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A VERTICAL HANDOVER TRIGGER MECHANISM BASED ON GRAY PREDICTION

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ABSTRACT

Cross layer handover schemes are expected to provide seamless services for mobile terminal in the heterogeneous wireless networks. To reduce the handover delay time, link layer must timely trigger handover protocols of layer 3 so that they can finish handover procedures before current wireless link terminates. Because of limited computing power with the mobile terminal and larger packet loss rate for vertical handover, in this paper, we propose a novel trigger mechanism based on gray prediction. Firstly, the time required to perform handover is estimated. Secondly, the time to trigger a Link_Going_Down is determined according to convex optimization theory, both considering the received signal strength from currently connected network and target access network. Simulation results show that this mechanism can obtain higher prediction accuracy with the same prediction step, and the packet loss rate can be controlled within 5% when the terminal moving speed less than 5m/s.

Keywords: *Heterogeneous Wireless Networks, Vertical Handover; Gray Prediction Theory; Link Layer Trigger; Required Handover Time*

1. INTRODUCTION

In the near future, it will be found the situation in which users of wireless networks will no longer be bound by a subscription of one network. Evolution of mobile technologies have resulted in NGWNs networks, which are expected to provide support for heterogeneous access technologies. On the other hand, mobile devices are currently built with different network interfaces, and it can connect to any combination of these net-works (GPRS, UMTS, WLAN, WiMAX, BLUETOOTH etc) [1]. The vertical handover procedure generally can be divided into three phase such as target network selection, handover decision and hand over implementation. The purpose of handover decision is to select the most appropriate moment to trigger the handover [2]. To get the status information timely and accurately from current and target access network is the premise of the handover decision. Media Independent Handover mechanism (MIH) provides a convenient for cross-layer information exchange during the process of vertical handover. Especially for hard handover mechanisms (such as between WLAN and WiMAX), effective MAC layer trigger mechanism can accurately predict the Link Going Down (LGD, link going down) and trigger network layer handover procedure in advance, greatly reduce handover delay and communication interrupt probability [3].

Link layer information is critical to layer 3 and above entities in order to better streamline handover-related activities such as the initiation and the execution of fast mobile IP procedures. If a layer 3 handover protocol does not finish before the switches in wireless links, the service continuity of a MN will not be guaranteed. On the other hand, if a L2 trigger does not correspond to a handover, system resources are wasted because the handover signaling messages exchanged between a MN and a wireless network become useless [4]. To solve this problem, many research proposed to select the most appropriate RSS threshold for handover decision, and find the balance between radio resource utilization and communication interrupt probability. N. Golmie [5] proposed an analytical model to estimate the LGD threshold in order to achieve a target handover packet loss performance. Inwhee Joe [6] and Manish Korde [7] propose a mobility-based prediction algorithm with dynamic LGD triggering for vertical handover. Sang-Jo Yoo [8] propose a new predictive handover framework, the time required to perform a handover is estimated based on the neighboring network conditions, and the time to trigger a Link_Going_Down to initiate handover is determined using a least mean square linear prediction. Jaesung Park [9] propose a mobility model that does not assume any radio

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propagation environments and movement patterns of a mobile node, k-step ahead RSSI value is predicted by using the AR(p) model with the RSSI values in a time window. Run-yun Zhang [10] calculates the received signal power using Gauss-Markov terminal moving model, improved the prediction accuracy by selecting correction factor.

Although the methods mentioned above apply dynamic prediction method for selecting LGD trigger time, but did not consider the target access network signal status. Jilei Yan [11] propose a handover trigger time selection strategy based on the prediction of RSS, predicts both the link down (LD) time of the current serving network and the link up (LU) time of the handover target network by AR model, which are the latest and the earliest trigger time threshold. This method has a good adaptability to the varying network overlapping environment, but it require higher computing ability for mobile terminal, do not discuss the multi-value selection of prediction algorithm.

In this paper, we propose a vertical handover trigger time selection strategy based on Gray Prediction (GP), determine the prediction step by estimation of handover required time, both consider the mobile terminal RSS from current connected network and target access network, and found the link layer handover trigger time to minimize the packet loss rate.

