Performance Study of Hierarchical MIPv6 with Dynamic MAP Grouping

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ABSTRACT

In this paper we extend the concept of abstract MAP (AMAP) node proposed in [6] so that the grouping of MAP nodes can be dynamically configured. As the higher MAP has wider coverage and may accommodate more mobile nodes, the issue of dynamic grouping is initiated by the higher MAP. And whether the grouping is allowed or not depends on the load condition of MAP nodes. In addition, for a mobile node, the dwelling time in an AR is also refined so that the mobile node can select a more appropriate MAP. Our simulation results show that the proposed scheme can effectively reduce the number of local binding updates and the AMAP can achieve the load balance among MAP nodes.

1: Introduction

Several kinds of services and applications supported over Internet lead to a great increment in both numbers of the Internet users and information providers. As the number of devices connecting to Internet increases, demand of IP address becomes imminent accordingly. The IP protocol version 6 (IPv6) is, therefore, treated as the most convincing protocol for the coming third generation (3G) all-IP network due to its large addressing space. In order to provide always-connected service, the technologies of mobility management were proposed for the provisioning of seamless handoff during the movement of mobile devices. The basic idea of mobile IP is to use the home agent (HA) of the mobile node (MN) as a registration point for the care-of-address (CoA) of the mobile node when it visits a foreign network. Any node can then send packets to the mobile node through HA by using the tunneling path from HA to MN. Furthermore, the route optimization (RO) approach was proposed for the direct path between the correspondent node and the mobile node [1, 2]. When comparing to IPv4, the newly deployed version 6 protocol has a more overall consideration in providing mobility management. For examples, the route optimization is performed as a fundamental part in mobile IPv6; the security protocol (IPSec) is used for the protection of binding update messages among mobile node, correspondent node, and home agent; the auto-configuration mechanism makes the obtain of care of address more easily; the extension headers provides a more flexible way in dealing with the problems may caused by RO; etc.. Although the route optimization can provide the direct transmission path from correspondent node (CN) to the mobile node, the process of binding update is complex because the procedure of return routability is necessary in RO for security consideration. And this procedure shall be performed whenever the mobile node moves into a new foreign network. Therefore, even by using RO, the quality of service may also be affected if a mobile node is moving in high speed.

In order to improve the performance during handoff in mobile IPv6 environment, the fast handoff procedure [3] was proposed to deal with the configuration of CoA, duplicated address detection (DAD), etc., in advance so that the handoff latency can be reduced; and the hierarchical mobile IPv6 (HMIPv6) [4, 5] was proposed to reduce the number of binding updates during the movement of mobile node by selecting a suitable mobility anchor point (MAP). The fast handoff procedure is only suitable for the environment that the access router (AR) of the mobile node being to go visit is predicable (e.g. train, car in the freeway, etc.). This issue is not the major constraint for the HMIPv6 environment and, therefore, HMIPv6 is more applicable for the mobile node with random movement (e.g. car/people moving around in the city). In this paper, we focus on the issue of the selection of MAP in HMIPv6. Both of the moving speed of mobile node and the load balance among MAP nodes are the most important criteria for the selection of MAP in HMIPv6. Generally, a higher layer MAP, if its load is sustainable, is more appropriate to be assigned for the nodes with higher mobility so that its number of binding update can be minimized. Several studies have been devoted to this issue recently. Most of them select the MAP for a mobile node by estimating the moving speed of the mobile node. However, the estimated moving speed may have large difference with the actual speed because the speed is estimated from the dwelling time in previous AR and the coverage of that AR. A low speed moving node may also have very short dwelling time in an AR with wide coverage.

