# LOAD CONTROL SCHEME AT LOCAL MOBILITY AGENT IN MOBILE IPv6 NETWORKS

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**Abstract** — In IP-based mobile networks, a few of mobility agents (e.g., home agent and foreign agent) are used to support seamless mobility. In terms of network performance, scalability at these agents is one of the most important issues in mobile networks. In Hierarchical Mobile IPv6 (HMIPv6), a new mobility agent, called mobility anchor point (MAP), is deployed in order to handle binding update procedures locally. However, the MAP can be a single point of performance bottleneck when there are a lot of local movements. This is because the MAP handles signaling traffic as well as data tunneling traffic. Therefore, it is required to limit the number of mobile nodes serviced by a single MAP to provide a certain quality of services with mobile users. In this paper, we propose a load control scheme at the MAP utilizing admission control algorithms. In terms of admission control, we use cutoff priority scheme and new session bounding scheme. For the purpose of performance evaluation, we develop Markov chain models for two admission control algorithms and evaluate on-going MN dropping and new MN blocking probabilities. As a result, the proposed load control scheme can reduce the blocking probability and provide more satisfied services with users.

**Index Terms —** Hierarchical Mobile IPv6, Load control scheme, Markov chain, Blocking probability.

## I. Introduction

IN IP-based mobile networks, a few mobility agents (e.g., home agent and foreign agent) are used to support seamless mobility. In terms of network performance, scalability at these agents is one of the most important issues in mobile networks.

In Hierarchical Mobile IPv6 (HMIPv6) [1], a new mobility agent, called mobility anchor point (MAP), was introduced in order to handle binding update procedures in a local manner. However, the MAP can be a single point of performance bottleneck when there are a lot of mobile nodes (MNs) which are using the MAP as their serving MAP. This is because the MAP handles signaling traffic as well as data tunneling traffic. In other words, when a lot of MNs are serviced by a single MAP, the MAP suffers from traffic overload and it results in higher processing latency and MAP blocking. Therefore, it is required to control the number of MNs serviced by the MAP to provide a certain quality of services with mobile users. However, the current HMIPv6 specification does not concern with this problem. According to the HMIPv6 specification, an MN can select a MAP with a lighter traffic load. However, the detailed procedures are not mentioned. Furthermore, although an MN takes the current load at the MAP into considerations, a load control mechanism at the MAP is also needed for scalable and fault-free mobile services.

In this paper, we utilize admission control algorithms, which are widely used for resource management in wireless access networks, for the load control scheme at the MAP. Specifically, we use two well-known guard channel schemes [5], i.e., cut-off priority scheme and new MN bounding scheme. In terms of performance analysis, we develop Markov chain models for two schemes and evaluate MAP blocking probabilities for new and on-going MNs. As a result, the proposed load control scheme can reduce the ongoing MN dropping and new MN blocking probabilities and provide more satisfied services with users, compared with no load-control scheme [1] and threshold-based load control scheme [2, 3].

The remainder of this paper is organized as follows. Section II describes the MAP operations with load control schemes using admission control algorithms. In Section III, we evaluate our load control schemes based on Markov chain model and present numerical results. Section IV concludes this paper.

## II. Protocol Description

### A. Preliminaries

In admission control algorithms over wireless/mobile networks, the handoff session has priority to the new session. This is because a mobile user suffers from more severe service degradation when the handoff session is dropped rather than the new session is blocked. Therefore, we classify MNs into three classes to consider this feature.

- *New MN*: When an MN enters into a MAP domain, the MN performs the initial binding update to the MAP. New MN refers to this kind of MNs.
- *Handoff MN*: When an MN, which is serviced by a MAP, moves into another MAP domain, the MN performs a handoff toward the new MAP domain. Since the handoff MN was one of the registered MNs at the previous MAP domain, the handoff MN should have higher priority than the new MN.
- *Refresh MN*: In Mobile IPv6, a lifetime is specified in the binding update message, which indicates a valid time of the binding information. After the specified lifetime, the information is expired and the MN should refresh the binding information. Refresh MN is an MN performing the binding update for refreshment.

