A PFMIPv6 Scheme Based on Handover Failure Probability for Mobile Nodes

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***Abstract*— This paper proposes a new PFMIPv6 scheme which employs the handover failure probability (to be determined by speed and direction of mobile nodes) as well as the signal strength and load status as in conventional methods. Our scheme is more efficient in choosing MAG with 47% reduction of handover latencies, 34% reduction in signaling cost and 14% increase in throughput. Moreover, in WLAN/Wi-MAX heterogeneous cell, we may selectively use a bandwidth as the 4th factor to further enhance the throughput.**

***Index Terms*—PMIPv6, PMIPv6-PT, Handover Failure Probability, Bandwidth, Handover Latency, Signaling cost, Network Gain**

I. Introduction

Packet loss in handover has been considered as a major drawback of traditional PMIPv6. To prevent this, Fast Proxy Mobile IP version 6 (PFMIPv6) places buffers in each MAG of Previous Mobile Access Gateways (pMAG) and Next Mobile Access Gateways (nMAG), and establishes a bidirectional tunnel between them. Then, during handover, the packets from LMA (Local Mobile Anchor) go toward the buffer of Previous Mobile Access Gateways (pMAG) and to the buffer of a Next Mobile Access Gateways (nMAG) through the tunnel. However, PFMIPv6, also considerably generate handover latency and signaling cost in roads or real-time services with heavy traffic. Therefore, previous study of PFMIPv6-PT [2], sets a tunnel between MAGs beforehand and activates the tunnel whenever a mobile node is connected to the Access Point (AP) of the relevant MAG. This method shows considerable reduction in handover latency. Yet, PFMIPv6-PT has a signaling cost problem. This is due to Handover Initiate (HI) and/or Handover Acknowledge (HAck) message exchange between pMAG and nMAG which is not followed by actual handover to use the tunnels created in advance.

Our scheme improves PMIPv6-PT [2] by using the second order least square method [3] to predict the movement of mobile nodes, and finds candidate MAGs to which to perform a handover. In addition to signal strength and load status, we use handover failure possibility which depend on the speed and direction of mobile nodes. In addition to signal strength and load status, we use handover failure possibility which depend on the speed and direction of mobile nodes. We show via experiment our scheme reduces handover latency and signaling cost compared to conventional PMIPv6-PT [2] and also enhances the packet throughput.

II. A PFMIPv6 Scheme Based on Handover Failure Probability

A. Proposed Algorithm

First, in order to apply the second order least square method for the numerical estimation of mobile node movement, MAG and LMA are positioned in hexagonal cell structure on the rectangular coordinate system. Then, movements of mobile nodes are traced as a polynomial curve of degree 2 on a coordinate at every given interval by using the second order least square method. This process is used to identify APs to which the mobile nodes may belong. Then, identify the MAGs which cover these APs, and create tunnels for each pair of relevant MAGs. Only connected MAGs are candidate MAGs to be chosen for handover, and by limiting candidate MAGs this way, we can reduce signaling cost and handover latency.

The number of handovers can be estimated by dividing the time during which the mobile nodes stay inside the whole network by the average time for receiving service from a MAG. The MAGs to which mobile nodes connect are chosen considering the handover failure probability (based on the speed and direction of the mobile nodes) as well as load status and signaling strength.

Unlike [1], our scheme proposes the advanced Target MAG selection algorithm using the SAW (Simple Additive Weighted) algorithm with less computation. The failure rate in the k^{th} ring applying Mohanty's formula P_f^k was already described in [4]. Here, the estimated handover failure probability denotes the possibility that the current MAG does not handover to any adjacent target MAGs. In other words,

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failure of handover occurs when the handover time is longer than the duration of L2 triggering signal which sends handover requests. We can improve the estimation of failure probability by considering direction of mobile nodes under the hexagonal cell environment. The estimated failure probability is the sum of the three estimated failure probability: forward from k^{th} ring to $(K+1)^{th}$ ring, reverse to $(K-1)^{th}$ ring from k^{th} ring and move to another cell in k^{th} ring. The probabilities for the each directional movement of mobile node, P_k^+, P_k^-, P_k^{Stay} have been already described in [5]. Therefore, the handover failure probability to move forward/back from a cell in k^{th} ring or handover to another cell within the k^{th} ring can be expressed as follows:

$$P_f^k = P_{FMIPv6-PT}^{k+} + P_{FMIPv6-PT}^{k-} + P_{FMIPv6-PT}^{stay} \qquad (1)$$

$$P_{FMIPv6-PT}^{k+} = P_k^+ * P_f^k \qquad (2)$$

$$P_{FMIPv6-PT}^{k-} = P_k^- * P_f^k \qquad (3)$$

$$P_{FMIPv6-PT}^{stay} = P_k^{stay} * P_f^k \qquad (4)$$

In addition, MAGs candidates, MAG C_i are represented with three parameters: load status, signal strength and failure probability. These are expressed in Matrix D.

