An Efficient Fast Handoff Scheme with Network Mobility in Heterogeneous Networks

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Abstract-As many access technologies develop, more and more heterogeneous wireless networks appear around us. In this case, when whole mobile networks move from the visiting network to another, the handoff attracts the attentions especially. The exited handoff methods with network mobility merely extended the scheme of handoff in MIPv6 or integrated the exited methods into the uniform scheme but it can not make the good effect to really and truly solve the fast and smooth (packet lossless) handoff in heterogeneous wireless networks. In this paper, the fast handoff scheme is given and it provides Multi-Mobile Router (MMR) with a vicinage table to keep information about their vicinages access router. Using this method, it performs the Fast Handoff with network mobility effectively in heterogeneous wireless networks. In addition, we introduce the new entity TCS (temporary control server) to manage MMR procedure in order to complete fast handoff and reduce the power consumption of MMR. By analysis and simulations, we demonstrate that fast handoff scheme has the better performance than Basic NEMO.

Keyword-network mobility, fast handoff, Markov chain, multi-mobile router, heterogeneous networks

I. INTRODUCTION

A host on its home network can communicate with corresponding node through normal IP routing by the assigned permanent IP address. But if a node moves away from its home network to another subnet, the connection will break off. The host can not keep communication by its permanent IP address. It is necessary to keep the same IP address while the nodes move among different sub-networks. Mobile IP protocol enables hosts to keep the same IP address independently from their current location [1].However, now as the extend of mobile communication networks such as wireless LAN, PAN and CAN (Car Area Network), most of public traffic systems (e.g. bus, train, airplane) are needed to have a permanent IP address to the Internet even though moving around. Therefore, it ought to pay more attention to network mobility than host mobility. As more and more small or medium sized networks want to have whole mobility as same as the current mobile node has, the network mobility research is desired. Because of the existing Mobile IP solution not providing the network mobility, the new basic protocol for network mobility (Basic NEMO) was proposed in [2].

In NEMO, the main actors are: the Mobile Node (MN), the Home Agent (HA) and the Mobile Router (MR). When a mobile network moves into a new network, mobile Router needs to obtain the care-of address (CoA) from the visited network. As soon as the Mobile Router acquires a care-of address, it immediately sends a Binding Update to its Home Agent. When the Home Agent receives this Binding Update, it creates a cache entry binding the Mobile Router's Home Address to its care-of address at the current point of attachment. After the registration a tunnel is set up by the Home Agent to the care-of address. When packets addressed to the MN arrive to its home network, the Home Agent intercepts and forwards them to the care-of address through the bi-directional tunnel (HA - MR). Each node in mobile network is transparent mobility by using this bi-directional tunnel. As the extend of Mobile IPv6, the MR registers its network prefix as well as its care-of address through the extended binding update (Prefix Scoped Binding Update (PSBU) [3]) so that HA can properly intercept and tunnel the packets belonging to the mobile network prefix to MR's CoA. In the NEMO mechanisms, when a mobile network moves among networks, it will not be able to receive any message until it establishes a connection with the new COA and confirmed by his home network. During this period, packets forwarded to the old COA fail to reach the destination because the old COA has no information about the new location of the MR. The packets lost during the handoff time impact on the quality of communication, especially in the real-time operation where such disruptions are unacceptable. New extensions of the Mobile IP protocol have been then introduced in order to optimize handoff mechanisms. The possible solutions exist: Optimized Smooth Handoff [4], Fast Handoff procedures based on a hierarchical approach [5], to name a few. These solutions permit to limit latency, jitter and packet loss. IP layer handoff latency is defined as the sum of the link layer handoff latency and constant delay. The constant delay involves new prefix discovery and new care-of address creation, confirmation and registration. So, IP layer handoff latency can be reduced by reducing the constant delay[6][7]. The handoff control may reside in the network even though the decision to undergo handover may be arrived at between the MN and the network.