In the proposed load control scheme, the handoff MN and refresh MN are merged into the on-going MN class. In other words, the load control scheme considers two classes of MNs: **on-going MN** and **new MN**. In addition, the on-going MN has higher priority than the new MN.

### B. Basic Procedure

In this section, we describe the basic operation of the load control scheme at the MAP. As mentioned before, we utilize two admission control algorithms (i.e., cut-off priority scheme and new MN bounding scheme) to limit the number of MNs to be registered to a MAP.

In the cut-off priority scheme, the total number of MNs registered to a MAP is evaluated for admission control. On the other hand, in the case of new MN bounding scheme, the number of new MNs is compared with a threshold value to determine whether a new MN is accepted or not.

Based on two admission control algorithms, a MAP controls the number of MNs performing binding update to the MAP. Following procedures shows the admission control algorithm at the MAP.

**Step 1**: An MN receives Router Advertisement (RA) [4] messages with MAP options from all available MAPs in its current location and then the MN chooses one of them as its serving MAP. Then, the MN sends a Binding Update (BU) message to the MAP for local binding update.

**Step 2**: The MAP performs the admission control algorithm for the MN sending the BU message.

i) in the case of on-going MN

If($C_{used}$<$C_{MAP}$)
the MAP accepts the MN and $C_{used}$ ++
Otherwise
the MAP rejects the MN

ii) in the case of new MN

A) *Cutoff priority scheme*
If($C_{used}$ <$K_2$)
the MAP accepts the MN and $C_{used}$ ++
Otherwise
the MAP rejects the MN

B) *New MN bounding scheme*
If($C_{new}$<$K_3$ and $C_{used}$<$C_{MAP}$)
the MAP accepts the MN and $C_{new}$ ++/ $C_{used}$ ++
Otherwise
the MAP rejects the MN

**Step 3**: The MAP sends binding acknowledgement (BACK) to the accepted MN and binding no acknowledgement (BNACK) to the rejected MN. The rejected MN re-tries binding update to another MAP or performs binding update to the HA and CNs directly.

In the above procedure, $C_{used}$, $C_{new}$, and $C_{MAP}$ denote the number of MNs currently registered to the MAP, the number of new MNs currently registered to the MAP, and the MAP capacity, respectively.

## III. Performance Evaluation

In this section, we evaluate the proposed load control scheme using Markov chain models. In terms of performance factors, we consider a new MN blocking probability ($P_{NB}$) and an on-going MN dropping probability ($P_{OD}$). The new MN blocking probability refers to the probability that a binding update request of a new MN is rejected at the MAP because the total number of MNs (i.e., cut-off priority scheme) or the number of new MNs (i.e., new MN bounding scheme) exceeds the threshold value. In addition, the on-going MN dropping probability is the probability that there is no available capacity at the MAP.

In addition, we investigate the utilization (U) at the MAP. Utilization represents how much MAP capacity is used in the average state. If utilization is less than the maximum MAP capacity, it means the under-utilization. Otherwise, it refers to the over-utilization.

### A. System Model and Assumption

To develop the Markov chain models for performance evaluation, we assume the following system model.

1. The MAP capacity ($C_{MAP}$) is represented by the

maximum number of MNs can be serviced by a MAP.

2. All MNs are classified into either on-going MN or new MN.
3. An MN performs a binding update to only one MAP, which may be the most appropriate MAP chosen by MAP selection scheme.
4. If the binding update request is rejected by the MAP, the rejected MN performs another binding update procedures to another MAP or the HA/CNs.

Under the above system models, we assume following models related to arrival and departure processes.

A. 1. The arrival processes for the on-going and new MNs follow Poisson distributions with rate of $\lambda_O$ and $\lambda_N$ , respectively.

A. 2. The residence times of the on-going and new MNs follow Exponential distributions with mean of $1/\mu_O$ and $1/\mu_N$ , respectively.

A. 3. In case that there is no separation between on-going MN and new MN, the total offered load is the sum of the on-going MN offered load and the new MN offered load.

$$\rho_T = \rho_O + \rho_N$$

*B. Markov Chain Analysis*

Based on the above system model, we develop Markov chain models for four schemes: no load control scheme [1], threshold-based scheme [2, 3], cut-off priority scheme [5], and new MN bounding scheme [5].

