Minimizing Handoff Latency and Packet Loss in NEMO

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Abstract

This paper proposes a handoff scheme for Network Mobility (NEMO) to minimize the handoff delay and packet loss. This scheme is acronymed as MMHM (Multiple mobile router handoff management) scheme that addresses the handoff management in multihomed mobile network. In the proposed scheme, the effect of router discovery and Duplicate Address Detection (DAD) that have direct impact on the handoff procedure is eliminated. The cooperation of multiple mobile routers in carrying the traffic of one another during handoff process results in minimum packet loss. The mathematical modeling is carried out proves that the proposed scheme reveals better performance compared with the NEMO basic support protocol.

Keywords: *NEMO, Handoff, Multihomed, Multiple Mobile Routers.*

1. Introduction

With the development of the various mobile communication technologies such as (laptops, smart phones and PDAs), the users expected to be always connected to the best available access network. They expect to benefit from the application and services on their mobile devices while they move. This integration of heterogeneous networks will, however, lead to heterogeneities in access technologies and network protocols. The need for providing continuous connectivity to the mobile users has brought the Internet Engineering Task Force (IETF) to develop the Mobile IPv6 that manages host mobility [1].

When several devices connected in a local area network or personal area network move together, MIPv6 would inefficiently handle and manage the mobility of the entire network and maintain the sessions for every moving device on the network. Mobility using MIPv6 would increase the signal overhead, power consumption, bandwidth consumption and manageability. Furthermore, MIPv6 protocol cannot handle network mobility. Therefore, the IETF created a working group named Network Mobility (NEMO) Working Group [2] with the objective of developing mechanisms that provide permanent Internet connectivity to all Mobile Network Nodes (MNN) via their permanent IP addresses as well as maintain ongoing sessions as the mobile network changes its point of attachment to the Internet.

The NEMO working group has proposed NEMO basic support protocol [3] which is an extension of the MIPv6 that support network mobility management. They named a device which is a mobile router (MR) that provides continuous connections to the mobile network and manage the mobility of the mobile network rather than an individual mobile node. The mobile router is connected to the Internet through an egress interface and would act as the default gateway to the mobile network nodes. However, it is common that mobile devices may have more than one interface such as PDAs, smart phones, laptops, and may provide multiple connections to the Internet for the mobile device. In this case, the mobile device is called multihomed device. Many previous researches address the mobility management in multihoming environment to provide vigorous, ubiquitous Internet access [4-8]. A multihomed mobile network is a mobile network that is connected to the internet either via multiple network interfaces of the MR or via multiple mobile router. The mulihomed mobile router (MMR) may equipped with different access technologies such as (UMTS, WLAN, GPRS and Bluetooth), thus it would perform vertical handoff from one access technology to another. On the other hand, the horizontal handoff is performed when the network moves within the same access technology.

The Multihoming provides constant access to the internet and improves the overall connectivity of the mobile network. Some benefits can be obtained from multihoming in NEMO like load balancing and sharing, fault tolerance, redundancy, and reliability. The configuration of multihomed NEMO [9] can be classified according to three variables x,y,z, where x,y,z refer to the number of multiple mobile routers exist in the mobile network, the number of HAs and the number of mobile network prefix respectively.

In this paper, the context (n,1,1) configuration of multihomed NEMO is used. The multiple mobile router handoff management (MMHM) scheme is proposed to provide continuous connectivity for the MNN and eliminate the handoff delay and packet loss during handoff. In this scheme, only one tunnel will be active to carry the traffic to/from the mobile network.

The remainder of this paper is organized as follows. Section 2 gives an overview on handoff in NEMO BSP. Section 3 presents some related work concerning multihoming in NEMO. Section 4 describes the handoff operation of the proposed MMRH scheme in detail. Section 5 presents the mathematical analysis and results. Finally section 5 concludes the paper.

2. Handoff in NEMO Basic Support

This section describes the basic operation of NEMO basic support protocol (NEMO BSP) with a brief description of the handoff procedure when a MR moves away from its home network.

