A Novel Domain Re-organizing Algorithm for Network-layer Mobility Management in 4G Networks

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Abstract—**The hierarchical mobile IP is efficient for reducing signaling overhead. However, since user mobility characteristics are always in changing, the pre-planned network topology would become invalid or even lead more signaling cost if no adjustment to be adopted. This paper introduces a novel domain re-organizing algorithm for mobile IP. When high handoffs frequency happens between two neighboring access routers, which are yet in the different domains respectively, domain re-organizing scheme will makes these two access routers into the same domain. In this way, the inter-handoff will change to intra-handoff. The simulation results show that the algorithm obviously reduces the signaling cost and handoff delay.**

Keywords: 4G networks, Mobile IP, Cellular mobile network, Mobility Management, Handoff, Domain Re-organizing

I. INTRODUCTION

Mobility Management is an integral functional aspect of mobile communication system. The main purpose of mobility management is to enable mobile terminals to communicate with each other continuously while moving – while minimizing data losses and satisfying the needs of demanding low-latency, isochronous, and real-time applications. The mobility management problems, including handoff, location update, paging, AAA and security, exist in physical layer, link layer and network layer of the mobile communication system. The traditional mobility management in current 2.5G and 3G mobile communication networks incorporating data services (such as GPRS, UMTS and CDMA2000) and public WLAN are loosely based on IP, but domain specific protocol make it difficult to implement inter-network roaming with real-time fast and seamless handoffs. However, clearly IP services are defacto across all these network and a mobility management framework based on IP makes the most practical sense.

IP technology performance fundamentals have improved to support voice, data and video services. Many universities, the IETF and IRTF began to research IP mobility support since 1990s. Standards for IP mobility have been developed and outlined in [1]. 3GPP and 3GPP2 also regard IP mobility as one of the key technologies of 3G and 4G networks.

The mobility management in legacy mobile communication system is fast, robust and reliable while mobility support of IP is universal, flexible and scalable. So the main purpose of Network-Layer Mobility Management (NMM) is to combine the advantages of mobile communication technology and IP technology to form an enhanced mobility management for next generation All-IP wireless/mobile Internet. By extending Mobile IP protocol, we have implemented the functions of hierarchical NMM including location update, fast handoff based on L2-trigger, IP paging and QoS control on Network Simulation platform (NS).

This paper is organized as follows. Section II gives the overview of Hierarchical Mobile IP. In Section III, an algorithm for domain re-organizing is provided and the scheme is described. After that, in Section IV, analytical results are presented, followed by the conclusions in Section V.

II. OVERVIEW OF HMIP

Hierarchical Mobile IPv6 (HMIPv6) aims to minimize the signaling cost and reduce the handoff delay using a local anchor point called Mobility Anchor Point (MAP). The MAP is a router located in a network visited by Mobile Node (MN), which is used by the MN as a local Home Agent (HA) and intended to limit the amount of Mobile IP signaling outside the local domain. The detailed protocol specification can be found in [2] and the general model of operation is illustrated in Fig. 1.

When an MN enter a MAP domain, whose boundaries are defined by means of the Access Routers (ARs), it performs a home registration with its HA. If the MN changes AR within a local MAP domain, it only needs to register the new address with the MAP. When MN changes ARs, which are located in different MAP domains, it needs to perform a home registration again.

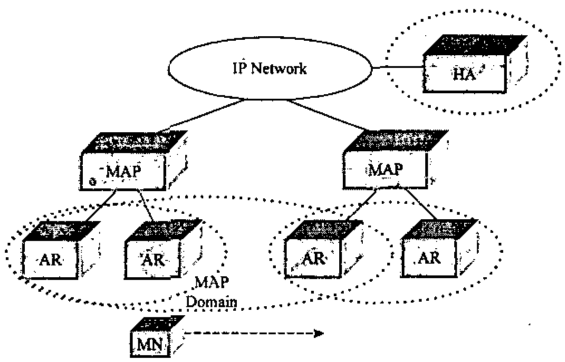

Fig.1 The general model of HMIP

The hierarchical mobile IP is efficient for reducing signaling overhead. However, since user mobility characteristics are always in changing, the pre-planned network topology would become invalid or even lead more signaling cost if no adjustment to be adopted. When high handoffs frequency happens between two neighboring ARs, which are yet in the different domains respectively, it will cause a lot of inter-domain handoff signaling cost and delay.

III. Domain Re-organizing Algorithm and Scheme

As mentioned above, domain re-organizing algorithm, which is based on real-time measurement of handoff strength, is to make different cells with highest handoff frequency into the same domain. In this way, the inter-domain handoff will change to intra-domain handoff and the signaling cost is limited in the local domain.

A. Domain Re-organizing Algorithm

Fig. 2 shows the cellular mobile network domain structure. The hexagon cells represent ARs and the ellipse is MAP domain.

