Handoff Tactics for NEMO and Integrated Network

HUI-MIN HUANG† and JIA-LIN CHANG

***Abstract*—**Our aims to revise the handoff method for NEMO and integrated 3G and NEMO network. These methods include horizontal handoff in NEMO and vertical handoff in integrated 3G and NEMO network. This paper took advantage of the NEMO's characteristics to propose a novel horizontal handoff method. Beside, we adopt the conception of hierarchical network and propose HO to assist the vertical handoff. Our method decreases handoff latency, control packets and network latency for handoff. The simulation shows that the handoff latency be decreased by about 3000ms for horizontal handoff. The average result shows that our method decreases control packet by about 47.3% and network latency by about 38.7% for vertical handoff. The simulated results demonstrate our method is better than the traditional NEMO system.

***Keywords*—**NEtwork Mobile (NEMO), Horizontal Handoff, Vertical Handoff, Heterogeneous Wireless Network, Hierarchical Network

I. INTRODUCTION

THIRD Generation (3G) mobile communication system is the most popular system. However, 3G mobile communication system does not satisfy high-speed mobile users. Consequently, one burgeoning issue is extensively discussed— NEtwork MObile (NEMO). Popular issues include hierarchical Mobile Router (MR), Router Optimization, Multihoming and so on for the NEMO network. There is little research spread out into such topics as bandwidth management, security and authentication, authorization and accounting (AAA), etc. [1]

As for handoff, the theses already put forward mostly focus on handoff for a single system. However, heterogeneous wireless network is the trend of the future. The handoff methods for a single system are not enough for the heterogeneous wireless network. Those methods have considerable overhead and handoff latency in the heterogeneous wireless network.

So, this paper focuses on the handoff issue for integrated NEMO into the 3G network. We designed a comprehensive handoff method that includes horizontal handoff in NEMO network and vertical handoff in heterogeneous wireless network.

The rest of this paper is structured as follows. The existing methods are described and discussed in section II. Section III describes in detail the proposed method. The introduction of handoff tactics is divided into two parts: horizontal handoff and vertical handoff. Section IV describes in detail the simulation. The introduction of simulation is divided into two parts: simulated environment and simulated results. Finally, we provide conclusions and future work in Section V.

II. BACKGROUND[2]-[6]

This section introduces the NEMO network and handoff method in NEMO. Subsection A is a summary of the NEMO Network. Subsection B is the horizontal handoff in NEMO. Subsection C is the vertical handoff in integrated 3G and NEMO system.

A. NEMO Network

One goal of NEMO protocol is network mobility. NEMO enables mobile networks to attach to different points in the Internet. The system is an extension of Mobile IPv6 (MIPv6) and allows session continuity for Mobile Host (MH) in the mobile network as the network moves. It also allows MH in the NEMO to be reachable while moving around. NEMO is designed for a large number of MH that moves together. All passengers on public transportation is a typical example. NEMO aims to decrease the handoff latency. [4]

The MR, which connects the network to the Internet, runs the NEMO protocol with it's HA. MR changes its attachment to the Internet. It also provides connectivity and reachability for all MH in the NEMO as it moves. To change Care-of address (CoA) is just MR when change the service BS. (MH will not change the CoA when it move with the MR.) [4]

Figure 1 shows the conception of what the NEMO is like. Each MH and MR has their Home Agent (HA). MR updates new CoA with its HA, that is the so-called Binding Update (BU), when it left the old Base Station (BS) to go to a new BS. After it entered a scope of new MR and successfully registered with the MR, MH updates BU, too. No matter how the MR moves, MH does not update BU when MH does not leave MR. Thus each movement only updates MR's CoA if the MR serves a lot of MH. So, the NEMO system decreases a large number of registered and BU packets. Besides, the NEMO system also decreases packet latency and packets lost as a result of a short registration time.

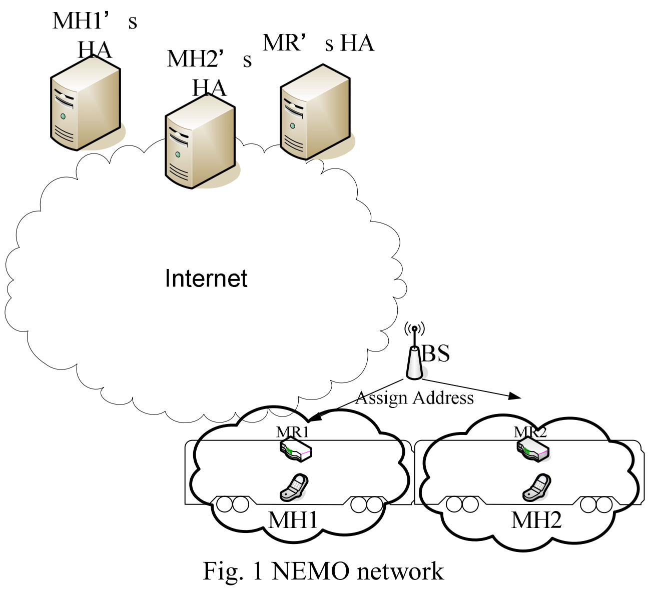


Fig. 1 NEMO network

We do not introduce too much due to the space of the publication. The other detailed interpretation for NEMO is described in [2]-[6].

