Improved Location Management Scheme Based on Autoconfigured Logical Topology in HMIPv6*

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Abstract. Though some studies involving general micro-mobility exist, micro-mobility research concerning a mobile node (MN) moving between Mobile Anchor Points (MAP) is lacking. In Hierarchical Mobile IPv6 (HMIPv6), a MN sends a binding update (BU) message to a MAP when the MN performs a handoff. This scheme reduces the handoffs and BUs performance costs. However, the total signaling cost of HMIPv6 rapidly increases with the number of corresponding nodes (CN) for a MN moving among MAPs. In this paper, we propose a scheme based on logical topology with autonomous configuration allowing a MN to move around between MAPs without performing a BU. We perform the performance evaluation for packet delivery and location update costs through a novel analytic approach. We show that the proposed scheme is approximately two times better than the existing one in terms of the total signaling costs through performance analysis. Furthermore, our scheme also reduces the location management cost effectively.

1 Introduction

Mobile IP (MIP) [1] is a de facto standard to address global mobility [2] for mobile users. It has been proposed and developed by the Internet Engineering Task Force (IETF). With the emergence of the global systems, such as IMT2000, MIP is becoming increasingly important for the macro-mobility support, though it contains some problems with location management. Specifically, when a mobile node (MN) moves its location, it delivers a changed Care of Address (CoA) to it's Home Agent (HA). Potentially leading to time delay as a result of the handoff requiring frequent registrations with the HA.

In the Hierarchical Mobile IPv6 (HMIPv6) [3], there is the MAP similar to the Gateway Foreign Agent (GFA) in MIPv4. A MN sends the message to a MAP only when the MN performs local handoffs. However the signaling cost of HMIPv6 rapidly increases as the number of corresponding nodes (CN) increases in a MN when the MN moves between MAPs globally. Thus, a new scheme capable of reducing the

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signaling cost is required. In this paper, we specified in demonstrating a new location management scheme to solve the problem [7]. In this scheme, a MN does not register to CNs and HA, when the MN moves between adjacent MAPs through the wired connection. Though the scheme decreases location update costs it increases the packet delivery cost since the MAPs are connected to each other.

We propose a new location management scheme to support the macro-mobility allowing for smooth and fast handoffs. Each of the MAPs autonomously configures the logical topology with the neighboring MAPs. For a location update, it is not necessary to send signals from a MN to HA and CNs. A MN only performs the registration with a MAP to receive a Regional Care-of-Address (RCoA) and OnLink Care-of-Address (LCoA). In this scheme, the total signaling cost is lower than that of the HMIPv6 [6] and the forwarding scheme [7] up to 17 forwarding steps.

This paper is organized as follows. In section 2, the previous location management schemes are described. The motivation of our work and the new scheme are presented in section 3 based on HMIPv6. In section 4, the performance of the proposed scheme is evaluated. Finally, we conclude our paper, giving future direction.

2 Related Works

MIPv6 uses the same basic network entities as MIPv4 except that it is unnecessary for the Foreign Agent (FA). CoA is supplied to a MN using IPv6 without the support of AR, with a HA capable to process all of the data delivered to the destination in a tunnel. The data to be delivered to the MN is sent directly without passing through the HA. Hence, packet delivery routing is used efficiently.

HMIPv6 scheme has a new component called the MAP, along with some upgraded functionalities in MN and HA except CN [3]. If MN changes it's current address within a MAP, it performs a local BU. The MAP encapsulates all of the packets that are delivered to the MN. If the MN changes its local domain, the MN only registers the changed address to the MAP. During this time the RCoA is never changed, this becomes a merit in registrations. MAP's decreased signaling costs and can also be used for executing fast handoffs. If the MN moves into a new domain, the MN sends a new BU to all nodes on the list. Therefore the total signaling cost is proportionally increased depending upon the number of CNs. If we apply the scheme of [5], this problem does not occurr. Though in this scheme, Access Router (AR) undesirably has the same functionality as a MAP. In HMIPv6, a MAP offers specified functions such as an authentication, billing, and so on [3]. Therefore, AR cannot perform MAP's functions in the general system. Hence, we need a new scheme which is different from the method presented in [5].

