Application Layer Mobility Supporting by Dynamic Home Agent with Location Awareness

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Abstract—**Mobility management is important to wireless networks, but increased speed and efficiency are hampered by problems of triangular routing, signaling overhead and binding cache support. A new approach called Mobile IP with Home Agent Handover (HH-MIP) proposed to enjoy most of the advantages of ROMIP but with only a small increase of signaling overhead. The HH-MIP approach is an efficient mechanism to eliminate ROMIP shortcomings without introduces large signaling cost, and the results show that HH-MIP could reduce both transmission path and handoff latency efficiently as compared with the previous mechanisms. Although HH-MIP has great performance, it demands all routers in Foreign Networks to support combined functionalities of both Temporary Home Agent (THA) and foreign Agent (FA). Nevertheless, not all of routing devices can adjust to implement the functionality of HH-MIP in the existing Internet. This paper proposes an adaptive mobility management scheme called Dynamic Home Agent with Location Awareness (DHA-LA). We attempt to implement the mobility management protocol on application layer. Therefore, the DHA-LA could break the deploy limitation of HH-MIP and doesn't need to modify any routing devices in the Internet. DHA-LA proposes the advantage of partial deployment and resolves the problem of global THA discovery. Simulation results demonstrate that the performance of DHA-LA with partial THA deployment can be close to or better than other protocols that are fully FA established.**

Keywords-Mobility Management, MIP, ROMIP, THA

I. INTRODUCTION

Due to the rapidly development of wireless and hand-held technologies, people can have Internet connection anytime and anywhere. They can enjoy the network communications without the restrictions on the wired cabling. However, the design of the original TCP/IP protocol suite has not been considered to the mobility. This will make the application development of the wireless network limited. To satisfy users with mobility requirement, an efficient protocol supporting mobility is needed for mobile wireless networks. Thus, many mobility management approaches had been proposed [1].

Mobile IP (MIP) [2] is the most common solution for offering seamless handoff to mobile devices over the Internet. In MIP, a mobile node (MN) uses two IP addresses: a fixed home address (HoA) and a care-of-address (CoA) that changes at each new point of attachment. A router called Home Agent (HA) on an MN's home network is responsible for maintaining the mapping of HoA to the CoA. When an MN moves to a new foreign network, the MN obtains a CoA from the Foreign Agent (FA) and registers the CoA with its HA. In this way, whenever an MN is not attached to its home network, the HA gets all packets destined for the MN and arranges to deliver to the MN's current point of attachment by tunneling packets to the MN's CoA.

When the communicating peer (Corresponding Node, CN) has a packet destined to the MN, the packet will be sent with the HoA as destination address. Therefore, the packet will be sent to the home network of the MN as shown in Figure 1. If the MN already leaves its home network, the HA will send the packet to the MN's current FA by tunneling via the MN's CoA. The FA then forwards the decapsulated packet to the MN. If the MN has a packet destined to CN, the packet is sent by direct routing without passing through home network.

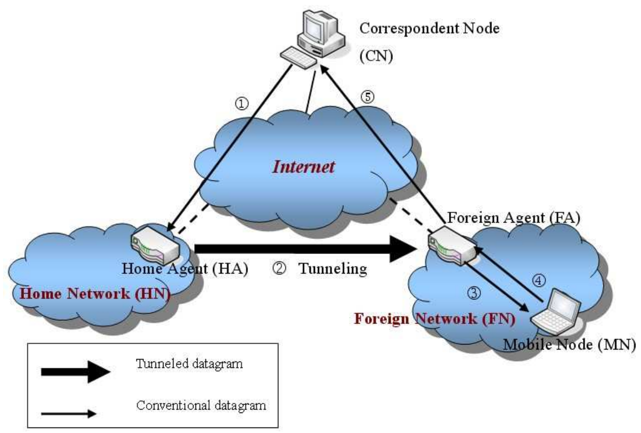

Figure 1. Data delivery in MIP

Some inefficiencies were identified in MIP: (1) triangular routing from the CN to the HA then to the MN leads to unnecessarily large end-to-end packet delay [3], (2) the HA is inevitably overloaded due to tunneling operations, and (3) when an MN is far away from its home network, the long signaling path for CoA registration leads to a long handoff latency resulting in a high packet loss.

