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Proposal for Packet Assignment Scheme for Video Transmission Using Multicast Distribution in WLAN Systems

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Abstract—In this paper, we have proposed a packet assignment scheme in a frame structure, which is suitable for video transmission using multicast distribution in wireless LAN systems. Multicast distribution transmits data packets to nearby receiving terminals using single transmission rate. The same data packet is simultaneously distributed to multiple terminals. However, there is a problem when multicast distribution is performed using a single transmission rate. The efficiency of the entire radio network decreases if packets fail to arrive at a receiving terminal far from the access point or if distribution to a faraway terminal occurs at a low transmission rate. Therefore, multicast distribution has the issue that it cannot be performed at a transmission rate that is suitable for all support terminals. The packet assignment scheme proposed in this paper is realized by assigning multiple transmission rates to packets that are encoded by scalable video coding[1] in a frame structure to resolve this issue. The proposed scheme enables multiple terminals with different signal to noise ratios to receive multicast packets during radio propagation. Moreover, we confirmed the performance of the proposed scheme by using an evaluation scheme, which evaluates metrics consisting of propagation parameter and quality of experience. Evaluation using indexes of both the physical layer and upper layer is a breakthrough process, which has never been used before.

1. Introduction

In recent years, mobile terminal have been using various multimedia applications and services. With rise in demand, the number of terminals using wireless LAN (WLAN) [2] is increasing. Moreover, content distribution using multicast communication that can efficiently use the communication band is increasing.

However, in wireless transmission, multicast signals may not reach all terminals when using a single transmission rate. The transmission rate should be selected based on appropriate modulation because the terminals have different signal to noise ratios (SNR) depending on their distances from the access points (AP). Therefore, in order to transmit to terminals belonging to all multicast groups in the area, it is necessary to use a low transmission rate at which the terminal farthest from an AP can receive signal of adequate quality. It is difficult to achieve multicast distribution of large transmission data such as video contents and audio contents. Furthermore, radio exclusion band time is expended and transmission efficiency of the entire wireless system will be lowered if a low transmission rate is always used.? In multicast transmission, data packets such as video contents and audio contents are transmitted to a specified group of terminals at the same time. Thus, multicast transmission is often used by broadcast distribution services.

Multicast wireless transmission has other issues as well. Wireless transmission has propagation error due to low SNR and radio interference because WLAN systems use 2.4 GHz of unlicensed band. When radio interference occurs, multicast transmission is more susceptible to packet loss than unicast transmission. Packet collisions that occur during interference result in packet loss. This is because, unlike unicast, multicast distribution does not have retransmission control functionality following packet collision. Therefore, the high transmission rate is weakened under the effect of interference waves and transmission quality is significantly lowered. Moreover, real time video streaming transmissions cause block noise and video freezing due to frequent packet loss. Therefore, various issues associated with multicast transmission must be overcome when multicast is used for video streaming and other purposes and where high quality is required.

In order to solve the issues of such distribution type video transmission, video transmission using FEC based error recovery technology [3] and SVC system [4]-[6] has been proposed. In this paper, we propose a packet assignment scheme based on a frame structure suitable for video transmission using multicast distribution in WLAN systems. The proposed scheme protects against packet loss due to radio interference and propagation errors and video streaming can be performed using multicast distribution from the AP to remote terminals even in an environment with poor SNR. Specifically, multiple packets are coded using scalable video coding (SVC) scheme and transmitted to the terminals by assigning plurality of transmission rates

