Adaptive MAP Selection with Load Balancing Mechanism for the Hierarchical Mobile IPv6

Ying-Hong Wang, Chih-Peng Hsu* and Chien-Shan Kuo

Department of Computer Science and Information Engineering, Tamkang University, Tamsui, Taiwan 251, R.O.C.

Abstract

The Hierarchical Mobile IPv6 (HMIPv6), which is drawn up by the IETF (Internet Engineering Task Force), utilizes the Mobile Anchor Point (MAP) to reduce the considerable number of binding update (BU) messages among the mobile node (MN), the correspondent node (CN), and the home agent (HA). According to the HMIPv6 mechanism, the MAP of higher layer can efficiently reduce the frequency of performing binding update; the higher loading of service is the bottleneck of the whole network. Because the bandwidth of the MAP which can serve is finite, the whole network will be crashed due to the overloading if the MAP serves as the gateway at the same time. This paper proposes a MAP selection mechanism that takes the mobile node's particular characteristics which include the mobility velocity and quantity of communication services into consideration, the proposal can manage the MAPs efficiently. Besides, we design a MAP load balancing mechanism to avoid the network crash due to the overloaded MAP.

Key Words: Hierarchical Mobile IPv6, MAP Selection, Load Balancing, Binding Update, Home Agent

1. Introduction

The Hierarchical Mobile IPv6 (HMIPv6) [1] was proposed by Internet Engineering Task Force (IETF) to decrease the signaling overhead that is incurred in Mobile IPv6 networks when mobile nodes (MNs) perform handoffs frequently. In HMIPv6 networks, the mobility anchor point (MAP) is utilized to decrease the number of binding update (BU). In other words, the goal of MAP is to localize the handoff and therefore the MAP could reduce the amount of whole network signaling traffic for mobility.

In HMIPv6 networks, an MN configures two care-of-address (CoAs): a regional care-of-address (RCoA) and on-link care-of-address (LCoA). An RCoA is an address on the MAP's subnet. The MN configures an RCoA when it receives a Router Advertisement (RA) message with MAP option. On the other hand, the LCoA is the on-link CoA configured on the MN's interface based on the prefix advertised by its access router (AR).

Figure 1 illustrates the operations of HMIPv6. When the MN enters the MAP domain, it will receive the MAP option message and configure the RCoA and LCoA. Then the MN immediately performs the procedure of binding update to its home agent (HA), which will bind the MN's home address and RCoA, and that of local binding update to the MAP, which will bind the MN's RCoA and LCoA. If the correspond node (CN) communicates with the MN, the procedure is as the following steps. Step 1: because the CN's binding cache does not have the latest address of MN, the packet is sent to the MN's HA. Step 2: the HA tunnels the packet to the MAP. Step 3: the MAP tunnels the packet to the MN. Step 4: the MN receives the packet and performs the procedure of binding update to the CN, which will obtain the MN's RCoA. Step 5: because the CN has known the MN's latest address, it can send the packet to the MAP directly. Step 6 is the same as the step 3.

*Corresponding author. E-mail: 892190090@s92.tku.edu.tw

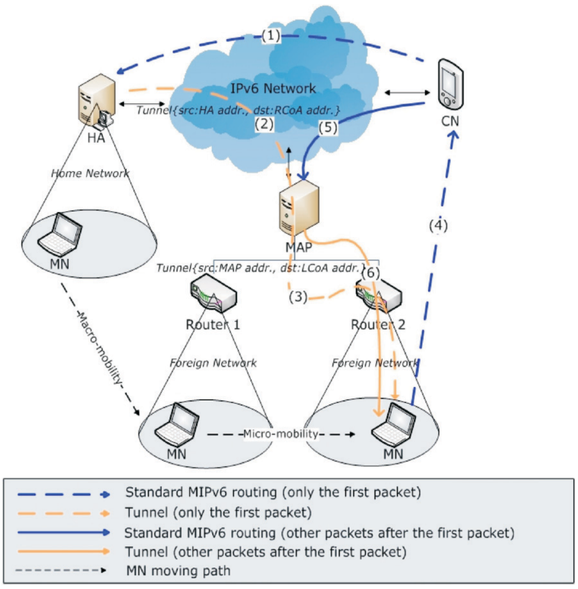

Figure 1. The operations of HMIPv6.