To remedy the problem of triangular routing and reduce the packet loss during handoff, Route Optimization MIP (ROMIP)

[4] was proposed. ROMIP allows every CN to cache and use binding copies. Local bindings in a CN enable most packets in a traffic session to be delivered by direct routing.

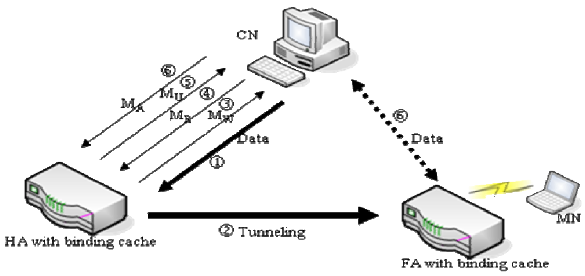

Figure 2. Data delivery in ROMIP

Figure 2 shows the data delivery sequence in ROMIP approach. Initially, the CN only knows the MN's HoA and will send packets to HA. HA encapsulates the received packets (tunneling) to MN's current FA. The FA then forwards the decapsulated packets to the MN. In addition, the HA also sends a Binding Warning Message (M_W) to inform CN that the MN is not staying in its home network. The CN then reply with a Binding Request Message (M_R) to ask for MN's current CoA. The HA sends a Binding Update Message (M_U) containg MN's CoA information to the CN. The CN responses with a Binding Acknowledge Message (M_A) to confirm the receipt of M_U. Therefore, the CN can send packets to MN's CoA directly.

The remainder of this paper is organized as follows. Section 2 briefly surveys related mobility management approaches. Section 3 describes the previously proposed HH-MIP scheme. Section 4 shows the proposed DHA-LA approach. Section 5 evaluates their performances. Finally, we conclude in Section 6.

II. Related Work

In the highly mobility condition, more CoA update messages will cause more signaling latency and result in packet lost in the handoff progess of MIP approach. Thus, Hierarchical Mobile IP (HMIP) scheme has been proposed. In the HMIP, FAs are divided into two different levels, GFA and FA, based on domain structure as shown in Figure 3. When the MN moves and change it FA/CoA which still managed by same GFA, the binding update messages needn't to be sent to its HA. This approach also called Localized/Regional Registration (RR) [1].

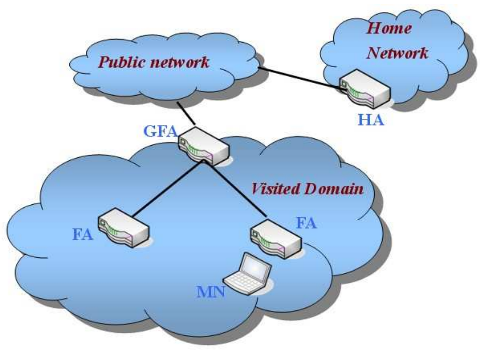

Figure 3. HMIP/RR approach

In the HMIP approach, the HA only need to know which GFA the MN currently located and the GFA only keep track of which FA the MN currently located. Therefore, when the MN moves among the same GFA domain and obtains a CoA from new FA, the MN only needs to register the CoA with GFA without notifying HA. The MN sends binding messages to HA and GFA only when MN handoff into different GFA domain. The HMIP uses hierarchical GFA and FA to achieve the purpose of localized registration. However, the system efficiency is based on the selection and stability of the GFA.

In the Dynamic Hierarchical Mobile IP (DHMIP) [5], each MN can dynamically select a suitable FA to act as its GFA and the signaling overheads can be distributed among the network domain as shown in Figure 4.

