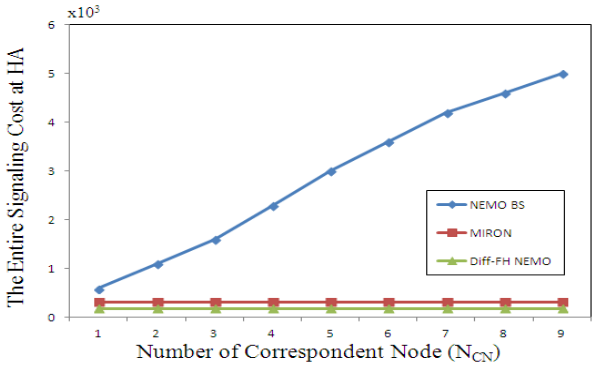

Fig. 9 N_{CN} versus the entire signaling cost at HA.

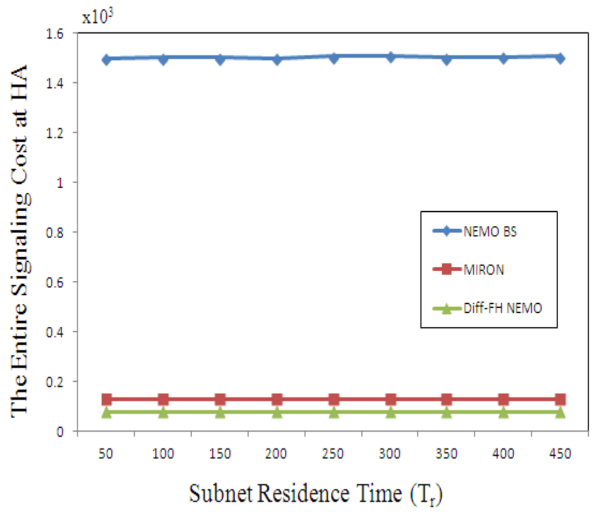

Fig. 10 T_r versus the entire signaling cost at HA.

5. Conclusion

Extensive numerical analyses are carried out to corroborate Diff-FH NEMO scheme design legitimacy. This article presents a mathematical model in comparison to the state-of-the-art of network mobility protocols under different scenarios and operation conditions. It examines the cost occurs due to delivery of packets through optimized route, binding update, cost of transmission, processing power amongst the network entities and lookup by mobility agent and the delegation of prefix. At the HA entity, the numerical results showed that the proposed (Diff-FH NEMO) scheme generally offers a better performance in terms of signaling cost and packet delivery cost when the number of nodes increased compared with the current standard NEMO BS protocol and MIPv6 based Route Optimization (MIRON) scheme. The future research plan is to study the impact of various performance metrics such as session-to-mobility ratio, packet arrival rate and the capability to be changed in size on the proposed network for the entire signaling cost.

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