B. Horizontal Handoff in NEMO

MH changes its point of attachment to the network, and the access network may provide features to minimize the interruption to sessions in progress. This is called handoff. A handoff between equipment of the same system is called horizontal handoff. The horizontal handoff will update the MR's current mobility binding and new CoA by BU.

The horizontal handoff is semisoft handoff or soft handoff in traditional NEMO. The data packet need to be redirected by MH's HA, MR's HA, BS and MR to MH. When MR will moves in new BS, MR receive data packet both at a new BS and old BS in the period of handoff. (As shown in Figure 2)

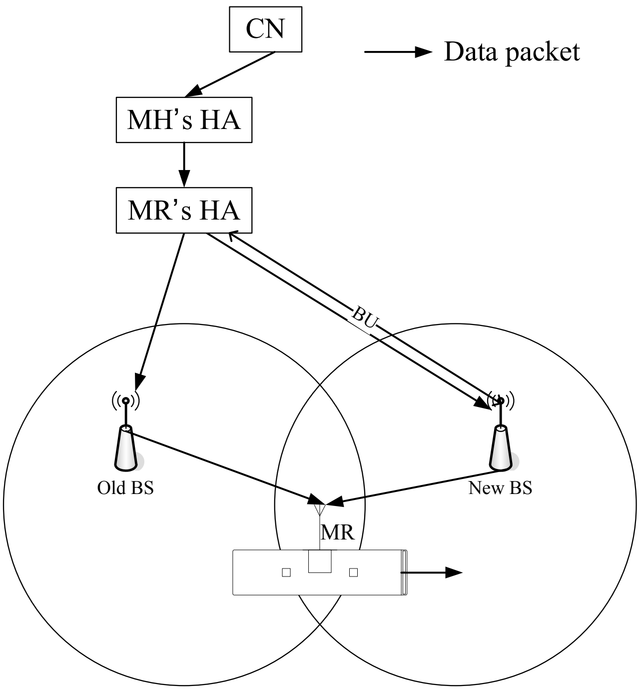


Fig 2 Horizontal Handoff in NEMO

When MR moves in new BS, MR will register itself at a new BS, as shown in Figure 3. Then, the new BS confirms the registered messages with the MR's HA. The registered messages include authentication, authorization and accounting (AAA). BS assigns a CoA and bandwidth for MR after a confirmable MR and executes BU to the MR's HA. The BU is to update the MR's CoA. MR's HA will send the data packet to this CoA, when Correspond Node (CN) wants to send data packet to MH in MR.

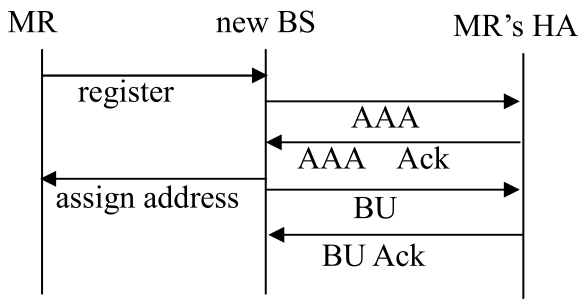


Fig. 3 the message driftage of horizontal handoff in NEMO

C. Vertical Handoff in Integrated 3G and NEMO System

Old service system could not provide service for MH when the MH moves out system's service area. A handoff between equipment of difference system is called vertical handoff when MH moves out a system range to another system.

There are two cases of vertical handoff in integrated 3G and NEMO. The first one is when MH moves from NEMO to 3G, the other one is when MH moves from 3G to NEMO. Figure 4 shows the message driftage of vertical handoff in the two cases. MH provides BS with a registered message, and when MH moves off NEMO and moves in the range of BS. BS confirms the registered messages with the MH's HA. BS becomes the MH's Foreign Agent (FA) after confirmable MH. BS assigns CoA and bandwidth for MH. (It is shown as the black line in Figure 4 (a)) Then, BS executes BU to the MH's HA. HA notifies CN of CoA. (Blue line in Figure 4 (a)) CN tunnels a route from CN to BS. CN sends a data packet by tunnel. Then, BS redirects the packet to MH. (It is the red line in Figure 4 (a)).