The rest of paper is organized as follows. In Section II, handover prediction model is described in detail. In Section III we provide the steps of handover trigger time selection. In Section IV, simulation results and corresponding analysis are described. Section V concludes this paper.

2. TRIGGER TIME SELECTION

2.1 Gray Prediction Model

During the handover prediction process, storage and operation of the signal measurement data are all handled by mobile terminal. For the restrictions of the terminal performance, it is impossible for excessive samples in real-time prediction processing. Compared to other prediction theory, gray prediction model is more suitable for short time series prediction, which can find sequence characteristics from short data series, and keep higher prediction accuracy [12].

We employ gray theory model GM (1, 1) for signal strength prediction. Assume that the signal strength sequence from wireless base station is:

$$X^{(0)}=\{x^{(0)}(1),x^{(0)}(2),\cdots,x^{(0)}(n)\} \tag{1}$$

Through one time accumulate and generate 1-AGO sequence:

$$X^{(1)}=\{x^{(1)}(1),x^{(1)}(2),\cdots,x^{(1)}(n)\} \tag{2}$$

Where $x^{(1)}(k)=\sum_{i=1}^{k}x^{(0)}(i) \quad k=(1,2,\cdots n)$。

Establish the first-order linear differential equations for $X^{(1)}$:

$$\frac{dx^{(1)}}{dt}+ax^{(1)}=u \tag{3}$$

Where α is the development coefficient, u is the gray role degree.

To Solve equation (3), we get the gray prediction equation:

$$\hat{x}^{(1)}(k+1)=[x^{(0)}(1)-\frac{u}{a}]\mathrm{e}^{-ak}+\frac{u}{a} \qquad (k=1,2,\cdots n) \tag{4}$$

Structure the accumulation matrix B and constant term vector Y_n,

$$B=\begin{bmatrix} -0.5[x^{(1)}x(1)+x^{(1)}x(2)] & 1 \\ -0.5[x^{(1)}x(2)+x^{(1)}x(3)] & 1 \\ \vdots & \vdots \\ -0.5[x^{(1)}x(n-1)+x^{(1)}x(n)] & 1 \end{bmatrix} \tag{5}$$

$$Y_n=(x^{(0)}(2),x^{(0)}(3),\cdots x^{(0)}(n))^{\mathrm{T}} \tag{6}$$

Using least squares method to estimate the parameter vector:

$$\hat{\alpha}=(a,u)^{\mathrm{T}}=(B^{\mathrm{T}}B)^{-1}B^{\mathrm{T}}Y_n \tag{7}$$

Derivative Equation (4) is:

$$\hat{x}^{(0)}(k+1)=(1-e^{a})[x^{(0)}(1)-\frac{u}{a}]\mathrm{e}^{-ak} \tag{8}$$

Assume $x^{(1)}(0)=x^{(0)}(1)$, get the prediction equation:

$$\hat{x}^{(1)}(k+1)=[x^{(0)}(1)-\frac{u}{a}]\mathrm{e}^{-ak}+\frac{u}{a} \tag{9}$$

$$(k=0,1,\cdots,n)$$

$$\hat{x}^{(0)}(k+1)=\hat{x}^{(1)}(k+1)-\hat{x}^{(1)}(k) \tag{10}$$

If the RSS sampled value of mobile terminal at time t is $x^{(0)}(t)$, along with the $(n-1)$ sampled values before it, composed a n-dimensional sequence:

$$x^{(0)}=(x^{(0)}(t-n+1),x^{(0)}(t-n+2),\cdots,x^{(0)}(t)) \tag{11}$$

According to Equation (8), we can get the p-step gray prediction Equation:

$$\hat{x}^{(0)}(t+p)=[x^{(0)}(t-n+1)-\frac{u}{a}](1-\mathrm{e}^{a})\mathrm{e}^{-a(t+p-1)} \tag{12}$$

2.2 Received Signal Pretreatment

Measured RSS values contain random errors caused by the shadowing effects, imperfect receivers, and interferences by the other wireless

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transactions. It may cause handover failure if directly applied for trigger decision. To solve the problem, weighted moving average process is usually employed to filter out the measurement uncertainties and obtain the low frequency components of the measured RSS values.

