

The Study of Dynamic Video Frame Mapping Scheme for Multimedia Streaming over IEEE 802.11e WLAN

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Abstract

The recent trend in Internet traffic indicates the proliferation of multimedia streaming services over wireless networks. The multimedia streaming over wireless access in unison with great mobility brings challenges to sustain the mobile user video quality high. Up to the present, several studies have been performed in order to provide prioritization of stations or services over WLAN IEEE 802.11 for improving the quality of multimedia service. The IEEE 802.11e draft specification aims to extend the original IEEE 802.11 MAC protocol to support QoS. In this paper, we propose a dynamic video frame mapping scheme to improve the streaming quality of SVC(Scalable Video Coding) bitstream over IEEE 802.11e. Our scheme dynamically maps the video packets to appropriate access categories based on both the significance of the video data and the client buffer occupancy. Simulation results show that the proposed scheme improves the streaming quality by improving the receiving rate of important data to decode a SVC bitstream.

Keywords: *Multimedia Streaming; SVC; IEEE 802.11e; QoS*

1. Introduction

Internet traffic is rapidly increasing today and a growing proportion of the traffic is propagated over wireless networks such as WLAN (Wireless LAN), WMAN (Wireless MAN), and UMTS (Universal Mobile Telecommunications System). Especially IEEE 802.11 WLAN technology has become very popular because of its advantage in price and bandwidth. Among the internet services over WLAN, the multimedia streaming is expected to increasingly dominate the Internet traffic grows in future. However, in the past decade, the Internet has mostly offered a best-effort delivery service.

To support the varying QoS (Quality of Service) requirements of emerging application such as those involving continuous media, a new standard IEEE 802.11e has been specified [1]. This standard aims to support QoS by providing differentiated classes of service at the MAC (Medium Access Control) layer to enhance the ability of physical layers to deliver time-critical traffic in the presence of traditional data packets. The EDCA (Enhanced Distributed Channel Access) of 802.11e standard defines four ACs (Access Categories). These four ACs have different transmission priorities. The transmission priority is the probability of successfully earning the chance to transmit when individual ACs are competing to access the wireless channel, the higher the transmission priority, the better is the opportunity to transmit. However, For a wireless channel, unavoidable burst loss, excessive delays, and limited bandwidth become challenges for efficient multimedia transmission. Consequently, several advanced mechanisms were proposed based on 802.11e to support multimedia transmissions and in particular video transmission quality [2]. Most of the proposed mechanisms improved the performance by adjusting the operation of 802.11e MAC,

such as contention window size [3], TXOPlimit [4] and data transmission rate [5]. However, the mechanisms did not exploit the characteristics of multimedia streaming into consideration thereby limiting the performance improvements that can be obtained. To solve this problem, [6] proposed a MPEG-4 frame mapping algorithm. MPEG-4 standard defines three types of video frames for the compressed video stream, including I(Intra-coded), P(Predictive-coded), and B(Bidirectionally predictive-coded) frame. Each frame type has different priority according to the frame dependency. To guarantee the transmission of I frames, the mapping algorithm allocates video frames to ACs according to the priority of MPEG-4 frame. However, this algorithm reduces the throughput of other low priority service flow like best-effort because it has to share AC with video traffic. Also, previous schemes only consider single multimedia flow.

In this paper, we propose a video frame mapping scheme to transmit SVC (Scalable Video Coding) bitstream over IEEE 802.11e EDCA. Our scheme maps the packets to an AC_VI according to the types of video data and the client buffer status to guarantee the transmission of important video packets. The rest of the paper is organized as follows. In the next section, we present some background information on the basic concepts of IEEE 802.11e EDCA and SVC and review the enhancements of the legacy MAC as proposed in IEEE 802.11e standard. In Section 3, we present dynamic video frame mapping scheme over IEEE 802.11e EDCA. Detailed description of our simulation results are presented in Section 4. Finally Section 5 concludes the paper and discusses some of our future work.