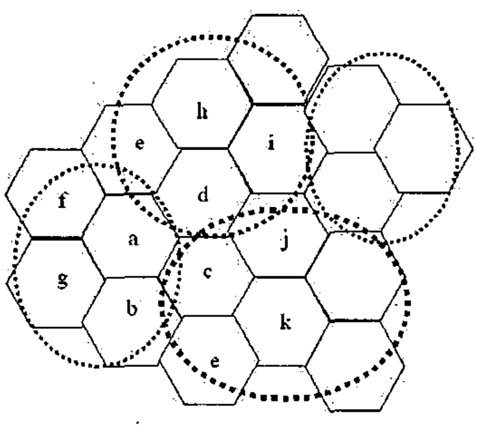

Fig.2 The cellular mobile network domain structure

The whole network can be described as a pre-planned cells set:

$AN = \{a,b,c,d,e,f,g,\ldots\}$

The pre-planned MAP domain set is:

$MN = \{(a,b,g,f),(d,e,h,i),(c,e,j,k),\ldots\} = \{M_1, M_2, M_3, \ldots\}$

The set of neighbor cells of special cell is:

$N(i), i = a,b,c\cdots j$; (e.g., $N(a) = \{b,c,d,e,f,g\}$)

Define $H_{i,j}(t)$ as the handoff times between cell i and cell j during t, where $t = T_N - T_1$. And $H_{i,j}(t)_{intra}$ is the intra-handoff times, $H_{i,j}(t)_{inter}$ is the inter-handoff times. If the neighbor cells set of i is $N(i)$, the handoff times happened in cell i during t is:

$$H_i(t) = \sum_{j\in N(i)} H_{i,j}(t) \quad (1)$$

$$H_i(t)_{intra} = \sum_{j\in N(i)} H_{i,j}(t)_{intra} \quad (2)$$

So the relative handoff frequency between cell i and j is:

$$HF_{i,j}(t) = \frac{H_{i,j}(t)}{H_i(t)} \quad (3)$$

Assume that the number of the neighbor cells of i is n_i. The cells, whose relative handoff frequency is greater than λ / n_i (λ is a weight factor) and which are not under the same MAP domain as i, make up of tight neighbor cells set $N_t(i)$. The tight neighbor cells represent the high inter-handoff frequency cells with i.

Then, assume that j is one of cells in $N_t(i)$ and to be re-organized into the same MAP domain as i. λ_1 is the cost factor of intra-handoff and λ_2 is factor of inter-handoff ($\lambda_2 \geq \lambda_1$). So the benefit gained from the domain re-organizing algorithm can be expressed as:

$$B_{i,j}(t) = (\lambda_2 - \lambda_1) \times (H_{i,j}(t) - H_j(t)_{intra}) \quad (4)$$

When $B_{i,j}(t) > k (k > 0)$, the domain re-organizing scheme will be performed.

B. Domain Re-organizing Scheme

We take the cellular mobile network structure described in Fig. 2 for example. At the beginning, cell a performs neighbor discovery based on handoff information between cell a and its neighbor to come into being the set of neighbor cells:

$N(a) = \{b,c,d,e,f,g\}$

After t, where $t = T_N - T_1$, cell a counts the relative handoff frequency with cells which are in the set of neighbor cells according to Eq. 3.

$$HF_{a,j}(t) = \frac{H_{a,j}(t)}{H_a(t)}, (j \subseteq N(a))$$

Thereinto, cell d and e, whose relative handoff frequency is greater than $\lambda / 6$, make up of the tight neighbor cells set $N_t(a)$.

Thus, the benefit of cell d and e gained from the domain re-organizing algorithm can be expressed respectively as following:

$$B_{a,d}(t) = (\lambda_2 - \lambda_1) \times (H_{a,d}(t) - H_d(t)_{\mathrm{intra}}) \quad (5)$$

$$B_{a,e}(t) = (\lambda_2 - \lambda_1) \times (H_{a,e}(t) - H_e(t)_{\mathrm{intra}}) \quad (6)$$

Because $B_{a,d}(t) > k, B_{a,e}(t) > k (k > 0)$, but $B_{a,d}(t) > B_{a,e}(t)$, cell d is chosen to be re-organized into the same MAP domain as cell a.

The domain re-organizing scheme is shown in Fig. 3:

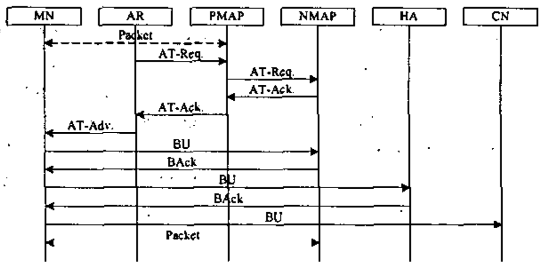

Fig.3 Domain re-organizing scheme

1) Cell d (AR) sends message AT-Req. to its original MAP (PMAP); If PMAP finds no other cells is performing the re-organizing scheme now, it will send the message AT-Req. to the destination MAP (NMAP) whose domain cell d is going to join in.

2) NMAP updates the domain set and sends the AT-Ack message back to the PMAP and PMAP sends the AT-Ack message to cell d.

3) Then cell d updates its MAP address and broadcasts the AT-Adv. message periodically, which includes the new MAP address.