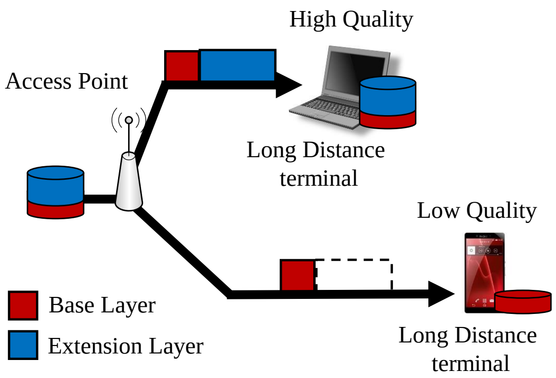

Figure 1: SVC method applied to wireless LAN

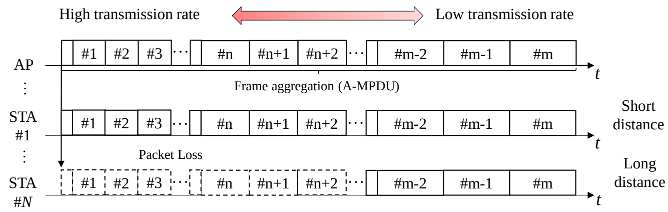

Figure 2: Proposed scheme using packet arrangement

(a combination of modulation level and coding rate) in a frame structure. The SVC scheme is divided into a base layer and enhancement layer, where the base layer consists of the basic video to be transmitted. The enhancement layer is an additional element that is added to the base layer. The video playback quality is low when the base layer alone is played. This quality is significantly enhanced by using the enhancement layer. The packets from these different layers are transmitted at an appropriate transmission rate to realize an optimal video distribution that ensures all terminals in the area can receive transmission signals of good quality. In this structure, the base layer packet is transmitted at a low transmission rate. Therefore, it is not susceptible to interference and propagation errors and it is possible to communicate the packet to a distant terminal. The packet in the enhancement layer is transmitted at a high transmission rate because its data size is large. Therefore, video distribution through multicasting can be done even in environments with poor SNR and to faraway terminals.

We confirmed the performance of the proposed assignment scheme by using an evaluation method that evaluates combined metrics of propagation parameter and quality of experience (QoE). Evaluation using indexes of both the physical layer and upper layer is a breakthrough method, which has never been used before.

Section II explains the algorithm of the proposed scheme. Section III confirms the performance of the proposed scheme by means of throughput characteristics and confirms the effect on video quality in terms of QoE. Section IV is a summary of this paper.

2. Outline of proposed scheme

This section explains the algorithm of the proposed scheme.

Multicast distribution has the issue that it cannot be provided at an optimal transmission rate to all terminals. In order to solve this issue, we proposed a scheme of assigning multiple transmission rates to packets coded by SVC method as shown in Fig.1. SVC method is a video coding scheme standardized by H.264/AVC [1]. It has a hierarchical structure unlike normal video coding. SVC broadly comprises of base layer, which constitutes the basic video, and enhancement layer, which converts the basic video into one of high image quality. A video of low resolution is obtained when the base layer packet alone is decoded whereas a video of high resolution can be obtained when a packet that includes the enhancement layer is decoded.

Fig.2 shows the packet arrangement of the proposed scheme using this characteristic. The horizontal axis represents time and the square in the figure represents a packet. Packet sizes appear to be different because different transmission rates are assigned. However, the packet sizes are the same in Fig.2. The proposed scheme assigns multiple transmission rates within the multicast frame in the form of high transmission rate and low transmission rate to be transmitted simultaneously. In Fig.2, three transmission rates are assigned within a single frame structure. Transmission rates are assigned to packets in each hierarchy as coded by SVC on this frame. For example, a base layer packet is assigned a low transmission rate and an enhancement layer packet is assigned a high transmission rate. The receiving terminals that are closer to an AP can receive all packets with high and low transmission rates. The receiving terminals that are far from the AP cannot receive packets assigned with a high transmission rate. However, they can receive packets with a low transmission rate. Therefore, the proposed scheme performs multicast distribution to distant terminals that are not supported by conventional multicast distribution and provides video streaming with high resolution to receiving terminals close to the AP.

In conventional multicast distribution, packets that are transmitted at a low transmission rate can be delivered to a receiving terminal at a long distance from the AP and packets that are transmitted at a high transmission rate result in a high quality video. The proposed scheme satisfies both these conditions.