Choi and Choo propose a scheme, which forwards the connection information to adjacent MAPs [7]. This scheme has some shortcomings on the process latency in tunneling, and it has demands that state information to be maintained by each MAP. This scheme is only operated within optimized hops since each MAP extracts location information depending on the delivered packets. Another approache is required to address the scheme.

In addition to the HMIPv6 specification [6], mobility-based MAP selection schemes have been proposed in the literature [10, 11]. In these schemes, a MN selects its serving MAP based upon its mobility. For example, the fastest MNs select the furthest MAP while the slowest MNs select the nearest MAP. In addition, an adaptive MAP selection scheme, where an MN selects a serving MAP by estimating session-to-mobility ratio (SMR), was proposed in [12]. The SMR is defined by the ratio of the session arrival rate to the mobility rate. The smaller a MN's SMR, the further the selected MAP will be from the MN. Note that a small SMR indicates that the MN is moving faster than the the rate of session arrivals. Additionally, the aim of [9] is to give a MN the information regarding the MAPs. The MN can select a favorite MAP out of these MAPs

3 The Proposed Scheme in HMIPv6

In this paper, we propose a scheme to solve the existing problem using the autoconfigured logical topology, while examining in detail the MN's operation. The scheme does not require a BU in HA and CNs to autonomously configure the logical topology between neighboring MAPs [8]. Subsequently applying the scheme to find neighboring MAPs for each MAP of an initial MN in HMIPv6.

3.1 Motivation

Each MAP configures by using the autoconfigured logical topology having route and cost information between MAPs. Each MAP also forecasts the neighboring MAP's movement location, and performs a BU. Through the autoconfigured logical topology, it is possible to support fast handoff based on anticipated information as well as location update and packet delivery costs. It is also possible to transfer the profile for authentication in advance since neighboring MAP's information on the security architecture, called AAA(Authentication, Authorization, Accounting) is known, and applying the QoS resource reservation.

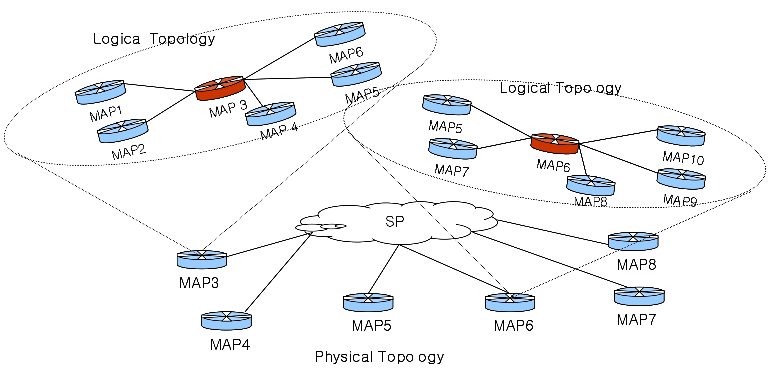

Fig. 1. Logical topology between MAPs

This paper is restricted to, on the practical side, the same administrator domain for the autoconfigured logical topology. We assume that the information between MAPs is known in advance. Fig. 1 shows the autoconfigured logical topology between MAPs [9]. Each MAP must be accessible to the information for neighboring MAPs to configure the autoconfigured logical topology with neighboring MAPs. If a MAP stores the information on a single static table, when a new MAP is added, the neighboring MAPs may have to update the table themselves in order to reconfigure the autoconfigured logical topology [9]. This is fairly burdensome. This paper highlights the fact that each MAPs uses the scheme, updating and configuring the logical topology autonomously.

3.2 The Proposed Scheme Based on Logical Topology

In this paper, the MAPs are named by sequence numbers such as MAP1, MAP2,..., MAPq for convenience. MAP1 already has a table to manage the neighboring MAPs and generates another table to manage the MN. In addition, MAP1 registers all CNs connected to HA and MN using its own RCoA. When HA and CN have the BU message, they store the MN's RCoA to use while connecting with a MN. A BU message does not transmit to HA and CNs when MN moves within MAP. Instead, MAP receives this message to record the information for the location update based on MN's LCoA.