2. Related Work

2.1. Scalability Extension of H.264/AVC

The SVC is an extension of motion-compensated transcoding that achieves a high degree of spatial, temporal and quality scalability. An SVC bit-stream consists of a base layer and one or more enhancement layers. The omission of some or all of the enhancement layers still allows a reasonable quality of, albeit with some combination of decoded video reduced SNR (Signal-to-Noise Ratio), temporal and spatial resolution. The base layer is a bitstream conforming to H.264/AVC that ensures backward compatibility with legacy decoders. It provides low quality of video with low resolution, low frame rate (temporal resolution), or low picture fidelity(PSNR: Peak Signal-to-Noise Ratio). The enhancement layers include the information of the frames with higher resolution, frame rate, or PSNR, but it cannot be decoded without a base layer [7].

The SVC defines three types of video frames for the compressed video stream, including I(Intra-coded) frame, P(Predictive-coded) frame, and B(Bidirectionally predictive-coded) frame. The I frame is encoded independently and decoded by itself. Thus, the I frame is just a frame coded as a still image, without any relationship to any previous or successive frames. The P frame is encoded using prediction from the preceding I or P frame in the video sequence. Thus the P frame requires the information of the most recent I frame or P frame for encoding and decoding. The B frame is encoded using predictions from the preceding and succeeding I or P frames. That is, the B frame is predicted from the two closest I or P frames from the past and the future. According to the coding relation, the most important video type in SVC bitstream is the I frame, with the P frame being more important than B frame [2].

From the hierarchical structure of SVC encoding presented above, a video frame may be considered undecodable directly or indirectly. Direct undecodable indicates that there are not enough packets for the video frame being received to decode the frame. Indirect undecodable happens when a frame is considered undecodable because some frame it depends on is directly undecodable. As a consequence, if essential video frame can have a higher priority

over other video frames, more video frames will be decodable and will result in better video perceived quality under similar lossy conditions.

2.2. IEEE 802.11e EDCA (Enhanced Distributed Channel Access)

The IEEE 802.11 standard provides contention based channel access(DCF: Distributed Coordination Function) and controlled channel access(PCF: Point Coordination Function). The DCF mode, usually used for best-effort services, is basically a random access method. All stations have the same access probability to the wireless medium without different user priorities. The PCF mode gives stations chances of accessing the wireless medium by polling with the same priority. Although the PCF mode is able to support real time services, it does not consider the differentiating frames with different priorities [8].

The IEEE 802.11e EDCA is designed to enhance the 802.11 DCF mechanisms by providing a distributed access method that can support service differentiation among different classes of traffic. EDCA classifies traffic into four different AC as illustrated in Figure 1. The four access categories include AC_VO for voice traffic, AC_VI for video traffic, AC_BE for best effort, and AC_BK for background traffic. Each AC has its own buffered queue and behaves as an independent backoff entity. The priority among ACs is then determined by AC-specific parameters, called the EDCA parameter set [1].