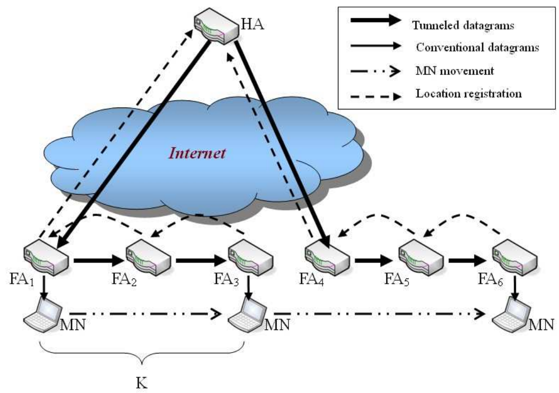

Figure 4. DHMIP approach

DHMIP uses dynamic GFA assigment to balance the loading of FAs. However, multi-layer FAs may create triganle route problem and result in higher transmission delay.

III. HH-MIP

We previously proposed a mechanism called MIP with Home Agent Handover (HH-MIP) [6] to reduce signaling overhead and enhance system performance. The HH-MIP introduces the concept of Temporary HA (THA). The HA of an MN maintains the binding of the THA address for the MN. Handover of the THA requires the MN to update the binding cache in its HA. The handoff of an MN to a new FA only triggers registration of the new CoA to the THA (instead of the HA) when the THA of the MN remains unchanged. Since the THA of an MN is selected to be close to the current location of the MN, HH-MIP reduces the handoff latency and shortens the signaling path of registration as well.

Data delivery in HH-MIP is similar to that in ROMIP as explained in the following. Initially the CN sends packets to the home address of the destined MN, the HA intercepts and sends the packets to the THA by tunneling, and the THA tunnels the packets to the current location (FA) of the MN. Meanwhile, a binding copy of MN's THA is sent by HA to the CN so that later packets can be directly delivered to the THA, and THA tunnels the packets to the current location (FA) of the MN. Therefore, regular data delivery in HH-MIP requires the packets sent by the CN to be tunneled twice before they reach the destined MN.

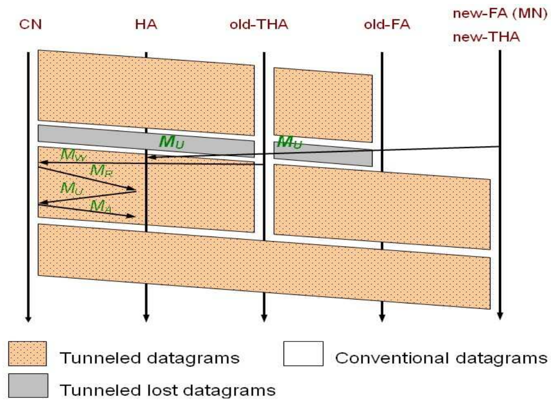

Figure 5. Flow diagram for data delivery in HH-MIP

Four messages are used for binding update of THA as in ROMIP: (1) Binding Warning Message (M_W), (2) Binding Request Message (M_R), (3) Binding Update Message (M_U), and (4) Acknowledgement Message (M_A). The HA just after having tunnels the first packet sends an M_W back to the CN informing that the MN is not in the home network. In response to the received M_W, the CN sends an M_R to the HA asking for binding update. The HA replies with an M_U containing the requested CoA (i.e. THA's address). Finally, CN sends an M_A to the HA acknowledging the successful binding update. Figure 5 illustrates the process of data delivery in HH-MIP.

