Analyis of Handover Blocking Probability Based Packet Loss for Adaptive Vertical Handover

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ABSTRACT: *Smartphones and tablets including phone, calendar and others are the necessities of modern man. They are one of the MN (Mobile Nodes), each with wireless network capabilities. Necessities of modern human MNs are almost included in every cellular module available in LTE/3G and Wi-Fi module for high-speed Internet. Until now, MN mobility management is handled in a traditonal way, but network-based mobility management is used in this paper. Then, carriers can manage and maintain the network for low-cost. In addition, this work considered the fact that a large number of users use the Wi-Fi and LTE/3G, and using Cross-Layer-Based handoff.*

Keywords: PMIPv6, MIPv6, Mobility Management, Cross-Layer, Vertical

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1. Introduction

The Mobile Nodes (MN) which is used in our daily lives today contain a lot of functions. The smartphone which includes phone, schedule and other features in one MN has been established as a must-have of modern persons. As users who deal with their business by utilizing their wireless terminals such as smartphone as a kind of MN are getting more and more, the data exchange with wireless network has been extremely increased. Besides, the kinds of networks being used are a lot. A lot of MNs connected with available network, it selects an available network at this time and moves to it. Additionally, users can exchange data without interruption through the permanence of service by migrating networks.

If various wireless access techniques co-exist, two types of handovers are possible [1]. One is the horizontal handover, and the other is vertical handover. The horizontal handover refers to the handover within the same network, and the vertical handover refers to the contrary. In addition to the horizontal and vertical handovers, the handovers can be divided into two types depending on the subject to sense a terminal get out of an access network and enter another access network. One is the host-based handover, and the other is the network-based handover. The host-based handover means that the MN of user who is provided with service literally senses the change of network, and carries out the handover. The network-based handover means that the MN does not recognize separately its getting-out-of-the network, and the network recognizes it and carries out the handover. Most handovers which are carried out are horizontal handovers, which are host-based handovers which are carried out by the terminal. The network-based mobility management techniques are carried out with cheaper cost than host-based mobility management techniques in calculating the total expenses in general [2].

After carrying out the vertical handover, the MN must carry out the binding update to new IP address in order to maintain the data transmission to new path through connecting with the original TCP. The IETF established the mobile IPv6 [3] in order to solve the problems that IP address is updated when the MN moves from one network to the other network. At [4] it discussed the problem of the quick handover in the WLAN. In order to solve this problem in the vertical handover, the cross layer-based prediction RSS (Received Signal Strength) method can carry out the vertical handover in the heterogeneous wireless network. This study analyzes the performance of the handover which utilizes the a-little-cheaper network-based mobility management technique of various mobility management techniques. And this study composes the performance analysis environment the composition which is similar to the real environment by using LTE/3G and Wi-Fi which are widely being used.

The rest of this paper is organized as follows. In Section 2, we explained the section perpendicular to the handover study mobility management. In Section 3, the cross-layer prediction method based on using RSS (Received Signal Strength) introduces how to apply the MIPv6 and PMIPv6. In Section 4, Constituting a network model, the performance evaluation carried out with the proposed information. In Section 5, according to perform performance, the results of the different approaches are evaluated and discuss future research directions.

2. Related Work

Variety of the MN (Mobile Node) protocols have been introduced to support the mobile services. In particular, the mobility of the network layer has been developed by the IETF.

PMIPv6 specifications: [5] The improved performance enacted after PMIPv6 FMIPv6 [6] and HMIPv6 [7] have been developed. The Performance Analysis of the IPv6 mobility management protocol was developed to help the expansion of the MIPv6. [8], [9] For example, the performance analysis of MIPv6, PMIPv6, a combination of research and PMIPv6 for HMIPv6 and HMIPv6 was made to perform the characteristics and performance indicators for each mobility management protocol.