MH provides MR with registered message, when MH moves off 3G and moves into the range of MR. MR confirms the registered messages with the MH's HA through BS. MR becomes the MH's New Access Router (NAR) after confirmable MH. MR assigns CoA and bandwidth for MH. (Shown as the dark-line in Figure 4 (b)) Then, MR executes BU to the MH's HA. The BU is to update the Home Address of MR at this time. MH's HA notifies CN of MR's home address. (Blue line in Figure 4 (b)) CN tunnels a route from CN to MR's HA. CN sends data packet by the tunnel. MR's HA redirects the packet to BS that MR stayed at and BS redirects the packet to MR. Lastly MR redirects the packet to MH. (Red lines in Figure 4 (b)).

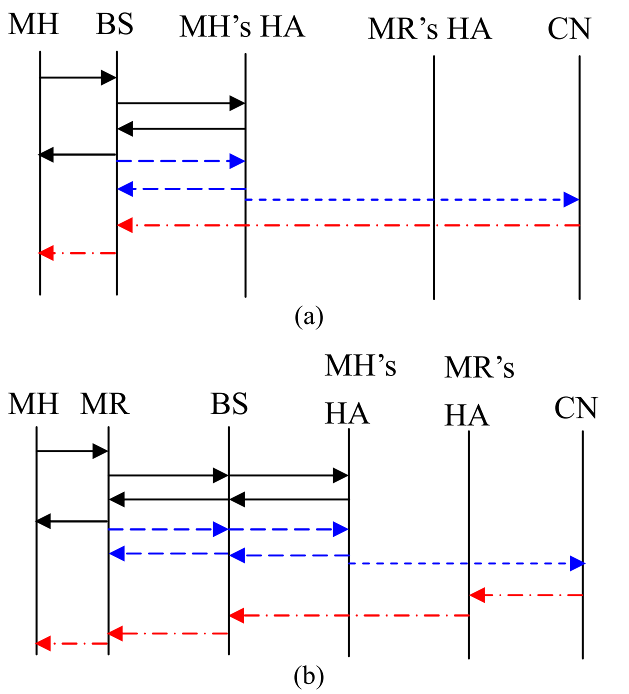


Fig. 4 the message driftage for MH moves in (a) 3G from NEMO (b) NEMO from 3G

MH requests the BS or MR to resend the lost data packet when the MH moves in the BS or MR. BS or MR will request CN to resend the lost packet by the above-mentioned tunnel. Then, the packet is redirected to MH from BS or MR.

The above-mentioned handoff tactic is a mode that MH is a new user of new service provider. However, this tactic causes grave handoff latency. If connected services are broken by the length of time that it takes to start the system and search the service provider, the user will endure it no longer. We make a description of our handoff tactic in the next section. We emphasize that this paper focuses on the integrated 3G and NEMO network.

III. THE HANDOFF METHOD FOR INTEGRATED 3G AND NEMO

A. *Horizontal Handoff—send packets in advance machine*

NEMO was devised for public transportation such as buses, trains, rapid transit and passenger trains, etc. Most public transportation has the characteristic that they move in a fixed route. We can utilize this characteristic to revise the horizontal handoff for the NEMO network.

When public transportation moves in a new BS, MH cannot receive data packets until MH is finished with registration and tunnel. As for a train carriage, the number of passengers is about 40 in a carriage. As for rapid transit, the number of passengers is about 20~60. As for high-speed rail, the number of passengers is about 100. There is a great quantity of packets that MHs demand to send when the public transportation pulls up to a station. So, NEMO will confront the problem that the system has insufficient bandwidth or a crowded internet.

We revised the above horizontal handoff in subsection B in section II. There are a great number of registered packets to be sent between MR's HA and BS when the public transportation moves out the region of old BS. The new BS will very busy, if it is still sending data packets for MHs. We propose the idea that CN sends data packet in advance because the public transportation moves in a fixed route. CN starts the bi-cast to send the data packet for MH according to the schedule of public transportation. (Shown in Figure 5)