In the above operations of HMIPv6, the MAP acts like the MN's local home agent so that it receives all packets which are sent to the MN and tunnels them to the MN. In the case of multiple MAPs, if the MN moves out the current MAP domain, it needs to select another MAP and to register with the new MAP.

Multilevel HMIPv6 network has multiple MAPs, each MAP can exist at any level in the network hierarchy including at the leaf level of the AR, and several MAPs can be located at the same level and function independently without interfering with each other. However the higher MAP has wider service domain, so it can efficiently reduce the frequency of the MN's handoff. Therefore, it is important for the MN to select the suitable MAP in multilevel HMIPv6 networks.

The remainder of this paper is organized as follows. Section 2 introduces common MAP selection mechanisms in detail. The research proposes the dynamic MAP selection mechanism via analyzing the MN's particularities in Section 3. Section 4 is about the simulation results. Section 5 concludes this paper.

2. Related Works

How an MN selects an appropriate MAP, which plays an important role in optimizing the location update and packet delivery procedures and reducing the signaling overhead in the networks as a whole, is an important issue. Many researchers have been devoted to solving it in recently years. In general, MAP selection mechanisms can be classified into three categories: distance-based mechanism, velocity-based mechanism and topology-based mechanism. Besides, the load balance of MAPs is also important. Because balancing each MAP's load is good for the stability of the whole network and can avoid some MAP from breaking down.

2.1 Distance-Based Mechanism

Distance-based mechanism is mentioned in the HMIPv6 specification [1]. That each MN selects the furthest and available MAP is the principle of the distance-based mechanism. An MN can obtain the hop distance between the MAP and itself from the DISTANCE field in the MAP option message, and then MN selects the furthest MAP to register. Figure 2 illustrates the operations of MN selecting MAP.

However, this mechanism has some disadvantages. First, the furthest MAP may be close to or even served as the gateway of the foreign network. Therefore, if each MN selects the furthest MAP, the MAP will become a bottleneck of the networks because of its overload. Second, if the MN moves only few or limited area within the foreign network, it is unnecessary to select the furthest MAP to register. In this condition, registering with the furthest MAP will increase the registration delay because the hop distance between the MN and the furthest MAP is comparatively larger than that between the one and the closer MAP.

2.2 Velocity-Based Mechanism

MAP selection mechanisms are based on the MN's

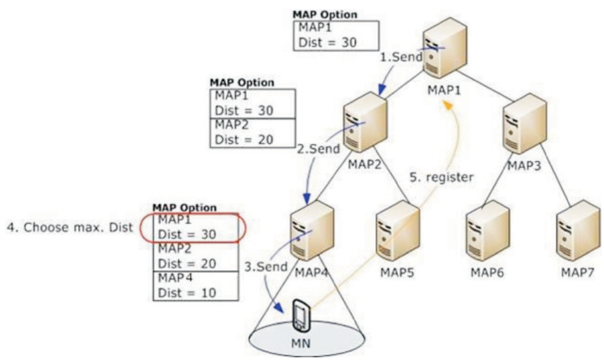

Figure 2. The operations of MN selecting the furthest MAP in distance-based mechanism.

velocity [2–5]. In these velocity-based mechanisms, there are two main steps: the estimation of MN's velocity and the selection of suitable MAP to register. The key point is how to estimate the MN's velocity because it is difficult to calculate the precise value of velocity. In other words, the estimated velocity is not the actual velocity. In order to overcome the extreme error of estimated velocity, using the historical velocity to emend is the recommendable method. When the MN's velocity is estimated and then the MN can select suitable MAP by the selection table that records the mapping relation between the mobility type and correspond MAP.

2.3 Topology-Based Mechanism

Because the accurate velocity of MN is hard to estimate, topology-based MAP selection mechanism uses the MAP topology instead of the estimation of velocity [6,7]. Kumagai [6] designs the mobile history to record two pieces of information: the IP address of ARs and the time which the MN visited. Each MN holds its mobile history and sends the mobile history to the new AR when entering its coverage. When the AR receives the mobile history, then it calculates the area-covered rate of each upper MAP. If some MAP has the largest value of area-covered rate, the MN registers with it.