First, equidistant average the sampling of received signal. As shown in Figure1, assume mobile terminal sampling the RSS with cycle t_m and get the time series $m(q)$.

$$d(n) = \frac{1}{N_m}\sum_{q=0}^{N_m-1} m(n\cdot N_m - q) \qquad (13)$$

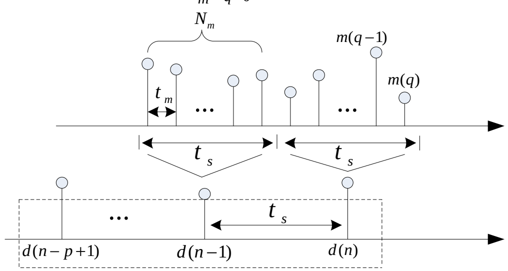

Figure 1: Received Signal Pretreatment

Then use weights moving average method to handle $d(n)$,

$$\bar{d}(n) = \begin{cases} d(0), & n = 0 \\ (1-\alpha)\bar{d}(n-1) + \alpha d(n), & n > 0 \end{cases} \qquad (14)$$

Where α is the smoothing factor, $\bar{d}(n)$ is the average RSS value after the nth measurement.

2.3 Required Handover Time

LGD trigger should be fired at least in the required handover time before the current link is down. The required handover time is different according to the network topologies, layer 3 handover protocols, and handover policies of the neighbor networks. For vertical handover, if the LGD trigger is generated on time in a “make before break” manner, the new link with the target access network can be established before the current link is down. During the set up period for the new link, mobile terminal can continue to send and receive data using the current network link. Therefore, a service disruption can be avoided by an appropriate estimation of required handover time.

Here we use WLAN and WiMAX overlay network environments, layer 3 handover protocols is Fast Mobile IPv6. As shown in Figure 2, the required handover time include two phase, t_{hp} and t_{hp} . t_{hp} is the preparation time for Layer-2 and Layer-3 with the current network, t_{hn} is the handover execution time with the new network using the new interface.

$$t_{hp} = t_{L2p} + t_{FH} = t_{L2p-nbr} + t_{L2p-ind} + t_{FH} \qquad (15)$$

According to MIH, $t_{L2p-nbr}$ is the message exchange time to obtain the neighboring information, $t_{L2p-ind}$ is the handover indication message exchange time to the current PoA.

The value of t_{hn} depends on the type of target access network. For WiMAX it includes scanning, synchronization & ranging, basic capability negotiation, key exchange & authorization, and registration times.

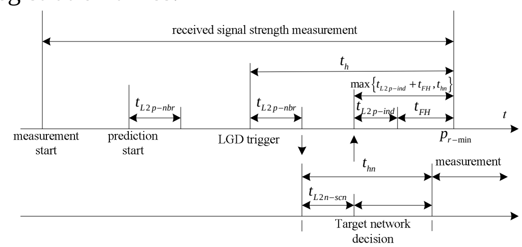

Figure 2: Required Handover Time

In summary, the estimation of required handover time is

$$t_h = t_{L2p-nbr} + t_{L2n-scn} + \max\{t_{L2p-ind} + t_{FH}, t_{hn}\} \qquad (16)$$

So the prediction step can be calculate as follow,

$$p = \left\lceil \frac{t_h + \Delta h}{t_s} \right\rceil \qquad (17)$$

Where Δh is a marginal time.

2.4 Determine Handover Trigger Time

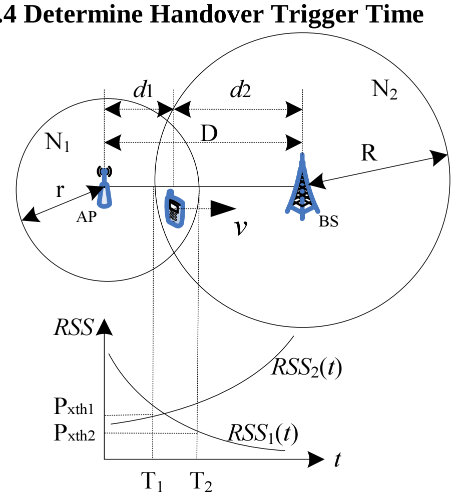

Figure 3: Handover Scene

As shown in Figure 3, when mobile terminal away from current connect network N1 and approaching target access net work N2 with moving speed v . The RSS from the two networks can be representing by monotonic function.