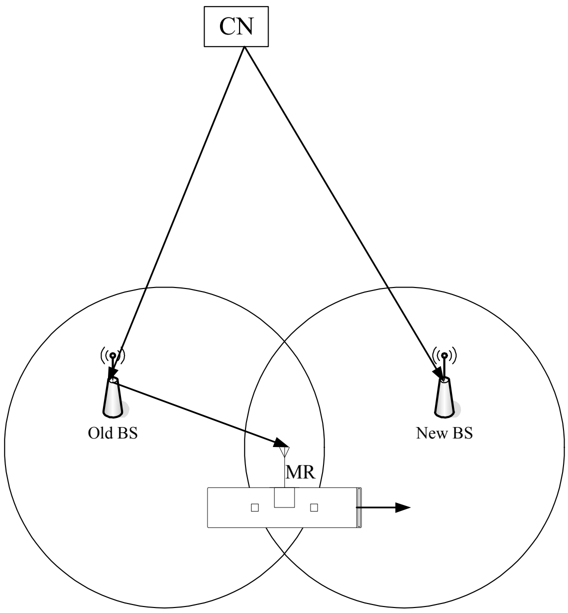


Fig. 5 horizontal handoff of NEMO

Figure 6 shows the data packet is sent in advance (Green line in Fig.6) and the message driftage of horizontal handoff. (Black and blue line in Fig. 6) MH receives the data packet immediately from MR after completing registration. (Red line in Fig. 6) To compare with the Figure 2, this method does not wait for the MR's HA to redirect the data packet. We not only increase the used rate of idle bandwidth in the new BS before handoff but also decrease the deliverable packet latency for handoff. We call this method as "send packets in advance machine".

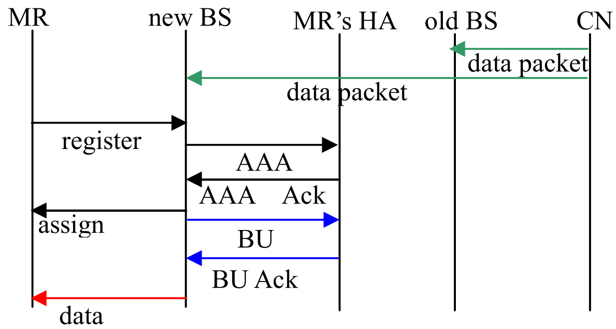


Fig. 6 data packet is sent in advance and the message driftage of horizontal handoff

As far as unfixed routes of public transportation are concerned, this type of public transportation has a characteristic that there are fewer passengers than a fixed route of public transportation. We utilize the Candidate Access Router Set (CAR-set) in Multicast-based Mobility (M&M) system that was proposed by Ahmed Helmy etc. [7],[8] For example, a handoff can predict a new BS when the car moves to an AR. (Shows as AR5 shown in Figure 7) Before the handoff, the CN starts bi-cast transmission (AR1 and AR5). If the handoff cannot predict a new AR, the CAR-set is AR1.4.5.6.8.9 and 10 while the MH detects the strong signal of AR5. Before the handoff, the CN starts multicast transmission (AR1.4.5.6.8.9 and 10). The CAR-set is a member of a multicast tree and receives the same packets through the multicast address (MCoA). Other specific explanations are provided in [9].

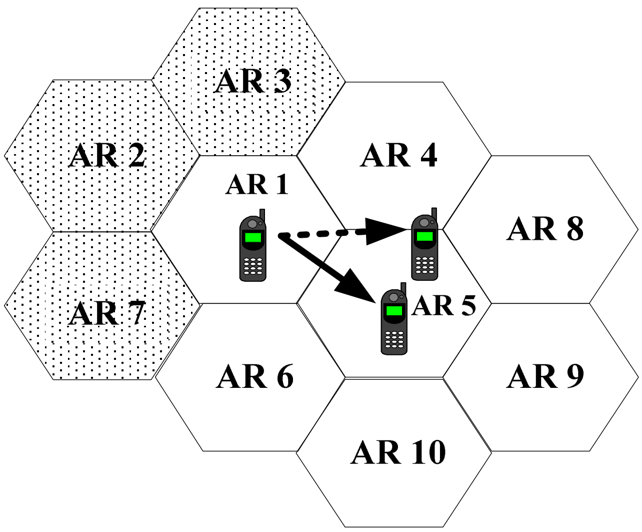


Fig. 7 CAR-set in M&M system

Therefore, the MH moves to any router in the CAR-set—even without a complete handoff, it will not cause packet flow interruption. The data packets of unfixed route are less than the data packets of fixed route due to the lack of passengers. So, multicast transmission will not consume too much bandwidth in this method.

B. Vertical Handoff in Integrated 3G and NEMO– HO-table

We utilize the idea of the hierarchical network [10], and propose a HandOff table (HO-table) to decrease the handoff latency. Each MR and BS will maintain an HO-table. The table records the MHs that are about to handoff, and all the information for those MH. MR and BS will exchange the HO-table that is maintained by them when the public transportation pulls up to a station. The table informs the other side that MHs will move out itself and move to the other system. New service provider assigns a CoA to MH and delivers the unsent data packet according to the records in HO-table. MH moves out of NEMO and moves into 3G, as shown in Figure 8. MR exchanges HO-table with BS, as shown by the line 1 in Figure 8. BS assigns a CoA for MH, as shown by the line 2 in Figure 8. BS updates BU to MH's HA, and redirects the data packet to MH (As shown by the line 3 in Figure 8). The registered time is decreased due to the assistance of MR.

