# A Comparative Study of Mobility Anchor Point Selection Schemes in Hierarchical Mobile IPv6 Networks *

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## ABSTRACT

In Hierarchical Mobile IPv6 networks, how an mobile node select an appropriate mobility anchor point (MAP) has a vital effect on the overall network performance. In this paper, we evaluate the performances of four MAP selection schemes: the furthest MAP selection scheme, the nearest MAP selection scheme, the mobility-based MAP selection scheme, and the adaptive MAP selection scheme. The dynamic schemes (i.e., the mobility-based and the adaptive MAP selection schemes) achieve more desirable performances than the static schemes (i.e., the furthest and the nearest MAP selection schemes), since the dynamic schemes consider mobility of MNs. Also, the dynamic schemes can achieve load balancing among MAPs, where the adaptive MAP selection is better than the mobility-based MAP selection scheme.

## Categories and Subject Descriptors

C.2.1 [**Computer-Communication Networks**]: Network Architecture and Design—*wireless communication, packet-switching networks*

## General Terms

Algorithms, Performance, Standardization

## Keywords

Hierarchical Mobile IPv6, mobility anchor point, MAP selection, performance comparison

## 1. INTRODUCTION

Hierarchical Mobile IPv6 (HMIPv6) [1] was proposed by Internet Engineering Task Force (IETF) to mitigate the high signaling overhead that is incurred in Mobile IPv6 networks when mobile nodes (MNs) perform frequent handoffs. In HMIPv6 networks, a mobility anchor point (MAP) handles binding update (BU) procedures due to handoffs within a MAP domain in a localized manner, which reduces the amount of network-wide signaling traffic for mobility. Especially when HMIPv6 is deployed in a large-scale wireless/mobile network, multiple MAPs are employed to provide scalable mobile services. In this environment, it is important for an MN to select the most suitable MAP among the available MAPs.

An MN needs to consider several factors when selecting the appropriate MAP in a foreign network. In the HMIPv6 specification [1], two MAP selection schemes were recommended. The first scheme is a distance-based selection scheme, where an MN chooses the furthest MAP, in order to avoid frequent re-registrations. This scheme is particularly efficient for fast MNs performing frequent handoffs, because by choosing the furthest MAP, the fast MNs reduce the frequency of changing the serving MAP and informing the HA and their CNs of this change. However, since each MN has different mobility characteristics, the furthest MAP may not constitute an appropriate solution for some MNs (e.g., slow MNs). Furthermore, if all MNs select the furthest MAP as their serving MAPs, this MAP would become a single point of performance bottleneck, resulting in a higher processing latency. The alternative scheme recommended in [1] is to announce the MAP's information (e.g., traffic load on the MAP), so that an MN can choose a MAP by considering MN's mobility characteristics and MAP's current state.

In addition to above schemes, mobility-based MAP selection schemes have been proposed in the literature [2, 3]. In these schemes, an MN selects its serving MAP depending on its mobility. For example, the fast MNs select the furthest MAP while the slow 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 [4]. The SMR is defined by the ratio of the session arrival rate to the mobility rate. The smaller the SMR of an MN is, the further MAP will be selected by the MN. Note that the SMR of an MN being small means that the MN is moving faster compared to the rate of session arrivals.

To the best of our knowledge, no comparative study among these schemes has been conducted. In this paper, we compare four MAP selection schemes: the furthest MAP selection scheme, the nearest MAP selection scheme, the mobility-based MAP selection scheme, and the adaptive MAP selection scheme. We analyze and evaluate their performances quantitatively with focus on the binding update traffic and the packet tunneling overhead. Furthermore, we discuss how MNs are distributed among MAPs (i.e., load balancing).

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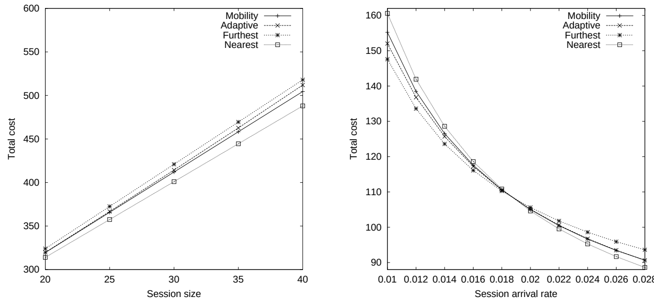
**Table 1: Cost functions: Binding update cost**

| Scheme | Binding update cost |
|---|---|
| Furthest | $E(N_D^H) \cdot B_{HA} + E(N_C) \cdot B_M^H$ |
| Nearest | $E(N_D^L) \cdot B_{HA} + E(N_C) \cdot B_M^L$ |
| Mobility and Adaptive | $\pi_L \cdot C_{BU}^{Nearest} + \pi_H \cdot C_{BU}^{Furthest}$ |