2.4 MAP Load Balance Mechanism

Masaki [8] adopts the concept of distributed location management to design MAP load balance mechanism. Each MAP has its maximal service quantity. If an MN selects the MAP whose service quantity reaches its upper bound, the registration message will be forwarded to the next MAP candidate. Besides, the MAP load balance mechanism makes use of the number of hop to extend each MAP's service coverage. Figure 3 illustrates the registration (binding update, BU) condition of the MN in different MAP's domain. In Figure 3, we assume that the number of hop is two and the MAP 2, MAP3 and MAP4 received MAP1's MAP option message initially.

However, this mechanism has several drawbacks. First, the value of hop number is hard to determine. Because if the value of hop number is too large, the MAP will has extreme overload and the packet delay will be much longer. On the other hand, the performance of MAP load balance will achieve little. Second, if some MAP reaches high load (even close to crash because of its overload), the mechanism can't balance the MAP's load instantly.

3. Dynamic MAP Selection Mechanism

In this section, we proposed a dynamic MAP selection mechanism that takes an MN's particular characteristics which include the mobility velocity and quantity of communication services into consideration. Because the performance of the HMIPv6 networks relies on the session activity and mobility, the cost of packet delivery and the number of binding update can't be passed over. Besides, the dynamic map selection mechanism also integrates the MAP load balance mechanism which improves the disadvantages of the method which Masaki proposed in [7]. Figure 4 is the overview of proposed mechanism

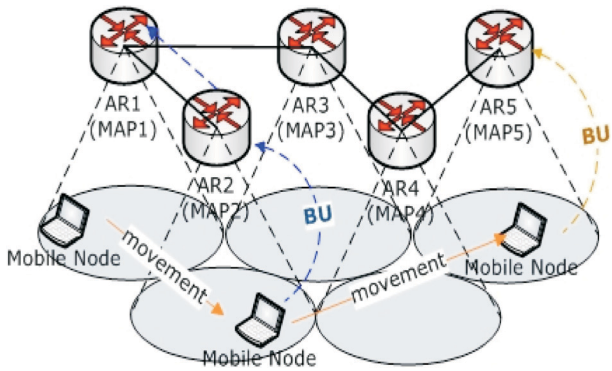

Figure 3. The registration condition of the MN.

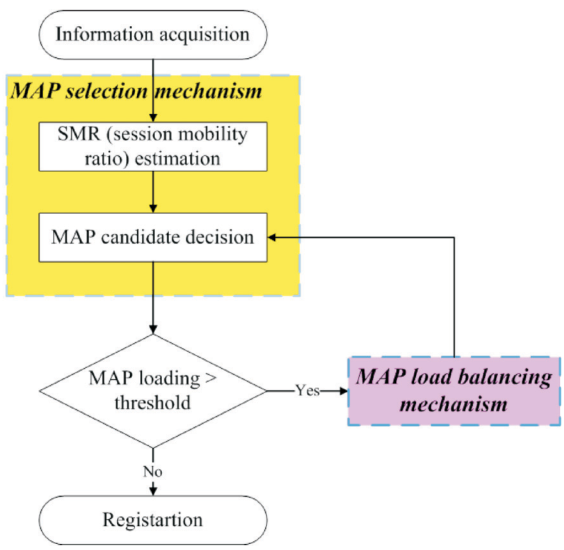

Figure 4. The overview of the dynamic MAP selection mechanism.

which contains four phases: (1) information acquisition, (2) MAP selection, (3) MAP load balancing, and (4) registration.

3.1 Information Acquisition

In the multilevel HMIPv6 networks, an MN receives multiple RA messages which contain the corresponding MAP's information. Then the MN can make the MAP list and create an information table which includes available information from the MAPs (i.e. the hop count and the MAP's loading).

3.2 MAP Selection Mechanism

The procedure of MAP selection mechanism has two steps: the estimation of SMR (session mobility ratio) and the decision of the suitable MAP candidate. First, the SMR of an MN is defined as follows:

$$\mathrm{SMR} = \frac{\text{session arrival count}}{\text{mobility rate}} \tag{1}$$

where session arrival count means that the amount of ongoing session of the MN, which could be calculated by MN itself; and mobility rate expresses as the AR's coverage is divided by the dwell time which the MN within in the AR's coverage.

