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Joint Application and Physical-Layer Design for IPTV Services over WiFi Network

Chunsu Ahn◆, Jeongmin Noh*, Sangyeob Lee*, Daewon Song°

ABSTRACT

In this paper, we present a novel joint application physical-layer design (JAPLD) strategy to cost-effectively transmit linear channels for a portable IPTV service over WiFi-based wireless mesh networks. With this approach, the application layer cooperates with the physical layer to maximize the visual quality. First, in application layer, the standards of wireless network quality for stably transmitting high data-rate streams are first set and inform to mesh environment APs. If the tvFree, a portable IPTV device, moves and the wireless network quality goes out of the preset, the connected AP obtains the wireless network quality between the tvFree and the neighboring AP. If the measured wireless network quality satisfies the previously set conditions, the connected AP guides the tvFree to connect a nearby AP with good quality, though which AP-driven handover (ADH) proceeds in physical layer. Experimental results show that the proposed ADH is able to achieve the performance improvement compared with device-driven handover (DDH) using the IEEE 802.11k standard. Via experimental, we show that the average handover time of ADH is 61% shorter than that of DDH, and thus the received frame rate is higher and the visual quality will be much better.

Key Words : Portable IPTV, Set-top Box, UDT, WiFi-based wireless mesh network, Joint application-physical layer Design(JAPLD), AP-driven handover(ADH), Device-driven handover(DDH)

Ⅰ. Introduction

IPTV service, optimized for broadband multimedia service, has the fastest technological development, and in Korea, it has surpassed cable and satellite services and has become the service used by the most households since 2018[1].

In 2018, the world's first portable IPTV 'tvFree' using a tablet device was introduced, which allow customers to watch TV while moving within their home, breaking away from the experience of watching TV in a fixed location and the 3rd generation tvFree was released in 2021. As a result, customers can comfortably watch TV while washing dishes, at the dining table, or on the bed before going to bed. The tvfree tablets is equipped with the IPTV services as an Android app, allowing customers to experience the UX, which is almost as similar to that of IPTV set-top by running the IPTV app. In order to provide services on the move as if receiving more than 270 linear channel services at a fixed location, the AP is equipped with a UDT-based data transfer protocol that can change the multicast stream received from the broadcasting center to unicast to deliver it to the tvFree.

The broadcasting center transmits more than 270 linear channels in FHD resolution for high-definition vie-wing and SD resolution for viewing on electronic program guide (EPG) screen at the same time. There is no problem in terms of visual quality in a wired

◆ First Author : LG Uplus Corp. Ltd., acsmno2@gmail.com, 정회원
° Corresponding Author : LG Uplus Corp. Ltd., dsong@lguplus.co.kr, 정회원
* Affiliation, LG Uplus Corp. Ltd., jmnoh@lguplus.co.kr, 정회원; sangyeob@lguplus.co.kr
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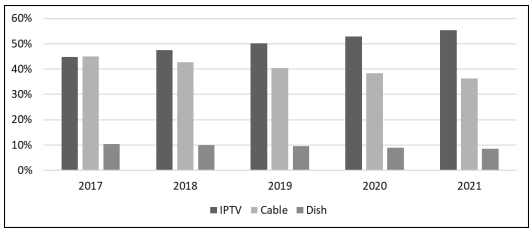

Fig. 1. The market share of broadcast service provider[2]

set-top box, but network quality is important in a portable IPTV connected wirelessly, and when watching in a shaded area such as a corner of a house. To overcome the fluctuation of the network quality, the tvFree fully utilizes these two resolution streams by changing the stream according to the signal strength of WiFi network and provides a seamless service even in a weak electric field environment. As the number of wireless connected devices at home increases, more and more customers are installing two or more APs to expand network quality coverage, which is an inherent problem of Wifi.