In [6], we proposed the concept to group a number of MAP nodes into an abstract MAP (AMAP) so that the management domain of location can be enlarged. However, the size of AMAP proposed in [5] is fixed and is inflexible to be adjusted with respect to the moving behavior of mobile nodes. In this paper, we extend the fixed AMAP to be dynamically configured according to the moving behavior and the load of MAP nodes. Furthermore, the estimation of dwelling time of mobile node in an AR is also refined so that the mobile node can select a more suitable MAP to improve the overall network performance. This paper is organized as follows. In the following section, the operation scenario of MAP and related studies are briefly reviewed. The proposed schemes of dwelling time estimation and the establishment and release of an AMAP are stated in section III. In section IV, we examine the performance of the proposed scheme through simulations. And, finally, conclusions are provided in the last section.

2: Overview Of Hierarchical MIPv6

As mentioned in previous section, too frequent binding updates will suffer the quality of services of real time applications. The basic concept of HMIPv6 is to deal with the binding update procedure in a hierarchical way. A router is chosen by the mobile node as an anchor point, i.e. MAP, for binding update. Two kinds of CoA are defined in HMIPv6. The regional care of address (RCoA) can be treated as the address of MAP supported for the mobile node and this address is also used by the mobile node for binding at its HA and correspondent node (CN); while the on-link care of address (LCoA) is used as an identification of the mobile node within the MAP coverage. The router advertisement (RA) with MAP option is periodically sent from the highest AR to the lowest AR and to inform the mobile nodes of the status, including validness, preference, distance, etc. for each MAP. And the mobile node can select a suitable MAP for binding when it moves into a new network. Thus, once the mobile node has informed HA and CN about its current RCoA through binding update, there is no need to perform binding update when MN changes AR within the MAP coverage domain. And when MN moves into a new AR and obtains a new LCoA, it only needs to inform its MAP for LCoA update. Thus, MAP shall maintain a mapping table for each pair of RCoA and LCoA. Packets destinated to MN will, therefore, be routed to MAP according to RCoA firstly, and MAP will tunnel the packets with LCoA of MN, by referring to the mapping table, and forward to MN. So, if MN travels within the area of its MAP domain, MN may have different LCoA, it does not require to inform its HA and CN for binding update because its RCoA does not change. The operation procedure is illustrated in Figure 1. In Figure 1, it shows that when the mobile node moves with micro mobility it only needs to perform local binding, however, both of local binding update and remote binding update are required if macro mobility is happened. As the network is hierarchically constructed in HMIPv6, it is easy to deduce that if a higher layer MAP is selected for a mobile node, then this mobile node will have a wider MAP domain. A wider MAP domain means that the frequency binding update performed by this mobile node can be reduced because the RCoA of the mobile node is not changed. However, a higher layer MAP needs longer latency for registration LCoA when the mobile node changes AR within a MAP domain and, according to the characteristics of hierarchical topology, the number of AR decreases as the hierarchical level is getting higher.

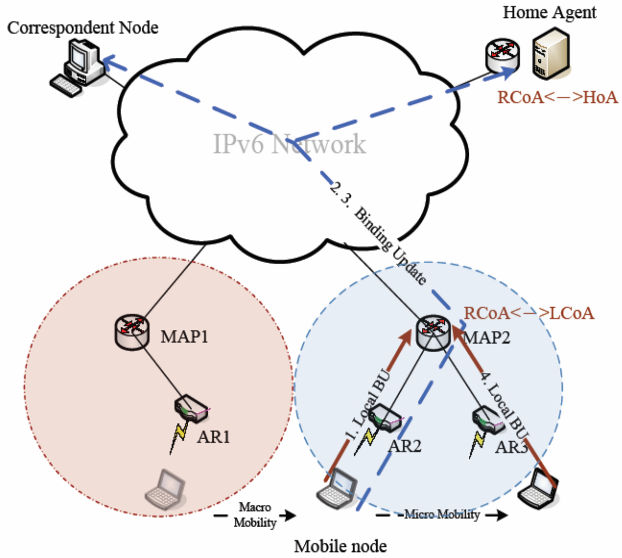

Figure 1 Operation procedure of HMIPv6

On the contrary, it is not appropriate to assign the highest MAP for all mobile nodes within this MAP domain. Because MAP shall execute the translation of RCoA and LCoA, packet encapsulation for tunneling, etc. and the QoS of packet delivering will be suffered if the MAP is overloaded. The load balance issue shall be considered among MAP nodes. Therefore, a reasonable approach is to assign higher level MAP for the mobile nodes with higher moving speed and the slow mobile nodes select lower level MAP.