3. Evaluation of proposed packet assignment scheme

In this section, the evaluation results of the proposed scheme are explained.

In order to confirm the effectiveness of the proposed scheme, we evaluated the throughput in the medium access control (MAC) layer and evaluated the user experience quality of the video by ITU-T G.1071[7]. Video is considered as the application in the case of multicast distribution because QoE of the video reproduced by the receiving terminal is important. Several evaluations of packet losses and throughput have been performed in the MAC layer. However, in multicast distribution of videos, QoE in users at the receiving terminal is important. Therefore, the proposed scheme is evaluated from the viewpoint of QoE of the user.

3.1. Evaluation conditions for throughput characteristics

The evaluation conditions of the proposed scheme were as follows. The packet size was 1,500 bytes. Moreover, the packets were concatenated and transmitted using frame aggregation with a frame length of 64 Kb. The bandwidth was 20 MHz and the transmission speed was IEEE 802.11a standard [2] compliant. Other access control parameters conformed to the IEEE 802.11 standard. The proposed scheme assigned multiple transmission rates. Therefore, the packets in the multicast frame were assigned three transmission rates at a ratio of 1:1:1. The transmission rates selected were 9, 12, and 38 Mbit/s and 9, 18, and 38 Mbit/s. When packets in a hierarchy coded by SVC were lost, the evaluation was performed under the assumption that all packets of the same layer were discarded.

3.2. Evaluation conditions for video quality

The objective quality evaluation method standardized by ITU-T G.1071[7] was used for evaluation of video quality. ITU-T G.1071 is a planning model for objective quality assessment of video transmissions and is a model that evaluates quality using video coding bit rate and packet loss as input parameters. However, the video quality of the base layer was evaluated using bit rate of the base layer video encoded by SVC as input as ITU-T G.1071 cannot evaluate the quality of hierarchically structured SVC. Moreover, video quality of the enhancement layer was evaluated using bit rate obtained by adding bit rate of the enhancement layer to bit rate of the base layer.

3.3. Objective evaluation method for video quality

The mean opinion score (MOS) calculation method is described below. In equation (1), the intermediate parameter Qv to be converted to MOS was calculated by subtracting $QcodV$ (degradation of quality in the encoding process) and $QtraV$ (packet loss in the communication process) from 100. $QcodV$ is obtained from equation (2), where $a1, a2, a3$, and $a4$ are constants. $QtraV$ is obtained from equation (3), where $b1, b2$ are constants. These constants correspond to the assumed image quality and, here, we have focused on high resolution images.

$$Qv = 100 - QcodV - QtraV \tag{1}$$

$$\begin{aligned} QcodV = &a1v \cdot e^{a2V \cdot BitPerPixel} \\ &+ a3V + ContentComplexiy + a4V \end{aligned} \tag{2}$$

$$QtraV = b1V \cdot log(b2V \cdot FreezingRatioE + 1) \tag{3}$$

ITU-T G.1071 is an objective model for evaluation of video quality in a wired network. Therefore, even though it is not an evaluation method for the WLAN environment, $QcodV$ was calculated by converting bit error of the WLAN into packet loss. The bit error rate of the WLAN was determined using SNR of the receiving terminal with respect to transmission rate of the AP. Therefore, evaluation of the proposed scheme was performed by varying the SNR. The coding bit rate is normally used for calculation of $QtraV$ to quantify quality degradation of the transmitted content. However, this study used throughput obtained by the proposed scheme as input parameter to evaluate the associated video quality. The evaluation index, MOS, was evaluated in five stages from 1 to 5—5: Excellent, 4: Good, 3: Fair, 2: Poor, 1: Bad. Additionally, MOS was non-linear to quality.

