IEEE 802.21 Buffer Predicting Seamless Handoff (BPSH) Scheme for WAVE-WiMAX Heterogeneous Handoff

TIN-YU WU, YA-CHUN LI, WEI-TSONG LEE, JEN-WEN DING and YU-CHIN WANG

Department of Electrical Engineering
Tamkang University
Taipei, 251 Taiwan
E-mail: {tyw; wtlee}@mail.tku.edu.tw, liyc0610@gmail.com

Department of Information Management
National Kaohsiung University of Applied Sciences
Kaohsiung, 807 Taiwan
E-mail: jwding@cc.kuas.edu

Since Wireless Access in Vehicular Environment (WAVE) is a draft amendment to the IEEE 802.11 standard, the integration of WAVE (IEEE 802.11p) and Wireless Metropolitan Area Network (IEEE 802.16) becomes a concerned issue to mobile network users. During the roaming between the two heterogeneous wireless networks, the quality of multimedia services for users depends heavily on seamless handover, which should be provided by the middleware between IP and MAC protocol stack. For this reason, we design the heterogeneous handoff of WAVE-WiMAX by seamless handoff scheme from buffer prediction of IEEE 802.21. IEEE 802.21 is designed to provide the basic platform for seamless heterogeneous handoff. Due to the integration function provided by IEEE 802.21, users are able to use the original services between heterogeneous wireless networks. In this paper, a dynamically adjusted buffer component with an algorithm to predict the buffer size is proposed to enhance the functionality of IEEE 802.21. The services and communication flows among service specific layer, buffer and IEEE 802.21 Media Independent Handover (MIH) function are described and analyzed. According to the analysis of the connection process and simulation, buffer prediction and pre-allocation indeed can reduce the influence of handover between heterogeneous wireless networks.

Keywords: heterogeneous handoff, seamless handoff, media independent handover (MIH), IEEE 802.11p, WiMAX

1. INTRODUCTION

With the evolution of wireless network technology, the integration of mobility and information services has become an urgent issue in the modern world. In this paper, wireless communication network handover studies involve two IEEE family members, IEEE 802.11p (WAVE) and IEEE 802.16 (WiMAX). The network device may also change the multimedia service to suit an user’s habit when the user is using mobile devices from the open space into the vehicle, and vice versa.

Since the cover scopes of these two systems are quite different, in order to avoid the interruption of network services, while a mobile device moves from one to another, the network service has to exchange promptly, and this is known as heterogeneous handoff. To solve these heterogeneous handover problems, IEEE proposed the IEEE 802.21 [2]
standard that proposes a middleware function called Media Independent Handover function (MIH) as the platform for heterogeneous wireless networks. The purpose of this function is to make network users feel no distribution of network service exchange among heterogeneous handovers. In this paper, the IEEE 802.21 MIH based service system is proposed. This system presents a Service Specific Layer, which is composed of a network selector and a buffer management device. Within this system, the buffer management will predict the handoff time, and inform the buffer device to store the required data to serve users during the handovers. Also, by this system, we can approach the purpose of MIH function.

The rest of this paper is organized as the following. Section 2 introduces the MIH system; section 3 presents our system architecture and the algorithm of the handoff time prediction system; the following section 4 describes the experiment of our studies; and the final section concludes this paper and discusses the future works.

2. OVERVIEW OF MEDIA INDEPENDENT HANDOVER

The first standard of IEEE 802.21 [1] was adopted in 2006. The purpose of the IEEE 802.21 is to achieve the seamless handoff among heterogeneous communication systems. The basic architecture of IEEE 802.21 establishes a Media Independent Handover function (MIH) between Layer 2 (MAC Layer) and Layer 3 (Network Layer), as shown in Fig. 1.

![Fig. 1. Architecture of MIH function.](image)

The Media Independent Handover function provides a Service Access Point (SAP) on the bottom in order to communicate with the physical layers (Layers 1 and 2). Further, the above layer (Layer 3 above) can ask for required information through the Media Independent Handover function. The Media Independent Handover function generally provides three types of services: Event Service, Command Service, and Information Service. The MIH Event Service (MIES) provides services including event classification and event filtering. The MIH Information Service (MIIS) has the capability for obtaining necessary information for the handover that includes neighboring maps, link layer information, and services availability. The MIH Command Service (MICS) accepts the
management and control command from the above layers and enables MIH users to manage and control link behaviors relevant to handovers and mobility.