A number of RSS-based handover algorithms have been developed for cellular communication. [13] proposed a handover method based on the RSS to determine when to initiate a handover process. This approach is a large amount of unnecessary hand-over which is triggered by generating a ping-pong approach to move the developing region between the two adjacent network MNs. [14] was used in the space between two limit values, such as hysteresis to prevent the ping-pong phenomenon such. [15] proposed a hand-over method based on taking into account the hysteresis of the RSS limit to improve the performance. In a heterogeneous wireless network, the MN and a signal it receives of varying intensity in the various networks is used. [16] proposed a neural network to determine the network to perform a handover process from the RSS-based approach. If the RSS only considers the vertical handover, because to get the best result, [17], taking into account both the distance between the RSS and the MN and a base station, and preventing handover to the base station is not correct. However, in most cases depends on the distance RSS with the heterogeneous wireless network receives the same problem. [18] defines the handover of available bandwidth costs and make a financial cost as a function in, offered at any time in the best of wireless policy based handover system to determine the selection system [19]. This policy-based handover system reduces the cost, performance, network characteristics and dynamics, including the efficiency of power consumption. The main goal is to avoid the problem of a handover unstable. [20] proposed a handover cost function from the side is similar to that suggested by the use of the available bandwidth to the actual RSS of two important parameters in [21]. This method is just one of the RSS processes only limit and cause the occurrence of the ping-pong phenomenon.

3. Cross layer based adaptive vertical handover

This chapter is composed as below. First, it introduces the features of the heterogeneous network vertical handover in the wireless, and defines the network model. Second, it explains problems of the vertical handover. Third, it defines the number of the vertical handover, the probability of connection interruption, and the network utilization in order to analyze the performances in diverse environments.

The proposed method of the vertical handover in the heterogeneous wireless network is explained as two aspects. One is the prediction RSS mechanism and the adaptation vertical handover which are going to be explained in this chapter. The other is the cross layer mechanism which is going to be explained in the next chapter. The adaptation vertical handover using the prediction RSS mechanism is composed of the aspect of prediction RSS using hysteresis when handover occurs and the aspect to determine the optimum wireless network. At the first aspect, the polynomial regression-based prediction RSS method proposes a prediction whether the MN moves close to the network or far from the network. At the second aspect, the handover cost is determined on the base of MDP (Markov Decision Process) function. The cheapest network becomes the optimum network for handover. The second stage is the burden distribution and permanence. The adaptation vertical handover method is as follow. The SWGoS is adapted as some important statistics, and is expressed as follow.

$$SWGoS = W_B \sum_{k=1}^{K} kB_k + W_D \sum_{k=1}^{K} kD_k \quad (1)$$

B_k and D_k shows blocking and interruption of the each class k traffic, and W_B and W_D shows the weighted value of blocking and interruption of each connection. This study set the value of W_B and W_D as 1 and 10. Third, the network usage rate is adapted as separate performance analysis. The high network usage rate shows better performance.

The RSS method using hysteresis is adapted in order to avoid unnecessary handover due to ping-pong effect. When it is assumed the H_1 shows the hysteresis between LTE/3G and WWAN, the low limit value is expressed as $S_{WLAN,1}$, and the high threshold value is expressed as $S_{WLAN,2}$, and the size between two threshold values of H_1 is expressed as $\Gamma H_1 = |S_{WLAN,2} - S_{WLAN,1}|$. Even though the MN does not carry out the unnecessary handover within two threshold values but exchange data properly, if the MN is adjacent to the low threshold, the signal of RSS of the serving network becomes weak and thus the data speed is decreased so that it causes a low utilization and high probability of interruption.

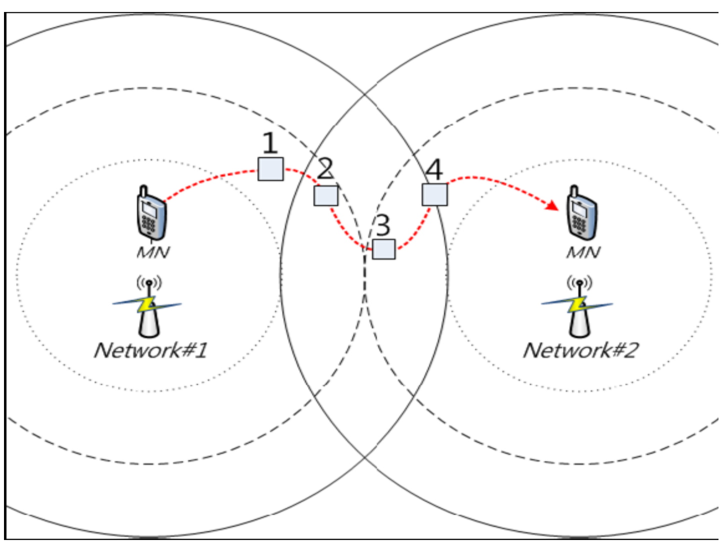

Figure 1. Across the network of MN

Figure 1 shows the process that the MN moves from the network 1 to the network 2. At the RSS-based handover method, the MN carries out the handover when it is in the overlapping area of two networks so that the handover carrying-out man occur at point