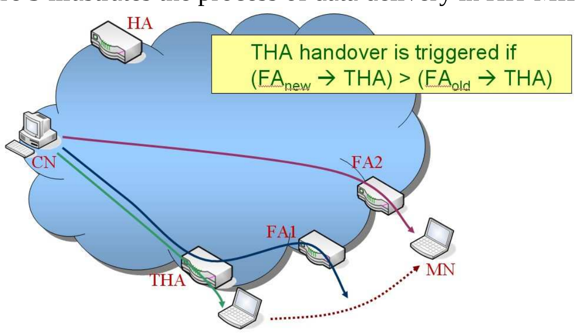

Figure 6. Selection of THA in HH-MIP

Initially, an MN will select its HA as the THA. HH-MIP adopts an aggressive approach in selecting the THA for an MN: whenever an MN is moving away from the HA or the previous THA, the MN triggers the handover of THA. As illustrated in Figure 6, if the distance (hop count) from FA2 (MH's current location) to THA is longer than the distance from FA1 to THA implying that the MN is moving away from THA, FA2 is selected as the new THA, and the MN notifies its HA of the new THA. On the other hand, if HA is closer to FA2 than THA implying that the MN is moving back to HA, HA should be selected as the new THA.

IV. DHA-LA

In HH-MIP approach, all FAs have to support and act as THA for MN. However, it is very difficult to implement THA functionality in every FA of the entire Internet. Moreover, network devices may not provide mobility management functions due to security concerns. If we can implement the THA functionality on the application layer and operated on a server to provide mobility management service, the protocol deployment will become more easily. Therefore, the idea of application layer approach called Application Layer Mobility Supporting by Dynamic Home Agent with Location Awareness (DHA-LA) is proposed in the paper.

A. Basic Idea

As mentioned above, we implement the THA functionality on the application layer. Although application layer mechanism can have partial protocol deployment benefits, it creates a service searching problem. The mechanism used to search a THA-aware server with nearest location and highly service quality (low system load or transmission latency) becomes more critical. This kind of mechanism is called Global Dynamic HA Discovery Solution [7]. In order to reduce globally search which may increase in handoff latency, we propose an application layer THA scheme with location awareness called DHA-LA to assist suitable THA service discovery.

In DHA-LA approach, the THA and HA functionalities are running upon application layer. The THA maintains a neighbor list containing neighboring THA servers. There is a special THA server called Rendezvous Point (RP) maintains a list of all THA servers. Figure 7 illustrates the operation of DHA-LA. When the MN leaves its home network and visits a foreign network, it asks for candidate THA servers via RP query messages. If the THA2 is chosen based on RTT estimation, THA2 will maintain current address binding of the MN. The HA keep address of THA2 which currently services the MN. The data delivery method is same as original HH-MIP.

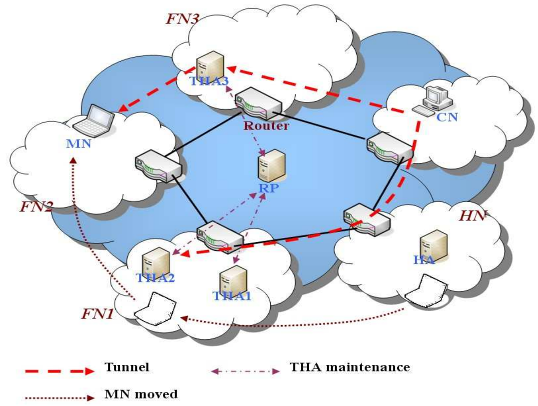

Figure 7. Operation of DHA-LA

A handoff threshold called Round-Trip Time Threshold (TH_{RTT}) is used to decide that THA must hand over or not. Each time the MN changes its point of attachment and sends a binding update message to serving THA, the serving THA computes the new value of round trip time (*RTT*) between THA and MN. If the *RTT* is smaller than TH_{RTT}, only localized registration is needed. But if *RTT* is larger than TH_{RTT}, THA handoff procedure is triggered. In the THA handoff procedure, the serving THA sends a THA candidate list to the MN. The MN than chooses another THA act as new serving THA by server load and *RTT* value.