3: Dwelling Time Estimation and AMAP Configuration

3.1 Dwelling Time Estimation

According to the descriptions in section 2, mobile nodes with higher moving speed are better to arrange higher MAP node. Therefore the speed estimation of mobile node is a key issue for the selection of a appropriate MAP node. The speed is normally estimated through the statistics of the dwelling time in ARs. However, the estimation may also cause large estimation error especially when the travel distance of the mobile node in the AR is much shorter than the set standard distance *d*. Thus, the dwelling time may not reflect the actual speed. For example, as shown in Figure 2, assume the mobile node is moving in a constant speed, the dwelling time of the mobile node in AR2 is quite shorter than that is in AR3.

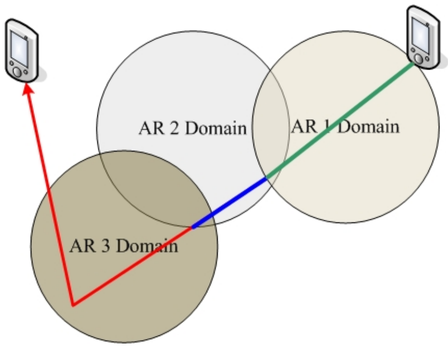

Figure 2 Difference of dwelling time in AR

Generally, the AR with Mobile IPv6 capability shall periodically advertise its prefix, named route advertisement (RA), for address auto-configuration. The mobile node can use this information to a MAP node may cover several ARs and the dwelling time can be calculated depending on the receipt of RA message of RA that is sent by current AR. The average moving speed of mobile node can be derived the division of the diameter of the coverage of an AR and the average dwelling time in an AR. And, normally, the average dwelling time in an AR is the average of dwelling time measured from the traveling over latest consecutive ARs. However, large difference may cause if the travel distance of the mobile node in the AR is much shorter than the set standard distance *d* as shown in Figure 2. In this paper, we propose a probabilistic MAP selection scheme, named probabilistic hierarchical MIPv6 (PHMIP), to deal with this issue. The proposed PHMIP scheme takes the average dwelling time and the frequency of handoff (change of MAP) into considerations. In order to reduce the estimation error, we suggest to eliminate the largest and the smallest dwelling time when performing average. Thus,

$$dwell\_time\_\mu = avg(eliminate\ the\ Max\ and\ Min\ by\ ratio)$$

In addition, a mobile node may travel over a number of AR, however, it does not need to change MAP because those ARs are within the same MAP domain. So, the frequency of changing MAP shall be considered as a heuristic to determine whether it is necessary to allocate a higher MAP for it. In PHMIP scheme, we define a parameter $\mathrm{P}_{\mathrm{MAPHO}}$ to indicate the probability of changing to a new MAP as follows

$$P_{MAP\_HO} = \frac{number\_of\_MAP\_handover}{number\_of\_MAP_{nearest}\_change}$$

By using the average dwelling time and the probability of changing MAP, whether the mobile node needs to switch to a lower level MAP is determined by its dwelling as well as the probability $\mathrm{P}_{\mathrm{MAPHO}}$. The procedure of PHMIP is illustrated in Figure 3. It is noted that the parameter α is treated as the control threshold of $\mathrm{P}_{\mathrm{MAPHO}}$.