In the case of new MN bounding scheme, two-dimensional Markov chain model is used whereas the approximated one-dimensional Markov chain models are used for other schemes. In the following Markov chain model, state *i* represent the number of MNs in a MAP domain. $q(i, i')$ denotes the transition rate from state *i* to state $i'$

i) No load control scheme

In the current HMIPv6 specification, no load control scheme is applied. In other words, all MNs, including new MNs and on-going MNs, are accepted regardless of the number of MNs currently serviced by the MAP. Therefore, some of MAPs may be overloaded and MNs that are served by these MAPs suffer from higher latency. Fig. 1 shows the one-dimensional Markov chain model in the case of no load control scheme.

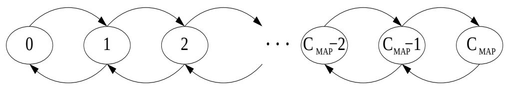

Fig.1. Markov chain model of no load control scheme

ii) Threshold-based load control scheme

In the threshold-based load control scheme, when the total number of MNs in a MAP domain exceeds a threshold value ($K_1$), a MN, requesting binding update to the MAP, is redirected to another mobility agent. Because there exist no distinction between new MN and on-going MN, no priority is not given to the on-going MN. In addition, since the threshold value is less than the total MAP capacity, underutilization may occur. Fig. 2 shows the one-dimensional Markov chain model in the case of threshold-based load control scheme.

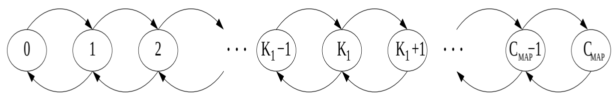

Fig. 2. Markov chain model of threshold-based scheme

iii) Cut-off priority scheme

In the cut-off priority scheme, the number of total MNs served by a MAP is used to control the load at the MAP. Let $K_2$ be the threshold value in the cut-off priority scheme. If the total number of MNs is less than $K_2$, the new MN is accepted; otherwise, the new MN is blocked. The on-going MN is rejected only when the MAP capacity is used up.

Fig. 3 depicts the approximated Markov chain model for the cut-off priority scheme.

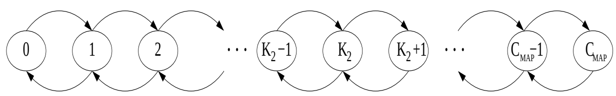

Fig.3. Markov chain model of cut-off priority scheme

$$q(i,i+1) = \rho_O + \rho_N \qquad (0 \le i < K_2)$$
$$q(i+1,i) = 1 \qquad (0 \le i < K_2)$$
$$q(i,i+1) = \rho_O \qquad (K_2 \le i < C_{MAP})$$
$$q(i+1,i) = 1 \qquad (K_2 \le i < C_{MAP})$$

iv) New MN bounding scheme

In this scheme, the number of new MNs is bounded for load control. Let $K_3$ be a threshold value in the new MN bounding scheme. If the number of new MNs is less than $K_3$, a new MN is accepted; otherwise, the new MN is blocked. The on-going MN is rejected only when the MAP capacity is used up. Fig. 4 shows the Markov chain model for the new MN bounding scheme.

In this Markov chain model, state $(i, j)$ refers to a state that there are $i$ new MNs and $j$ on-going MNs. $q(i, j; i', j')$ denote the transition rate from state $(i, j)$, to state$(i', j')$.