2.1 NEMO Basic Support Operation

The IETF has proposed NEMO basic support protocol which is an extension of MIPv6 to manage the mobile network while moving from its home network and attached to a visited network. The NEMO BSP proposes one mobile router (MR) in a mobile network that works on behalf of all mobile nodes in performing mobility functions. The MR provides continuous connectivity to the MNNs within its network through an ingress interface. These MNNs are unaware of the network mobility and they don't perform any mobility functions as illustrated in Fig. 1.

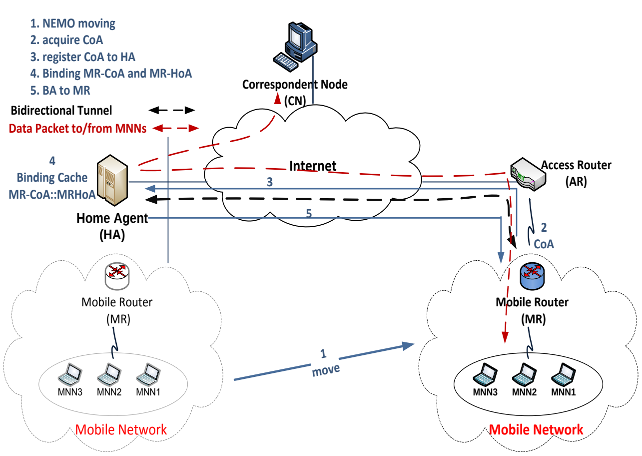

Fig. 1 NEMO BSP operation where numbers represent sequenced operation for NEMO

The MR in the mobile network has two addresses; the permanent address which is called the home of address (HoA) that is assigned to the MR in it is home network. The temporary address is called Care of Address (CoA) that obtains at the visited network. The MNN within the mobile network obtained their addresses according to the MR prefix which is called the mobile network prefix (MNP) that remains fixed even if the mobile network moves to another point of attachment.

When the MR moves to another network (performs handoff) and acquire CoA, it sends binding update (BU) message to the home agent (HA) to register its CoA and bind it with MR-HoA. Once the MR receives binding acknowledgement (BA) from the HA, a bidirectional tunnel is established between the MR and HA. The end points of this bidirectional tunnel is the HoA and CoA of MR. All the outgoing and ingoing packets between the MNN inside the NEMO and a node outside the NEMO are intercepted by the HA and routed through this bidirectional tunnel.

2.2 Handoff Delay in NEMO

When a MR changes its point of attachment to the Internet, handoff occurs. The MR handoff goes through the following steps; each step causes a delay that affect the overall handoff delay:

- Link layer handoff (L2 handoff) delay: this delay represents the time when a MR changes its physical connection and associated to an access point. It is not necessary that MR changes its network if the access point is in the same network, in this situation the CoA doesn't change.
- Movement Detection (MD) delay: this delay is associated with the time interval of router discovery. It is the time that MR discovers that it has been disconnected from the HA and determines its network layer movement when it receives router advertisement (RA) messages from the new Access Router (AR) [10].
- DAD delay: this delay represents the time for verifying the uniqueness of CoA. The MR generates its CoA from the prefix contained in RA received from AR using IPv6 stateless autoconfiguration mechanism, and then verifies the address uniqueness using Duplicate Address Detection (DAD) process. The DAD procedure delay takes (1-2) sec [11].
- Registration delay: this delay represents the time of the BU/BA procedure of MR until the MR receives its first packet through its newest connection [11], [12].

It is obvious from the above handoff delay analysis, that the CoA configuration and DAD procedure have the great impact for increasing the handoff delay that needs more attention.

3. Related Work

Many schemes have been proposed to address the handoff efficiency in multihomed NEMO. Some researchers have benefit from the multiple interfaces that equipped in the mobile router such as a mobile node with WLAN and GPRS. For example, Petander [11] addressed the handoff performance issue by proposing a novel Make Before Break (MBB) handoff scheme. In MBB scheme, the MR is equipped with two network interfaces, one for data communication and the other for scanning networks. These interfaces will take over the operation of each other, once a better connectivity is found; the scanning interface take over the data transmission and the other reverts to a scanning role. Chen [13] studied the Internet connectivity of multi-interfaced MR equipped with (WLAN-CDMA and GPRS) egress interfaces. An inter-interfaces handover decision algorithm is proposed to provide seamless handover between different interfaces.