Many researches are based on IEEE 802.21 standard [2-8], and paper [7] is taken as an example. This paper proposed a SCTP-based IEEE 802.21 middleware to achieve seamless handover and handoff decision device that assists to solve network selecting problems, operates the IEEE 802.21 executing handover procedures and collation, and evaluates information of server provider.

3. SYSTEM ARCHITECTURE AND IMPLEMENTATION

With the purpose of media independent handover between heterogeneous networks, this paper proposes an IEEE 802.21 based middleware device, which is composed of three sub-areas: Service Specific Layer (SSL), Buffer Device, and MIH Function, as shown in Fig. 2.

When a mobile device moves from a network service to another, the Service Specific Layer can get the information of new network service provider by the Information Service of MIH. When the handoff event triggers, MIH will send the MIH_Event to Service Specific Layer by Event Service. Next, the Network Selector will evaluate which network service to select, and the Buffer Management will predict the buffer size. After the evaluation and calculation, the Buffer Management device will inform the buffer device to store data that user needs when the handover is proceeding.

3.1 Service Specific Layer

Heterogeneous handoff includes IEEE 802.16 and IEEE 802.11p networks services to explain the state process of Service Specific Layer during the handover, as shown in Fig. 3 that illustrates the states of the middleware device. The procedure starts at the first state (INITIAL), and then establishes IP connection (CONNECTING). The third state is to establish an initial network connection (NETWORK_ENTRY), and next the Layer 2 connection (LINK_UP). At this moment, if an event is triggered, it will start evaluating
Fig. 3. The middleware state process.

for network selection (Network Select State). After the evaluation of our algorithm, Service Specific Layer will decide if the handover is necessary. If it is, Service Specific Layer will communicate with the new service provider (SCAN state) and the handoff will be performed (Handover_Initiate state). Service Specific Layer will disconnect from the previous network service (Link Down state) and return to the procedure of network connection establishing state (NETWORK_ENTRY state).

3.2 Function and Architecture of Service Specific Layer

In multi-network services, a device has to decide whether the handover should be executed or not, and this is Service Specific Layer. In order to reduce the transmission time and to accelerate the handover decision, Service Specific Layer is established between MIH layer and the upper layer. Service Specific Layer connects to the upper layers and accepts the Information Elements from MIH. When the handover event triggers or the handoff command is proposed, Service Specific Layer will choose the most suitable network according to the Information Elements.

The most important two parts of Service Specific Layer are Network Selector and Buffer Management. When the handoff event triggers, Network Selector will evaluate the network condition and choose the most suitable network service. On the other hand, Buffer Management will predict the buffer size according to our proposed algorithm. Afterwards, buffer management adjusts the buffer device to a suitable size to store users’ needed data during the handoff. As mentioned before, during the handoff, there will be service disconnection in one time period, which makes users uncomfortable. The purpose of seamless handover is for users to ignore the handoff progress.
3.3 Network Selector Device

The network selecting strategy is to set IEEE 802.11p as high priority. In other word, if two kinds of network services, IEEE 802.16 and IEEE 802.11p, coexist, IEEE 802.11p network service will be adopted, and IEEE 802.16 network service will be taken as the backup network service.

3.3 Buffer Device

When the handoff is executing, the network service will be disconnected in certain time period and data cannot be transmitted. At this moment, users may sense the interruption of the service. Thus, the purpose of seamless handover is to let users not conscious of the interruption during the handoff and for this reason, Buffer Device is established. During the handover, users’ required data will be stored in the buffer device and users will not be aware of any change of the service quality.

4. BUFFER MANAGEMENT AND SIZE PREDICTION

As mentioned previously, during the handoff, the service disconnection in one time period will make users uncomfortable. The aim of seamless handover is to make users ignore the handover progress.

4.1 Buffer Size Prediction Algorithm

Fig. 4 illustrates the proposed buffer size prediction scheme that consists of four basic components: Buffer Device, Buffer Management Device, Service Specific Layer (SSL) and MIH function (MIH). Buffer Device is used to pre-store the data for the handoff and Buffer Management Device is responsible for executing the prediction rules for the buffer efficiency. As the role of middleware to communicate with MIH function, SSL has the network selector device to evaluate which network is worth changing. In addition, the MIH function is the implementation of the IEEE 802.21 to work for seamless handoff.