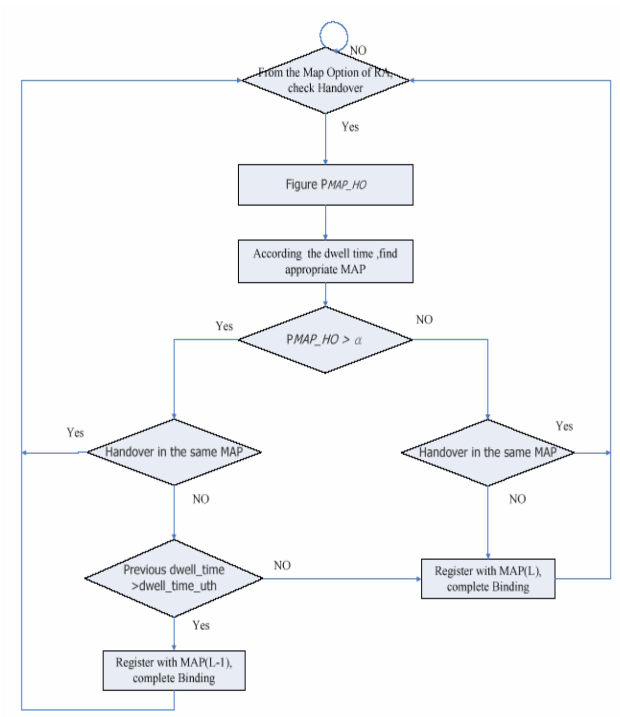

Figure 3 Procedure of PHMIP

3.2 Dynamic Configuration of AMAP

In order to construct the abstract node and to inform mobile nodes that which MAP nodes are grouped as an abstract node, we add two fields, one bit for indicating add to this group (A) and three bits for auxiliary binding ratio (ABR), in the reserved part of the MAP option message in neighbor discover extension in the IETF RFC [4]. The modified MAP option message is shown in Figure 4. The field A is a indication bit to signal the its downstream AR to add to this abstract node; and the size field (in hop count) is to specify the scope of the abstract node. And the ABR field is to indicate the load condition of the mobile node.

Type	Length	Dist	Pref	R	A	ABR	Resv
Valid Lifetime							
Global IP address for MAP							

Figure 4 Modification of MAP option message

Basically, the preference field (Pref.) of the MAP option message is designed to inform the following MAP nodes of its priority being selected. In our scheme, this field is attached with a more semantic meaning. We reflect the load condition of the MAP in this field.

When the MAP node is overload, it will establish the AMAP with its child. A higher level MAP node will send NS to query lower level MAP node about the load of its successors for their load and decide whether to invite them for grouping or not. If AMAP is established, the higher level MAP will add the MAP option of the invitation to its RA. The invited node will return its load by NA frequently until the RA is not including its MAP option. The query/response procedure is illustrated in Figure 5. If all lower MAPs are overload, the AMAP will not be establish. The mobile node will choose the higher MAP (if this higher level MAP can offer it).

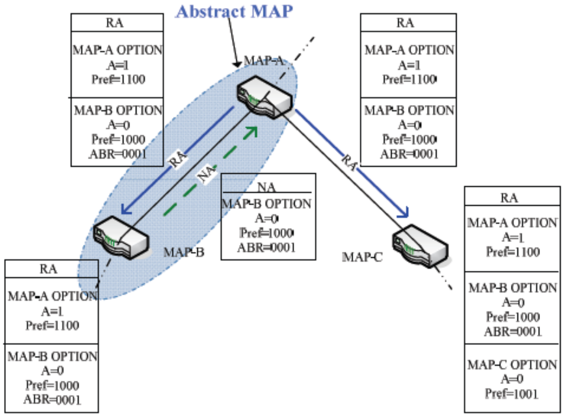

Figure 5 The query/response procedure for grouping

Although the AMAP has the advantage of extending the management domain for lower level MAP, the routing overhead occurred because packets may be routed to the MAP, whose original management domain does not cover the current location of the mobile node, and forward to its current AR. This backward and forward phenomenon is depicted in Figure 6.