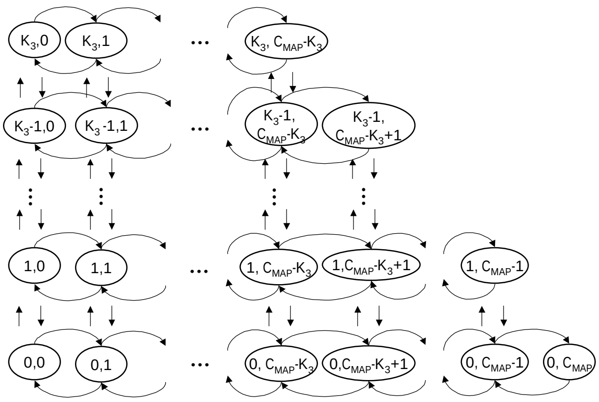


Fig.4. Markov chain model of new MN bounding scheme

$$
\begin{aligned}
q(i, j; i-1, j) &= i \cdot \mu_N \quad (0 < i \le K_3, 0 \le j \le C_{MAP}) \\
q(i, j; i+1, j) &= \lambda_N \quad (0 \le i < K_3, 0 \le j \le C_{MAP}) \\
q(i, j; i, j-1) &= j \cdot \mu_O \quad (0 \le i \le K_3, 0 < j \le C_{MAP}) \\
q(i, j; i, j+1) &= \lambda_O \quad (0 \le i \le K_3, 0 \le j < C_{MAP})
\end{aligned}
$$

Table 1 and 2 show the new MN blocking probability and on-going MN dropping probability for each scheme. In the case of threshold-based scheme, $P_{NB}$ and $P_{OD}$ are 0. This is because the threshold-based scheme always limits the number of MNs below the threshold value, which is smaller than the MAP capacity. However, it may result in a lower utilization, which is analyzed in the next section.

TABLE 1. NEW MN BLOCKING PROBABILITY.

| Scheme | $P_{NB}$ |
|---|---|
| No load control scheme | $\dfrac{(\rho_O + \rho_N)^{C_{MAP}} / C_{MAP}!}{\sum_{n=0}^{C_{MAP}} (\rho_O + \rho_N)^n / n!}$ |
| Threshold based scheme | 0 |
| Cut-off priority scheme | $\sum_{k=K_2}^{C_{MAP}} \dfrac{(\rho_O)^{k-K_2} \cdot (\rho_O + \rho_N)^{K_2} / k!}{\sum_{n=0}^{K_2} (\rho_O + \rho_N)^n / n! + \sum_{n=K_2+1}^{C_{MAP}} (\rho_O)^{n-K_2} \cdot (\rho_O + \rho_N)^{K_2} / n!}$ |
| New MN bounding scheme | $\dfrac{\sum_{n_2=0}^{C_{MAP}-K_3} \frac{(\rho_N)^{K_3}}{K_3!} \cdot \frac{(\rho_O)^{n_2}}{n_2!} + \sum_{n_1=0}^{K_3-1} \frac{(\rho_N)^{n_1}}{n_1!} \cdot \frac{(\rho_O)^{C_{MAP}-n_1}}{(C_{MAP}-n_1)!}}{\sum_{n_1=0}^{K_3} \frac{(\rho_N)^{n_1}}{n_1!} \sum_{n_2=0}^{C_{MAP}-n_1} \frac{(\rho_O)^{n_2}}{n_2!}}$ |

TABLE 2. ON GOING MN DROPPING PROBABILITY.

| Scheme | $P_{OD}$ |
|---|---|
| No load control scheme | $\dfrac{(\rho_O + \rho_N)^{C_{MAP}} / C_{MAP}!}{\sum_{n=0}^{C_{MAP}} (\rho_O + \rho_N)^n / n!}$ |
| Threshold based scheme | 0 |
| Cut-off priority scheme | $\dfrac{(\rho_O)^{C_{MAP}-K_2} \cdot (\rho_O + \rho_N)^{K_2} / C_{MAP}!}{\sum_{n=0}^{K_2} (\rho_O + \rho_N)^n / n! + \sum_{n=K_2+1}^{C_{MAP}} (\rho_O)^{n-K_2} \cdot (\rho_O + \rho_N)^{K_2} / n!}$ |
| New MN bounding scheme | $\dfrac{\sum_{n_1=0}^{K_3} \frac{(\rho_N)^{n_1}}{n_1!} \cdot \frac{(\rho_O)^{C_{MAP}-n_1}}{(C_{MAP}-n_1)!}}{\sum_{n_1=0}^{K_3} \frac{(\rho_N)^{n_1}}{n_1!} \sum_{n_2=0}^{C_{MAP}-n_1} \frac{(\rho_O)^{n_2}}{n_2!}}$ |