When MIH LINKUP event triggers, the SSL network selector will evaluate the new network and the current network. If the handoff is necessary, SSL will send the buffer management device a command to initial the buffer size prediction process, and buffer management then will predict the buffer size with the following three main steps:

**Step 1:** Once receiving the initial command from SSL, the buffer management device calculates the required network service exchange time that is recorded as “TH” (the unit for TH is micro seconds) during the handoff.

**Step 2:** The buffer management device then calculates the required data volume corresponding to the TH value. The required pre-stored data volume will be expressed as “BH” (the unit for BH is byte.) After calculating the BH value, buffer management will send buffer device a BM_BS.IND message to inform the buffer device to adjust the buffer size and get ready to pre-store the required BH volume data.
Step 3: The buffer management calculates the required time as “TB” (the unit for TB is ms) to store the BH volume data. Then, the buffer management device will send the value to SSL. SSL waits for TB seconds, and then sends MIH a BM_TB.IND to initial the handover process. The purpose of this step is to enforce the handoff execution, even if the original network is disconnected before the required data is pre-stored.

4.2 Buffer Management Device

The buffer management device is used to execute the prediction rules. First, the device calculates the required network service exchange time during the handoff. The network service exchange time (TH) is the function of the handover execution time. Second, the buffer management device can calculate the pre-stored required data volume (BH) based on the type of users’ requested service. And the BH volume data will be ready for the network service exchange period (TH microseconds).

In this section, two handoff scenarios are used to explain how the buffer size prediction algorithm works. Scenario 1 illustrates IEEE 802.16 network service links up and the IEEE 802.11p network service going down, and Scenario 2 presents the contrary handoff process. The two handoff scenarios are discussed in detail in the following.

Scenario 1:

The left side of Fig. 5 shows the status of SSL. When the handoff event triggers, SSL will turn to the first status and evaluate which network service will be adopted. After making the decision, SSL will send MIH a MIH Scan.REQ message, and then turn itself into the second status (2.Scan). After the scan, MIH will send a MIH_Scan.RSP to SSL, and SSL will move to the third status (3.Handover_initate). In this status, SSL not only
transmits with the original network service, but also predicts the buffer size. After the buffer size calculation, SSL will send the buffer device a command to adjust the buffer size and to pre-store the required data. When the time TB microseconds pass, SSL sends MIH_Down.REQ to MIH and simultaneously moves into the fourth status (4.Link down). While accepting the MIH_Down.RSP from MIH, SSL enters the fifth status (5.Network_Entry) and the system will execute the ranging operation. The registration to the BS, such as authentication, register service and SF/CS Capabilities, will be finished in this status. After receiving the MIH_DSA.RSP, SSL enters the sixth status (6.Link_up), which means that the connection with the new network service has been established, and the handover process has been completed.

In Scenario 1, the interval between SSL sends the MIH_Down.REQ and SSL gets the MIH_Link_up.IND message is shown in Fig. 5. The service is interrupted by the handover, and it is the Value TH(802.1p to 802.16), which should be calculated by the algorithm. As shown in Fig. 3, the interrupted time of service exchange from IEEE 802.11p to IEEE 802.16 is the sum of 2 periods of the command sent from MIH to the
IEEE 802.11MAC, 6 periods of the command sent from SSL to MIH, 4 periods of the command sent from MIH to the IEEE 802.16 MAC, 10 periods of the request sent from IEEE 802.16 MAC to the BS, the period of the Response time of the IEEE 802.11MAC to disconnect the original network, the period of the Response time of Service Specific Layer, and finally the period of the BS authenticated requests. In addition, the random backoff time of IEEE 802.16 is considered. Buffer Management should also detect the quality of network for expecting the packet error rate. The formula can be given by:

\[ TH(802.11p \text{ to } 802.16) = 10(Txb + E(r) \times T_{\text{backoff}}) + 2Tmf + 6Tsm + 4Tmx + Tf1 + (Ts1 - 2) + (Tx1 - 7) + (Tb1 - 5). \]  

(1)

In this scenario, time duration parameters are defined in following Table 1.