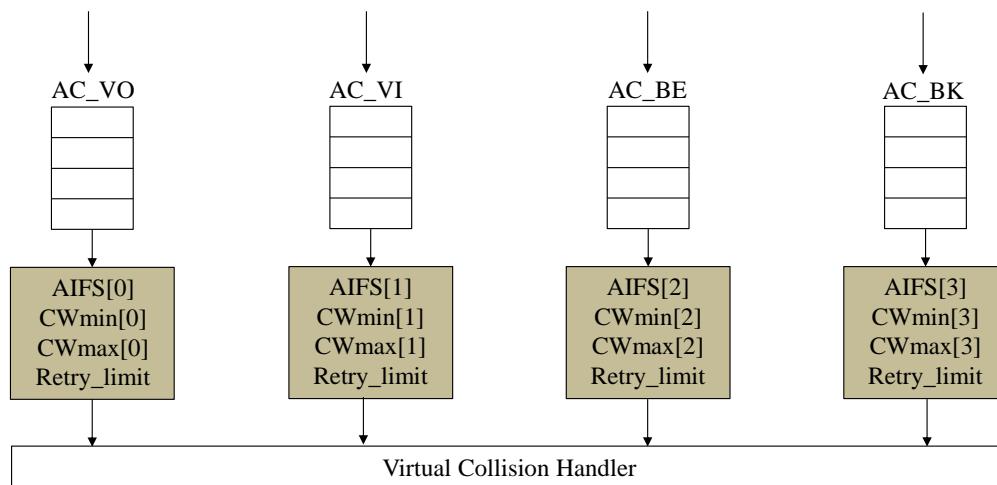


Figure 1. IEEE 802.11e MAC EDCA

The EDCA parameter set includes CWmin(minimum Contention Window size), CWmax(maximum Contention Window size), AIFS(Arbitration Inter Frame Space), and TXOPlimit(Transmission Opportunity limit). Each AC behaves as a single EDCF station virtually. When more than one AC finishes the backoff at the same time, the collision is handled in a virtual manner at the internal collision handler. The highest priority traffic is selected among them and transmitted, and rests of them defer with increased CW. Figure 2 shows the timing diagram of the EDCF channel access. As shown in Figure 2, the station determines that the medium is idle for greater than or equal to a DIFS period which is the same as the DCF mode of IEEE 802.11. The value of AIFS[AC], CWmin[AC], and CWmax[AC], which are referred to as the EDCF parameters, are announced by the beacon frames from the AP. The AP can announce these parameters dynamically depending on the network conditions. Each channel access function maintains a state variable AIFS[AC] and CW[AC] that is set to the

initial value of the parameter $CW_{min}[AC]$. The smaller $AIFS[AC]$ and $CW_{min}[AC]$, the shorter the channel access delay for the corresponding priority. After successful transmission, the backoff time for the AC will be expired. However, smaller $CW_{min}[AC]$ may increase the probability of collisions. These parameters, $AIFS[AC]$, $CW_{min}[AC]$, and $CW_{max}[AC]$, can be used in order to differentiate the channel access among different priority traffic [2-3].

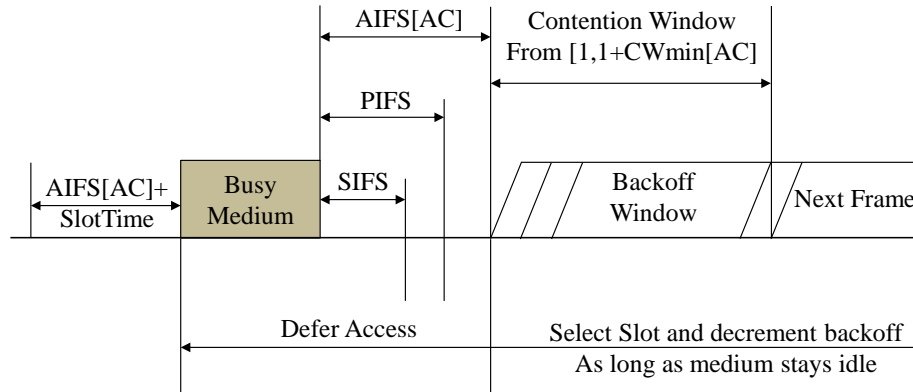


Figure 2. IEEE 802.11e Basic Channel Access Method

2.3. Enhancement Proposals for IEEE 802.11e

Several efforts proposed advanced mechanisms to improve the transmission of video over an 802.11e network. In [3], authors designed an adaptation of CW size to improve system throughput. In [4], TXOPlimit is used to provide priority service. In [9], the retransmission scheduling is based on EDF (Early-Deadline-First), considering the playout deadline. However, even though all of above schemes perform better than 802.11e, they do not consider the data significance within a specific traffic type. For video traffic, there are different significances associated with different types of encoded video data. If the video packets are transmitted according to the significance of their encoded layers we can improve the video quality.

To support QoS transmission of hierarchical coding video over an IEEE 802.11e network, a cross-layer design architecture has been proposed. In [10], the authors propose cross-layer architecture to improve video transmission over an IEEE 802.11e network. they also propose a packet mapping algorithm, based on the traffic specification of IEEE 802.11e EDCA, and encoded H.264 video data is allocated into different precedence AC queues according to the video coding significance. However, the mapping algorithm is static and leads to the additional delay of other low priority AC. Also the video data which is mapped to low priority AC will result in unnecessary transmission delay and packet losses. In [2], MPEG-4 video packets are dynamically mapped to the appropriate AC based on both the significance of the video data and the network traffic load. However these schemes did not consider the priority of video flows.

In this paper, we propose a video frame mapping scheme for improving the quality of SVC video transmission over IEEE 802.11e wireless network. In the proposed video transmission approach, video packets are mapped into the sub ACs in AC_VI according to the types of video frame and the client buffer status. By considering both the frame type and client buffer status, we could prioritize the transmission of important video data.