4) The MNs who are in dormant state will register with the new MAP; and the other MNs who are in active state keep communications with correspond node using the original local care of address (LCoA). And after a period of time, all the MNs will register with the new MAP.

IV. Simulation Scenario and Result Analysis

We have given the proposal of hierarchical network-layer mobility management (HNMM) and built the framework based on Network Simulator version 2 (NS2). By extending Mobile IPv6 protocol, we implements the functions of mobility management including location update, fast handoff based on L2-trigger, IP paging and QoS control etc.

The domain re-organizing algorithms and scheme have also been implemented in HNMM framework. Performance evaluation results are to be given here. The simulation area is an $400m \times 400m$ area with seven 802.11b wireless access points. Radio transmission range is 100m and Cell overlap distance is 20m. Data rate is 11Mb/s. A free space propagation channel model is assumed. The pre-planned MAP domain set is shown as Fig. 4. The neighboring ARs are divided into groups and construct the MAP domains. For example, Cells 1,3 are belonging to MAP1 domain; cells 2,5 are MAP2 domain and cell 4,6,7 are MAP3 domain. The MAPs are connected with Cells (ARs) through 10Mb/s fixed link, whose delay is 2ms. And another two host nodes are connected with these wired-wireless network through routers with 100Mb/s bandwidth and 16ms total link delay, one acts as the HA and the other is a TCP traffic producer.

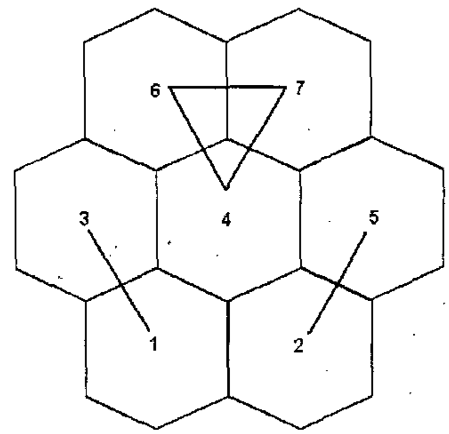

Fig.4 Pre-planned MAP domain set

There are 28 MNs in the simulation area. Among those, there are 20nodes (N1) reciprocate along the breadth with an even speed in the simulation area of MAP1 and MAP2. And other 8 nodes (N2) obey the four-direction random mobility model. N1 presents the hot spot with high handoffs frequency happens between two neighboring cells, which will trigger the domain re-organizing algorithm. The Fig. 5 shows the traces of all MNs. We select two durations before and after domain re-organizing scheme to make analysis.

Fig.5 Traces of all MNs

The improvement of signaling cost after domain re-organizing scheme is shown in Fig.6, in which the speed of MNs changes between 4m/s to 16m/s.

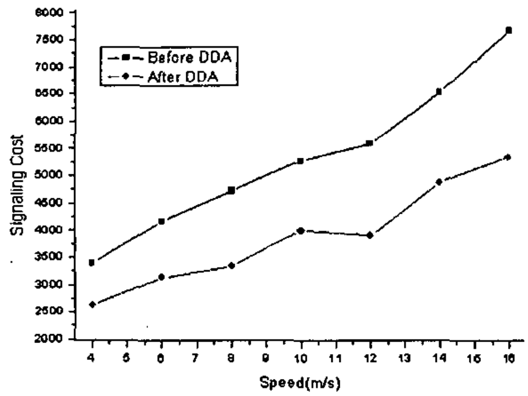

Fig.6 Signaling Cost vs. Speed of MNs

And also, Fig.7 shows handoff delay of every MNs. All the handoffs happen in the two durations we study. The speed of MN is 10m/s. And the system average handoff delay before re-organizing scheme is 39.5ms. But after re-organizing scheme, the system average handoff delay is improved obviously and the value is 12.4ms.

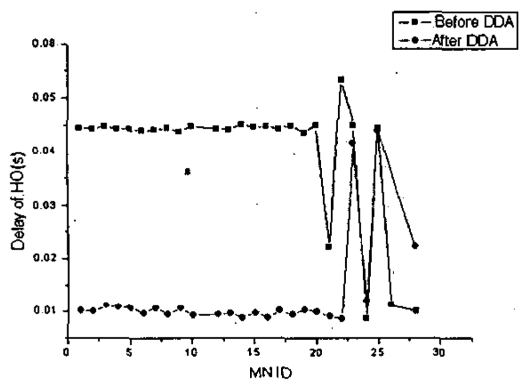

Fig.7 Comparison of handoff delay before and after reorganizing scheme

As mentioned above, it is obvious that the results, which are got by using the domain re-organizing algorithm, outperform that without using.

V. CONCLUSIONS

This paper presents a novel domain re-organizing algorithm and scheme for Hierarchical Mobile IP. The algorithm makes those two neighbor ARs, which have high handoff frequency but are located in different MAP domain, into the same domain. In this way, the inter-handoff will change to intra-handoff. The simulation results show that the algorithm obviously reduces the signaling cost and handoff delay. In the next step, we will dive on it deeper and need to establish more realistic models before anyone can be convinced that this can really work.

ACKNOWLEDGEMENT

This work is supported by Intel Research Council under Grant No. 14765.

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