In WiFi-based mesh networks, the seamless handover is essential due to movement, and the device-driven handover(DDH) between APs will be carried according to the standards of the device manufacturer using the IEEE 802.11k[3,4]. The tvFree device currently available is the Samsung tablet 'S6 Lite' and supports the latest WiFi technologies such as 802.11k/v[5]. In addition, the mesh AP supports the function of succession of the SSID and password of the main AP and is upgraded to the WiFi standard 'Easy Mesh R2'[6]. Therefore, when the tvFree is activated, it connects to the main or mesh AP with a better signal and provides service. When the customer moves into the house, if the quality of the connected AP is lower than the network quality set in the device and the quality of the other AP is better, the tvFree is handed over to this AP, i.e. DDH. However, such a handover is not suitable for a service requiring real-time high speed transmission such as a portable IPTV. Because the real-time broadcasting stream requires a stable high date-rate transmission through UDP protocol, it is difficult to retransmit when the network quality is poor, and when the network signal strength does not reach the minimum guaranteed range, playback video freezes or breaks and visual quality degradation due to converting SD channels is inevitable.

1.1 Related Works

Many studies have been conducted on IEEE 802.11 to reduce handover delay for multimedia application[7-9]. Also, algorithms for handover decision considering load distribution or user trajectory were presented in [10,11]. However, the total interruption time in the application layer during handover consists of the handover time and the time required to complete the transmission of data queued in the target AP's transmit buffer. Therefore, to provide high QoS(Quality of Service) for mobile media device in mesh network, determining the threshold to trigger handover so that buffer underflow does not occur in the application is a key factor. To the best of our knowledge, no prior works have presented performance improvement by applying a handover threshold optimized for the target application.

1.2 Contributions

In this paper, we propose a Joint Application-Physical Layer (JAPLD) algorithm to cost-effectively transmit linear channels for a portable IPTV service over WiFi-based wireless mesh networks. With this approach, the application layer cooperates with the physical layer to maximize the visual quality. In application layer, the 'IPTV app', pre-installed in the tvFree, sets the standards of wireless network quality for stably transmitting high data-rate streams and informs to mesh environment APs. If the wireless network quality is out of the preset in the tvFree because of moving in the house, the connected AP is notified and obtain the wireless network quality between the tvFree and the neighbor AP. If the measured wireless network quality satisfies the previously set conditions, the connected AP guides the tvFree to connect a nearby AP with good quality, though which AP-driven handover (ADH) proceeds in physical layer.

Ⅱ. The Proposed System

This section describes how to transmit more than 270 linear channels to a portable IPTV and an algorithm that can improve visual quality in a WiFi-based wireless mesh AP environment.

2.1 A new Method for Transmitting of Linear Channels

Mobile IPTV service is provided in Korea by transmitting contracted channels on a unicast basis so that they can be transmitted to mobile phones out of about 270 channels provided through IPTV. For the traditional unicast transmission, various resolutions are generated in advance for each channel according to the wireless environment and transmitted according to network conditions. In this case, as the number of linear channels provided increases, a lot of equipment including transcoders will be additionally required in the broadcasting center, and the cost of CDN will increase in proportion to the number of subscribers.

As explained earlier, unlike Mobile IPTV, a Portable IPTV provides IPTV service without additional equipment investment and more than 270 linear channels are already reached at the L2 switch near the home through the QoS-guaranteed muti-service provisioning platform (MSPP) network and are serviced as well. When a customer gives a command to watch a specific channel, the set-top receives the stream via UDP protocol through an IGMP command to the AP. On the other hand, in the proposed method, the tvFree receives the stream via UDT protocol through an IGMP command to the AP that converts the UDP packet into UDT for wireless transmission and transmits it to a Portable IPTV as depicted in Figure. 2. If the network condition becomes unstable during viewing, it is possible to provide a seamless viewing experience by changing to an SD resolution stream although the visual quality is degraded.