If the value of SMR is smaller than a threshold, the MN shall registers with the higher level MAP. Because the mobility is relatively larger than the number of session arrival, it will lead to the higher cost of binding update in this condition. On the other hand, the MN registers with the lower level MAP because of reduction of transmission delay. We consider that the power saving of each MN so that the MAP need to maintain the threshold of SMR. Therefore the MAP could offer more services under it's maximum loading. The research focuses on the estimation of MN's velocity in order to keep the extreme error away. For example, we assume that MN moves at the same velocity in the scenarios such as Figures 5 and 6. However, the estimation of velocity in the former scenario is more than the later one (according to the circle illustrated in each figure).

The research adopts the historical velocity of MN to rectify the incorrect estimation as follows:

$$e\_speed_{MN} = (1-\alpha)\times e\_speed_{est} + \alpha\times e\_speed_{his} \tag{2}$$

where e_speed_{est}, e_speed_{his} and e_speed_{MN} are the estimation of velocity, the historical velocity of MN and the reliable estimation of velocity. Especially, the e_speed_{his} is defined as the average of collection that collects MN's all previous velocities no more than one standard deviation. Besides, the decision of weight value α is dynamic. The value of e_speed_{MN} is depend on the relationship between e_speed_{his} and e_speed_{MN}, if the difference between e_speed_{his} and e_speed_{MN} is greater than the standard deviation of velocity, it means that the incorrect estimation was happened by the situation illustrated in Figure 5 or Figure 6. In the situation, we ignore the estimation of velocity and to use the historical velocity as the reliable estimation of velocity of the MN. In other words, the value of α is 1. Otherwise, if the difference between e_speed_{his} and e_speed_{MN} is less than the standard deviation of velocity, the reliable estimation of velocity is according to the ratio between the difference value and the standard deviation. We consider that the movement of an MN belongs to micro-mobility which has the property of movement: stable movement. We utilize the concept of normal distribution to determine the value of α as follows:

$$\begin{cases} \alpha = 1 \quad if \quad \left| e\_speed_{MN} - e\_speed_{his} \right| \ge e\_speed_{SD} \\ \alpha = \dfrac{\left| e\_speed_{MN} - e\_speed_{his} \right|}{e\_speed_{SD}}, \quad otherwise \end{cases} \tag{3}$$

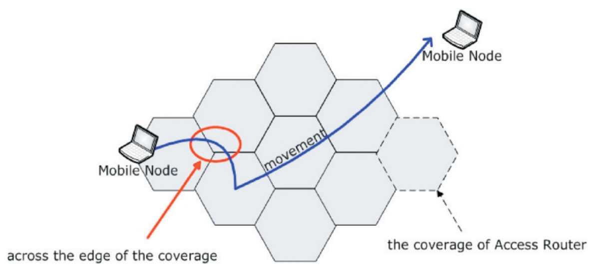

Figure 5. The incorrect estimation of the MN's velocity.

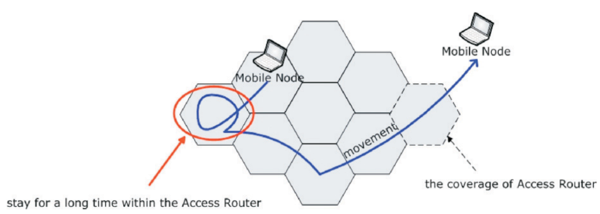

Figure 6. The other incorrect estimation of the MN's velocity.

where e_speed_{SD} presents the standard deviation of velocity which defined as follows:

$$e\_speed_{SD} = \sqrt{\frac{\sum_{k=1}^{k=t-1} (e\_speed_k - e\_speed_{his})^2}{t-1}} \quad (4)$$

In short, using the concepts of standard deviation which integrates with the property of normal distribution and of dynamic reflection with historical velocity is helpful to obtain more exactly estimation of the MN's velocity.

According to the result of SMR estimation, the MN can select a suitable MAP candidate.

3.3 MAP Load Balancing Mechanism

If an MN selects the MAP which reaches predefined upper bound of service quantity, the following procedure will enter MAP load balance mechanism. Otherwise the procedure will enter registration phase.