### C. *Numerical Result*

In this section, we investigate the numerical analysis. For the numerical analysis, $C_{MAP}$ is assumed to be 50. The arrival rate of new MN is assumed to 1/30 whereas the residence time of new MN in a MAP domain is varied from 400s to 800s. The residence time of on-going MN is 600s and the arrival rate of on-going MN is set to as follows:

$$\lambda_O = \sigma \times \lambda_N \times N$$

where $\sigma$ is the fraction of new MNs performing the handoff or refreshment and $N$ is the number of neighbor cells. In this analysis, $\sigma$ and $N$ are set to 0.025 and 4. In terms of threshold values (i.e., $K_1$, $K_2$, and $K_3$), two values (i.e., 40 and 45) are evaluated.

Fig. 5 shows the new MN blocking probability in the no load control scheme and the cut-off priority scheme. As shown in Fig. 5, the new MN blocking probability of the cut-off priority scheme is higher than that of the no load control scheme. Also, as the threshold value decreases, the blocking probability increases. However, the relative ratio between two schemes does not change as the offered load increases.

On the other hand, Fig. 6 shows the on-going MN dropping probability in the no load control scheme and cut-off priority scheme. Since the cut-off priority scheme reserves an amount of MAP capacity for on-going MNs, it is possible to reduce the on-going MN dropping probability. Furthermore, the on-going MN dropping probability of the no load control scheme drastically increases as the offered load increases, whereas the on-going MN dropping probability of the cut-off priority scheme remains in almost the same level. Consequently, no load control scheme is not good in terms of scalable and continuous mobile services.

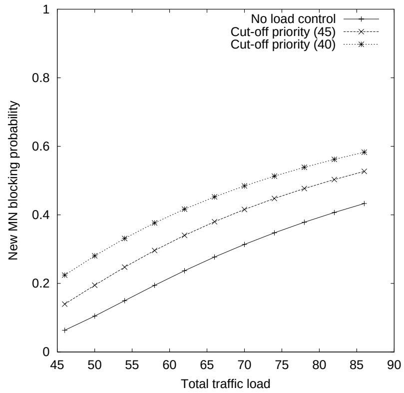


Fig. 5. New MN blocking probability: No control vs. Cut-off

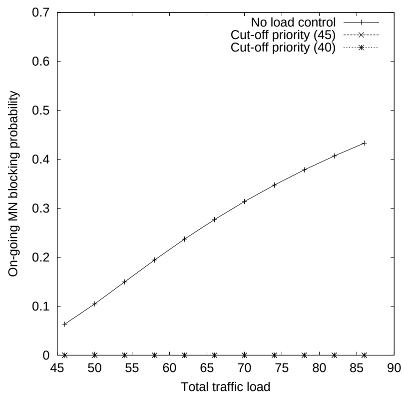


Fig. 6. On-going MN dropping probability: No control vs. Cut-off

Fig. 7 and 8 compare the new MN blocking probability and the on-going MN dropping probability between the no load control scheme and the new MN bounding scheme. As similar to Fig. 5, the new MN blocking probability of the new MN bounding scheme is larger than that of the no load control scheme. However, the difference between the no load control scheme and the new MN bounding scheme can be reduced by increasing the threshold value. In addition, the relative ratio does not change as the offered load increases.

On the other hand, the new MN bounding scheme shows lower on-going MN dropping probability than the no load control scheme. Therefore, the new MN bounding scheme is more benefit than the no load control scheme in terms of seamless mobile QoS.