In the context of the present trend towards ubiquity of networks and global mobility of services, we see that network access is provided by a large diversity of technologies with coverage overlaps. In this heterogeneous wireless network environment, how to conduct the efficient fast handovers is a critical issue. Since WiFi networks are often deployed to cover certain indoor regions such as offices or outdoor regions such as campuses and the emerging and then WiMAX network is considered to be able to provide global coverage, we would consider a heterogeneous wireless network (WiMAX-WiFi) as the research target in this paper.

In this paper it proposes a fast handoff scheme to improve the handoff with NEMO in heterogeneous wireless network. It is particularly useful for real-time traffic. Fast handoff scheme provides MMR with a vicinage table in order to keep information about their vicinages AR (i.e. other access router close to them), then these information will be transmitted to the temporary control server (TCS) which is the new entity introduced by us. Using the information about other access router in the table the MMR can register with the new access router in advance to reduce the delay. It is possible to have fast handoff by performing all configurations and confirming steps on the new network before actually leaving the old one. This is considered a soft handoff as opposed to a hard handoff, which happens when the access router becomes unreachable before handoff is accomplished. It can guarantee that the packets are not loss when the mobile network roams between the different access router coverage. In addition, TCS can make the power of MMR to be saved and it will be described in Section II.

The rest of the paper is organized as follows. Section II describes the description of fast handoff with NEMO in heterogeneous wireless network and fast handoff process. Section III presents evaluation and simulation results. Section IV concludes the paper.

II. FAST HANDOFF APPROACH WITH NEMO IN HETEROGENEOUS NETWORKS

We consider a heterogeneous wireless network (WiMAX-WiFi) as the research target in this paper. The description of system architecture is Figure 1. When a mobile network roams from one administrative domain to another {moving(2) in Figure 1}, it is called macro mobility. When a mobile network traverses different subnets, or different access points but under the same administration (i.e. in the same domain), it is referred to as micro mobility{moving(1) in Figure 1}.

The fast handoff scheme with network mobility in heterogeneous networks aims to reduce the handoff. The basic idea of fast handoff approach is to introduce the Multi-Mobile Router (MMR) as the central management node which equipped with one or multiple wireless interfaces (such as WLAN and 3G interfaces).The external interface can periodically receive the information (such as IP addresses and access rate) of its adjacent access router and save them into a vicinage table of MMR. There are update messages sending between new and previous access router which are used to put entries into the vicinage table in order to exchange their IP address. When the previous access router receives an update message, it extracts the source IP address (i.e. the IP address of the new access router) and puts it into the vicinage table. At the same time, the new access router can add a new entry (i.e. the IP address of the previous access router) into its vicinage table after sending the update message. Periodically the vicinage table of MMR should be transmitted to the temporary control server (TCS) in its home network and TCS will substitute for MMR to manage this table.

If there are no any mobile network roams between two networks, it is obvious that MMR doesn't execute a handoff between a couple of access routers. MMR will initiate the sleep procedure by sending a sleep request to temporary control server (TCS). The sleep request includes the prefix of the MNs inside the mobile network and the IP address of external interface. The address will later be used by the TCS to notify the MMR of new incoming requests via short messages. In sleep procedure, MMR does not periodically receive the information of its adjacent access router and it will reduce the power consumption of MMR. So no entries are put into the corresponding vicinage table even though access routers are physically close.