2, point 3, and point 4. If the MN moves close to the area where the network overlapping starts or ends, severe ping-pong effect occurs. While the RSS method carries out the handover at point 4, the point 4 is the place where the MN receives the very weak RSS from the network 1. This provides the low data speed so that the possibility of the network interruption is very high. Thus, this study proposes the prediction RSS-based handover in order to carry out the handover at the point 2 when the MN is expected to move to the network 2. The prediction RSS mechanism has two advantages. First, by carrying out the handover before the RSS begins to be weak, the prediction RSS mechanism can acquire good QoS (Quality of Service) and high data transmission speed. Second, it can prevent unnecessary handover and reduce the possibility of network interruption certainly.

4. Performance Evaulation

4.1 Network Modeling

Consider the network model is configured to perform the horizontal and vertical hand-over handover between one of the two different network terminals.

The number of hops is defined below to describe the distance between a certain point between the communicating entities. In the proposed network model data / control packets, which are exchanged between the MN and the CN it must be transmitted through the GW. For example, if the route optimization of MIPv6 (RO) has been set, the data packet transmitted from the MN CN is made through $h_{c-G} + h_{L-A} + h_{A-M}$, h_{A-M} is connected to the air of the MN and the AR. In addition, h_{A-A} is expressed by $\sqrt{h_{L-A}}$ [24], [25].

Various messages relating to the IPv6 mobility support is used in the mobility management protocol. Message size to consider in analyzing the mobility model are as follows:

- L_{RS} : RS (Router Solicitation) message size, 52.
- L_{RA} : RA (Router Advertisement) message size, 80.
- L_{BU-HA} : MN sent from the HA BU (Binding Up) message size, 56.
- $L_{BAck-HA}$: In response to the HA MN BAck (Binding Acknowledgment) message size, 56.
- L_{BU-CN} : Size BU message transmitted from the MN to the CN, 66.
- $L_{LBU-MAP}$: In the MN transmits the MAP LBU (Local Binding Update) message size, 56.
- $L_{LBAck-MAP}$: The MAP in response to the MN LBU (Local Binding Acknowledgment) message size, 56.
- $L_{PBU-LMA}$: A transfer from the LMA MAG PBU (Proxy Binding Update) message size, 76.
- $L_{PBAck-LMA}$: In the LMA sent to MAG PBAck (Proxy Binding Acknowledgment) message size, 76.
- L_{HoTI} : HoTI (Home Test Init) message size, 64.
- L_{CoTI} : CoTI (Care-of Test Init) message size, 64.
- L_{HoT} : HoT (Home Test) message size, 74.
- L_{CoT} : CoT (Care-Of Test) message size, 74.
- L_{FBU} : FBU (Fast Binding Update) message size, 56.
- L_{FBAck} : FBAck (Fast Binding Acknowledgement) message size, 56.
- L_{UNA} : UNA (Unsolicited Neighbor Advertisement) message size, 52.
- $L_{RtSol\ Pr}$: RtSolPr (Router Solicitation for Proxy Advertisement) message size, 52.
- $L_{Pr\ RtAdv}$: PrRtAdv (Proxy Router Advertisement) message size, 80.
- L_{HI} : HI (Handover Initiate) message size, 52.
- L_{HAck} : HAck (Handover acknowledge) message size, 52.
- L_{T} : Size tunneling header, 40.
- L_{D} : User data packet size, 120.

Like the FMIPv6, FPMIPv6 is composed of the prediction mode and the post.

Defining the handover latency of Pre-FPMIPv6 to $L_{HO}^{(Pre\text{-}FPMIPv6)}$, and is expressed as follows.

$$L_{HO}^{(Pre\text{-}FPMIPv6)} = T_{L2} + T_{PRE\text{-}P} \tag{2}$$

$T_{PRE\text{-}P}$ is composed of a first data packet $d_{mag\text{-}packet}$ to send to the MN the IP layer to the total connection delay D_π and nMAG. Therefore, $T_{PRE\text{-}P}$ is expressed as follows.

$$T_{PRE\text{-}P} = D_\pi + d_{mag\text{-}packet} \tag{3}$$

D_π is assumed to have a delay time such as the $d_{wl}(L_{UNA})$ of the paper $d_{mag\text{ - }packet} = d_{wl}(L_D)$.