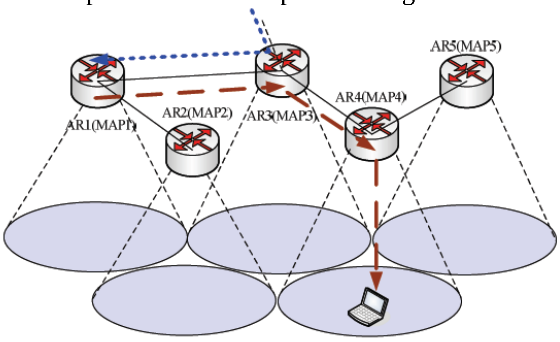

Figure 6 Overhead of routing in backward and forward

In order to reduce the overhead of backward/forward, the AMAP shall be able to release a MAP node from an AMAP. The proposed criteria of releasing a MAP node are separated into two cases:

(1) The master node of AMAP (i.e. the higher level MAP of an AMAP) finds that load of its sponsor MAP node is overload through the "Pref." field of the RA message periodically advertised by MAP nodes.
(2) The master node of AMAP finds that the routing cost (especially caused by the backward and forward phenomenon) exceeds a predefined threshold. The routing cost is defined as

$$Cost_{re-routing\_bw\_ratio} = ABR_{maximum} \times \frac{2delay(master \rightarrow member) + delay(master \rightarrow AR_{farthest})}{delay(master \rightarrow AR_{farthest})}$$

If either of the above cases is occurred, the master node will initiate the release procedure by using the MAP option message.

4: Simulations

The performance of the proposed scheme is examined through exhaustive simulations by using ns2. A three-level MAP topology, as shown in Figure 7, was adopted during our simulation. We assume the mobile nodes are moving according to the random waypoint mobility model [8] with either high mobility or low mobility as shown in Table 1.

Table 1 Parameters of high/low mobility

MH Speed Type	Speed(m/s):Uniform distribution	Mean of dwell time
High mobility	8-19	125
Low mobility	2-5	25

Three schemes were simulated and compared. The BHMIP scheme is the traditional scheme and it always chooses the highest level MAP node, which is not overloaded, as the anchor point. The PHMIP and PAMAP are our proposed schemes, where PHMIP only adopts the dwelling time estimation and probabilistic MAP change (without AMAP). The simulations results of success ratios of local binding updates (LBU) for the high mobility environment (80% of mobile nodes are with high mobility) and low mobility environment (20% of mobile nodes are with high mobility) are depicted in Figure 7 and 8, respectively. It indicates that the proposed scheme has higher successful ratio especially for the high mobility environment. The main reason is that the BHMIP scheme can neither allocate appropriate MAP to the MN nor can group MAP nodes to extend the management domain.

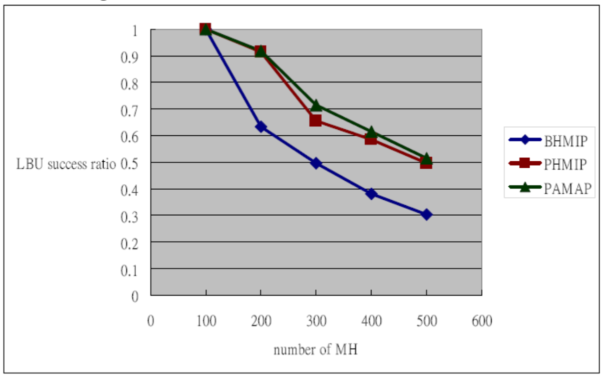

Figure 7 Success ratios of LBU for high mobility

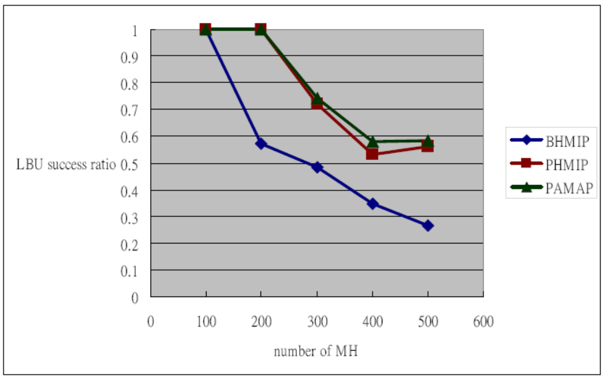

Figure 8 Success ratios of LBU for low mobility

The latency of LBU is depicted in Figure 9. It shows that the proposed scheme has better performance than the traditional BHMIP scheme. In addition, we also found that the latency of the proposed scheme is less sensitive to the increase of number of MN because the proposed scheme can choose the appropriate MAP node and configure AMAP to share the load.