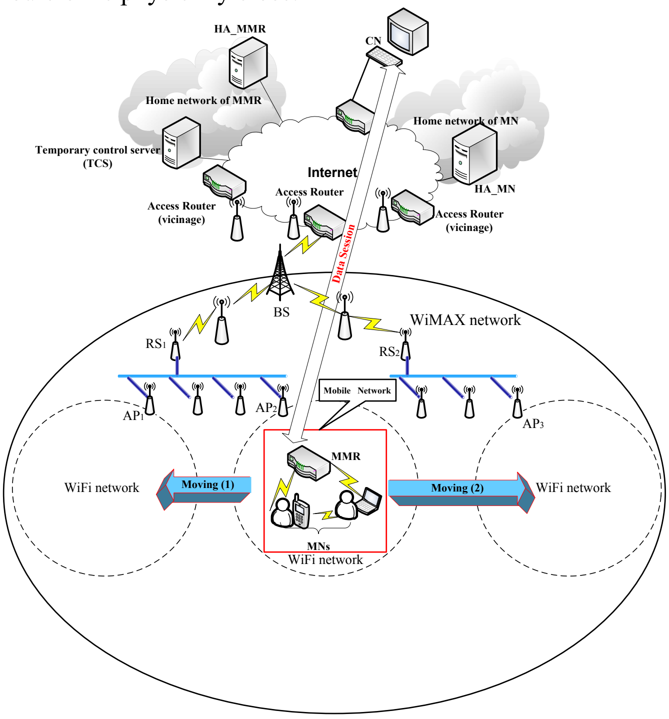

Fig. 1. System Architecture

In the TC mechanism, the MMR will carry out a sleep procedure when it decides to disconnect from the Internet. The MMR will solicit the TCS as its agent during the disconnection period. The mobility parameters considered by me are signal strength, monetary cost, and bandwidth. Signal strength has the highest weight because the MMR has to be handed off to the network with the best signal. This is important for partially overlapping networks because as the MMR transitions across the overlapping area, the signal strength of the one network starts to weaken as the other strengthens. We use a network elimination factor En, first introduced in [9], to eliminate networks with signal strength below the threshold. When MMR finds that the receive signal strength (RSS) of serving access router is below defined threshold, it means that handoff is possible to happen. TCS will be notified first and will trigger a wake-up procedure. In the wake-up process, the TCS will activate the MMR via SMS and establish a connection with the corresponding node (CN) to hold the session. TCS will give MMR the information of new access from vicinage table. After the MMR reconnects to the Internet, the transfer process will help to build the link between the CN and the internal MNs. This way, the MMR can stay offline but remain reachable from the Internet.

Using the vicinage table's entries, MMR can make the access routers to advertise the information in its own wireless network about mobility states offered from the other adjacent access routers. In addition, this mechanism is provided the conventional and periodic advertising one in order to give the MMR a description of the surrounding environment as complete as possible. After a MMR receives the vicinage table messages sent from TCS, it stores them into its own Advertisement List. The MMR uses the Advertisement List in order to send an advanced registration to the coming access router. When a MMR is moving towards a new access router, it can complete the fast registration in advance. This fast registration is possible to be accomplished because the information of the coming new access router has already been stored in the list of the MMR. Otherwise, according to Basic NEMO protocol, the MR must wait for the Advertisement message after mobile network moves into the new network. After having sent all Registration Request messages, the MR empties its table. It is the task of the new access routers to refresh the vicinage Advertisement List of the MR with the new entries. By this fast registration, MMR can receive the prefix information from the new AR and associates with the new AR by creating a COA in advance. After this process MMR can sends its Binding Update message to its own HA_MMR to update its old binding between home address and old COA. The re-association is possibly accomplished before mobile network actually moves away from its old network, so the handoff delay is less than that of Basic NEMO protocol. The handoff process describes in Figure 2.