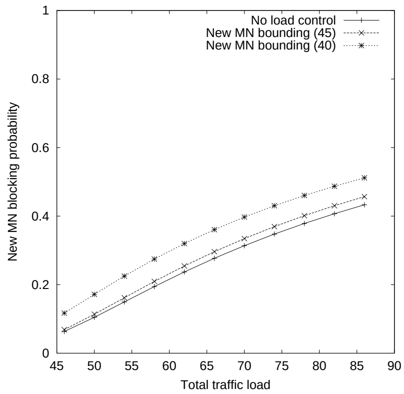


Fig. 7. New MN blocking probability: No control vs. New MN bounding

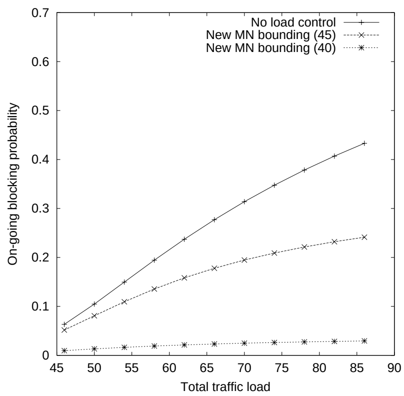


Fig. 8. On-going MN dropping probability: No control vs. New MN bounding

When we compare the cut-off priority scheme with the new MN bounding scheme, the new MN bounding scheme shows lower new MN blocking probability and higher on-going MN dropping probability. As described before, the new MN bounding scheme uses the number of new MNs for admission control, so that the new MN blocking probability of the new MN bounding scheme is less sensitive to the total traffic load than that of the cut-off priority scheme. Consequently, it exhibits lower new MN blocking probability.

However, the new MN bounding scheme does not limit the number of on-going MNs until there is no remaining MAP capacity. Therefore, the reserved portion for on-going MNs is used more aggressively and it results in higher on-going MN dropping probability.

In addition to the on-going MN dropping and new MN blocking probabilities, the MAP utilization has been investigated. To obtain the MAP utilization, the average number of MNs in a MAP domain should be determined. In the load control schemes using one-dimensional Markov chain, the average number of MNs can be obtained from the below equation.

$$E(N) = \sum_{k=0}^{C_{MAP}} k \cdot p_k$$

On the other hand, the average number of MNs in the new MN bounding scheme is as follows.

$$E(N) = \sum_{i=0}^{K_3} \sum_{j=0}^{C_{MAP}-i} (i+j) \cdot p(i,j)$$

Then, the MAP utilization can be expressed as the below equation.

$$U = \frac{E(N)}{C_{MAP}}$$

Fig. 9 shows the utilization at the MAP for each load control scheme. No load control scheme shows the highest utilization among various schemes. The new MN bounding scheme also shows high utilization compared with the cut-off scheme and the threshold-based scheme. On the other hand, the cut-off scheme and the threshold-based scheme have relatively lower utilization. This is because the cut-off priority scheme and threshold-based scheme limit the total number of MNs whereas the new bounding scheme limits only the number of new MNs. Although the threshold-based scheme can reduce the blocking probability by conservative mechanism and show the similar utilization to the cut-off priority scheme, it may not be a feasible solution. Because it is difficult to determine a suitable threshold value and it requires more modifications to support the communications between mobility agents.

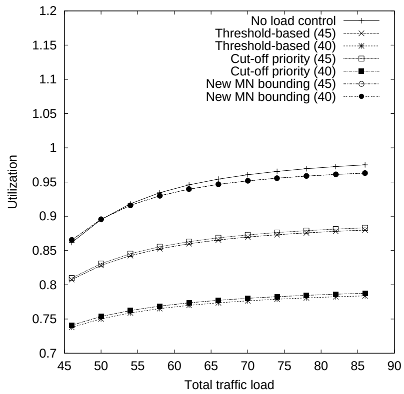

Fig. 9. Utilization at the MAP (U)

## IV. CONCLUSION

In this paper, we propose a novel load control scheme at the MAP for scalable mobile services. We utilize the well-known guard channel admission control algorithms, specifically cut-off priority scheme and new MN bounding scheme. In terms of performance analysis, we have developed Markov chain models for each load control scheme and evaluated the on-going MN dropping and the new MN blocking probabilities. Also, we have conducted the MAP utilization for each scheme. As a result, the proposed load control scheme can reduce the on-going MN dropping probability while keeping the relative ratio of the new MN blocking probability to a constant value and the utilization to a high level.

## ACKNOWLEDGEMENT

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