B. *Protocol Operation*

In DHA-LA, RP is the centralized manager used to maintain the THA server list. It acts as DHA-LA portal for MNs. We propose using the traditional DNS system to assist MN finding suitable RP. Each upper layer DNS domain registers a RP server, i.e. tha.edu.tw, tha.ca.jp or tha.edu.cn. Each time a THA server powers on, it registers itself to RP with its IP address. The RP searches whois database with THA's IP address to find the city that THA server located. The RP then sends a neighbor list to THA server containing limited number of neighboring server. The RP also sends *ADD_THA* messages to THA servers in the neighbor list.

In order to maintain an accurate THA list, each THA server has to periodically send a *Hello* message to the RP. The *Refresh Interval* (3 times *Hello Interval*) is the maximum time that RP should wait to receive the next *Hello* before declaring that THA server as unreachable. When a THA server is unreachable, RP sends *Refresh_THA* messages to related THA servers and remove its registration. Figure 8 illustrates the THA maintenance flow.

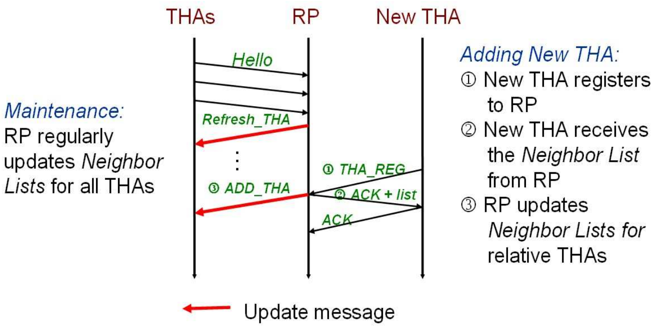

Figure 8. THA registration flow

When the MN leaves its home network and visits a foreign network, it sends a query message (*query_THA*) to the RP. The RP searches whois database with MN's CoA to find the city that the MN currently located. The RP then replies a message ($query\_d_{MN\text{-}THA}$) to the MN containing a candidate THA server list. Each time the MN changes its point of attachment and sends a binding update message to serving THA, the serving THA computes the new *RTT* value between THA and MN. If the *RTT* is smaller than TH_{RTT}, only localized registration is needed. But if *RTT* is larger than TH_{RTT}, THA hand over procedure is triggered. In the THA hand over procedure, the serving THA sends a THA candidate list to the MN. The MN than chooses another THA server and sends a binding update message to the new THA server. Figure 9 shows the message flow of THA handover.

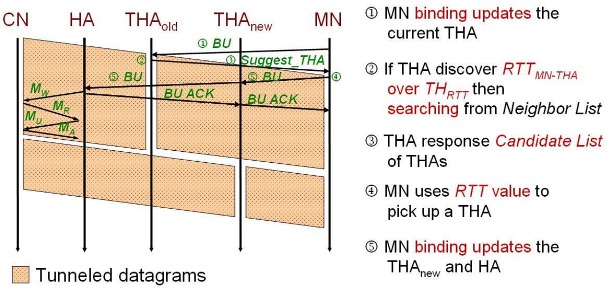

Figure 9. Message flow of THA handover

In order to enhance performance, we propose a dynamic TH_{RTT} mechanism:

- When the MN initially registers itself in a THA ($THA_{(x)}$) with a binding update message, the $THA_{(x)}$ will calculates and records the RTT value (RTT_{MN}) and distance ($query\_d_{MN\text{-}THA}$) between $THA_{(x)}$ and MN. The $THA_{(x)}$ will set the initial value of TH_{RTT} to $2*RTT_{MN}$ and reply a binding acknowledgement message.
- When the MN moves among different foreign networks, $THA_{(x)}$ will recalculate TH_{RTT}. If the new TH_{RTT} is higher than handover threshold, then the $THA_{(x)}$ queries a new candidate THA list with distance limitation ($query\_d_{MN\text{-}THA}$) and sends to the MN. Otherwise, a localized registration is needed.
- If the $THA_{(x)}$ cannot find any candidate THA server, it will double the TH_{RTT} and query distance ($query\_d_{MN\text{-}THA}$) thresholds.