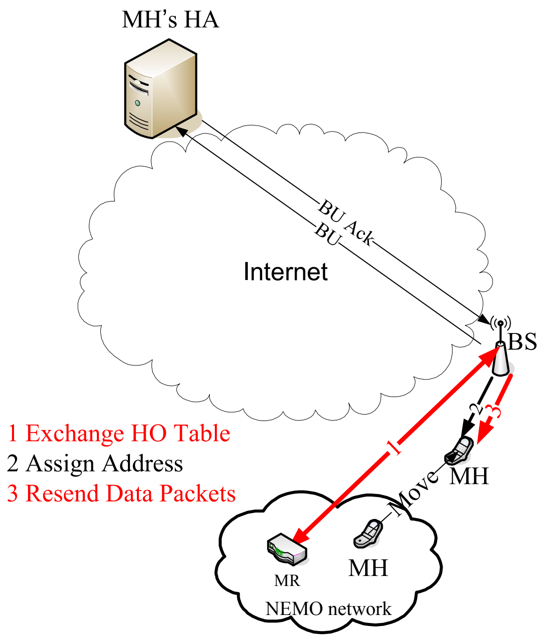


Fig. 8 concept of vertical handoff from NEMO to 3G

Figure 9 shows the process to vertical handoff in integrated 3G and NEMO. The blue MH will move out of NEMO and move into the 3G system. The MH's data packet is delivered from BS to MR before starting handoff. Then, MR redirects the data packet to MH, as shown by the blue line in Figure 9. BS assigns a CoA for MH after MR exchange HO-table with MR. (Dotted blue line 2 is shown in Figure 9.) BS delivers unsent data packet to MH directly instead of MR after finishing registration. (Blue line 3 is shown in Figure 9.) MH is still staying in the scope of MR in this moment, it receives data packet from both MR and BS, and therefore decreases handoff latency. If MH moves out of NEMO, it will request BS to resend the scarce data packet.

The green MH will move out of 3G and move into the NEMO system. MR assigns a CoA for MH after MR exchange HO-table with BS. (Dotted green line 2 is shown in Figure 9.) The MH's data packet is delivered from MR after handoff. Then, MR redirects the data packet to MH, as shown by the green line 3 in Figure 9. MH is still staying in the scope of BS in this moment, it receives data packet from both MR and BS, as shown by the green line in Figure 9. If MH moves out of 3G, it will request MR to resend the scarce data packet.

The green MH will move out of 3G and move into the NEMO system. The MH's data packet is delivered to MH from BS before handoff begins. When handoff starts, BS redirects the data packet to MR, as the green line shows in Figure 9. MR assigns a CoA for MH after BS exchange HO-table with MR. (Dotted line 2 is shown in Figure 9.) BS delivers unsent data packet to MR instead of delivering to MH directly after finishing registration. (Green line 3 is shown in Figure 9) MH is still staying in the scope of BS in this moment, it receives a data packet from both BS and MR. If MH moves out of 3G, it will request MR to resend the scarce data packet.

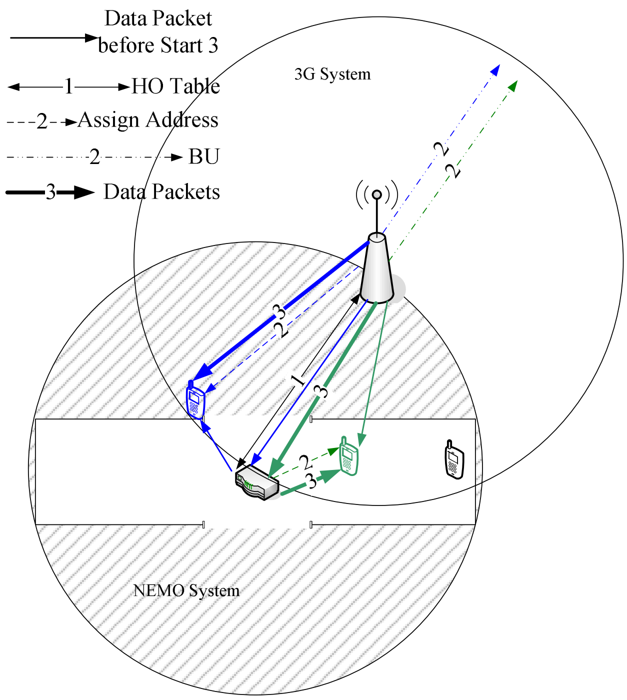


Fig. 9 the process for vertical handoff in integrated 3G and NEMO

MR and BS reserve cache to storage data packet for every MH communication. When the MH requests to resend the losing packet, MR (or BS) looks for the packet in the cache first. The size of the cache for every communication is allotted according to the type of communication. The cache will be released when the MH move out the scope of MR (or BS).