Re-FPMIPv6 handover latency is defined as a $L_{HO}^{(Re\text{ - }FPMIPv6)}$, is represented as follows:

$$L_{HO}^{(Re\text{ - }FPMIPv6)} = T_{L2} + T_{RE\text{ - }P} \tag{4}$$

$T_{RE\text{-}P}$ includes a time to receive the first data sent from the exchange time, nMAG between the time the necessary information related to the MAG connected to the IP layer. Note that a data packet is tunneled to nMAG As in pMAG sent to the MN. $T_{RE\text{-}P}$ is expressed as follows.

$$T_{RE\text{-}P} = D_\pi + d_{wd}(L_{HI}, h_{A\text{-}A}) + d_{wd}(L_{HAck}, h_{A\text{-}A}) + d_{buff\text{ - }packet} \tag{5}$$

To analyze the handover failure of each mobility management protocol, [28], [29], [30] use the proposed handover blocking probability here. It may fail for various reasons, such as when the handover is a handover latency is high noise in the signal without being able to accommodate for the MN exists; no radio channels are available. For example, if the remaining time the MN stays in the network is less than the handover completion time, it is due to the loss of the link information and the radio channel and the handover failure to the MN.

$L_{HO}^{(\cdot)}$ is assumed to represent a hand-over delay in the specific mobility management protocol that was developed in the previous subsection. Note that is used as the protocol indicator. $E\lceil L_{HO}^{(\cdot)} \rceil$ refers to the value of $L_{HO}^{(\cdot)}$. T_R is assumed to represent the network residence time using the probability density function $f_R(t)$. For simplicity, $L_{HO}^{(\cdot)}$ is considered that by using the cumulative distribution function $F_T^{(\cdot)}(t)$ with an exponential distribution. And also $L_{HO}^{(\cdot)}$ is the only barrier elements handover, the handover probability block p_b is expressed as follows.

$$\begin{aligned} p_b &= \Pr(L_{HO}^{(\cdot)} > \mathrm{T_R}) \\ &= \int_0^\infty (1 - F_T^{(\cdot)}(u))\, F_R(u)\, du \\ &= \frac{\mu_C E\lceil L_{HO}^{(\cdot)} \rceil}{1 + \mu_C E\lceil L_{HO}^{(\cdot)} \rceil} \end{aligned} \tag{6}$$

μ_C is the probability of boundary crossing of the MN. Assuming the coverage of the AR has occurred in a circle, the phenomenon of μ_C is [24], [27], [31] and it is expressed as follows:

$$\mu_C = \frac{2v}{\pi R} \tag{7}$$

And v is the average moving speed of the MN in the above formula, R is the radius of the coverage of the AR.

The MN may be loss of data packets destined to the MN when the buffer management that does not exist in the network side for causing the handover. The amount of packet loss occurring during handover $\varphi^{(\cdot)}_p$ is defined as the sum of the loss of the data packet sent from the MN to the CN.

$$\varphi^{(\cdot)}_p = \lambda_S E(S)\, L_{HO}^{(\cdot)} \tag{8}$$

λ_S is the MN and the average session arrival probability of the air interface, and $E(S)$ is the average length of the packet session. In the above formula $\varphi^{(.)}_p$ is directly proportional to the $L^{(.)}_{HO}$. FMIPv6 and FPMIPv6, but such fast hand-over protocol, the packet loss is not caused by the packet buffer, the delay of the packet communication is generated [31].

Most of the RSS-based handover algorithm to select a destination network to handover is the strongest network signal strength. Since MN is to specify a strong network signal strength, and the available bandwidth of the network is insufficient to cause an imbalance between the network traffic. Therefore, this chapter proposes a cost-based approach to define the MDP handover cost of all wireless networks. Then, the handover to the wireless network with the lowest cost to the handover to achieve the object of the spray load. In this paper, the MDP approach reduce the bandwidth allocation problem as MDP according to the Markov decision theory network, resulting in a cost for performing the handover connection [21]. It can lead to a large state space for the accurate modeling of the MDP but studies so far two assumptions, for example made the assumption of link independence and path costs [32]-[35]. Simplified model proposed in the link [35] is the computational complexity in a multi-service network, further reducing losses in the status area. Also, MDP analysis was successfully employed to determine the optimal code for the single- and multiple-code of the resource management of the LTE / 3G [36].

MDP status of the wireless network is based in accordance with the acceptable bandwidth, the network is assumed to support the k class of service for each of the QoS requirements. Now the total capacity C_w represents the relationship between birth rate and death rate of Markov processes with μ^i_k of λ^i_k as follows:

$$\mu^i_k \pi(i) = \lambda^i_k \pi(i\text{-}1), \qquad i = 1,.....,C_w \tag{9}$$

$$\sum_{i=0}^{C_w} \pi(i) = 1 \tag{10}$$

In the above formula, k is a traffic class, and i shows the state of the receiving bandwidth.