3. Dynamic Frame Mapping Scheme over IEEE 802.11e EDCA

In this section, we propose an adaptive frame mapping scheme to improve the quality of streaming service. Our scheme dynamically assigns SVC video packets to the appropriate AC based on both the significance of the video data and the priority of multimedia flows. Our scheme is different with previous static mapping algorithm because we do not obstruct the transmission of other service traffics by only using AC_VI and we also consider the client buffer occupancy to prevent buffer underflow and overflow.

3.1. Packet Mapping Scheme based on the Significance of the Video Data

For the SVC video stream, there are three frame types for the compressed video stream namely I frame, P frame, and B frame. Based on the coding dependence, the loss of more important video frames would deteriorate the delivered video quality. For example, one I frame loss will cause all frames in the same GOP to be undecodable, at the same time, one B frame loss just affects itself. Based on the significance of video frame perceived in the application layer, the channel access priorities used to prioritize the transmission opportunity at the MAC layer are set with the I frame as the highest, the P frame below I but above B's priority, and the B frame set at the lowest priority. If the queue is full and data has to be dropped, then B frames are dropped first, then P frames, followed by I frames. The loss effect on the video transmission quality will decrease according to this priority mechanism.

Figure 3 depicts the proposed AC architecture for video data. In the proposed AC architecture, AC_VI has three sub ACs and each type of video data is mapped to the appropriate sub AC. We exploit a field called TOS(Type of Service). Originally, the TOS field in the packet header defines how a datagram should be delivered, *e.g.* delay, precedence, reliability, minimum cost, throughput etc, and is now used by differentiated services. However, in the proposed design, the priority of video frames is pre-marked in this field and is passed to the network layer. The network layer in turn expresses the same QoS existence to an EDCA-based MAC layer. After that, MAC layer could make use of the priority information to determine the most suitable allocation in ACs accordingly.

In proposed architecture, packets of I frame are mapped to Sub_AC_I, packets of P frame are mapped to Sub_AC_P, and B frame are mapped to Sub_AC_B. We give the highest priority to Sub_AC_I. When AC_VI win the competition to access the wireless channel, packets in the Sub_AC_I queue are transmitted first. After the queue of Sub_AC_I is empty, packets in the Sub_AC_P queue are transmitted. Packets in the Sub_AC_B queue are transmitted when there are no packets in the Sub_AC_I and Sub_AC_P. Our mapping algorithm enhances higher priority to I frame without throughput reduction of other ACs by only considering AC_VI to map the video packets.