The searching candidate THA mechanism is the same as in the RP. When the THA handover procedure is triggered, The serving THA searches whois database with MN's CoA to find the city that the MN currently located. The serving THA replies a *Suggest_THA* message to the MN containing a candidate THA server list from its neighbor list. By using this location awareness searching mechanism, we can choose a suitable THA server with lower handoff latency. Moreover, the DHA-LA can achieve a better performance in a partial THA deployment than other protocols that are fully FA established.

V. Performance Evaluation

A. *Simulation Environment*

We use a simulation program to evaluate the DHA-LA approach. The network topology used in the simulation is shown in Figure 10. Each point in the topology is a network domain and is connected based on the Taiwan Academic Network (TANet) [8]. Each network domain is a campus network of college or university. The simulation parameters are listed in Table 1.

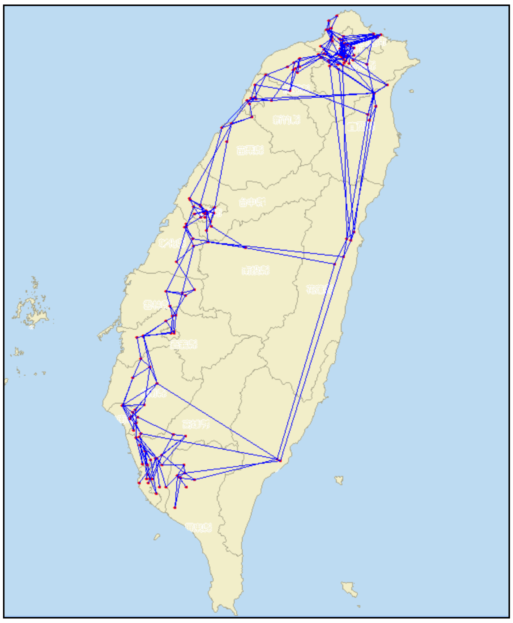

Figure 10. Network topology

The MN randomly moves between neighbor domains based on the network topology. The link cost is calculated as follow:

$$\text{Link Cost} = \text{transmission delay} + \text{propagation delay} = \frac{\text{packet size}}{\text{link capacity}} + \frac{\text{distance}}{\text{EM speed}} \ (\text{ms}) \quad (1)$$

TABLE I. SIMULATION PARAMETERS

Parameter	Value
Packet size of a signal	8 Kbits
Wire link capacity	100 Mbps
Wireless link capacity	54 Mbps
Wireless access distance	0.25 km
EM speed	299792.458 km/s
The number of domain	176

The threshold called TH_{RTT} is used to trigger THA handover. We use different threshold values to evaluate system performance listed in Table 2.

TABLE II. DIFFERENT THRTT THRESHOLDS

TH_{RTT}	Equation
Dynamic TH_{RTT}	1. $TH_{RTT} = 2 \times RTT_{MN\text{-}THA}$, $RTT_{MN\text{-}THA}$ is the initial threshold
Fixed TH_{RTT}	2. $TH_{RTT} = \text{avg. end-to-end delay}$
	3. $TH_{RTT} = \frac{\text{avg. end-to-end delay}}{2}$
	4. $TH_{RTT} = \frac{\text{avg. end-to-end delay}}{4}$

B. Simulation Results

Figure 11 shows the comparison of signaling cost between different approaches. We note that the average signaling overhead of DHA-LA reduces as the numbers of THA server increases. The signaling overhead is lower than ROMIP in most case because of localized registration. Dynamic TH_{RTT} achieves smaller signaling cost than fixed TH_{RTT} because higher threshold reduces the probability of THA handover.