By forming the MDP in the process of birth and death process, the long-term average of the relative value relationship between the set g and $v(i)$ compensation loss is expressed as follows.

$$v^w(C_w) - v^w(C_w\text{-}1) = \frac{\sum_{i=0}^{K} r^{wi} \lambda^w_i}{\overline{\lambda}^w_{Cw\text{-}1}} \; \frac{E(\overline{\lambda}^w, C_w)}{E(\overline{\lambda}^w, C_w\text{-}1)} \tag{11}$$

$$v^w(i) - v^w(i\text{-}1) = \frac{g}{\overline{\lambda}^w_{i\text{-}1} E(\overline{\lambda}^w, i\text{-}1)}, \qquad 1 \le i \le C_w \tag{12}$$

The $E(\overline{\lambda}^w, i)$ and g in the above formula is expressed as follows.

$$E(\overline{\lambda}^w, i) = \frac{1/i! \prod_{i=0}^{i\text{-}1} \overline{\lambda}^w_i}{\sum_{n=0}^{i} 1/n! \prod_{i=0}^{n=1} \overline{\lambda}^w_i} \tag{13}$$

$$g = \sum_{i=1}^{k} r^w_i \lambda^w_i - C_w(v^w(C_w) - v^w(C_w\text{-}1)) \tag{14}$$

r^w_i and λ^w_i denotes the arrival rate of the Class i traffic at each network coverage and network w.

And, in a Class k network w connection arrival rate λ^w_k and is calculated on the Online which is a EWMA (Exponentially Weighted Moving Average) model, such as $\lambda^w_{k,new} = (1\text{-}\alpha).\ \overline{\lambda}^w_{k,old} + \alpha = (1\text{-}\alpha).\ \lambda^w_k / 1\text{-}B^w_k)$. In the EWMA model $\overline{\lambda}^w_k$ represents the average number of connections from the network w and Class k according to the time unit that is updated at regular intervals. And, $\lambda^w_{k,new}$ is the new predicted arrival rate, $\lambda^w_{k,old}$ is the previous predicted arrival rate, and B^w_k is connected to the class k ratio of the off time, α a has a constant (0, 1).

Formula according to the difference between the relative values obtained in (14) and (15), the cost of the k class handover connection in the network w of the receiving person for i is defined as $\Gamma^{w}_{k}(i)$, and expressed as follows.

$$\Gamma^{w}_{k}(i) = \begin{cases} \dfrac{v^{w}(i + b_k) - v^{w}(i)}{\mu_k}, & (i + b_k \le C_w) \\ \infty, & \end{cases} \quad (15)$$

In the above formula, b_k is the required bandwidth for the class k handover connection to the network w . If there is more than one possible neighbor network, the least cost network is the optimal network NET_{opt} and is selected when the MN to the handover. As a result, MDP cost-based approach select the appropriate network, improve the transmission quality, and has a load balancing do the advantages. Finally, the analysis is the time complexity of the MDP-based adaptive prediction RSS method. RSS is a polynomial regression analysis based prediction and system proceeds to the two kinds of MDP optimal cost-based approach for determining the destination network. First, the handover algorithm is to calculate the prediction RSS in a manner to obtain the linear equation Z using Gaussian elimination, each element of the linear equations is determined to be H before RSS. The time complexity of Gaussian elimination, the $O(Z^3)$, Z represents a matrix of $Z \times Z$. In the worst case, most of the N WLAN is able within the transmission range of the MN. Overall time complexity of a handover detection process are represented as follows:

$$O(NZ^3) \quad (16)$$

The polynomial function are determined constants Z is a period of time is necessary for each prediction RSS. Therefore, the time complexity of $N \ge M$ is represented by $O(NZ^3)$, or vice versa is represented by $O(MZ^3)$.

Secondly, in the MDP cost-based approach, we propose a network selected by the handover target network, the least cost in the best list. MDP time complexity for determining the least-cost network is a WLAN based on the $O(N)$.

4.2 Numerical Results

In this chapter, the results show the performance of mobility management protocols. For numerical analysis, [37] - [39] and utilizing the values of variables used.