Compared with the original handoff method, this vertical handoff method decreases much registered packet and network latency. Serious packet loss was due to the MH moving out the former scope or the bandwidth be used to register. The cache machine decreases the route of resending losing data packet, especially for vertical handoff.

Figure 10 shows the message driftage in our tactics for vertical handoff. HO-table be exchanged at a time no matter how much MH there are. (Shows as Green line in Fig. 10) Compared with the original handoff method (Fig. 4), our tactics decreases handoff control packets. Some steps have been omitted. (Compare the some black line in Figure 4and 10.) Our vertical handoff method will obvious decrease handoff latency and control packet when the number of MH is a large number.

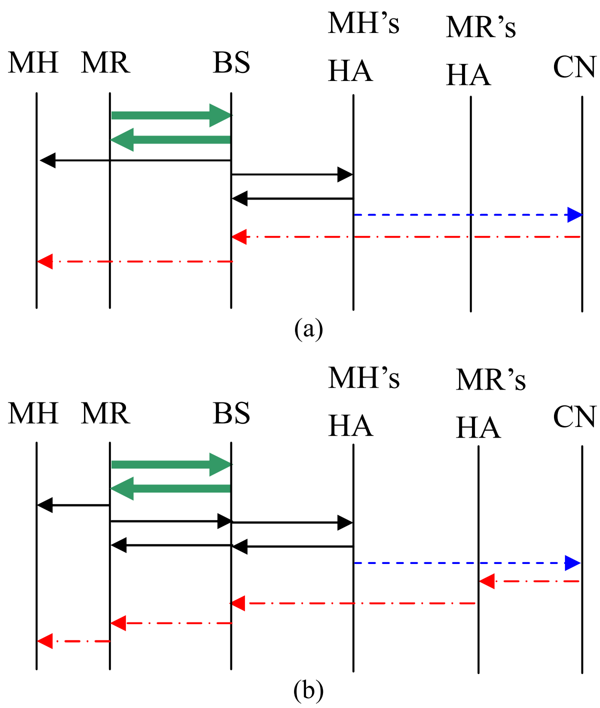


Fig. 10 the message driftage in our method for MH moves in (a) 3G from our method (b) NEMO from 3G

C. Contents and Establishing of HO Table

This subsection will introduce the proposed HO table. Little subsection *i* describes the contents of HO table. The usage and establishment of the HO table is described in subsection *ii*.

i. Example and Illustration for HO Table

BS and MR establish a table for possible MHs that are about to vertically handoff, respectively. We called this table HO Table. HO table includes information that AAA, HoA, the state of MH, and requested statement of MH. (Shown as Table 1) This table helps to comprehend the demand of bandwidth, QoS level and MH's state for new service system. This information is necessary for the new service system, so as to complete the continued request. The new service system will update CoA with MH's HA according to the HoA of MH in the HO table.

Table 1 shows the present state of MH for MR or BS to finish the MH's request. The AAA and HoA of MH will be used to register the MH. State shows the present state of MH. State includes Idle, Active and Sleep. QoS of performing application shows the QoS level for MH's request. QoS level includes Excellent, Good and Basic. Time of performing application shows surplus time of MH's request. The format of the time is Hour: Minute: Second. The four last data will be used to send data packet for the MH.

Table 1: an example of HO table

	AAA of MH	The HoA of MH	State	Type of performing application	QoS of performing application	Time of performing application
MH A	AAA data	IPv6 address	Active	1.TCP/IP: Audio 2.UDP: message	1.Good 2.Basic	1.00:20:30 2.00:10:00

The Application of HO table regards BS and MR as the hierarchical framework. When MH completed registration with upper strata, upper strata notified lower strata to finish local registration. MH does not need to register as the new call with new service system in this method. So, both registered time and handoff latency can be decreased by hierarchical framework.

ii. Establishing and Using of HO Table

This subsection introduces the system how to determine the MH that it is about to leave old system. We use Figure 11 to simplify the interpretation. The green circle represents the region of the 3G network, and the network contains a platform at a railway station. The blue circle with an oblique line represents the region of NEMO network, and the network contains a carriage. Two black circles represent the doors of the carriage, and they represent the region that MH will leave its network when MH moves in the circuit. The MH's information will be added to the HO table when it moves into the black circuit. In Figure 11, BS adds the information of MH1 into BS's HO table and MR adds the information of MH2 into MR's HO table. We know which one circuit is sphere of action in advance, because the public transportation moves in a fixed route and just one door of the carriage will be open.