4. Evaluation results

In this section, the evaluation results of the proposed scheme are explained. Fig.3 shows the throughput characteristics of the proposed scheme and the conventional scheme. The horizontal axis shows SNR and the vertical axis shows throughput. In the figure, the green line represents throughput performance at a single transmission rate of 12 Mbit/s. The red line is the throughput performance at transmission rates of 9, 12, and 36 Mbit/s in combination and the blue line is throughput performance at transmission rates of 9, 18, and 36 Mbit/s in combination. In conventional multicast, throughput of approximately 12 Mbit/s is obtained in an environment with SNR of 6 dB. However, the proposed scheme could obtain the same throughput in an environment with low SNR of up to 4 dB. Moreover, the proposed scheme exceeded the conventional throughput when transmitting at a constant transmission rate from 15 dB. As a result, we confirmed that the proposed scheme could communicate well even in an environment with poor SNR compared to conventional multicast frame transmission using a single transmission rate.

Fig.4 shows the QoE characteristics of the proposed method and the conventional multicast method. The horizontal axis represents SNR and the vertical axis represents MOS value. The green line represents throughput performance at a single transmission rate of 12 Mbit/s. The red line is the MOS value at transmission rates of 9, 12, and 36 Mbit/s in combination. The blue line is the MOS value at

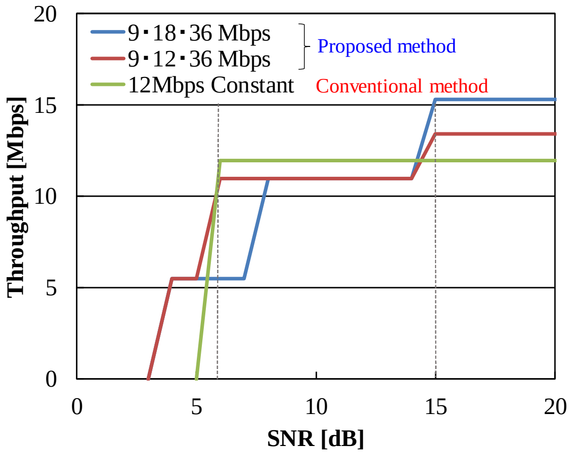

Figure 3: Throughput characteristics for SNR

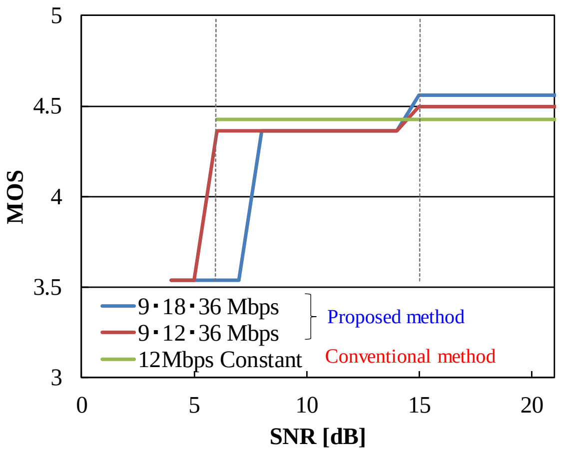

Figure 4: QoE characteristics for SNR

transmission rates of 9, 18, and 36 Mbit/s in combination. The MOS value when delivering at a single transmission rate of 12 Mbit/s to an environment with an SNR of approximately 6 dB was approximately 4.4. In the proposed method, the MOS value for an SNR of 4 dB was approximately 3.5. It was approximately 4.4 after 6 dB and 4.5 at 15 dB or more. Based on the evaluation results, we also confirmed that the proposed method can multicast to terminals with poor SNR condition with respect to QoE.

5. Conclusion

In this paper, we proposed a packet assignment method in a frame structure, which is suitable for video transmission using multicast distribution and evaluated throughput in the MAC layer and video quality in terms of QoE. As the evaluation results show, the new method made multicast distribution possible to receiving terminals far from the AP and with poor SNR condition while maintaining good video quality.

Acknowledgments

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