$h_{C-H} = 4$, $h_{C-L} = 4$, $h_{H-L} = 4$, $h_{L-A} = 4$, $h_{A-M} = 1$,
$E(S) = 10$, $\tau = 20ms$, $n = 3$, $L_f = 19bytes$,
$D_{wl} = [10,40]\ ms$, $D_{wired} = 0.5\ ms$, $BW_{wired} = 100Mbps$,
$T_{DAD} = 1000\ ms$, $T_{L2}^{Wi\text{-}Fi \rightarrow Wi\text{-}Fi} = 45.35\ ms$, $T_{L2}^{LTE/3G \rightarrow Wi\text{-}Fi} = 68.03\ ms$,
$T_{L2}^{LTE/3G \rightarrow LTE/3G} = 90.7\ ms$, $T_{L2}^{Wi\text{-}Fi \rightarrow LTE/3G} = 136.05\ ms$

1) Handover blocking probability

This chapter assumes the value of the v and R with 20 m / s and 500m. And D_{wl} is fixed at 10 ms and, p_f is increased from 0 to 0.7 with 0.05 interval.

Handover blocking probability analysis considers only performed for the handover latency of the barrier element. The value of p_f is increased to increase the probability of blocking hand-over. Handover blocking probability of Pre-FMIPv6 and FPMIPv6 is low but relative to other protocols, the probability of blocking hand-over MIPv6 is high. The following analysis deals with the PMIPv6. p_f and R are set to 0.2 and 500m and, v varies from 0m/s to 30m/s.

Figure 2 is a hand-over delay in the Pre-FMIPv6 and FPMIPv6 p_f, v, R represents the short enough to avoid blocking issues, to the handover cause. The reason is because the fast predictive performance is superior than other protocols of the hand-over protocol to prepare the MN by using the L2 information before performing handover to the new access network from the previous access network.

2) Packet loss

While the MN is performing the handover, data packets sent from the CN to the MN will be discarded without any buffering mechanisms.

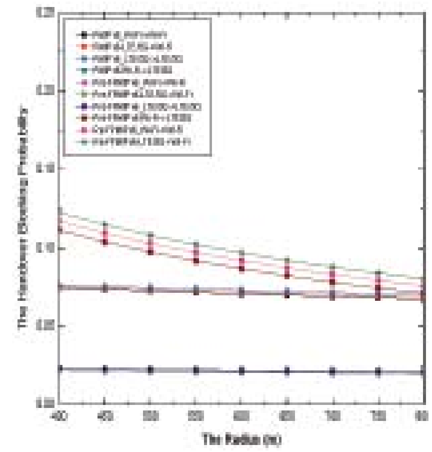

Figure 2. R handover blocking probability due to changes in

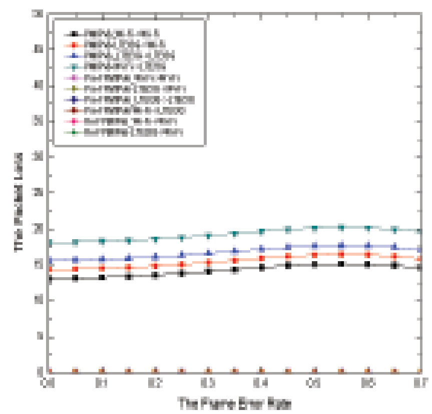

Figure 3. D_{wl} = 10 ms, p_f packet loss due to changes in

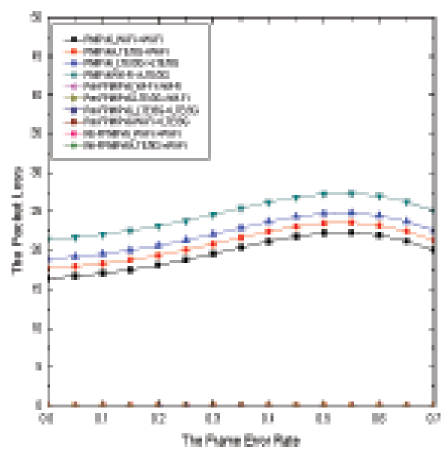

Figure 4. D_{wl} = 40 ms, p_f packet loss due to changes in

Figure 3 and Figure 4 shows the packet loss during the handover. At this point, λ_S and the E(S) is set to 1 and 10 respectively. Then, p_f by a different value of D_{wl}, it is vary from 0 to 0.7. Although the value of D_{wl} in Figure 4 is set to 40ms, the Figure 3 D_{wl} was set to 10ms. According to Figure 3 and Figure 4, p_f with a higher D_{wl} the value is shown to be a more destructive effect on the packet loss.