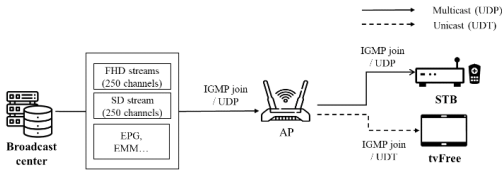

Fig. 2. The system configuration for portable IPTV

2.2 Device-Driven Handover

Let's assume a WiFi-based wireless mesh network in which two or more APs are installed and the tvFree can be connected. In this paper, it is assumed that two APs, main and mesh AP, are installed. When a customer runs the IPTV app installed in the tvFree device, it connects to the main AP, if the signal strength, received signal strength indicator (RSSI), of the main AP is bigger than the Mesh AP, to receive service, and if the customer moves from place to place in his or her home, the tvFree will continuously scan the RSSI of two APs in background. If the RSSI of the AP connected to the device itself is below the minimum quality for keep connecting and the RSSI from other AP is strong enough for handover, DDH will be proceeded as describe in Figure. 3.

If a device does not provide DDH, when the signal of the connected AP is disconnected, it will scan for connectable APs and connect, so it will take a longer time and the quality provided to customers will be

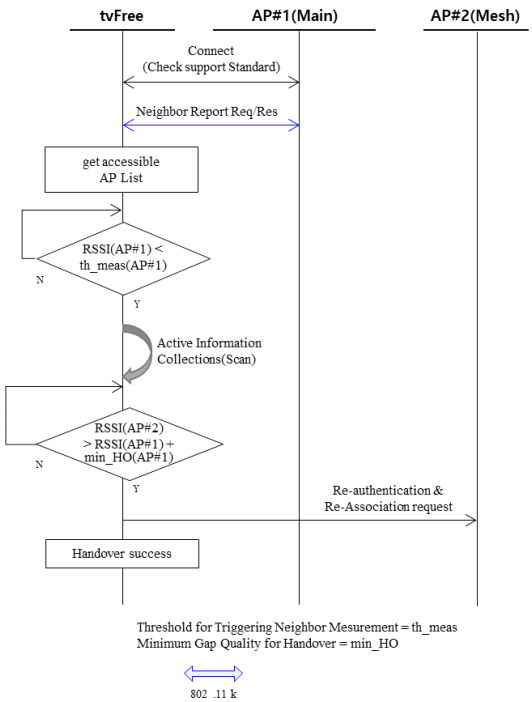

Fig. 3. The flow of device-driven handover

much worse. However, the conditions for executing DDH may differ depending on the device manufacturer and product. In particular, in services that require a stable high date-rate transmission such as a Portable IPTV, the handover situation required by the service and the conditions preset in the device are different. A sui-table handover may not be provided for this.

2.3 AP-Driven Handover by Joint Application Physical-Layer Design

It is described how to improve specific quality of service using joint application physical layer design (JAPLD). In order to stably receive a Portable IPTV service, high-speed transmission must be possible, and the quality standard of wireless network is set first. If the RSSI of the main AP is bigger than the mesh AP, the tvFree connects to the main AP. After that, in the application layer, the IPTV app installed in the tvFree transmits the device information for the minimum quality to the connected AP equipped with the Easy Mesh R2 protocol. The AP applies the handover parameters that matches the device ID received from the tvfree among the parameter set for each target service. If the wireless network quality is out of the preset while the customer is moving from place to place in the house, the connected AP requests to the tvFree whether the mesh AP can provide better quality. The main AP receives the RSSI between the tvFree and the mesh AP. If the notified signal strength satisfies the handover condition, the tvFree is guided to proceed with the handover, and the tvFree connects to the mesh AP, and ADH is executed as shown in Figure 4.