$$D = C_i\,[\rho_{i1}, S_{i2}, P_{f\,i3}] \qquad (5)$$

Since it is desirable to select an MAG with the lowest load status, the highest signal strength and the lowest handover failure possibility, the factors of the MAG candidates are standardized to get Matrix R as follows:

$$x_{i1} = \frac{\rho_1^{\max} - \rho_{i1}}{\rho_1^{\max} - \rho_1^{\min}} \qquad for \qquad i = 1,2,3,...n \qquad (6)$$

where,

$\rho_1^{\max}$: Maximum value among ρ values of MAG candidates, and

$\rho_1^{\min}$: Minimum value among ρ values of MAG candidates.

$$x_{i2} = \frac{S_{i2} - S_2^{\min}}{S_2^{\max} - S_j^{\min}} \qquad for \qquad i = 1,2,3...n \qquad (7)$$

where,

$S_1^{\max}$: Maximum value among S values of MAG candidates, and

$S_1^{\min}$: Minimum value among S values of MAG candidates.

$$x_{i3} = \frac{P_{f3}^{\max} - P_{fi3}}{P_{f3}^{\max} - P_{f3}^{\min}},\ for \qquad i = 1,2,3...n \qquad (8)$$

where,

$P_{f1}^{\max}$: Maximum value among P_f values of MAG candidates;

$P_{f1}^{\min}$: Minimum value among P_f values of MAG candidates,

and obtain

$R = (x_{i1}, x_{i2}, x_{i3})$.

When considering the weighting factoring;

$$w = (w_\rho, w_s, w_{pf})$$
$$where\ w_\rho + w_s + w_{pf} = 1\ and\ \ w_\rho > w_{pf} > w_s \qquad (9)$$

As a result, Matrix V is;

$$V = [v_{i1}, v_{i2}, v_{i3}] = [w_\rho x_{i1}, w_s x_{i2}, w_{pf} x_{i3}] \qquad (10)$$

In addition, the MAG with the maximum $w_\rho x_{i1} + w_s x_{i2} + w_{pf} x_{i3}$ value is selected from the MAG candidates.

This algorithm improved the estimation of current state of the optimized MAGs compared to the traditional method which only uses the signal strength to predict the handover pathway. This method is advantageous to select the best candidate of MAGs by utilizing the handover failure probability.
Acquired MAGs represents the optimal pathway for mobile nodes, and the tunnels established between MAGs are activated when mobile nodes are connected.

B. Other Consideration

In addition to three criteria mentioned above, we suggest the bandwidth of MAG coverage as a fourth factor to complete MAGs selections with more accuracy. The bandwidth allocation for each node varies depending on the characteristics of each network. Consider the specific network model which has several WLANs in WiMAX coverage [6]. In this case, each mobile node is assumed to use active streaming application and handover is designed to take place in three cases: between WiMAX and WLAN, only between WiMAXs and WLANs.

Considering the previous study of WLAN and WiMAX [6], we showed WLAN with free frequency, higher service capacity and higher data rate provides stable service to mobile nodes in M/M/1 model. In addition, the performance of WiMAX which applies M/M/1/K queuing model was also demonstrated. Based on [6], the mobile nodes within a nMAG coverage are assumed as active streaming mobile nodes which complete handover. On the other hand, elastic mobile nodes wait the activation of their applications in the nMAG coverage. For WLAN/WiMAX heterogeneous network [6], therefore, the expected bandwidth for new elastic mobile nodes coming in the MAG coverage can be described as follows [6].