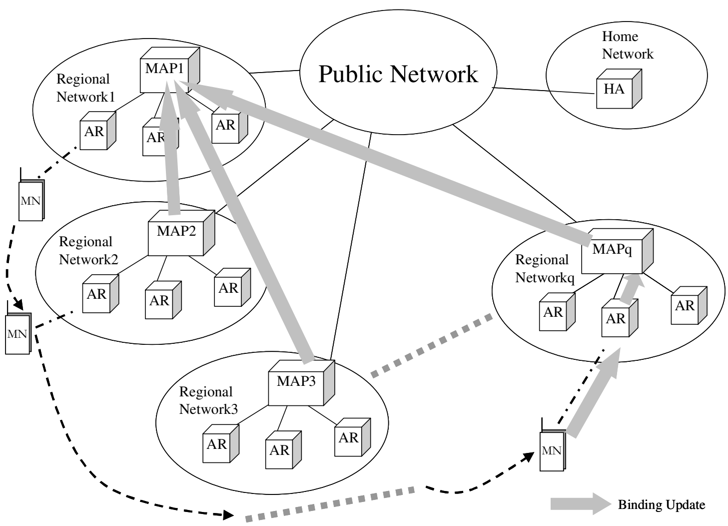

Fig. 2. Binding Update in the proposed scheme

A MN receives adjacent MAP information in the form of a table, which selects MAP2 because MAP2 has the smallest hop number in the table. For this step, we use the algorithm to select a MAP that has the shortest distance. MN sends MAP1's RCoA and initial MAP's RCoA to the MAP2 when MN registers to the MAP2. The MAP2 sends its RCoA and initial MAP's RCoA to the MAP1, and then the MAP1 compares the initial MAP's RCoA with itself. Therefore, when HA transmits data, the data is delivered by this route. This scheme saves signaling costs in comparison with the existing schemes, like HMIPv6. Similarly, when a MN moves from MAP2 to MAP3, the MN transmits the registration message (MAP2's RCoA, initial registration MAP's RCoA) to MAP3, and then MAP3 transmits two messages to MAP1. In this case, MAP1 deletes MAP2's RCoA in the MN's list since it contains the MAP's RCoA and records MAP3's RCoA. MAP1 and MAP3 are then linked through the registration. Therefore, the proposed scheme is not required to send the binding information to the HA and CNs.

As shown in Fig. 2, we consider a MN moving from MAP1 to MAPq as an example of global handoff. In the proposed scheme, the greatest achievment comes from a step reduction, while not continuously keeping links to several steps.In this paper, the maximum number of forwarding links allowed between MAPs is not fixed but optimized for each MN to minimize the total signaling cost. The optimal number is obtained, based on the operational difference between the existing scheme and the proposed one. MIPv6 allows MNs to move around the internet topology while maintaining the reachability and ongoing connections between the mobile and CNs.

To do this the MN sends the BU to its HA and all CNs communicating every time it moves. Hence, increasing the number of CNs influences the system performance in negative manner. However the proposed scheme is independent of the number of CNs while the MN moves in forwarding steps as we have discussed. In the next section, we evaluate the proposed scheme and calculate the optimal number of steps, comparing the number of forwarding links to the total signaling cost on the HMIPv6.

4 Performance Evaluation

In these sections, we compare and evaluate the performance of the proposed scheme based on HMIPv6, Forwarding scheme and HMIPv6. There is a signaling cost related to a location update and a packet delivery in the element, which influences the performance.

4.1 Modeling

4.1.1 Location Update Cost

Similar to [4-6], we define the following parameters for location updates.

- C_{rm} / C_{pr} / C_{be} / C_{hp} / C_{cp} : The transmission cost of the location update between the AR and the MN/ the MAP and the AR/ MAPs/ the HA and the MAP/ the CN and the MAP.
- C_{Uh} / C_{Ur} / C_{Uc} / C_{Uq} : The cost of the initial home registration/ the regional registration/ the CN registration/ signaling between two MAPs.
- C_{Up} : The home registration cost required to delete all previous forwarding links and create a new link.
- a_r / a_p / a_h / a_c : The processing cost for the location update at the AR/ MAP/ HA/ CN.