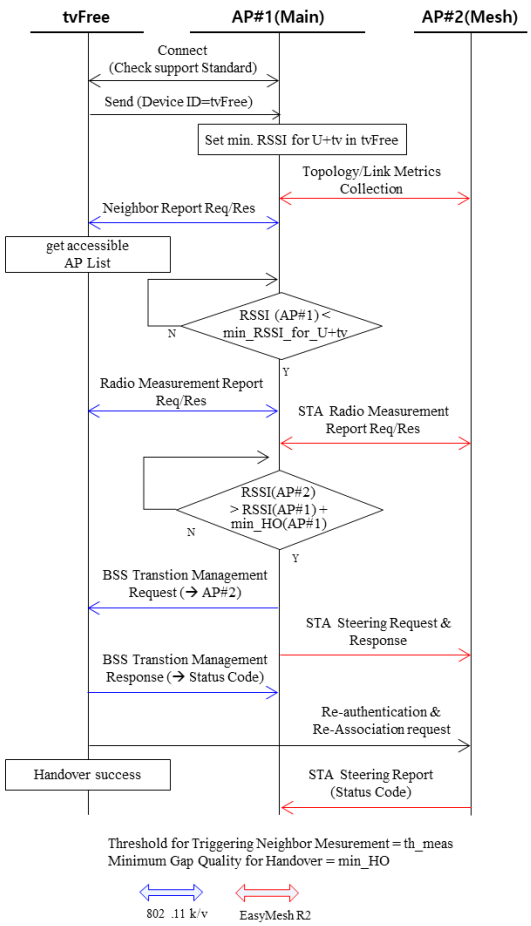

Fig. 4. The flow of AP-driven handover

Ⅲ. The Experimental Results

In order to prove the effectiveness of the proposed algorithm, data was collected and verified in situations where handovers could occur in actual customer homes, and it was confirmed that actual customer inconveniences were improved by app-lying the algorithm to APs in 300,000 households.

3.1 Experiments in a Real Customer Premises Environment

The four-bedroom, two-bathroom household, 138m2, which is one of the most common types of apartment in Korea, is shown in the figure 5. The experiment was conducted in a way that handover naturally occurs through movement within the house, starting with a strong signal at the start and tvFree device 'Samsung tablet S6 Lite' is used for the experiment. Stay 10 seconds at points A and B, 5 round trips.

The transmission speed and frame rate of 270 linear channels transmitted from the broadcasting center have already been determined. Therefore, in order to receive a Portable IPTV service stably, the criteria for handover are very important. In this paper, the RSSI value for ADH is determined based on the link speed described in the IEEE 802.11 standard.

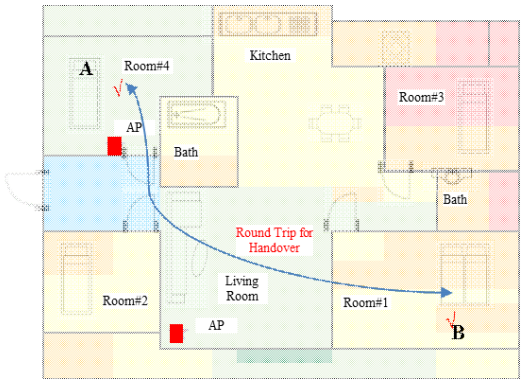

Fig. 5. Layout of the house

The data rate of the FHD channels sent from broadcasting center is approximately 11 Mbps and the frame rate is 29.97 [fps] and if the received frame rate by the device is less than 29.97 [frame/sec], it can be expected that the playback screen is frozen or broken. Since the player buffer size is 400 ms, playback stop does not occur when the handover time is within 400 ms.

3.2 Experimental Results

As shown in Table 1, while using the same UDT protocol, the average handover time of ADH is 61% shorter than that of DDH, and thus the received frame rate is higher and the visual quality will be much better. Figures 6 and 7 plot the remained data of player buffer during DDH and ADH, and it can be seen that the player buffer is restored more quickly

Table 1. Visual quality of DDH vs. ADH.

Handover Type	*Handover Time (sec)*		*Average Frame Rate (frame/sec)*	*Lowest Frame Rate (frame/sec)*
	Average	*Variance*		
DDH	1.3	0.3	21.7	0
ADH	0.5	0.1	29.1	19

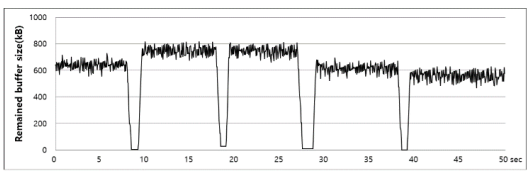

Fig. 6. The remained data size in player buffer during DDH

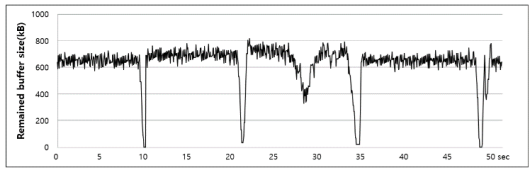

Fig. 7. The remained data size in player buffer during ADH

in ADH, allowing handover without noticeable playback interruption.