$$b^e_{wlan} = \frac{C_{wlan}}{d_{wlan}+1} = \frac{C_{wlan}}{(\frac{\rho^2}{1-\rho})+1} = \frac{C_{wlan}*(1-\rho)}{\rho^2-\rho+1} \quad (11)$$

where,

C_{wlan}: Cell capacity in WLAN,

d_{wlan}: Average number of awaiting elastic mobile nodes in WLAN [6]

$$b^e_{wi\max} = \frac{C_{wi\max}-S*B_s}{d_{wi\max}+1} = \frac{C_{wi\max}-\frac{\rho*(1-\rho^k)}{1-\rho^{k+1}}*B_s}{(\frac{\rho}{1-\rho}-\frac{(k+2)\rho^{k+1}-\rho}{1-\rho^{k+1}})+1} \quad (12)$$

where,

$C_{wi\max}$: Cell capacity in WiMAX;

$d_{wi\max}$: Average number of awaiting elastic mobile nodes in WiMAX;

S : Number of mobile nodes with the activated application;

B_s : Bandwidth of the activated mobile node in WiMAX environment, and

k : Buffer size of WiMAX cell.

C. Overall Handover Latency, Signaling Cost and Network Gain

Handover Latency described in earlier study [2] can be converted as follows:

$$T^{pt}_{L3} = \sum_{k=1}^{n} \{(1-P^{\bar{k}}_f)(t_{MN-pBS}+t_{pBS-pMAG} + t_{pMAG-nMAG-nBS-MN}) + (C_{i,j-PTavg}-1)*P^{\bar{k}}_f*T^{pfmip}_{L3}\} \quad (13)$$

where,

k: Number of handovers to selected MAG.

$C_{i,j-PTavg}$: Average number of tunnels established in MAG (i, j) (i: Ring number, j: MAG number in i[th] ring);

T^{pfmip}_{L3} : Handover delay of PFMIPv6

$p^{\bar{k}}_f$: Selected handover failure probability of k^{th} handover.

With the expression given in [2], the overall signaling cost can be calculated as follows:

$$C_{pt} = n*C_{i,j-PTavg}*[C_{pfmip}+P_f*\tau*\{h_{pMAG-nMAG}(L_{HI}+L_{HAck})+\tau*h_{pMAG-nMAG}*(L_{HI}+L_{HAck})] \quad (14)$$

where,

τ: Unit packet transmission cost,
n: Handover counts,
h: Hop numbers,

C_{pfmip} : Signaling cost of PFMIPv6,

L_{HI} : Packet length of HI message,

L_{HAck} : Packet length of HAck message.

The network throughput can be calculated as follows [5]:

$$C = n*\{C^{/MAG}_{i,j-Avg}*(1-\rho^{MAG}_{i,j-Avg})\} \quad (15)$$

where,

n: Handover counts;

$C^{MAG}_{i,j-Avg}$: Average capacity of the MAG that MN handovers to,

$\rho^{MAG}_{i,j-Avg}$: Average load status of the MAG that MN handovers to.

TABLE I. Comparison between the traditional method [1] and the proposed method

	Traditional Method [1]	Propose method
MAG determining factor	Load and signal strength	Load, signal strength, failure probability
Mobile node speed	Non-reflected	Reflected
Mobile node directivity	Non-reflected	Reflected
Method for optimal solution	TOPSIS	SAW

III. EXPERIMENTAL RESULTS

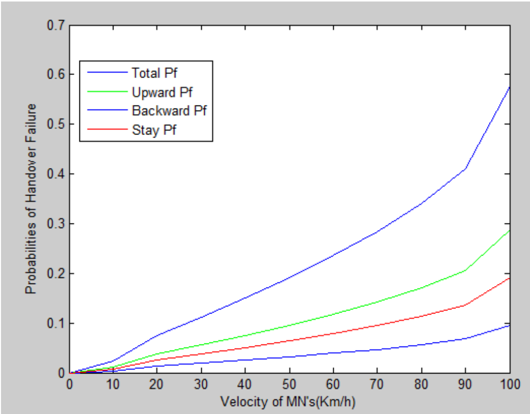

Fig.1.Handover failure probability by mobile speed

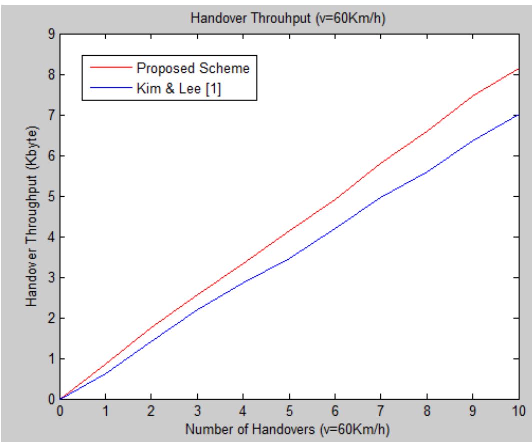

Fig.2.Network gain by handover counts

Basically, our simulation shows that the higher the speed is, the bigger the handover failure probability is in the order of forward, reverse and within the same ring. We set the weight factor, W as the rate of 0.15:0.35:0.5 for signal strength: failure possibility: load status. In the traditional method, the factor was set as 0.4:0.6 for signal strength: load status. In comparison with [1], proposed method enhances the network gain by 13.89 %.