<table>
<thead>
<tr>
<th>Sign</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tsm</td>
<td>The period of a command or an event sent from Service Specific Layer to MIH.</td>
</tr>
<tr>
<td>Tmf</td>
<td>The period of a command or an event sent from MIH to the IEEE 802.11 MAC.</td>
</tr>
<tr>
<td>Tmx</td>
<td>The period of a command or an event sent from MIH to the IEEE 802.16 MAC.</td>
</tr>
<tr>
<td>Txb</td>
<td>The period of a command or an event sent from the IEEE 802.16MAC to the BS.</td>
</tr>
<tr>
<td>Ts1 − 2</td>
<td>The Response time of the Service Specific Layer.</td>
</tr>
<tr>
<td>Tf1</td>
<td>The Response time of the IEEE 802.11MAC.</td>
</tr>
<tr>
<td>Tx1 − 7</td>
<td>The Response time of the IEEE 802.16MAC.</td>
</tr>
<tr>
<td>Tb1 − 5</td>
<td>The period of the Bs authenticates requests.</td>
</tr>
<tr>
<td>E(r) \times T_{\text{backoff}}</td>
<td>The expected packet error times in IEEE 802.16.</td>
</tr>
</tbody>
</table>

**Scenario 2:**

This scenario discusses the IEEE 802.16 to IEEE 802.11p handoff procedure. The network service is interrupted by the handover process since SSL sends Down.REQ message until SSL receives the MIH_Link_up.IND message. As shown in Fig. 6, the interrupted time of service exchange between BS and candidate infrastructure is the sum of 6 periods of the command sent from SSL to MIH, 8 periods of the command sent from MIH to the IEEE 802.11MAC, 4 periods of the command sent from MIH to the IEEE 802.16 MAC, 14 periods of the request sent from IEEE 802.11MAC to the candidate infrastructure, the period of the Response time of SSL, and finally, the period of the BS authenticates requests. In addition, the random backoff time of IEEE 802.11p is considered. Buffer Management should also detect the quality of network for expecting the packet error rate. The formula can be given by:

\[ TH(802.16 \text{ to } 802.11p) = 14(Txb + E(r) \times T_{\text{backoff}}) + 6Tsm + 8Tmx + 4Tmf + (Ts1 - 4) + (Tf1 - 2) + (Tx1 - 5) + (Tb1 - 7). \]  

(2)

In this scenario, time duration parameters are defined in the following Table 2.
From the above scenarios, it can be known that the service interrupted time triggered by each event and service interrupted time between these two network services are different. No matter what kind of situation happens, our system provides the most suitable service.
In this section, we will discuss the effect of the buffer device to users in the wireless network environment. First, we establish a simulated wireless network environment by NS-2 and dynamically adjust the size of the buffer device by our proposed prediction algorithm. By analyzing the result of the experiment, we attempt to figure out the effect of a dynamic buffer device to users.

### 5.1 Handoff Predict Function Scenario

As shown in Fig. 7, the simulated experiment environment includes a network service environment with six Access Points (APs). The transfer rate of each AP is 0.1MB and the APs can contact with one another and transmit data. Three users are included in the experiment and the location of each user has been decided randomly. A dynamically adjusted buffer device is set on each user, and the buffer size is adjusted with our proposed prediction algorithm. Finally, we observe the transmission of each user and analyze the result.

Fig. 8 presents the packet receiving situation of user A. In this figure, we find out that when there is no buffer device, user A will go through two handoffs; but when a 512Kb buffer device is set up, one service interruption caused by the handoff may be reduced. If adjusting the buffer size to 1024kb by our algorithm, the service interruption caused by the handover can be prevented.

Fig. 9 shows the packet receiving situation of user B. From the figure, we know that at the 72nd second, there is a service interruption caused by handover. Supposing there is a 51kb buffer device, the service interruption can be avoided. With our algorithm, we are able to adjust our buffer size to 384kb. Although we use 512Kb the buffer device that can solve this service interruption, we may also get the same result when we adopt the 384Kb buffer. Moreover, the 384Kb buffer device has saved the 128Kb buffer space and the data wasted during the transmission.

Fig. 10 is the packet receiving situation of user C. From the figure, it is know that
when we set a 512Kb buffer device, we may reduce one service interruption caused by
the handover. If we adjust buffer size to 1024Kb by our algorithm, the service interrup-
tion caused by handover can be avoided.

According to Table 3, we find out that in this simulated experiment, although a fixed
size buffer device for users may reduce the numbers and time of service interruption
caused by the handoff, some conditions are still inevitable. If we propose a dynamically adjusted buffer device, the service interruption caused by the handoff can be exactly avoided and our goal of seamless handoff can be achieved.

5.2 Buffer Devices in a Multi-user WLAN Scenario

In this section, a simulation of buffer devices in a multi-user WLAN environment is proposed. 10 users are included in our wireless network environment, and we dynamically adjust the buffer size by the prediction algorithm. Finally, by analyzing the users’ status, we discuss the effect of changing the buffer size to users.