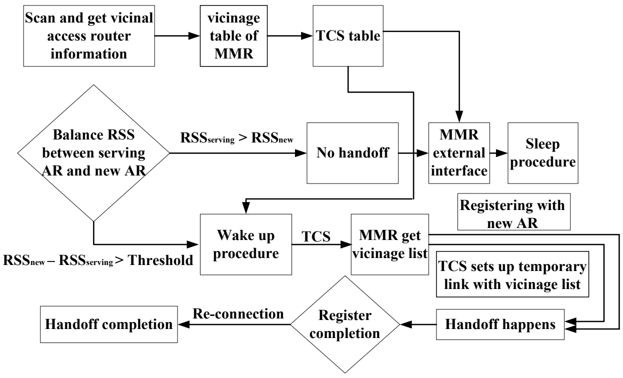

Fig. 2. Fast Handoff Process

If there are some levels of nested mobile network existing, Fast Handoff scheme can also implement the advance handoff in mobile network. When a mobile network moves into a new mobile network, the parent-MMR advertises messages stored in the vicinage Advertisement List each sub-MMR. Then the sub–MMR can know his surround environment and prepare for the new prefix configuration. This advanced registration help to reduce the delay of re-configuration and re-confirmation when moving into new network. Otherwise, according to Basic NEMO protocol, the MR must wait for the Advertisement message until mobile network moves into the new network. Then the process of re-association can begin. So the handoff delay with Basic NEMO is more than that of the fast handoff scheme.

III. EVALUATION AND SIMULATION RESULTS

A. Analysis and Evaluation

It assumes that it only considers the handoff delay as the constant delay involving new prefix discovery and new Care-of address creation, confirmation and registration.

For the wireless channel, a Rayleigh fading channel is considered and a two-state Markov channel model is used to approximate the error process at the frame level over the fading channel [8]. It can consider the two-state Markov channel model which has a work (w) state and a down (d) state, i.e., frame error probability is 1 in the down state and 0 in the work state. When the velocity and the carrier frequency are given, the average transmission error probability and state transition probabilities can be obtained from [8][9]. Let Pxy be the state transition probability from state $X\in[w,d]$ to state $Y\in[w,d]$ and ρ be the stationary probability in state $X\in[w,d]$. If a message consisting of m frames is lost over a wireless link, we define the Qm as the probability. Then Qm is given by:

$$Q_m=1-(1-\rho_d p_{dd})^m$$

For Router Solicitation, Binding Update, Register[10], the average transmission latency for them can be computed from:

$$T_z=\frac{1}{1-Q_m}\sum_{m=1} Q_m^{\,m-1}(1-Q_m)\times\sum_{m=1} T(m)$$

where $Z\in$[Router Solicitation, BU, Register]. T(m) is the average transmission time when a message consisting of m frames is successfully delivered. Then, T(m) is given by:

$$T(m)=m(\rho_w\times TSD+\rho_d p_{dw}\sum_{m=2} p_{dd}^{m-1}\times mTSD)$$

where TSD is the time slot duration (i.e., 4 ms). We consider that the transmission latency for these messages is $D_{process}$=T(m).Consequently, the handoff latency in the network mobility can be obtained from:

$$Handoff_{network\ mobility}=D_{RS}+D_{RE}+D_{BU}$$

The handoff process contains the Router Solicitation, Register and Binding Update. From the above section description, it knows that the process of Router Solicitation can be completed in advance by using the fast handoff scheme. In addition, fast Register can be executed, so the fast handoff scheme can reduce the time of handoff obviously.

It assumes[10][11] that the voice and data subscribers have the same probability distributions of moving speed. It defines the dwell time of MMR in the area of AR as a random variable Td which is assumed to have an exponential distribution with a mean rate μ. It assumes a uniform density of mobile router throughout the area and a user is equally likely to move in any direction. For two-dimensional mobility model, the average outgoing rate μ (i.e., average rate of crossing the AR boundary) of mobile routers can be given by:

$$\mu=\frac{\bar{A}L}{\pi S}$$

Here, $\bar{A}$ is the average moving speed of MMR (random variable), L is the length of circumference of the AR's area and S is the measure of AR's area. So, the average dwell time of MMR, is 1/μ.

It defines the state of the marked AR area by a two positive number (i, j), where i is the numbers of the channels used by data handoff requests, and j is the number of data handoff requests in the queue(There it only considers $\{i\} \in \{0,1,2\}$ and $\{j\} \in \{1,2\}$). It is apparent from the above assumptions that (i, j) is a Markov chain[12] given in Figure 3.