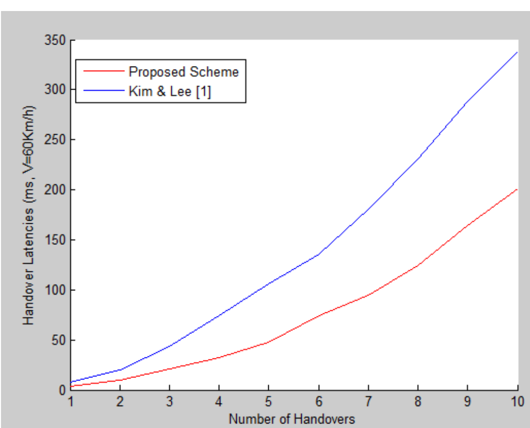

Fig.3.Handover Latencies by handover counts

We verify that the number of the created tunnels is reduced by using the least squares method, and the overall handover latency is reduced by 47.54%. In terms of signaling cost, mobile nodes create tunnels to all MAG candidates regardless of their directivity. Nonetheless, since the number of the created tunnels is reduced by using the least squares method, the signaling cost is reduced by 33.25 %.

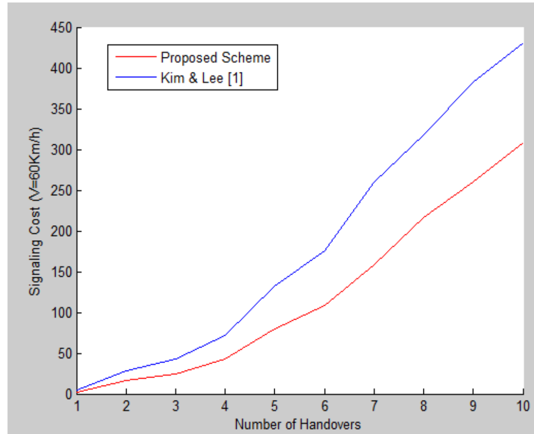

Fig.4.Network signaling cost by handover counts

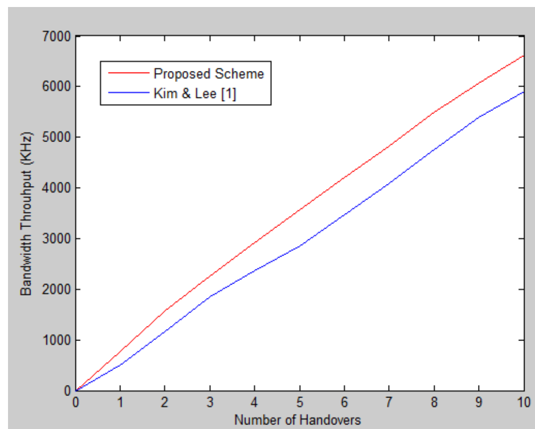

Fig.5.Network Bandwidth Gain by handover counts

Lastly, another experiment was performed by taking account of bandwidth as the 4th factor. We aimed to find optimal bandwidth by considering the WiMAX/WLAN Heterogeneous Network [6]. First, the bandwidth for each cell was calculated in accordance with the each status of WLAN and WiMAX. Then, we implemented the algorithm which utilizes the 4th factor, the biggest bandwidth value out of the calculated ones. In the experiment, for the weight factor W, signal strength: failure probability: load status: bandwidth was assigned as 0.15: 0.35: 0.35: 0.15. In addition, C_{wimax} , C_{wlan}, B_s and K were set as 1,000 Kbps, 600 Kbps, 50 Kbps and 100 respectively. Simulation demonstrated that this method is beneficial to increase bandwidth gain by 10.86 % compared to traditional method [1].

This experiment proved that bandwidth gain and optimized MAG selection for mobile nodes can be improved by actively utilizing the maximum bandwidth acquired from each MAG in heterogeneous network.

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