Multiple mobile routers in the same mobile network have much attention to the researcher. Tsukada [14] proposed the multiple mobile router management (MMRM) scheme that suggested using multiple MRs that serve the MNNs. The primary MR (PMR) in NEMO can detect the new joining MR via the router advertisement broadcasted by the new MR. The PMR establishes MR-MR tunnel with the new MR and regard this tunnel as a virtual egress interface. Thus, the PMR is responsible for selecting a path for each node attached to the mobile network dynamically. This paper will focus on Tsukada work, with modification to network scenario using two mobile routers already exist in the mobile network instead of joining and leaving MR. Mobile routers will register their CoAs using their own HoAs and only one directional tunnel will be active at a time rather using multiple CoAs registration using the HoA of the PMR and using multiple directional tunnel for carrying the traffic. The handoff operation of the mobile network is demonstrated and its performance is analyzed concerning the handoff delay and packet loss problems. Parkash [15] proposed a seamless handover scheme across heterogeneous networks, by using multiple MRs, each MR has its own Home Agent (HA) that belongs to different Internet Service Providers (ISPs). They suggest that the MR that undergoing the handover process sent two binding update messages to its HA (the first one using HoA of the stayed MR instead of its current CoA, the second is to use the CoA of the MR that is not under handover process) to support Network Mobility Basic Support (NEMO BS).

Others used additional entity to manage the handoff or manage resources or traffic, such as using Intelligent Control Entity (ICE) and integrated into multihomed NEMO architecture as propose by Lin [16] to manage handover, resources and adaptation for void zone. The information collected from Access Routers (ARs) and MRs within ICE domain stored in AR_INF table and MR_INF table in ICE respectively, helped to choose the best MR and AR during handover process. Slimane [8] introduced Mobile Network Proxy (MNP) entity as a central gateway at the Mobile Network Level. It managed handoff and traffic distribution between the multiple network routers by using unidirectional HA-MR tunnel. Two principles components implemented into the MNP, the environment detector component to detect the changes occurred of MRs and the policy decision component for mobility and traffic management.

Other work solutions are based on higher layer extension protocols for addressing multihoming in mobile network. Multihomed SIP-NEMO proposed by Huang [17] to solve multiple egress gateways in a mobile network. In addition to the REGISTER and INVITE methods, the REFER, SUBSCRIBE and NOTIFY methods are further utilized to handle the multihoming concern. SIP-NMSs negotiate and synchronize each other using the SUBSCRIBE and NOTIFY messages. Abdul-Razzaq [18] proposed two techniques for HIP-NEMO to reduce the packet during handoff, the HIP Multi-Homing (HIPMH) technique and HIP NEMO Cell Switching (HIPNCS) technique. In the HIPMH, the MR is equipped with two egress interfaces to provide direct path and multiple routes to the Correspondent Node (CN). In HIPNCS, the modified NCS algorithm is implemented at MR to check the RA message broadcast by other routers (ARs or neighbor MRs). The handoff execution decision depends on the Internet Connectivity Strength (ICS) parameters.

4. Handoff Proposed Scheme

The goal of the proposed scheme is to achieve seamless handoff and reduce packet loss during handoff by redirecting the traffic of one MR to another in the same mobile network. The network model illustrated in Fig.2 is considered in our analysis and can be implemented in any vehicular network (bus, long vehicle and trains). It consists of two mobile routers (MR1 & MR2) that are connected through a wired link and registered to the same HA. Each MR maintains a cache to keep the state of binding on neighbor MRs which contains the fields (HoA, CoA, a one bit flag (T) for tunnel status (Open/closed), Lifetime). Multiple bidirectional tunnel will be established to the HA, but only one tunnel will be active at a time to carry the traffic for the MNNs in the mobile network. The opened tunnel can be recognized through the flag (T) which is added to the BU message to indicate which tunnel is opened HA-MR1 tunnel or HA-MR2 tunnel.