5. Conclusion

This study analyzed the existing IPv6 mobility management protocol which was developed by the IETF, and compared it in terms of handover delay time, handover interruption probability, and packet loss. The following results are confirmed through the performance analysis. First, in order to improve the handover performance, the L2 information must be utilized. As Figures 4, 5 and 6 show that the handover delay time is reduced, the handover interruption probability is decreased too. Second, the buffering management mechanism must be introduced in order to prevent the packet loss when the handover occurs. As Figures 7 and 8 express, the quick handover protocol such as FPMIPv6 prevents the loss of data packet which the CN transmits. The results of the performance analysis of this study can be used in order to identify the feature and result index of each mobility management protocol. Besides, it can be used to facilitate the decision making for development of new mobility management protocol.

References

[1] Lee, S-H., Shin, D-R., Jeong, J-P. (2012). SePH: Seamless Proxy-based Handoff Scheme in IP-based Heterogeneous Mobile Networks, *The KIPS transactions*. Part C 19 (1) 71-82.

[2] Kim, K-T., Jeong, J-P. (2012). Cost Analysis of Mobility Management Schemes for IP-based NextGeneration Mobile Networks, *Journal of Korean Socieity Internet Information* 2012. Apr: 13 (3) 1-16.

[3] Johnson, D., Perkins, C., Arkko, J. (2004). Mobility support in IPv6, Jun. 2004. IETF RFC 3775.

[4] Pack, S., Choi, J., Kwon, T., Choi, Y. (2007). Fast-handoff support in IEEE 802.11 wireless networks, Commun. Surveys Tuts., 9 (1) 2-12, First Quarter.

[5] Johnson, D., Perkins, C., Arkko, J. (2004). Mobility Support in IPv6, IETF RFC 3775, June 2004.

[6] Koodli, R. (2005). Fast Handovers for Mobile IPv6, IETF RFC 4068, July 2005.

[7] Soliman, H., Castelluccia, C., ElMalki, K., Bellier, L. (2005). Hierarchical Mobile IPv6 Mobility Management (HMIPv6), IETF RFC 4140, August 2005.

[8] Koodli, R. (2009). Mobile IPv6 Fast Handovers, IETF RFC 5568, July 2009.

[9] Soliman, H., Castelluccia, C., ElMalki, K., Bellier, L. Hierarchical Mobile IPv6 (HMIPv6) Mobility Management, IETF RFC 5380, October.

[10] Gundavelli, S., Leung, K., Devarapalli, V., Chowdhury, K., Patil, B. (2008). Proxy Mobile IPv6, IETF RFC 5213, August 2008.

[11] Chai, H-S., Jeong, J-P. (2012). Security Analysis and Implementation of Fast Inter-LMA domain Handover Scheme in Proxy Mobile IPv6 Network, *The KIPS transactions*. Part C 19 (2) 99-118.

[12] Yokota, H., Chowdhury, K., Koodli, R., Patil, B., Xia, F. (2010). Fast Handovers for Proxy Mobile IPv6, IETF RFC 5949, September 2010.

[13] Pollini, G. P. (1996). Trends in handover design, *IEEE Commun. Mag*., 34 (3) 82-90, Mar. 1996.

[14] Zhangand, N., Holtzman, J. M. (1996). Analysis of handoff algorithms using both absolute and relative measurements, *IEEE Trans. Veh. Technol*., 45 (1) 174-179, Feb. 1996.

[15] Marichamy, P., Chakrabarti, S., Maskara, S. L. (2003). Performance eval- uation of handoff detection schemes, *In:* Proc. IEEE Conf. Converg. Technolog. Asia-Pacific, Oct. 2003, vol. 2, 643-646.

[16] Pahlavan, K., Krishnamurthy, P., Hatami, A., Ylianttila, M., Makela, J. P., Pichna, R., Vallstron, J. (2000). Handoff in hybrid mobile data networks, *IEEE Pers. Commun*., 7 (2) 34-47, Apr. 2000.

[17] Bing, H., He, C., Jiang, L. (2003). Performance analysis of vertical hand- over in a UMTS-WLAN integrated network, *In:* Proc. IEEE Int. Symp. Pers., Indoor, *Mobile Radio Commun.*, Sep. 2003, 1, p. 187-191.

[18] McNair, J., Fang, Z. (2004). Vertical handoffs in fourth-generation multinet- work environments, *IEEE Wireless Commun*., 11 (3) 8-15, Jun. 2004.