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$$RSS_1(t) = P_1(d_1) + C_{\delta_1} = P_1(v_0 t) + C_{\delta_1} \quad (18)$$

$$RSS_2(t) = P_2(d_2) + C_{\delta_2} = P_2(L - v_0 t) + C_{\delta_2} \quad (19)$$

Where $P_i(d_i)(i=1,2)$ represents the RSS if the distance of MN and PoA is d_i. C_{δ_1} and $C_{\delta 2}$ represent shadowing effects having a zero mean and a standard deviation of δ_1 and δ_2 respectively.

Assume at time T_1 the RSS of mobile terminal from network N2 is up to its minimum demodulation threshold $\mathrm{P_{rxth1}}$, and at time T_2 the RSS of mobile from network N1 is down to its minimum demodulation threshold $\mathrm{P_{rxth2}}$. If the required handover time is T_h and mobile terminal trigger the handover at time t. To complete the handover successfully, the bellow Equation should be met:

$$T_1 \le t + T_h \le T_2 \quad (20)$$

The packet loss rate during the handover can be calculate as bellow,

$$P_{\mathrm{loss}}(t) = \frac{\int_{T_1}^{t+T_h}\int_{-\infty}^{\mathrm{P_{rxth1}}-P_1(v_0 y)} \frac{\mathrm{e}^{-x^2/2\delta_1^2}}{\delta_1\sqrt{2\pi}} dxdy + \int_{t+T_h}^{T_2}\int_{-\infty}^{\mathrm{P_{rxth1}}-P_1(v_0 y)} \frac{\mathrm{e}^{-x^2/2\delta_1^2}}{\delta_1\sqrt{2\pi}} dxdy}{T_2 - T_1} \quad (21)$$

Through the derivative of the Equation (20), we can prove

$$\frac{d^2 P_{\mathrm{loss}}(t)}{dt^2} > 0 \quad (22)$$

Because the two base station are in close, we can assume that $\delta_1 = \delta_2$. Then according to convex optimization theory, if $\frac{dPloss(t)}{dt} = 0$, we can determine the most appropriate trigger time t_{opt} as follow,

$$P_1(v_0(t_{\mathrm{opt}} + T_h)) - P_2(L - v_0(t_{\mathrm{opt}} + T_h)) = P_{\mathrm{rxth1}} - P_{\mathrm{rxth2}} \quad (23)$$

From Equation (23) we can get the p-step prediction of RSS at time t,

$$\left|\hat{x}_1^{(0)}(t+p) - \hat{x}_2^{(0)}(t+p) - (\mathrm{P_{rxth1}} - \mathrm{P_{rxth2}})\right| \le \varepsilon \quad (24)$$

Where ε is a small positive number.

3. IMPLEMENTATION STEPS

3.1 Determine Handover Trigger Time

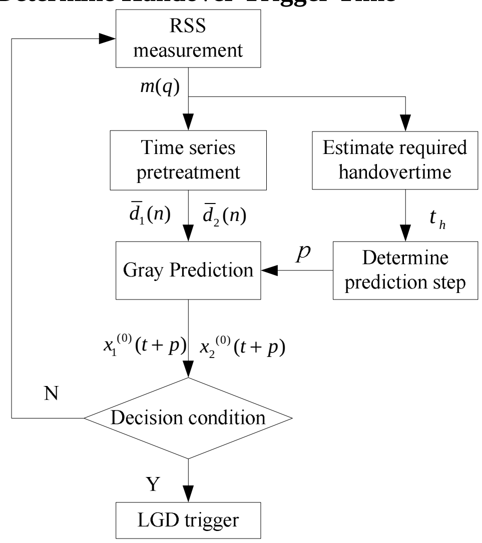

Figure 4: Implementation Steps

Assume the target access network have enough wireless resource to accept handover request, the proposed handover time prediction steps are as Figure 4:

1) Mobile terminal detect the neighbor networks and determine the target access network according to the trends of RSS.