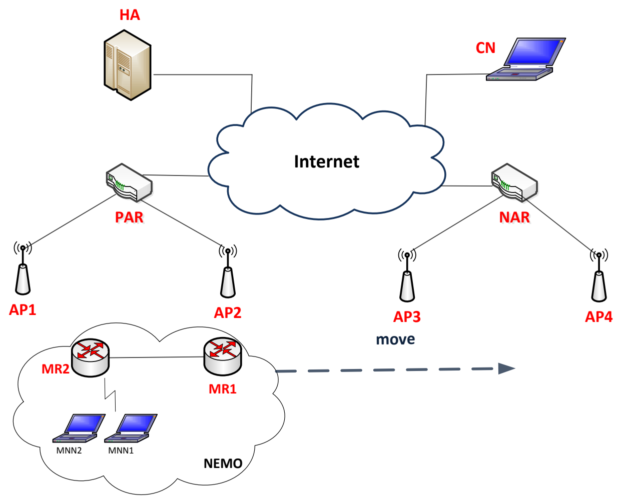

Fig. 2 Network diagram of the proposed scheme

It is assumed that the access routers (ARs) may have more than a couple of access points (APs). The AR collects the information about the APs belonging to it and stores it in a table named AP-table with one bit flag to indicate whether the AP is a boundary overlapping AP or not. The AP that has a common coverage area with the other AP that belongs to the other access router is called a boundary AP.

MR1 & MR2 are separated in different places, so that the handoff operation will happen at different times as the mobile network moves. MR1 scans its channel when it resides in the boundary overlapping area. When MR1 enters in a boundary area and detects two APs that belong to different AR; it must select the AP that belongs to the next AR (NAR) to perform handoff to prevent frequent handoff to the same subnet. Therefore, MR sends a query to its AR to determine whether the AP is a boundary AP or not. The AR checks the information maintained in the AP-table, and returns a message to MR1 to trigger to the AP belongs to the next AR.

The proposal assumes that the AR formulates the CoA for MR, does the DAD procedure and sends the unique CoA to MR through modified RA.

4.1 Care of Address Configuration and Duplicate Address Detection Procedure

Generally, MR configures its CoA according to the link layer information of MR and network prefix information of the AR using the IPv6 stateless Address Autoconfiguration mechanism. It is assumed that the AR will provide the CoAs to MR and performs the DAD procedure by itself instead of MR. After validating the uniqueness of CoA by AR; it delivers the generated CoA to the MR through the modified RA.

MR1 requests for multiple modified RA one for itself and the other for MR2 through sending a modified RS message to AR. The basic RS message is modified by adding two flags, one bit flag (C) and two bits flag (R) as shown in Fig. 3. The C flag indicates that the MR sends the RS message requesting a new CoA from AR. The R flag indicates that MR is requesting more than one modified RA.

8 bits		8 bits	16 bits
Type		Code	Checksum
C	R	Reserved	
Source link-layer address options			

Fig. 3 Modified router solicitation message format

According to this modification, AR will respond with multiple modified RA messages. The modified RA message contains two flags, a single bit flag (C) to indicate that modified prefix information option includes the new CoA for a MR and the flag (R) to indicate that the multiple modified RA message has been sent. The modified RA message format is as shown in Fig. 4.

8 bits	8 bits						16 bits
Type	Code						Checksum
Cur.Hop Limit	M	O	H	C	R	Res	Router Lifetime
Reachable Time							
Retransmission Timer							
Prefix information option							

Fig. 4 Modified router advertisement message format

4.2 Handoff Operation

When the mobile network moves away from its home network, MR1 performs handoff first to transfers the packets destined to MNN through the next AR (NAR), it requests for new CoA for itself and for MR2 from the NAR, while MR2 still connected to previous AR (PAR) in order to perform lossless handoff. Figure 5 shows the handoff procedure of the proposed multihomed mobile network MMHM scheme to manage the mobility of the multihomed NEMO.

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Both MR1 and MR2 are connected to PAR and MR2 is the default gateway for MNNs in the mobile network. When the mobile network moves and changes its point of attachment to the Internet, The following functions are executed.