In MAP load balance mechanism, we design the MAP Loading Table (MLT) to record the load condition of neighbor MAPs. Figure 7 illustrates an example of MAP load balance. We assume that the MAP2 overloads with services and the MN selects the MAP2 to register. In this situation, the MAP2 sends the "neighbor solicitation" message to its neighbor MAPs, then receives acknowledgement messages contains the load information of each MAP which named "neighbor advertisement" and refreshes its MLT. Then MAP2 sends the MLT to the MN. When the MN receives the MLT, it will choose the MAP which has minimum load value to register.

This mechanism has several advantages. First, it is not necessary for the MN to perform MAP selection mechanism again when the selected MAP2 is in overload condition. Except all MAPs in MLT are in high overload condition. Therefore the computing time is saved. Second, if the MAP2 is MN's best MAP candidate, the next better MAP candidate will be close to the MAP2. According to the result of the SMR estimation and the decision of the MAP candidate, the cost of binding update and packet delivery is best reduction. Hence it still good to choose neighbor MAP when the selected MAP candidate is overloading.

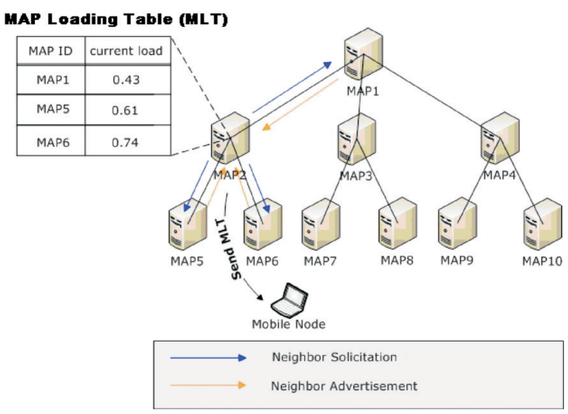

Figure 7. The MAP load balancing mechanism.

3.4 Registration

If the selected MAP candidate is available (not in heavy load condition), the MN can register with it directly. Otherwise the MN needs to wait until some MAP is available.

4. Simulation Results

In this section, we simulate two items: binding update cost and load condition of each level MAP. Besides, the proposed method will also be compared with the other methods: distance-based, velocity-based and topology-based mechanism as defined in section 2.1, 2.2 and 2.3, respectively.

There are three level MAPs in the simulation topology. The highest level (level 1) MAP manages three MAPs allocated in level 2, each MAP allocated in level 2 manages two MAPs allocated in the lowest level (level 3). The velocity of MNs with high mobility is between 51 to 90 m/s, and them with low mobility is between 1 to 50 m/s. Besides, we predefine the value of the SMR as the threshold in the simulation. The performance of the proposed method is evaluated by the network topology of simulation in Figure 8 and the relative parameters in Table 1.

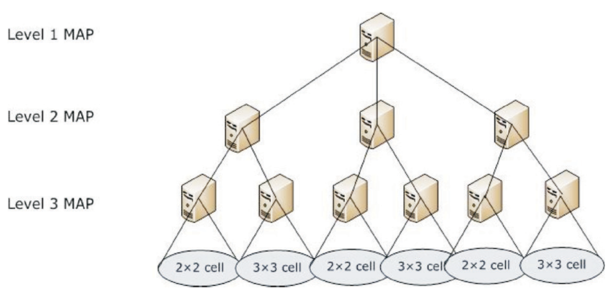

Figure 8. The simulation topology.

Table 1. The simulation parameters

simulation parameter	value
AR's diameter	200 m
simulation area	3000×600 m^2
high mobility: low mobility	4:1
MN's initial position	random distribution
The max. service quantity of level 1/level 2/level 3 MAPs	70/50/30
Mobility model	random waypoint

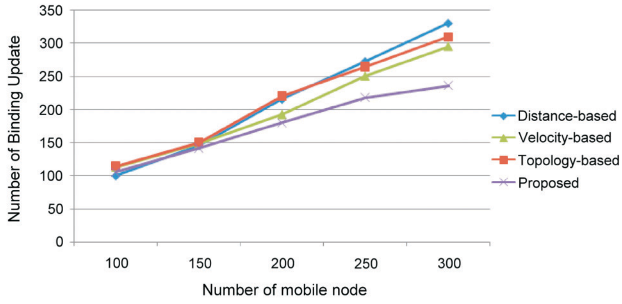

Figure 9. The performance of binding update cost.