First, we set a server for data transmission as shown in Fig. 11. In this server, we set a CBR that its transfer rate is 1.0MB/s to send data to each user from 10 seconds to 200 seconds. Three access points (AP1 ~ AP3) are set in this simulation, and based on IEEE 802.11 standards, the maximum bandwidth of AP1 is 11Mb. The AP2 and AP3 are set to simulate the IEEE 802.16 protocols, and the maximum DL bandwidth in the two APs is set by 40 Mb/s. In this simulation, 10 users (A to J) are included in the red region as the following Fig. 11. At the 30th second, these 10 users will move by 10m/sec in this environment, but the starting points and the terminal points are decided randomly. Each user is equipped with a dynamically adjust buffer device to predict the buffer size according to the handover time between APs.
The following Table 4 shows the status of the 10 users. In this simulation, users download 25Mb per second, so that, by the buffer algorithm, we adjust the buffer size to 600Mb between AP1 to AP2, and 500Mb between AP2 to AP3. From the simulation result, we know that our buffer prediction is effective in the multi-user scenario because seven users avoid the interruption handover and simultaneously, the other three users’ interruption time is reduced for 186 seconds. The three interruptions due to candidate AP can not support service. Because, the candidate AP has too many user and can not support enough bandwidth.

6. CONCLUSIONS

To sum up, to integrate these two heterogeneous network handoff services, IEEE 802.11p and IEEE 802.16, an IEEE 802.21 based function is proposed in this paper. This system can provide the network service information for users by MIH Information Service. With this function, while getting into (or out of) a vehicle, network service users will not be aware of the network service interruption. If the handover request triggers, Service Specific Layer will receive the correlation information through MIH Function,
calculate and predict the required data size, and then dynamically adjust the buffer device to store the required data during the handoff. From the original network service is disconnected to the new network service is established completely, users will not sense the interference of the service. With this system, we further approach the purpose of seamless handoff.

REFERENCES


Tin-Yu Wu (吳庭育) currently works as an Assistant Professor in the Department of Electrical Engineering, Tamkang University, Taipei, Taiwan. He received his M.S. and Ph.D. degrees in the Department of Electrical Engineering, National Dong Hwa University, Hualien, Taiwan in 2000 and 2007 respectively. His research interests focus on the next-generation internet protocol, mobile computing and wireless networks.

Ya-Chun Li (李亞峻) was born in Taipei, Taiwan, in 1986. He was graduating from Tamkang University in the end of 2008. Currently he serves the country in air force as electronically officer and he is still a member of the embedded system Lab in the Department of Electrical Engineering of Tamkang University.

Wei-Tsong Lee (李維聰) received B.S., M.S. and Ph.D. degrees in Electrical Engineering from National Cheng Kung University, Tainan, Taiwan. In 2003, he joined the department members of Electrical Engineering of Tamkang University as Associate Professor, and reached professor in 2007. His research interests are computer architecture, micro-processor interface and computer network.
Jen-Wen Ding (丁建文) is an Associate Professor of the Department of Information Management, National Kaohsiung University of Applied Sciences, Kaohsiung, Taiwan. He received his B.S., M.S., and Ph.D. degrees in Engineering Science from National Cheng Kung University, Tainan, Taiwan, in 1996, 1998, and 2001, respectively. His research interests include video streaming and multimedia communications. He has authored/co-authored over 30 refereed papers in journals, conference, and workshop proceedings. He also holds several patents in multimedia storage and communications. He received the Best Paper Award of 2007 Asia-Pacific Workshop on Visual Information Processing (VIP 2007). Dr. Ding was the Editor of the proceeding of 2008 Pacific-Rim Conference on Multimedia (PCM 2008) and the Guest Editor of the Special Issue on Ubiquitous Multimedia Computing: Systems, Networking, and Applications for International Journal of Ad Hoc and Ubiquitous Computing (IJAHUC). He has been invited to serve on technical program committee at many national and international conferences. He is also a member of the IEEE as well as IEEE Circuits and Systems Society.

Yu-Chin Wang (王裕欽) was born in Kaohsiung, Taiwan, in 1983. He received B.S. and M.S. degrees in Electrical Engineering from Tamkang University in 2008. Currently he is an associate engineer of Department of Mobile Phone in Inventec, http://www.inventec.com/.