MR1detects that it's about to move away from its network. It sends the modified RS message with the C flag and R flag are set requesting for multiple modified RA messages that contain new CoAs from the NAR. The NAR will respond with two modified RA messages (RA1 & RA2) that have prefix information option that includes the complete and validate IP addresses (CoAs). MR1 will map this new CoA with the previous CoA of MR2 to establish a tunnel to transport the traffic for MR2. MR1 sends two BU messages to the HA and MR with T flag is set in order that the HA opens the tunnel with MR1 and closed the tunnel with MR2 to redirect the traffic to the NAR, then to MR1 and MR2. Also, MR2 will update its binding cache, and binds its previous CoA with the new CoA of MR1 with T flag is set to redirect the traffic coming from MNNs to MR1 then to NAR.

Then, MR1 sends the modified RA2 message to MR2 that contains the valid new CoA for MR2. When MR2 receives the new CoA from MR1, it concludes that it will perform handoff in the near future. So it scans the channel and performs handoff and register the new CoA with the HA by sending BU message with T flag sets to open the tunnel with MR2 and close the tunnel with MR1.

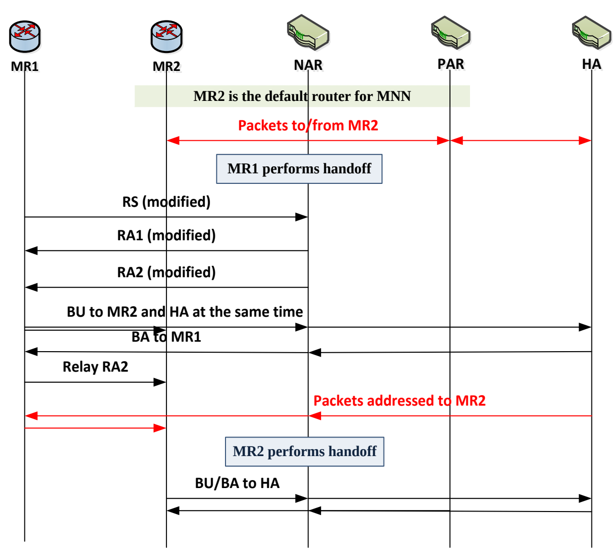

Fig. 5 Timing diagram for the proposed scheme

5. Performance Analysis

This section presents the assessment and comparison of the performance of the proposed scheme with the NEMO BSP. Handoff delay and packet loss are the critical metrics used to evaluate the handoff mechanism. The default parameters values in table 1 are used. Generally, the delay of the packet transmission consists of processing delay, transmission delay and propagation delay. This can be denoted as Eq. (1):

$$\text{Packet Delay} = T_{proc} + T_{trans} + T_{prop} \qquad (1)$$

Where T_{proc} is the time taken for processing a packet, T_{trans} is the time taken to transmit a packet as Eq. (2) and T_{prop} is the amount of time it takes for the signal to travel from the sender to the receiver, here it is referred as link latency.

Transmission delay = packet size / link bandwidth

$$(P/B.W) \qquad (2)$$

Let $t(p, d_{x-y})$ denote the transmission delay of a message of size P sent from 'x' to 'y'.

through the wireless link, it can be expressed as Eq. (3):

$$t(p, d_{x-y}) = T_{proc} + \frac{P}{B.W_{wireless}} + L_{wireless} \qquad (3)$$

through the wired link, it can be expressed as Eq. (4):

$$t(p, d_{x-y}) = \left(T_{proc} + \frac{P}{B.W_{wire}} + L_{wire}\right) \times d \qquad (4)$$

Table-1 Simulation parameters values

Parameters	Symbols	Values
L2 handoff delay	T_{L2}	50ms
Wired link bandwidth	$B.W_{wire}$	100Mbps
Wireless link bandwidth	$B.W_{wire}$	11Mbps
Wired link latency	L_{wire}	2ms
Wireless link latency	$L_{wireless}$	20ms
Packet arrival rate	λ_p	10 pckt/sec
Hops between MR and HA	d	2
Processing Delay	T_{proc}	2ms
Mobility speed	V	25m/sec
Packet size	P	512 byte
Binding Update size	P_{bu}	80 bytes
Binding Acknowledgement size	P_{ack}	40 bytes

5.1 Handoff Delay

The handoff delay is the interrupt time from the time MR leaves its network and the time that MR receives packets from another network.