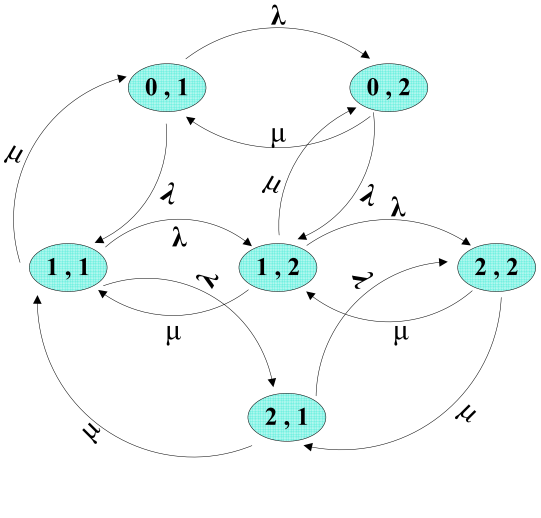

Fig. 3. State Transition Model

All the equilibrium probabilities p(i, j) are related to each other through the following state balance equations:

$$P(0,1) = \lambda P(1,1) + \mu P(0,2)$$
$$P(1,1) = \mu P(0,1) + \mu P(1,2) + \lambda P(2,1)$$
$$P(0,2) = \lambda P(1,2) + \lambda P(0,1)$$
$$P(1,2) = \mu P(0,2) + \mu P(2,2) + \lambda P(1,1)$$
$$P(2,2) = \lambda P(1,2) + \lambda P(2,1)$$
$$P(2,1) = \mu P(1,1) + \mu P(2,2)$$
$$\sum_{i=0}^{2} \sum_{j=1}^{2} p(i,j) = 1$$

The above balance equations noted the Markov chain means that it can depict all states how to transform. The average number of data handoff requests arriving and deleting in unit time are (1-D) λ where D is error downing probability of data handoff requests and λ is the arriving messages rate. We get the time-out probability P′ of a data handoff request:

$$P' = \frac{\mu E[Q]}{(1-D)\lambda}$$

E[Q] is average length of queue. So, failure probability of a voice handoff request is $P'' = D + (1-D)P'$. The handoff probability P of a data call is the probability that the call holding time exceeds the dwell time of the data user in an AR area (P=*p*{t ≥T},where μ=1/E[T]).Therefore, the average transmission delay:

$$T_{delay} = P\frac{LQ}{C\mu}, \; \left(C = \sum_{j=1}^{2} j \sum_{i=0}^{2} p(i,j) \right)$$

Equilibrium probabilities p(i, j) are related to each other through the state balance equations. However, note that any one of these balance equations can be obtained from other N-1 equations. Since the sum of all state probabilities is equal to 1. It can obtain independent equations, with λ and μ are two unknown variables. If it assumes the mobile network moves away from its own location with Basic NEMO and the fast handoff scheme respectively, it can obtain that the average transmission delay using fast handoff scheme is only 50% of the NEMO, even if the n-level nested network exist, the delay can reduce 35%, 25% and 15% when n is 1,2 and 3.

It can see that two schemes without and with fast handoff procedures with mobile networks in heterogeneous networks have differ in delay time. It is observed that the forced termination probability of data handoff and average transmission delay of data users can be reduced by employing fast handoff scheme. It also knows that there is no loss of data handoff except for negligibly small downing probability due to data handoff being transferred from a queue of one AR to another.