3.3 Results applied directly to customer devices

This algorithm was applied to 300,000 mesh AP customer devices, and 10,000 of them are enjoying a Portable IPTV service. Their quality data also confirmed the improvement in visual quality, the same as in the previous experiment. In Figure 8, the firmware upgrade over the air is conducted for both Easy Mesh R2 protocol and ADH on November 2022. With 2,000 sample customers using the tvFree device 'Samsung tablet S6 Lite', the average number of cases below the quality standard before the upgrade was 9,474[cases/day] with DDH, but after the upgrade 4,379[cases/day] with ADH. 54% improvement can be seen.

It was confirmed through actual data that the method applying the JAPLD algorithm for ADH compared with DDH by applying the proposed algorithm to the verification and device in the actual customer home environment showed better results.

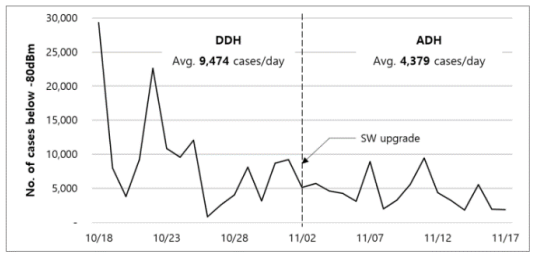

Fig. 8. The average number of cases below the quality standard

Ⅳ. Conclusions

We described in this paper a novel JAPLD strategy

that stably transmit linear channels for a portable IPTV service over WiFi-based wireless mesh network. This strategy makes proper use of the feedback of the obtained signal strength of mesh environment APs in such a way that the application layer cooperates with the physical layer. In application layer, the quality standard of wireless network for stably transmitting high data-rate streams are first set and inform to mesh environment APs. If the wireless network quality is out of the standards because of moving in the house, the connected AP will obtain the wireless quality between the tvFree and the neighbor AP. If the obtained wireless quality satisfies the previously set conditions, the connected AP guides the tvFree to connect a nearby AP with good quality, though which AP-driven handover (ADH) proceeds in physical layer. It was shown by various experiment results that the proposed ADH provides a better visual quality against DDH in both manual experiment of customer premises environment and real data collected from customer devices. This principle, if properly applied, might be a solution to ensure QoS for a various target services using WiFi-based wireless mesh network.

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Chunsu Ahn

Feb. 2010 : B.S. degree in Electronics and Computer Engineering, Hanyang University, South Korea

Feb. 2012 : M.S. degree in Electronics and Computer Engineering, Hanyang University, South Korea

Jan. 2012~Current : Researcher, LG Uplus Corp. Ltd.

<Research Interests> mobile telecommunications

Jeongmin Noh

Feb. 1999 : B.S. degree in Communication Intelligence Engineering, Korea Aerospace University, South Korea

Feb. 2001 : M.S. degree in Communications Intelligence Engineering, Korea Aerospace University, South Korea

Feb. 2008~Current : Researcher, LG Uplus Corp. Ltd.

<Research Interests> ICT technology, data communications

Sangyeob Lee

Feb. 1996 : B.S. degree in Electronic Computation, Pusan University, South Korea

Feb. 1998 : M.S. degree in Electronic Computation, Pusan University, South Korea

1998~Current : LG Uplus Corp. Ltd.

2022~Current : CTO, LG Uplus Corp. Ltd.

<Research Interests> mobile telecommunications, media engineering, electronic engineering

Daewon Song

Dec. 2007 : Ph.D. degree in Electrical and Computer Engineering, Florida Institute of Technology, USA

2008~Current : LG Uplus Corp. Ltd.

Jan. 2024~Current : Head of the Technology Development Group, LG Uplus Corp. Ltd.

<Research Interests> media engineering, ICT technology, electronic engineering