The handoff delay of the NEMO BSP is composed of the layer 2 handoff delay (T_{L2}), the CoA configuration delay (T_{CoA}), the DAD procedure delay and the HA registration delay(T_{reg}) that is computed as Eq. (5).

$$T_{HO-NEMO\ BS} = T_{L2} + T_{CoA} + T_{DAD} + T_{reg} \qquad (5)$$

T_{CoA} delay depends on the average of the minimum router interval and the maximum router interval (router discovery). The movement detection is Eq. (5).

$$(T_{md}) = \frac{1}{2}\left(\frac{MinRtrInterval + MaxRtrInterval}{2}\right) \quad (6)$$

T_{Reg} delay of sending BU message from MR to HA. This delay is equal to the sum of the delays of all the links delay between MR and HA, the delay between MR-AR (wireless link) and the delay between AR-HA (wired link) as shown in Eq. (7).

$$T_{reg} = \left(2T_{proc} + \frac{P_{bu}+P_{ack}}{B.W_{wireless}} + 2L_{wireless}\right) + \left(2T_{proc} + \frac{P_{bu}+P_{ack}}{B.W_{wire}} + 2L_{wire}\right) \times d \quad (7)$$

The handoff delay of the MMHM scheme, for MR1 is composed of layer2 handoff delay, the RA1 delay (T_{RA1}), the RA2 delay (T_{RA2})and the HA registration delay(T_{reg}) as Eq. (8). For MR2 handoff delay as Eq. (9) is composed of only the layer2 handoff delay TL2 and HA registration delay T_{reg}.

$$T_{HO-MMHM(MR1)} = T_{L2} + T_{RA1} + T_{RA2} + T_{reg} \quad (8)$$

$$T_{HO-MMHM(MR2)} = T_{L2} + T_{reg} \quad (9)$$

Figure 6 shows the impact of the number of hops on handoff delay. For NEMO support and the proposed scheme, the handoff delay increases with the increase of the hops between MR and HA. It can be noticed that the proposed performance is better than the Basic NEMO.

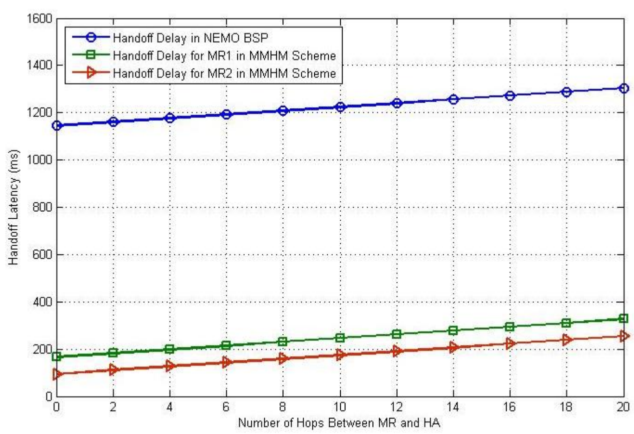

Fig. 6 Handoff delay vs number of hops between MR and HA

Figure 7 illustrate the handoff delay with respect to the router discovery. For the proposed scheme, only MR1 is affected by the router discovery since it performs handoff first and need to perform router discovery, MR2 is not affected by it since it relies on MR1 to deliver it the CoA that acquired from NAR.