[19] Wang, H. J., Katz, R. H., Giese, J. (1999). Policy-enabled handoffs across heterogeneous wireless networks, *In:* Proc. IEEE Mobile Comput. Syst. Appl. Conf., Feb. 1999, p. 51-60.

[20] Fang, Z., McNair, J. (2004). Optimizations for vertical handoff decision algo- rithms, *In:* Proc. IEEE Wireless Commun. Netw. Conf., Mar. 2004, V. 2, 867-872.

[21] Zhang, Q., Guo, C., Guo, Z., Zhu, W. (2003). Efficient mobility management for vertical handoff between WWAN and WLAN, *IEEE Commun. Mag*., 41 (11) 102-108.

[22] Guo, C., Guo, Z., Zhang, Q., Zhu, W. (2004). A seamless and proactive end-to-end mobility solution for roaming across heterogeneous wireless networks, *IEEE J. Sel. Areas Commun.*, 22 (5) 834-848.

[23] Howard, R. A. Dynamic Programming and Markov Processes.

[24] Zhang, X., Castellanos, J., Campbell, A. (2002). P-MIP: Paging Extensions for Mobile IP, *ACM Mobile Networks and Applications,* 7 (2) 127-141, March 2002.

[25] Lee, J.-H., Pack, S., You, I., Chung, T.-M. (2009). Enabling a Paging Mechanism in Network-based Localized Mobility Management Networks, *Journal of Internet Technology,* 10 (5) 463-472, October 2009.

[26] Lee, J.-H., Han, Y.-H., Gundavelli, S., Chung, T.-M. (2009). A comparative performance analysis on Hierarchical Mobile IPv6 and Proxy Mobile IPv6, *Telecommunication Systems*, 41 (4) 279-292.

[27] Lee, J.-H., Chung, T.-M. (2010). How much do we gain by introducing Route Optimization in Proxy Mobile IPv6 networks?", *Annals of Telecommunications*, 65 (5-6) 233-246.

[28] Yang, S., Zhou, H., Qin, Y., Zhang, H. (2009). SHIP: Cross-layer mobility management scheme based on Session Initiation Protocol and Host Identity Protocol, *Telecommunication Systems*, 42 (1-2) 5- 15.

[29] McNair, J., Akyildiz, I. F., Bender, M. D. (2000). An Inter-System Handoff Technique for the IMT-2000 System, *In*: Proc. of IEEE Annual Joint Conference of the IEEE Computer and Communications Societies (IN- FOCOM) 2000, p. 208-216, March 2000.

[30] Lee, J.-H., Kim, M., Koh, B.-S., Chung, T.-M. (2010). Adaptive Authen- tication and Registration Key Management Scheme based on AAA Architecture, *Intelligent Automation and Soft Computing,* 16 (4) 519-536.

[31] Makaya, C., Pierre, S. (2008). An Analytical Framework for Performance Evaluation of IPv6-Based mobility Management Protocols, *IEEE Transactions on Wireless Communications,* 7 (3) 972-983, March 2008.

[32] Ott, T. J., Krishnan, K. R. State dependent routing of telephone trafficProc. Int. Teletraffic Congr.

[33] Chung, S.-P., Ross, K. W. Reduced load approximations for multirate, *IEEE Trans. Commun*., 41 (8) 1222-1231.

[34] Hwang, R.-H., Kurose, J. F., Towsley, D. (2006). State dependent routing for Proc. IEEE Global Commun. Conf., Dec. 1992, *Comput. Commun*., 29 (11) 1948-1958, Jul. 2006.

[35] Hwang, R.-H. Routing in high-speed networks, Comput. Sci. Dept.,

[36] Chang, B.-J., Chang, P.-S. (2006). Multicode-based WCDMA for reduc- ing waste rate and reassignments in mobile cellular communications, *Comput. Commun*., 29 (11) 1948-1958, Jul. 2006.

[37] Banerjee, N., Wu, W., Das, S. K., Dawkins, S., Pathak, J. (2003). Mobility Support in Wireless Internet, *IEEE Wireless Communications*, 10 (5) 54-61.

[38] Han, Y.-H., Min, Min, S.-G. (2009). Performance Analysis of Hierarchical Mobile IPv6: Does it Improve Mobile IPv6 in Terms of Handover Speed?, *Wireless Personal Communications*, 48 (4) 463- 483, March 2009.

[39] Pack, S., Choi, J., Kwon, T., Choi, Y. (2007). Fast-Handoff Support in IEEE 802.11 Wireless Networks, *IEEE Communications Surveys & Tutorials*, 9 (1) 2-12.