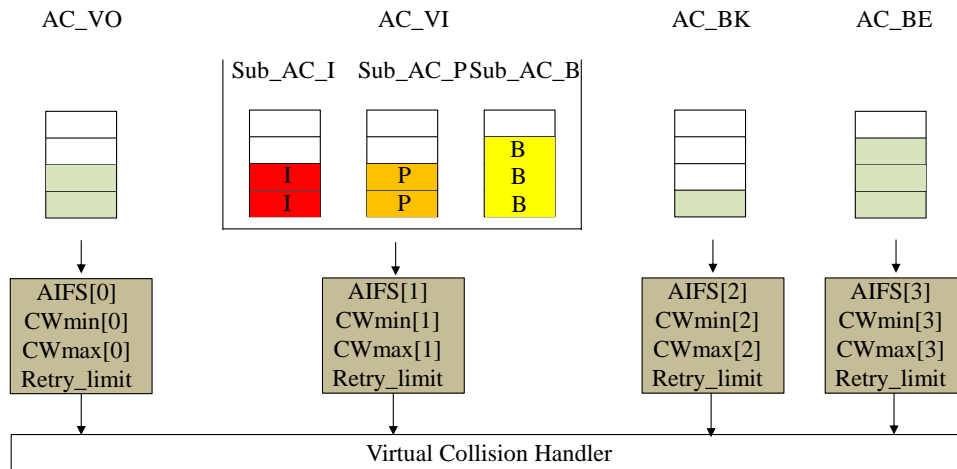


Figure 3. AC Architecture for Propose Packet Mapping Scheme

3.2. Packet Mapping Scheme based on the Buffer Occupancy of Clients

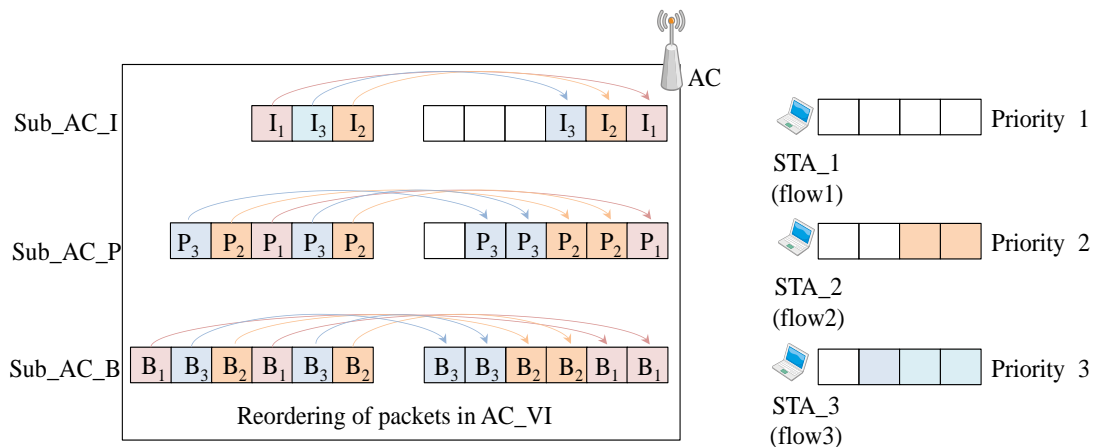


Figure 4. Packet Mapping Scheme based on the Buffer Occupancy of Clients

Previous mechanisms to improve the transmission of video over 802.11e networks only consider single video flow. When multiple video flows are transmitted over a 802.11e network, a client which is in danger of buffer underflow requires fast packet reception. To allocate high priority to a flow with less buffer occupancy, we propose a LBCFS (Low Buffer Client First Serve) scheme. The LBCFS scheme rearranges the packets in the AC_VI according to the client buffer status as shown in Figure 4. Reserved field in the block ACK is used to aware the client buffer status. After receiving the block ACK of previous TXOP, AP decides the priority of flows base on the client buffer status. The client who has the least amount of buffer has the highest priority and the client who has the most amount of buffer has the lowest priority. The packets of the highest priority flow are relocated in front of the queue. In our scheme, each Sub_AC rearranges the packets according to the priority of multimedia flows.

To guarantee the quality of streaming service, the proposed scheme assigns the video frame to the most appropriated Sub_AC in the AC_VI according to the significance of video type and rearranges the packets in the AC_VI according to the client buffer status. Figure 5 describes the proposed video frame mapping algorithm over IEEE 802.11e. At first, AC_VI competes with other ACs to access the channel. Once AC_VI seizes the channel for data transmission, I frame packets in Sub_AC_I are transmitted until Sub_AC_I is empty or the TXOPlimit time is over. If TXOPlimit is over, AC_VI competes to access channel again. If Sub_AC_I is empty and TXOPlimit is not yet over, P frame packets in Sub_AC_P are transmitted until Sub_AC_P is empty or TXOPlimit is over. Subsequently, B frame packets in Sub_AC_B are transmitted if TXOPlimit is still alive.