2) Analyze handover type and estimate the required handover time (t_h), then calculate the prediction step (p).

3) Mobile terminal sampling the reception signal of the two networks and pretreatment using time cycle of t_s, get the time series $\bar{d}_1(n)$ and $\bar{d}_2(n)$.

4) If $\bar{d}_1(n) \le P_{\mathrm{init}}$, we assume $x_1^{(0)}(t) = \bar{d}_1(n)$, $x_2^{(0)}(t) = \bar{d}_2(n)$, and execute p-step prediction for RSS from two network according to Equation (12).

5) When Equation (22) is met, stop the prediction procedure and get the most appropriate trigger time (t_{opt}).

4. SIMULATION AND PERFORMANCE ANALYSIS

4.1 Simulation Environments and Parameters Setting

Handover scene is as Figure 1, N1is WLAN and N2 is WiMAX. The two networks can get the neighbor network information from the MIH Information Server.

WLAN network using Fritz path loss model to simulate the actual signal sample values,

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$$\frac{P_r(d)}{P_r(d_0)} = -10\beta \log(\frac{d}{d_0}) + X_\sigma \qquad (25)$$

Where d is the distance between the receiver and the transmitter, $P_r(d)$ denotes the received signal power level in watts at distance of d, β · is the path loss exponent, and $P_r(d_0)$ is the received power at the close-in reference distance of d_0. X_σ is a random variable with Gaussian distribution having a zero mean and a standard deviation of δ dB.

According to the method introducing in [7],

$$Pr(d_0) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 {d_0}^2 L} \qquad (26)$$

Where P_t is transmitted signal power, G_t and G_r are the antenna gains of the transmitter and the receiver respectively, L is system loss and λ is wavelength.

WiMAX using Cost231-Hata path loss model：

$$\begin{aligned} L(\text{dB}) = 46.3 + 33.9 \lg f_c - 13.82 \lg h_b - \alpha(h_m) + \\ (44.9 - 6.55 \lg h_b) \lg d \end{aligned} \qquad (27)$$

where f_c is the carrier frequency, h_b and h_m are heights of the transmitting and receiving antenna respectively. For urban environment, the antenna correction factor is set as

$$\alpha(h_m) = 3.2[\lg 11.75 h_m]^2 - 4.97 \qquad (28)$$

The parameter settings as shown in Table 1:

Table 1: Parameters Setting

Para.	value	Para.	value
f_c	2500MHz	$P_t G_t$	100mW
h_b	50m	G_r	1
h_m	1500m	λ	0.125m
r	500m	L	1
R	1500m	d_0	1m
D	1700m	β	3
f_c	2500MHz	$P_t G_t$	100mW
t_m	10ms	P_{rxth1}	-75dB
t_s	50ms	P_{rxth2}	-90dB
T_h	250,500ms	Δh	0
p	5	ε	0.5
δ	0-2dB	P_{init}	-60dB
v	1-5m/s	α	0.25

4.2 Prediction Error Analysis

To analyze the prediction accuracy proposed in this paper, we evaluate the p-step prediction errors. As shown in (29), P_e is the average dB scale prediction error from the prediction start sample point to the actual Link_Down sample point.

$$P_e = \left(\sum_{i=n_p}^{n_d} \left| \left[\frac{P_r(i)}{\hat{P}_r(i)} \right]_{\text{dB}} \right| \right) / (n_d - n_p) \qquad (29)$$

Where $P_r(i)$ and $\hat{P}_r(i)$ are the observed signal power and p-step predicted signal power, respectively; n_p and n_d are the sample sequence number at the prediction start time and at the actual Link_Down time, respectively.

According to (23), prediction start time margin can be calculated as follow:

$$t_p = \frac{d_0}{v} \left(\frac{P_r(d_0)}{P_{rxth1}} \right)^{\frac{1}{\beta}} \left[1 - 1 / \left(\frac{P_{init}}{P_{rxth1}} \right)^{\frac{1}{\beta}} \right] \qquad (30)$$

We can get the value of n_p by rounding for t_p with sampling interval.