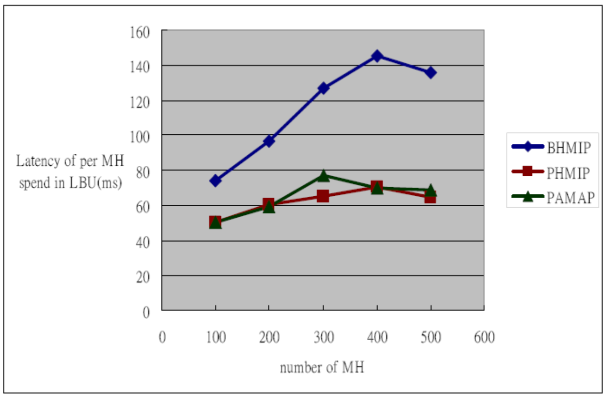

Figure 9 Latency of LBU in high mobility environment

The performances of load balance for the BHMIP and PAMAP scheme under high mobility environment are illustrated in Figure 10 and 11, respectively. As the proposed scheme takes the load into consideration during the selection and grouping of the MAP nodes, it demonstrates that the proposed scheme is superior to the traditional scheme.

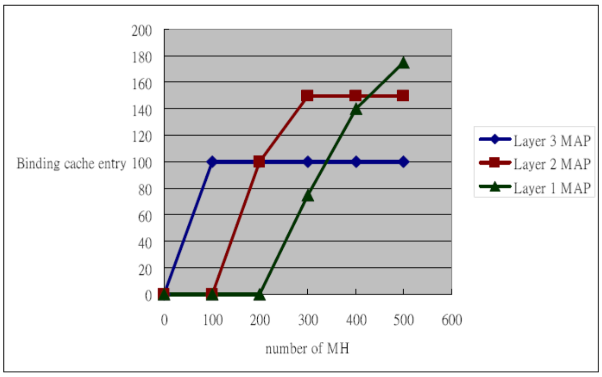

Figure 10 Load distribution among different levels MAP for BHMIP scheme

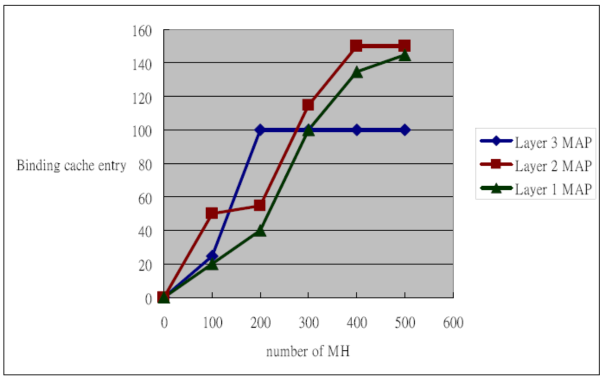

Figure 11 Load distribution among different levels MAP for PAMAP scheme

5: Conclusions

In this paper, we proposed an integrated dwelling time and probabilistic MAP change scheme for the selection of a appropriate MAP in mobile IPv6 environment. Furthermore, the concept of AMAP in [5] is extended for dynamic configuration. Our simulation results illustrate that the proposed scheme can achieve the better performance in selecting an appropriate MAP node and distributing load among MAP. Future researches may focus on the integration the HMIPv6 and the fast handoff procedure in a more smooth way so that the frequency and latency of handoffs can be more reduced.

Acknowledgement

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