4.1 The Cost of Binding Update

We setup the MNs with high mobility occupy eighty percent of all MNs for observing the influence occurs by the binding update frequently. Figure 9 illustrates the performance of binding update cost between four different mechanisms. The binding update cost of all methods are almost similar when the number of MN is less than 150. On the other hand, when the number of MN become larger, it is obvious to discover that the proposed mechanism is greater than other mechanisms. Especially, in the situation with number of MNs is more than 250, it is still superior because the proposed mechanism can exactly let each MN register with the suitable MAP which efficiently reduces the binding update cost.

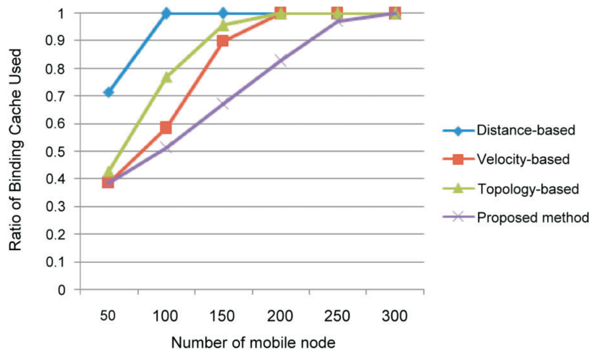

Figure 10. The load condition of level 1 MAP.

4.2 Load Condition of Each Level MAP

In this subsection, we discuss the variation of the binding cache used when the number of MNs increases. It is known that the higher level MAP has larger overloads. Hence, undoubtedly, the load condition of the higher level MAP can indicate the performance of MAP load balance mechanism. Figure 10, Figure 11 and Figure 12 shows the load condition of level 1, level 2 and level 3 MAP, respectively.

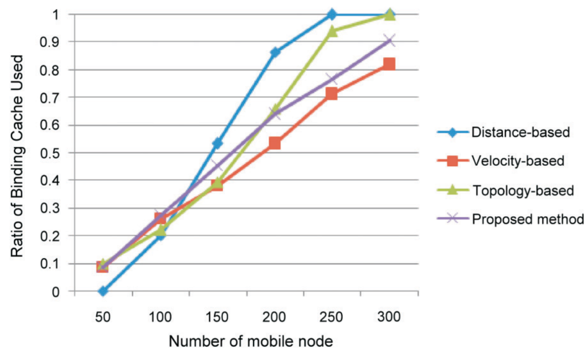

Figure 11. The load condition of level 2 MAP.

Figure 10 illustrates the load of level 1 MAP tardily reaches its upper bound in proposed mechanism because the proposed mechanism active its load balancing at the right time to slow down its highly overhead when the loading almost reach the threshold. Besides, the efficiently balancing let the utility rate of the lower level MAPs increases obviously, especially, it is clear in level 3 MAP (see Figure 12).

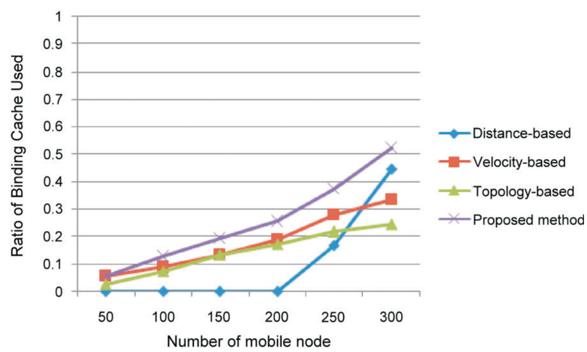

Figure 12. The load condition of level 3 MAP.

5. Conclusion and Future Work

In this paper, we propose a dynamic MAP selection mechanism which efficiently reduces the cost of binding update and packet delivery because the MN can correctly select the suitable MAP. Besides, according to the results of the simulation, the proposed method is robust.

In our future work, we will introduce the concept of fuzzy theory and predict the movement direction of the MN.

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