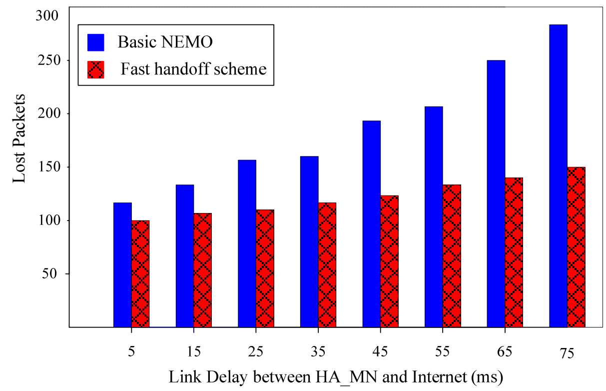

Fig. 4. Compare the Lost Packets with Two Schemes

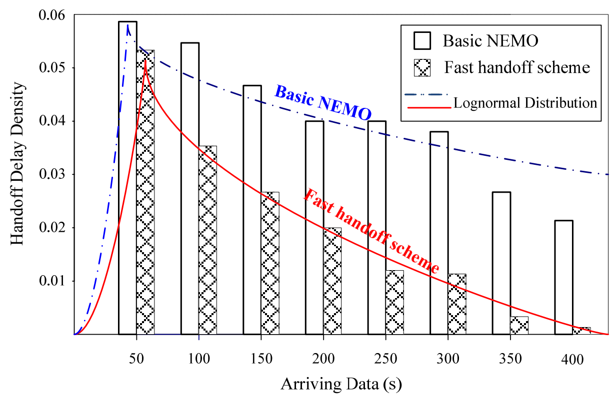

Fig. 5. Compare the Handoff Delay Density with Two Schemes

We consider a scenario, where a new flow is participated to a link that is already utilized just below its capacity, and the data arrival rate exceeds its capacity by the participation of the new flow. In a mobile network, a longer handoff delay will result in a higher amount of lost packets when data rates are the same. Handoff delay of NEMO is the time period from when the session is disconnected to the time point mobile network informs correspondent node where current its location is. We increase link delay between home agent and

Internet to simulate that the mobile network is far away from its home network, but the distance between the mobile network and HA_MN is fix. As shown in Figure 4, lost packets of Basic NEMO increase gradually, but those of fast handoff scheme keep steady.

In above scenarios, we assume a BER of 10^{-3}.We calculate the corresponding packet error rate as PER = $1-(1-\text{BER})^n$, with n denoting the packet length. These values are taken from 25 simulation runs where each run simulates 20 a/c handoff instances. It can be seen the main difference between both scenarios is the delay incurred by home registration (i.e. the Binding Update – Binding Acknowledgment) exchange. In the case where fast handoff scheme is not used, due to more frequent loss of either Binding Update or Binding Acknowledgment messages the handoff takes much longer. Use of the fast handoff scheme can improve the total handover delay performance by around 80%. Detailed plots of the delay distribution can be seen in Figure 5.

B. Simulation Results

In this paper, fast handoff scheme in heterogeneous networks is proposed to reduce the handoff in the network mobility environment. In order to analyze the performance, the proposed fast handoff with NEMO scheme is compared with Basic NEMO. Both fast handoff with NEMO scheme and Basic NEMO are implemented in OPNET. It uses 3G interface and 802.11 interface[13] as external and internal interface, respectively. Figure 6 depicts the handoff latency that is defined as the average time period from the time point at which the mobile network leaves one visited network to the time point at which CN receives the first packet. It makes the moving speed of mobile network in difference(15m/s and 20m/s) using two schemes respectively. It can see that the performance of fast handoff scheme is better than that of Basic NEMO especially when the time gets up to 60ms.

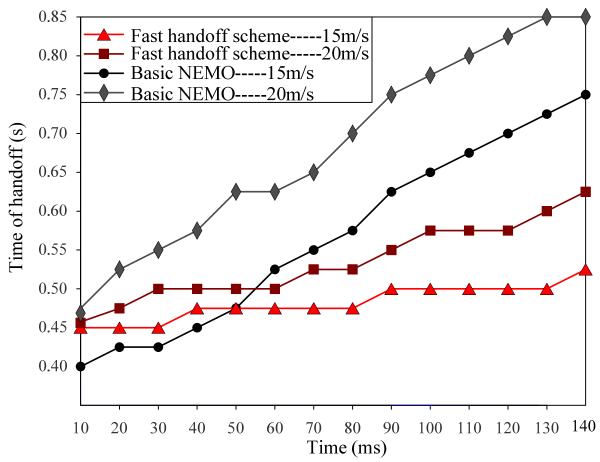

Fig. 6. Compare Handoff between Fast Handoff Scheme and Basic NEMO in Different Moving Speed