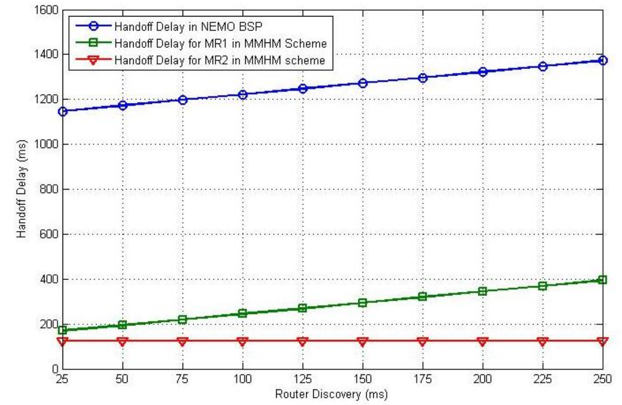

Fig. 7 Impact of Router Discovery on Handoff delay

5.2 Packet Loss

It represents the dropped packet during handoff; it mainly depends on the handoff delay. The packet loss gives an indication of the effect of handoff in the application. The packet loss increases during handoff with the increase in data rate. Here the packet loss is measured according to the offered data rate and as function of packet arrival rate.

Starting with an offered data rate of 100 Kbps and ending with 1000 Kbps by steps of 100 Kbits, the packet loss is as shown in figure 8. It can be noticed that the MMHM perform more efficient than NEMO BSP which means that the MMHM is more suitable for real time applications that send with high rate.

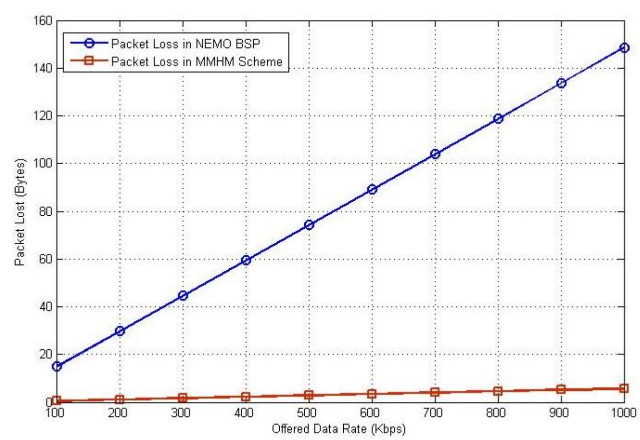

Fig. 8 Packet Loss as a function of offered data rate

Fig. 9 shows the packet loss as a function of packet arrival rate (λ_p) as Eq.(10). It is obvious from the results that the proposed MMHM scheme gives better performance than the NEMO when the number of packet arrival of MNN is increased.

$$PL = N \times \lambda_p \times T_{HO} \quad (10)$$

N: the number of MNN having an active communication session through MR which is 20.

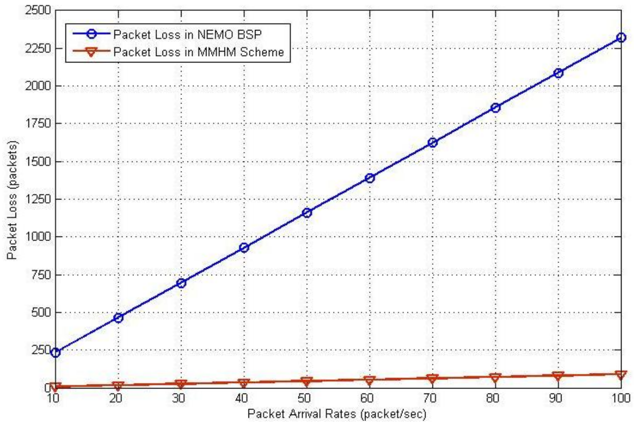

Fig. 9 Packet Loss as a function of packet arrival rate

6. Conclusion

In this paper, a multiple mobile router handoff management (MMHM) scheme is proposed to provide seamless handoff in multihomed mobile network. The multihomed NEMO configuration of the context (n,1,1) is used in the work. In this scheme, more than two mobile routers may exist in the mobile network that spatially separated from each other. These multiple mobile routers cooperate in delivering the packets destined to the MNNs in the mobile network that provide no interruption for services time, and reduce packet loss during handoff. The proposed scheme adds an overhead for tunneling the packet between MRs, but the effect of this tunnel is not remarkable compared with the results of handoff delay and packet loss. By avoiding the router discovery, DAD procedure and analyzing the results of the proposed MMHM scheme and NEMO BSP, it is clearly noticeable that the MMHM scheme performs more efficient than NEMO BSP for real time applications.

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