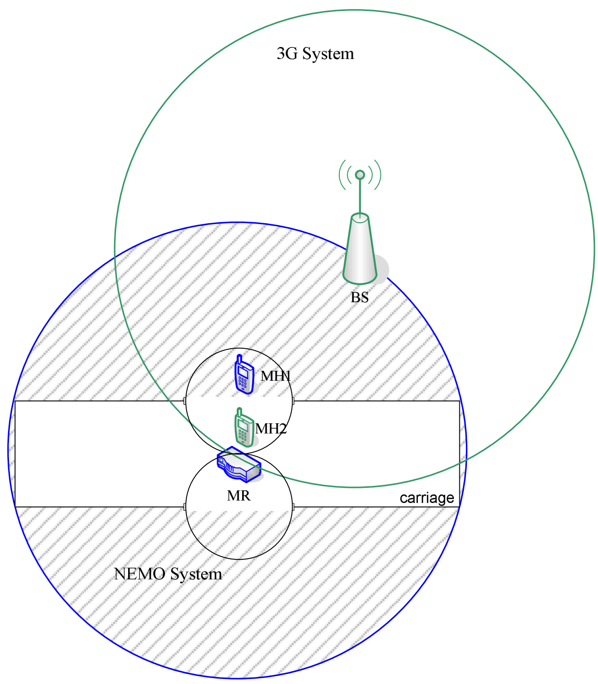


Fig. 11 establishing and exchanging of HO table

Travelers move to the door when the public transportation is about to reach the station. MR and BS update its HO table according to the reachable schedule for public transportation. The update will start ahead of time when MH moves in a large station or when the time is rush hour.

MR exchanges HO table with BS when the public transportation stops at a station. When MR and BS detect MHs entering his region and the public transportation moves out from the station, MR and BS start the handoff process respectively. MR and BS delete the data in HO table when MR and BS cannot detect MHs enter his region and the public transportation moves out of the station. MR and BS start the original handoff process when the HO table does not contain the MH's information.

IV. SIMULATION

A. *Simulated Environment*

In this section, an operational example for our proposed method can be displayed in Figure 12. [11] MHs move at random (for number between 10~100). The MR moves in a fixed route. So, HA of MR will notify CN the bi-cast address before horizontal handoff start. The service provider supplies horizontal or vertical handoff according to MHs move.

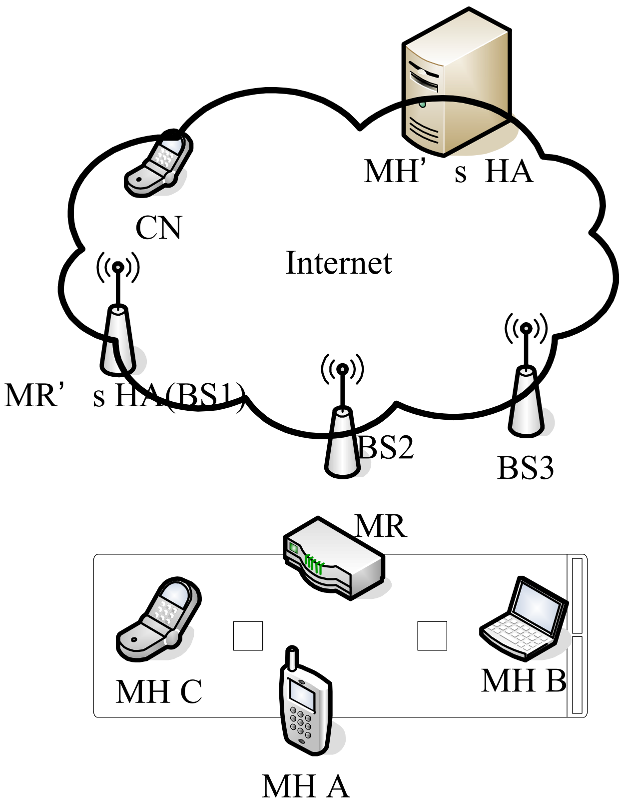
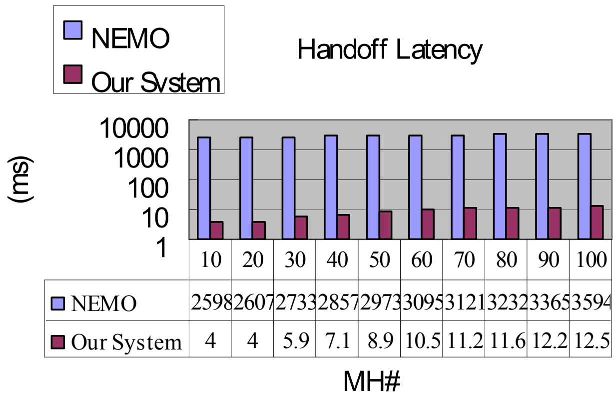


Fig. 12 simulated environment

We compare the handoff latency in the horizontal handoff. We compare the network latency and total number of control packets in the vertical handoff. [12],[13] All simulations be ran ten times, and we take the average value to be the results. The results are shown as follow subsection.