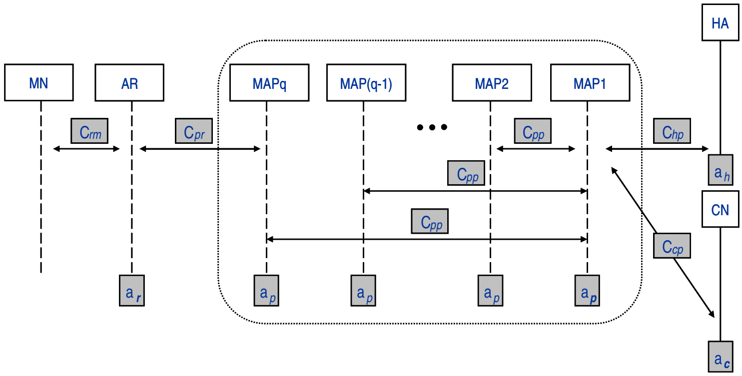

Fig. 3. Location update cost in the proposed scheme

In HMIPv6 scheme, if the MN moves out of the regional network, it must send the BU to CNs and the HA. On the other hand, Fig. 3 shows the location update procedure in the proposed scheme. It represents the signaling message flows for the location registration with the home network, regional location updates within a regional network, the connection between two adjacent MAPs, and the location update with the CN. According to the message flows, C_{Uh}, C_{Ur}, C_{Uc}, C_{Uq}, and C_{Up} are calculated as follows.

$$C_{Uh} = 2a_r + 2a_p + a_h + 2C_{hp} + 2C_{pr} + 2C_{rm},\ C_{Ur} = 2a_r + a_p + 2C_{pr} + 2C_{rm}$$
$$C_{Uc} = 2a_r + 2a_p + a_c + 2C_{cp} + 2C_{pr} + 2C_{rm},\ C_{Uq} = 2a_r + 2C_{rm} + 3a_p + 2C_{be} + 2C_{pr}$$
$$C_{Up} = 2a_r + 4a_p + a_h + 2C_{hp} + 2C_{pr} + 2C_{rm} + 2C_{be}$$

Let l_{hp}, l_{pr}, l_{cp}, and l_{be} be the average distances between the HA and the MAP in terms of the number of hops packets travel, the average distance between the MAP and the AR, the average distance between the CN and the MAP, and the average distance between the MAPs, respectively. We assume the transmission cost is proportional to the distance between the source and the destination routers, and the proportional constant is δ_U. Thus C_{hp}, C_{pr}, C_{cp}, and C_{be} can be expressed as $C_{hp} = l_{hp}\delta_U$, $C_{pr} = l_{pr}\delta_U$, $C_{cp} = l_{cp}\delta_U$, and $C_{be} = l_{be}\delta_U$, respectively. The transmission cost of the wireless link is generally higher than that of the wired link. We assume that the transmission cost per unit distance over the wireless link is ρ times higher than wired line one. The transmission cost between the AR and the MN can be written as $C_{rm} = \rho\delta_U$. The home registration, regional registration, the connection between the two MAPs, and location update cost with the CN can be expressed as follows.

$$C_{Uh} = 2a_r + 2a_p + a_h + 2(l_{hp} + l_{pr} + \rho)\delta_U,\ C_{Ur} = 2a_r + a_p + 2(l_{pr} + \rho)\delta_U$$
$$C_{Uc} = 2a_r + 2a_p + a_c + 2(l_{cp} + l_{pr} + \rho)\delta_U,\ C_{Uq} = 2a_r + 3a_p + 2(l_{be} + \rho + 2l_{pr})\delta_U$$
$$C_{Up} = 2a_r + 4a_p + a_h + 2(l_{hp} + l_{pr} + \rho + 2l_{be})\delta_U$$

Assume each MN may move randomly among N subnets and there are k subnets within a regional network. We use a discrete system to model the movements of each MN [4, 5]. Define a random variable M so that each MN moves out of a regional network at movement. At movement 1, MNs may reside in one of subnets 1 through N. At movement 2, MNs may move to any of the subnets. We assume MNs will move out to one of the other $N-1$ subnets with equal probability $1/_{N-1}$. The probability that each MN moves out of the regional network, i.e. the probability of performing home registration and the registration of the CNs at movement m is $P_h^m = \frac{N-k}{N-1}\cdot\left(\frac{k-1}{N-1}\right)^{m-2}$, where $2 \le m < \infty$. It can be shown that the expectation of M is $E[M] = \sum_{m=0}^{\infty} mP_h^m = 1 + \frac{N-1}{N-k}$.