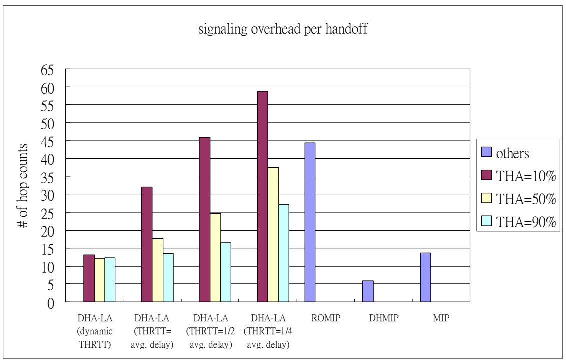

Figure 11. Comparison of signaling overhead between different approaches

Figure 12 shows the comparison of handoff latency between different approaches. In the MIP approach, binding messages are exchanged between the MN and HA result in highly handoff latency. In the ROMIP approach, the handoff latency is minimized by sending a binding update to the previous FA. DHMIP needs HA registration when the GFA changed. Therefore, the handoff latency is higher than ROMIP. Although the handoff latency of DHA-LA is higher than DHMIP and ROMIP, DHA-LA gains the benefit of partial deployment. Moreover, the average handoff latency of DHA-LA reduces as the numbers of THA server increases.

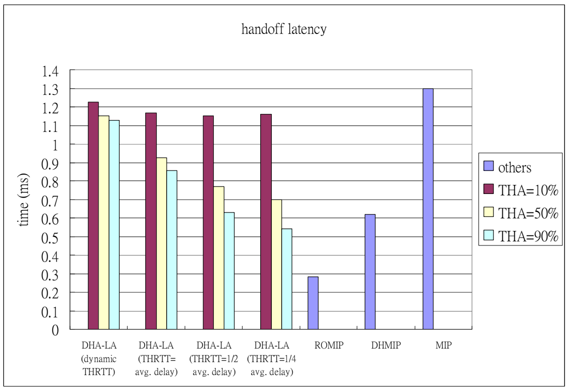

Figure 12. Figure Comparison of handoff latency between different approaches

Figure 13 shows the comparison of transmission time between different approaches. In ROMIP, packets are sent via directly route which is the best path. Thus, the transmission time is much lower in ROMIP approach. The triangle route problem occurs in the DHMIP and MIP approaches because the packets sent from CN are routed via HA. In DHA-LA, packets are sent through THA server. THA server is much close to the MN and the triangle route problem is reduced. Moreover, the performance of DHA-LA is close to ROMIP in higher THA server deployment.

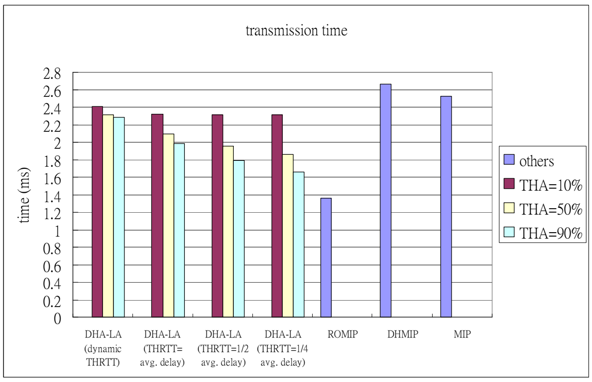

Figure 13. Comparison of transmission time between different approaches

VI. CONCLUSION

Most of the mobility management approaches demands all routers in networks to support mobility management functionalities. This paper proposes an adaptive mobility management scheme called Dynamic Home Agent with Location Awareness (DHA-LA). We attempt to implement the mobility management protocol on the application layer. Therefore, the DHA-LA could break the deploy limitation of general mobility management approaches and doesn't need to modify any routing devices in the Internet. DHA-LA proposes the advantage of partial deployment and resolves the problem of global THA discovery. Simulation results demonstrate that the performance of DHA-LA with partial THA deployment can be close to or better than other protocols that are fully FA established.

ACKNOWLEDGMENT

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