Figure 7 compares the delay for increasing arrival rate λ using two schemes, respectively. Typically, when fast handoff scheme is used, the delay in transmitting the message has been found to be reduced. Here also the delay incurred in the wireless part has been found to be 98% of the total end-to-end delay. Especially when frame error rate gets up to 0.8, the end-to-end delay will have a big gap between two schemes. The delay reduces with the use of fast handoff scheme, which takes care of the longer TCP retransmissions[14].

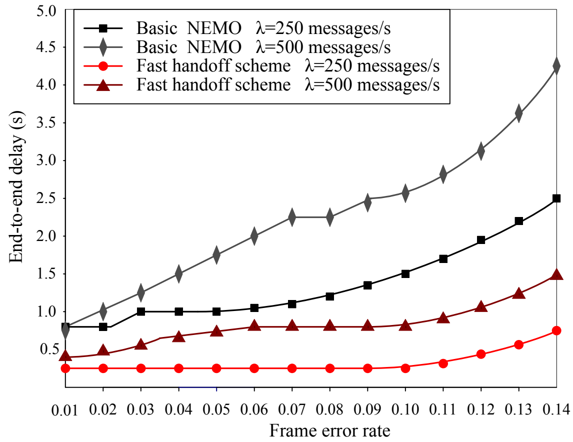

Fig. 7. Compare the Delay for Increasing Arrival Rate λ with Different Scheme

When it considers the nested network, the performances also can be improved by using the effective fast handoff scheme. Figure 8 depicts the performances of Basic NEMO and fast handoff with NEMO, while increasing the level of nested mobile network. For the handoff latency, Basic NEMO increases sharply when the level of nesting increases. However, fast handoff with NEMO keeps almost the same even if the level of nesting is increasing. The same results can be got for the RTT and the amount of lost packets[15].

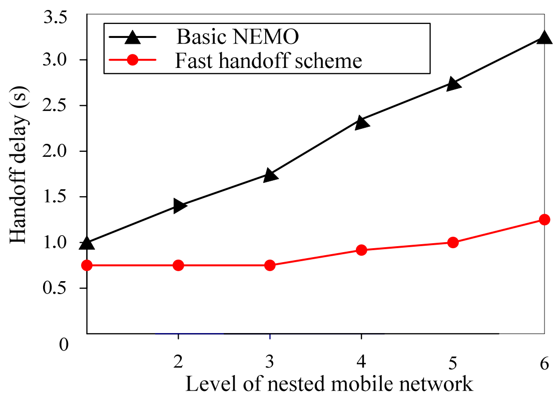

Fig. 8. Compare handoff delay in nested mobile network using two schemes

In Figure 9 and Figure 10, we compare the average handoff delay and jitter under different mobility modes{moving(1) and moving(2)} with using two schemes respectively.

Moving (2) is called macro mobility. In Figure 1, we can see AP_2 and AP_3 belong to the different administrative domains (RS_1 and RS_2). In moving (2), when an MMR is currently associated with AP_2, it periodically checks whether it should trigger a handover. If so, MMR will scan the candidate APs (AP_3 almost) in vicinage table. If this step fails, it will check whether its current $RSS_{serving}$ is larger than a predefined threshold. If so, MMR will not handover to another AP.

Moving (1) is referred to as micro mobility. In Figure 1, we can see AP_2 and AP_1 belong to the same administrative domain RS_1. In moving (1), When an MMR is currently associated AP_2, it periodically checks whether it should trigger a handover. If triggering a handover is needed, it will select the candidate APs (AP_1 almost) in vicinage table. The MMR then scans APs and calculates each AP's available bandwidth. Then, among those APs whose available bandwidths can afford the MMR's traffic demand, the MMR will select the AP with the strongest RSS to handover to.