Assume within the regional network, the average time each MN stays in each subnet before making a movement is T_f. The signaling cost of the HMIPv6 is proportionally increased by the number of CNs(γ). Therefore, the location update cost per unit time is represented as below.

$$C^{HMIPv6}{}_{LU} = \frac{E[M]\cdot C_{Ur} + C_{Uh} + C_{Uc}\cdot\gamma}{E[M]\cdot T_f}$$

The average location update cost in the proposed scheme is represented as follows, when the MN moves from the MAP0 to the MAPq.

$$C^{proposed}{}_{LU} = \frac{E[M]\cdot C_{Ur} + q\cdot C_{Uq} + C_{Up} + C_{Uc}\cdot\gamma}{E[M]\cdot T_f}$$

In the worst case, Route Optimization problem occurs in schemes that forward continuously between MAPs, regardless of the MAP Selection algorithm and distance between MAPs, register initially from MN, when MAP is arranged on a straight line equally with forwarding scheme. Though, it could be reduced on the transmission delay cost for forwarding between MAPs and location update cost in MAPs.

4.1.2 Packet Delivery Cost(Tunneling Cost)

Due to tunneling, extra costs for the packet delivery exist under the proposed scheme. The packet delivery cost includes the transmission and processing costs required to route a tunneled packet from the MAP0 to the MAPq, and further forwarding it to the serving AR of the MN. Assume;

- $T_{pr}/T_{be}/T_{cp}$: The transmission cost of packet delivery between the MAP and the AR/ MAPs/ the CN and the MAP;
- $v^{proposed}{}_p$: The processing cost of packet delivery at the MAP in our scheme;
- $v^{HMIPv6}{}_p$: The processing cost of packet delivery at the MAP in the HMIPv6.

We assume the transmission cost from delivering data packets is proportional to the distance between the sending and the receiving routers with the proportional constant δ_D. Therefore, the cost of each packet delivery procedure can be expressed as shown below.

$$C^{HMIPv6}{}_{PD} = v^{HMIPv6}{}_{p} + T_{pr} = v^{HMIPv6}{}_{p} + l_{pr}\delta_{D}$$
$$C^{proposed}{}_{PD} = T_{pr} + T_{be} + v^{proposed}{}_{p} = \delta_{D} \cdot (l_{be} + l_{pr}) + v^{proposed}{}_{p}$$

The worst case occurs when a MAP is arranged on a straight line equally with the forwarding scheme. Though it could reduce the transmission delay cost coming from the forwarding between MAPs and packet delivery cost in MAPs, same as location update cost. The load($v^{proposed}{}_{p}$) on the MAP for processing and routing packets to each AR depends on the number of ARs(k) under the MAP, and the number of links (q) between the first and the last MAPs. When the number of forwarding links is 0, the packet processing cost function is as follows. We assume on average there are ω MNs in a subnet. Then the total number of MNs in an MAP serves in a regional network is ωk on the average. Therefore, we define the total packet processing cost function at the MAP as follows.

$$\zeta k \cdot \lambda_{a}(\alpha\omega k + \beta log(k))$$

where λ_a is the average packet arrival rate for each MN, α and β are weighting factors of visitor list and routing table lookups, respectively, and ζ is a constant which captures the bandwidth allocation cost at the MAP. On the other hand, when the number of forwarding links (q) among MAPs has more than 0, the processing cost function is proportional to q . We assume u is the average number of neighboring MAPs in a MAP. The cost at the proposed scheme is represented as shown below.

$$u \cdot \zeta \cdot \lambda_{a}(\alpha\omega k u + \beta log(u)),\ (q > 0)$$

The $v^{proposed}{}_{p}$ value is the sum of the two proposed scheme.

$$v^{proposed}{}_{p} = \{u \cdot \zeta \cdot \lambda_{a}(\alpha\omega k u + \beta log(u))\} + \zeta k \cdot \lambda_{a}(\alpha\omega k + \beta log(k))$$

4.1.3 Total Signaling Cost

From analysis we obtain the overall average signaling cost function in the proposed scheme and in the HMIPv6. First of all, the HMIPv6's total signaling cost is represented as.