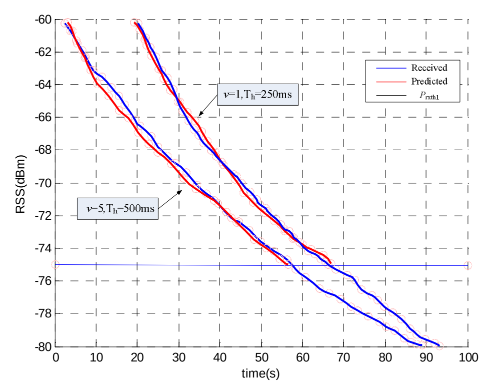

Figure 5: Prediction Signal Trace

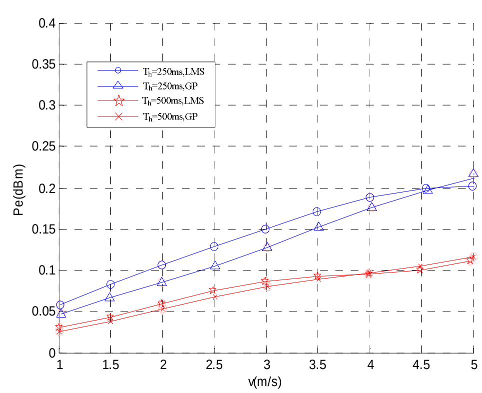

Figure 6: Prediction Error Rate

In the following experiment, we take WLAN for example and analyze the prediction result. The

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traces for a predicted and simulation observed signal are shown in Figure 5, and compares two traces with different mobile terminal moving speed and prediction step. Figure 6 compare the LMS prediction algorithm introduced in [14] and Gray Prediction (GP) algorithm proposed in this paper. We can see from the figure, for the same required handover time, prediction error become higher with the acceleration of terminal moving speed. For the same terminal moving speed, the longer required handover time means larger prediction step and relatively complex calculations, so the prediction error will increase also. For the same prediction step and the moving speed, GP algorithm has lower prediction error than LMS algorithm, and the superiority of GP will become more obvious when the required handover time is shorter. From Figure 6 we can conclude the prediction error rate can be controlled in 0.25dBm when the terminal moving speeds below than 5m/s.

4.3 Packet Loss Rate Analysis

The packet loss ratio comparison is shown in Fig. 7. Packet loss is due to the RSS of the terminal is lower than its demodulation threshold, it consist of the packet loss in the current connected network WLAN before finishing the handover and the packet loss in the target network WiMAX after completing the handover procedure. We can calculate it as follow:

$$P_{\text{loss}} = \{\text{sum}(T_k \mid P_1(T_k) < \text{P}_{\text{rxth1}}, T_1 \le T_k \le t + T_{\text{h}}) + \text{sum}(T_k \mid P_2(T_k) < \text{P}_{\text{rxth2}}, t + T_{\text{h}} < T_k < T_2)\} / (T_2 - T_1) \quad (31)$$

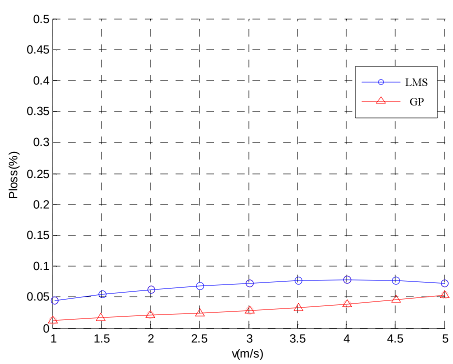

Figure 7: Packet Loss Rate

The packet loss rate during vertical handover with different terminal moving speeds is shown in Figure 7. LMS prediction algorithm only considers the RSS of the current connected network, but GP algorithm both consider the RSS of two networks. For the same algorithm, the packet loss rates become higher with the increase of terminal moving. When the terminal moving at the same speed, GP algorithm has lower packet loss rate than LMS; if the moving speed below than 5m/s, the packet loss rate is less than 5%.