**Table 2: Cost functions: Packet delivery cost**

| Scheme | Packet delivery cost |
|---|---|
| Furthest | $\omega \cdot L_S \cdot P_I^H + (1-\omega) \cdot L_S \cdot P_D^H$ |
| Nearest | $\omega \cdot L_S \cdot P_I^L + (1-\omega) \cdot L_S \cdot P_D^L$ |
| Mobility and Adaptive | $\pi_L \cdot C_{PD}^{Nearest} + \pi_H \cdot C_{PD}^{Furthest}$ |




(a) Effect of session size (b) Effect of session rate

**Figure 1: Total Cost**

# 2. ANALYTICAL MODELING

For the purpose of performance evaluation, we formulate the binding update (BU) cost ($C_{BU}$) and the packet deliver (PD) cost ($C_{PD}$) in a HMIPv6 network with a two-level MAP hierarchy. The network consists of two types of MAPs: higher MAP (HMAP) and lower MAP (LMAP). A LMAP domain covers a number of cells, whereas a HMAP domain covers several LMAP domains. Therefore, the average residence time of the HMAP domain is longer than that of the LMAP. The SMR is defined as $\lambda_S/\mu_C$, where $\lambda_S$ and $\mu_C$ are the session arrival rate and the cell crossing rate, respectively.

Tables 1 and 2 summarize the BU cost and the PD cost in four MAP selection schemes. Nomenclature used in the model is as follows. Superscripts, $H$ and $L$, stand for the HMAP and the LMAP, respectively.

- $E(N_D)(E(N_C))$: Average number of domain(cell) crossings.
- $B_{HA}(B_M)$: Unit binding update cost to the HA (MAP).
- $\pi_L(\pi_H)$: Steady-state probability selecting LMAP (HMAP).
- $\omega$: Ratio of packets going through the HA before the completion of the binding update procedure.
- $L_S$: Average session size (numbers of packets per session).
- $P_I(P_D)$: Unit packet delivery cost through indirect path (direct path).

Using the Markov chain, $\pi_L$ in the mobility-based and the adaptive schemes are derived from Eqs. (1) and (2), respectively. (note that $\pi_H = 1 - \pi_L$.)

$$\pi_L = \Pr(t > T_{th}) \quad (1)$$

$$\pi_L = \Pr(s > S_{th}) \quad (2)$$

where $t$ and $s$ are the residence time and the SMR, respectively. $T_{th}$ and $S_{th}$ represent the thresholds for the mobility-based and the adaptive MAP selection schemes, respectively.

# 3. NUMERICAL RESULTS

Figure 1(a) shows the total cost (the BU cost and the PD cost) as the average session size increases. As the session size increases, the portion of the PD cost to the total cost also increases. Therefore, the nearest MAP selection scheme outperforms other schemes because it always chooses the LMAP. (The PD cost is approximately proportional to the hop distance between the MAP and the MN.) However, as the session size becomes smaller, the differences among four MAP selection schemes are more and more negligible.

When the session arrival rate is low (the MN moves fast relatively), the BU cost has a greater impact on the total cost than the PD cost. Therefore, as shown in Figure 1(b), the furthest and the adaptive selection schemes, which have lower binding update costs, show lower total costs than the nearest and mobility-based schemes, respectively. However, the PD cost is more important than the BU cost when the session arrival rate is high. Hence, the mobility-based and nearest selection schemes show better performances in the case of the high session arrival rate. In short, the mobility-based and the adaptive selection schemes are more desirable since they are less dependent on the session arrival rate.

In terms of load balancing, the adaptive MAP selection scheme shows the better performance than the mobility-based scheme. Inherently, the furthest and nearest MAP selection schemes cannot support load balancing at all.

# 4. CONCLUSION

In this paper, we have conducted a comparative study for four MAP selection schemes: the furthest MAP selection scheme, the nearest MAP selection scheme, the mobility-based MAP selection scheme, and the adaptive MAP selection scheme. Overall, the dynamic schemes (i.e., the mobility-based and the adaptive MAP selection schemes) achieve more desirable performances than the static schemes (i.e., the furthest and the nearest MAP selection schemes). Also, the adaptive MAP selection scheme performs better in terms of load balancing than the mobility-based MAP selection scheme.

# 5. REFERENCES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