$$C^{HMIPv6}(k, \lambda_{a}, T_{f}) = C^{HMIPv6}{}_{LU} + C^{HMIPv6}{}_{PD}$$

We assume that the MN moves from the MAP0 to the MAPq, and thus the total signaling cost is calculated as.

$$C^{HMIPv6}{}_{TOT}(k, \lambda_{a}, T_{f}, q) = q \cdot (C^{HMIPv6}{}_{LU} + C^{HMIPv6}{}_{PD})$$

The total signaling cost in the proposed scheme is acquired as follows.

$$C^{proposed}(k, \lambda_{a}, T_{f}) = C^{proposed}{}_{LU} + C^{proposed}{}_{PD}$$

Then, the total singling cost is calculated as shown below.

$$C^{proposed}{}_{TOT}(k, \lambda_{a}, T_{f}, q) = C^{proposed}{}_{LU} + q \cdot C^{proposed}{}_{PD}$$

4.2 Analytical Results

We analyze the performance of our scheme based on the above expression. Table 1 lists some of the parameters used in our performance analysis. The total number of subnets that MNs may access through the wireless channels are limited, and we assume N =30. For the evaluation, we assume l_{hp} =20, l_{pr} =3, l_{cp} =10, and l_{be} =10.

Table 1. System parameters

Pkt process cost				Proportional cost		Wireless multiple	# of MNs/subnet
a_h	a_p	a_r	a_c	δ_U	δ_D	ρ	ω
30	20	15	10	0.2	0.05	5	15
Weight		Pkt delivery const.				# of neighbor MAPs	
α	β	ζ	η			u	
0.3	0.7	0.01	10			5	

In Fig.4, we assume that T_f =4, λ_a =0.3, and γ=5. In the proposed scheme, the MN calculates the total signaling cost and compares with those of standard HMIPv6 and packet forwarding scheme [7]. The total signaling cost of the proposed scheme is smaller than those of the HMIPv6 and packet forwarding scheme. The total signaling cost of the packet forwarding scheme is smaller than the HMIPv6 up until 8 forwarding steps (q ≤8). However when q ≥9, the cost of the packet forwarding scheme becomes greater than the HMIPv6 one, and the MN sends the registration message to the HA and the CNs, removing all of the previous links among MAPs. Although at q≥9, the total signaling cost changes little. In the worst case, the total signaling cost of the proposed scheme is smaller than those of the HMIPv6 and the Forwarding up until 17 forwarding steps (q ≤17). This scheme underlines the fact that it is more cost effective to manage the location of MN than both the HMIPv6 and the packet forwarding schemes.

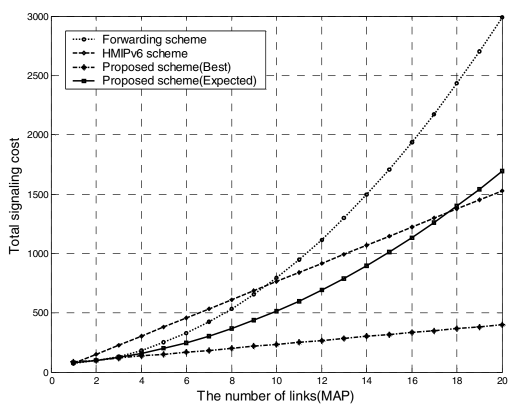

Fig. 4. The comparison of the total signaling costs

5 Conclusion

MIPv6 proposes optimal routing as a solution to the triangle routing problem in MIPv4. However, the signaling cost of HMIPv6 rapidly increases as the the number of CNs increase in a MN. Throughout this paper, we propose a new scheme through a logical topology, with a MN not required to register to CNs and the HA when the MN moves between adjacent MAPs. We use an algorithm to configure the logical topology. As a result of the logical topology, we are able to decrease the location update cost. In conclusion, we perform the simulations to depict the total signaling cost. We compared the proposed scheme to both the standard HMIPv6 and the forwarding scheme, subsequently illustrating the effectiveness of the proposed.

This paper assumes that the worst case is the average of the forwarding scheme when MAP is arranged on a straight line and the best cases of the proposed scheme. In the near future, we plan to conduct performance evaluation on our approach in detail.

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