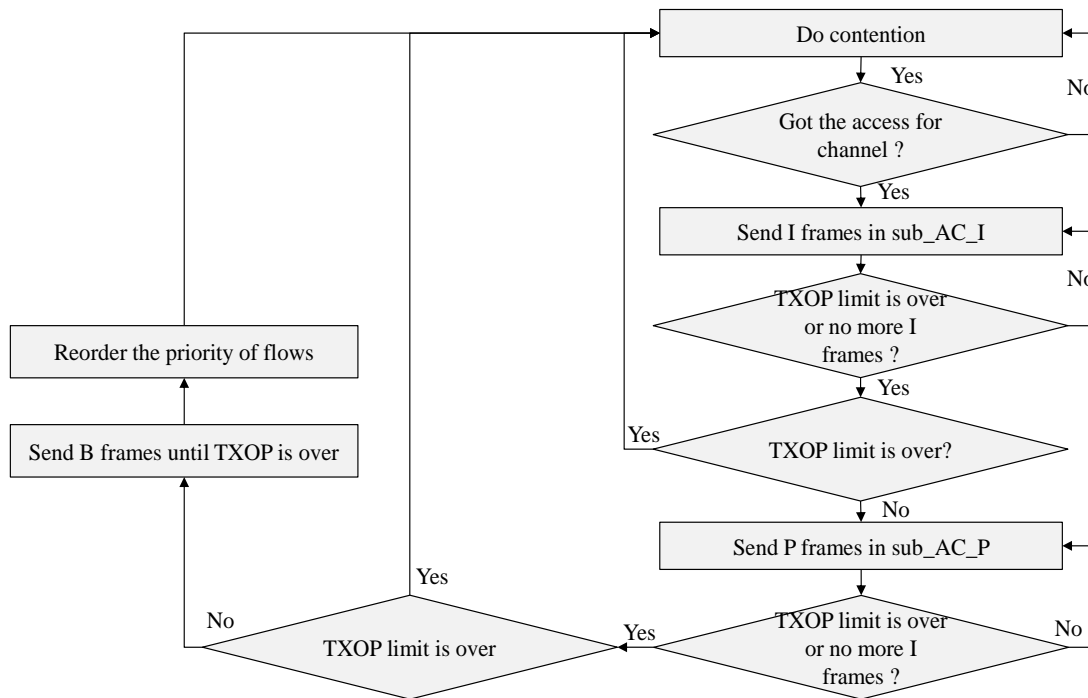


Figure 5. Dynamic Packet Mapping Algorithm based on the Video Type and Client Buffer Status

4. Simulation Results

This section presents the simulation results for the proposed frame mapping scheme. In order to evaluate the performance of the proposed scheme, we perform experiments on the basis of the ns-2(Network Simulator) of LBNL (Lawrence Berkeley National Laboratory). We construct a dumbbell topology as shown in Figure 6. The results of the proposed mapping algorithm are compared with the results derived from IEEE 802.11e EDCA and the static mapping algorithm in [10].

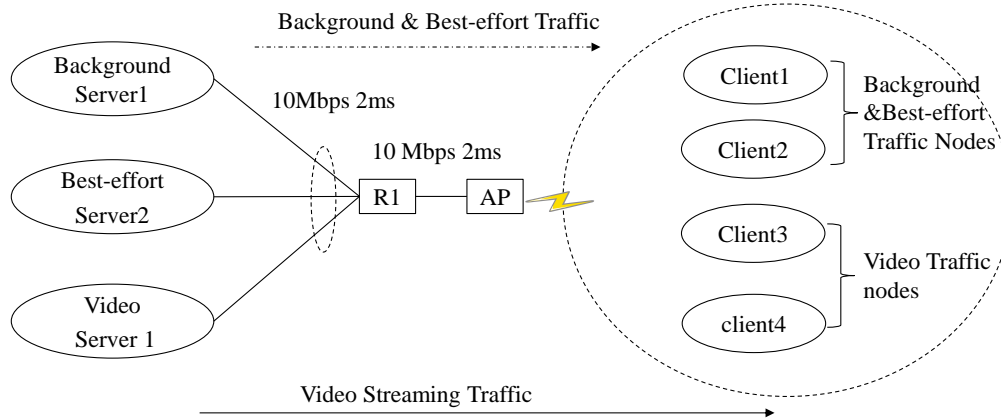


Figure 6. Network Configuration to Evaluate the Performance of the Proposed Packet Mapping Scheme

We use video clip foreman_cif_352x288.yuv for the simulation. Each video frame is fragmented into packets before transmission and the maximum transmission packet size over the simulated network is 1000bytes. Table 1 shows the number of video frames and packets of the video sources.

Table 1. The Amounts of Video Frames and Packets of the Video Sources

Video	Format	Frame number			Packet number		
		I	P	B	I	P	B
Foreman (1.7M)	CIF	10	90	199	160	366	199
Foreman (3M)	CIF	10	90	199	314	2083	661

At first, we measured the decoding success rate of each scheme. To evaluate the performance of proposed scheme, the simulation was performed for 10secs. From 0th sec, the video server sent a 1.7Mbps video stream. The best-effort server and background server transmitted TCP and UDP traffic. Figure 7 shows the decoding success rate of each packet mapping scheme. The proposed dynamic mapping and static mapping scheme successfully decoded whole I frames while the decoding success rate of B frames are lower than 802.11e EDCA. The decoding success rate of P and B frame of static mapping algorithm is higher than the proposed scheme because our scheme does not use other ACs to transmit video data. However, static mapping algorithm obstructs the transmission of other service flows. Figure 8 demonstrates the throughput of flows which using AC_BE and Figure 9 shows the throughput of flows which using AC_BK. The throughput of static mapping scheme is lower than dynamic mapping scheme because the flows which use low priority AC share the channel access probability with video flow.