5. CONCLUSION

When mobile terminal occur vertical handover in heterogeneous network, it is the key problem to find the most appropriate handover trigger time to minimize the handover delay time and packet loss rate, and improve the user QoS when roaming in different wireless networks. The main contribution of this paper is to apply Gray Prediction algorithm both in current connected network and target access network, and determine the handover trigger time according with convex optimization theory. Compare with the LMS prediction algorithm, this mechanism can further reduce the packet loss rate with the same computational complexity. But our proposed method does not consider the situation when mobile terminal moving with random variation of speed and direction, and it is our future research purposes.

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REFERENCES:

[1] Ionut BOSOANCA, Anca VARGATU, "An overview of vertical handoff decision algorithms in NGWNs and a new scheme for providing optimized performance in geterogeneous wireless networks", *Informatica Economică*, Vol. 15, No. 1, 2010, pp. 5-21.

[2] M. Zekri, B. Jouaber, "A review on mobility management and vertical handover solutions over heterogeneous wireless networks", *Computer Communications*, Vol. 35, No. 17, 2012, pp. 2055-2068.

[3] A. de la Oliva, A. Banchs, I. Soto, "An Overview of IEEE 802.21: Media-Independent Handover Services", *IEEE Wireless Communications*, Vol. 15, No. 4, 2008, pp. 96-103.

[4] Ben-Jye Chang, Jun-Fu Chen, "Cross-Layer-Based Adaptive Vertical Handoff with Predictive RSS in Heterogeneous Wireless Networks", *IEEE Transactions on vehicular technology*, Vol. 57, No. 6, 2008, pp. 3679-3692.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

[5] S. Woon, N. Golmie, Y.A. Sekercioglu, "Effective Link Triggers to Improve Handover Performance", IEEE 17th International Symposium on Personal, Indoor and Mobile Radio Communications, September11-14, 2006, pp. 1-5.

[6] Inwhee Joe, MinChul Shin, "A Mobility-based Prediction Algorithm with Dynamic LGD Triggering for Vertical Handover", 7th IEEE Consumer Communications and Networking Conference, January 9-12, 2010, pp. 1-2.

[7] Manish Korde, Binod Kumar, "Optimized and Smooth Handover between Wi-Fi and WiMAX using Link Layer Triggers", *International Journal of Computer Applications*, Vol. 49, No. 1, 2012, pp. 32-35.

[8] Sang Jo Yoo, David Cypher, Nada Golmie, "Predictive Handover Mechanism based on Required Time Estimation in Heterogeneous Wireless Networks", IEEE Military Communications Conference, Noverbem 16-19, 2008.

[9] Jaesung Park, Yujin Lim, "A Handover Prediction Model and its Application to Link Layer Triggers for Fast Handover", Wireless Personal Communications, Vol. 52, No. 3, 2010, pp. 501-516.

[10] Runyun Zhang, Yuhong Wang, Kaizhi Huang, "Terminal Moving State-based Link-Going-Down Trigger Algorithm", *Computer Engineering*, Vol. 36, No. 19, 2010, pp. 117-119.

[11] Jilei Yan, Linjing Zhao, Jiandong Li, "A Prediction-Based Handover Trigger Time Selection Strategy in Varying Network Overlapping Environment", IEEE Vehicular Technology Conference, September 5-8, 2011.

[12] Naiming Xie, Sifeng Liu, "Discrete grey forecasting model and its optimization, Mathematical Modeling", Vol. 33, No. 2, 2009, pp. 1173-1186.

[13] Wenbing Yao, Zeyun Niu, Xiaoming Fu, "Optimized FMIPv6 Using IEEE 802.21 MIH Services in Vehicular Networks", *IEEE Transactions on Vehicular Technology*, Vol. 56, No. 6, 2007, pp. 3397-3407.

[14] Sang-Jo Yoo, David Cypher, Nada Golmie, "LMS Prediction Link Trigger for Seamless Handovers in Heterogeneous Wireless Networks", IEEE Military Communications Conference, October 29-31, 2007.