In Figure 9 (a), we can see that when two mobile nodes (MNs) are onboard a mobile network, the fast handoff method reduces the handoff delay by 15 ms in comparison to Basic NEMO. As the number of data sessions increases, the handoff delay under fast handoff scheme is always lower than that of Basic NEMO whatever in moving (1) and moving (2). Furthermore, when the number of data sessions gets up to 4, the disparity is more obvious. When the number of nodes attached to the mobile network becomes 8, the fast handoff framework is capable of reducing the handoff delay up to 50% and 28% in (a) and (b) respectively.

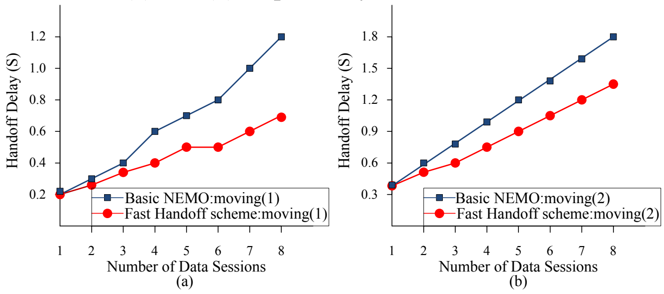

Fig. 9. Compare the Handoff Delay under Different Mobility Modes Using Two Schemes

We can see in Figure 10 that when the number of data sessions increases, the jitter under fast handoff scheme is also lower than that of Basic NEMO whatever in moving (1) and moving (2). The jitter plot is obtained by calculating the variation of the end-to-end delay for sessions that are being handed-off. Furthermore, the gap is more obvious under moving (2). Thus, we can demonstrate that the performance of using fast handoff scheme is better than that of Basic NEMO.

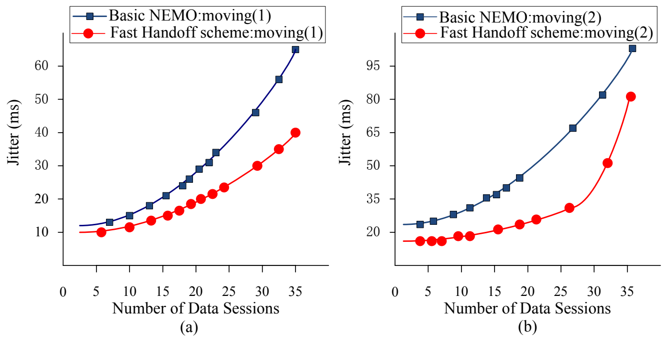

Fig. 10. Compare the Jitter under Different Mobility Modes Using Two Schemes

IV. CONCLUSIONS

The paper is to enable different mobile routers to access different subnets during a handoff and cooperatively receive packets destined for each other. In general, packet losses are directly proportional to handoff latency, however, the overlapped reception of packets from different subnets makes possible to minimize packet losses even without reducing handover latency. The effective fast handoff scheme defines a vicinage table into MMR in order to maintain the IP addresses of its adjacent access router. When any mobile network roams between two networks, the advanced information can make the MMR have new prefix discovery and new care-of address creation, confirmation and registration ahead of schedule. So the delay can be reduced and the packet loss can be avoided.

The main contributions of this paper are as follows: (1) gives the effective scheme which can obviously reduce the handoff delay with network mobility in heterogeneous wireless network, especially for real-time service. As the real-time service (videoconference) can not accept the long time for handoff, the fast handoff approach should deal with this problem; (2) compares the proposed scheme with the current NEMO handoff procedure. The result of simulation shows that the efficient fast handoff scheme can obviously reduce the total of handoff delay when the whole network roams in different visited networks.

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