To demonstrate the impact of the LBCFS scheme we performed additional simulation. For 10 seconds, two video flows with different bitrates are transmitted to different clients. The bitrate of video flow1 is 1.7Mbps and the total number of I frame packet is 160. The bitrate of

video flow2 has 3Mbps and the total number of I frame packet is 314. Therefore, video flow2 requires more packets to decode one I frame. In other words, the client buffer occupancy of video flow2 is consumed faster than that of video flow 1. However, the static mapping scheme does not consider the client buffer occupancy. Figure 10 depicts the decoding success rate of I frame at the clients. The decoding success rate of our dynamic mapping scheme is higher than that of the static mapping algorithm because we assign high priority to the client with lower buffer occupancy.

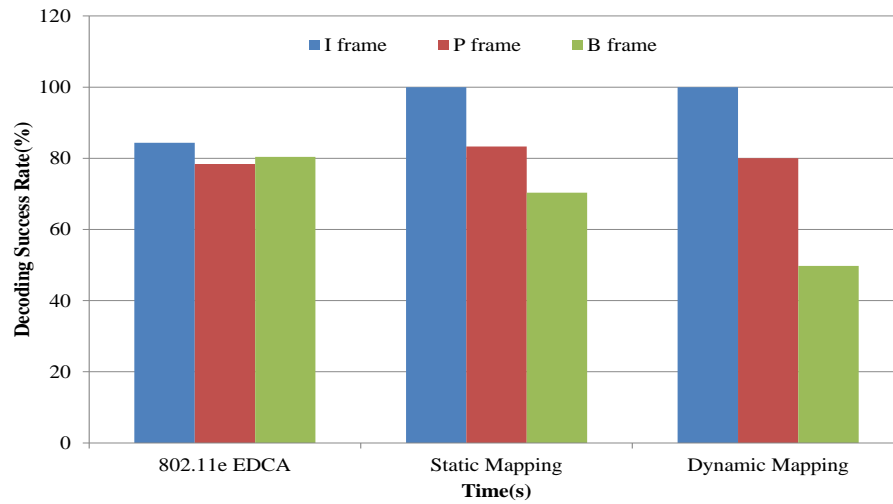


Figure 7. Comparison of the Frame Decoding Success Rate between Different Packet Mapping Schemes