B. *Simulated Results*

Figure 13 shows the handoff latency of horizontal handoff in NEMO. The system will not have handoff latency unless the bandwidth is heavy network load. Because the data packet is send in advance before handoff. It shows that our method is much better than the traditional NEMO method, because our proposed method delivers data packets in advance and NEMO uses soft handoff. The handoff latency is 4~15 ms of our method and 2500~3500 ms of the traditional NEMO method. The average result of our method reduces about 3000ms of handoff latency in horizontal handoff of NEMO. The handoff latency is obvious increase according to increased MH. But, the handoff latency of our system is still smaller than traditional NEMO.



	10	20	30	40	50	60	70	80	90	100
NEMO	2598	2607	2733	2857	2973	3095	3121	3232	3365	3594
Our System	4	4	5.9	7.1	8.9	10.5	11.2	11.6	12.2	12.5

Fig. 13 handoff latency in horizontal handoff

There are many control packets to be delivered for handoff in the traditional method. (Shown in Fig. 4) We used HO table and local registration to reduce costs for handoff and network latency. Figure 14 shows the total number of control packets for vertical handoff. Our method reduces the control packets between BS and HA. The great amount of MH makes obvious impression of our method. Our method is better than the traditional method by about 47.4% when the number of MH is 100. The average result of our method is better than the traditional method by about 47.3%.

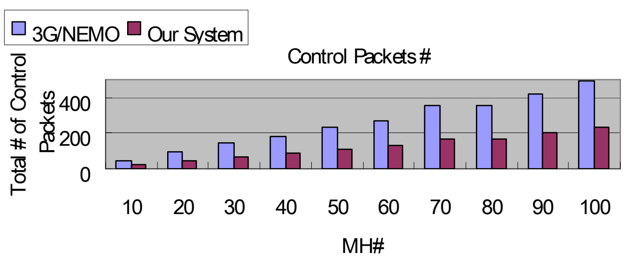


Fig. 14 cost for vertical handoff

Figure 15 shows the average of network latency per MH. Our method is better than traditional method by about 40.5% when the number of MH is 100. The average result of our method is better than traditional method by about 38.7%.

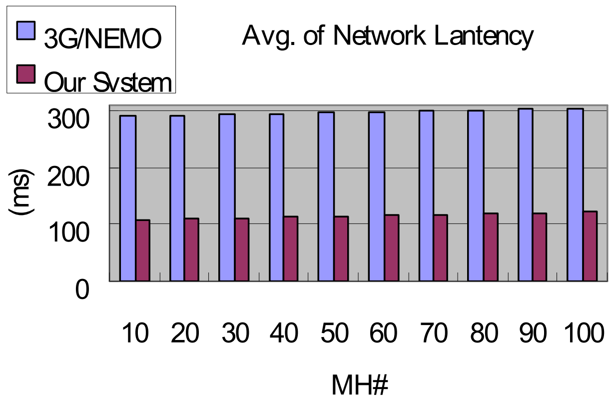


Fig. 15 average of network latency for vertical handoff

V. CONCLUSION AND FUTURE WORK

Both the integrated heterogeneous wireless network and NEMO are the trends of the future. This paper considers both trends and proposes suitable handoff schema. This schema includes not only vertical handoff for the heterogeneous network but also improved horizontal handoff for the NEMO network. We utilize just the NEMO character and idle bandwidth. So, the original system does not need much revision. Our method reduces about 3000ms of handoff latency in horizontal handoff of NEMO. Our method decreases 47.3 percent of control packets and 38.7 percent of network latency in vertical handoff in integrated network.

System, which can effectively utilize bandwidth, are an important issue in the heterogeneous wireless network. We will develop a bandwidth reserved method for MH in 3G and NEMO heterogeneous network in the future. [14],[15]

Moreover, multimedia application will be the trend. [16] Multimedia request is high QoS request. So, the issue of QoS control is very important for integrated 3G and NEMO networks. We will develop a QoS upgrade and degrade machinations for multimedia requests in the future. The aim is effective utilize the limited bandwidth.

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