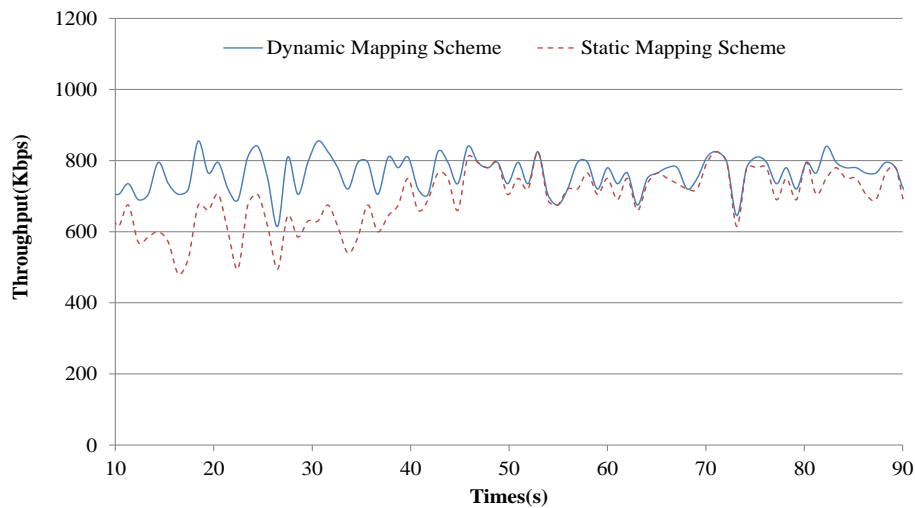


Figure 8. Throughput Comparison of Flows in AC_BE

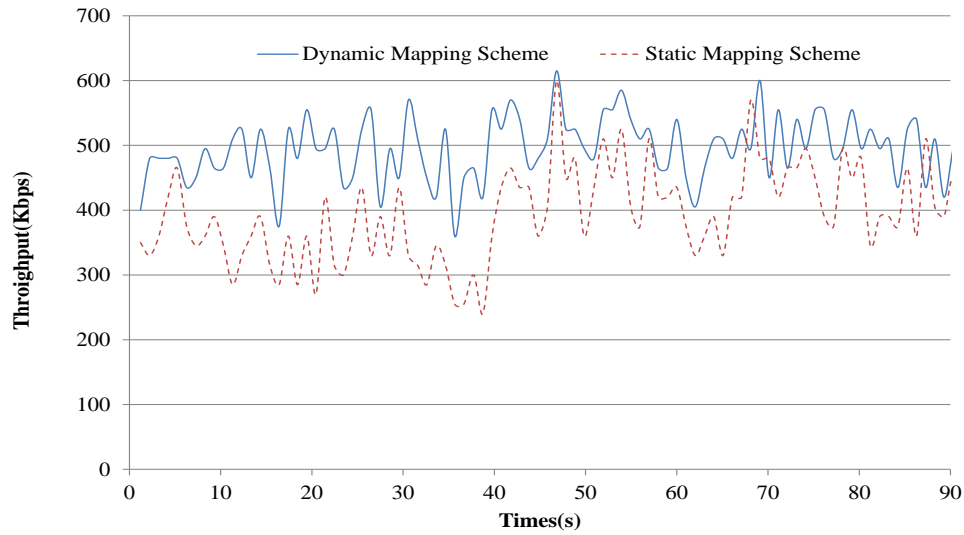


Figure 9. Throughput Comparison of Flows in AC_BK

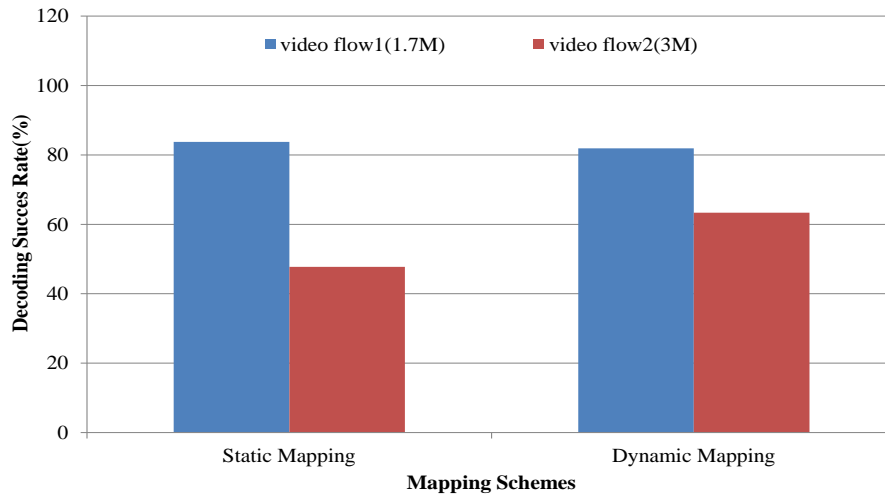


Figure 10. Comparison of the I Frame Decoding Success Rate of Two Video Flows

5. Conclusion

To improve the streaming quality of SVC over IEEE 802.11e EDCA, we proposed a dynamic video frame mapping scheme. We improved in the quality of the streaming by exploiting the hierarchical characteristics of video frame and the buffer occupancy of clients. In contrast to the previous static mapping scheme, our scheme guarantees the transmission of I frame which is the most important to decode frames without performance reduction of other low priority flows. Our scheme also improved the streaming quality by considering the

priority of video flows. When video flows compete for the channel access, our mapping scheme rearranges the transmission order according to the client buffer status.

Simulations show that the proposed scheme can improve the decoding success rate of I frames without performance reduction of low priority flows.

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