QoE Comparison of Retransmission and AL-FEC on Audiovisual Groupcast over Wireless LANs

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Abstract—This paper performs a QoE comparison of reliable transmission methods using retransmission and AL-FEC on audiovisual Groupcast over wireless LANs. We consider audiovisual groupcast with priority control by EDCA from a single access point to multiple wireless terminals. We compare four transmission methods: Groupcast, GCR Unsolicited Retry, GCR Block Ack, and Groupcast with AL-FEC. We perform a computer simulation under various network conditions to assess application-level QoS and evaluate QoE by a subjective experiment. As a result, we find that selecting the appropriate transmission method for the network conditions can enhance QoE.

Index Terms—wireless LAN, IEEE 802.11aa, AL-FEC, groupcast, audio and video transmission, QoE

I. Introduction

Thanks to the enhancement of communication bandwidth on wireless LANs [1], wireless LANs in multimedia services such as live streaming and multipoint online meetings have become popular. For efficient deployment of the services, multicast/groupcast has gained much attention.

The groupcast is a technique on the MAC layer to transmit the same data to multiple recipients simultaneously. Since the traditional wireless LAN standard [2] does not have the mechanism of acknowledgment for the groupcast, it cannot manage packet losses.

As the mechanism for reliable groupcast communications, IEEE 802.11aa GCR (GroupCast with Retries) was standardized in 2012 to enhance audiovisual transmission quality [3]. IEEE 802.11aa introduces GATS (Group Addressed Transmission Service), and GCR is a mechanism of GATS. GCR has two mechanisms: GCR Unsolicited Retry and GCR Block Ack. The former transmits a frame several times. In the latter mechanism, the transmitter sends several frames sequentially and then requests acknowledgment to each receiver. According to the result of the acknowledgments, the transmitter retransmits lost frames.

Besides, AL-FEC (Application-Level Forward Error Correction) is a famous technique for reliable communications. It attaches the redundant information to recover lost data in advance. When the receiver cannot receive a packet, it can recover the packet from the redundant information attached to the received packets. AL-FEC performs the attachment and recovery at the application layer.

Multimedia communications require QoS (Quality of Service) enhancement according to the characteristic of each medium. In particular, continuous media such as video and audio need to maintain the temporal structure; it is disturbed due to packet loss, network delay, and jitter. Furthermore, the disturbance affects QoE (Quality of Experience) [4]. The final recipient of the multimedia communications is the users. Then, the network services' ultimate goal is to provide sufficient QoE for the users.

In [5], Nunome and Komatsu compare GCR Unsolicited Retry and GCR Block ACK from an audiovisual QoE point of view. They show that GCR Block Ack can achieve higher QoE than GCR Unsolicited Retry. However, they do not compare with AL-FEC. Besides, Reference [6] assesses the effect of AL-FEC on QoE and QoS of H.264 video and audio transmission over MMT (MPEG Media Transport). The reference focuses on unicast communications over wired networks. Hence, it does not evaluate QoE on wireless groupcast communications with AL-FEC. Reference [7] performs a QoS assessment of audiovisual transmission over Wi-Fi multicast with AL-FEC on a high-speed train. AL-FEC can conceal the packet loss on the Wi-Fi multicast channel. However, the reference does not evaluate QoE.

GCR and AL-FEC are reliable communication mechanisms. However, the strategies are different. It is needed to clarify the characteristics of the mechanisms from a QoE point of view. This paper evaluates the QoE of video and audio groupcast communications over wireless LANs utilizing GCR and AL-FEC. QoE is affected by the lower layer QoS parameters; however, the relationship is generally complicated. We then need to tackle the assessment at the QoE level.

The remainder of the paper is structured as follows. Section II introduces the transmission methods. Section III describes the simulation method. Section IV explains the QoE assessment method. Section V presents the results. Section VI concludes this paper.

II. Transmission methods

This paper assumes that AP (Access Point) simultaneously transmits video and audio streams to plural receiver terminals. AP employs QoS control through EDCA (Enhanced Distributed Channel Access). EDCA classifies incoming traffic

into four ACs (Access Categories) and differentiates the ACs with priorities.

This study uses four transmission methods: Groupcast, GCR Unsolicited Retry, GCR Block Ack, and Groupcast with AL-FEC. The methods are summarized below. For details of the former three methods, please see [5].

A. Groupcast

Groupcast does not provide acknowledgment or retransmission. It cannot guarantee transmission reliability.

B. GCR Unsolicited Retry

GCR Unsolicited Retry transmits each MAC frame several times. In this paper, we consider transmission twice.

This method does not employ acknowledgment. Thus, its reliability is limited. On the other hand, the mechanism is not affected by the number of receiver terminals.

C. GCR Block Ack

GCR-BA adopts a Block Ack mechanism to Groupcast. The receiver acknowledges several MAC frames with a Block Ack. It can provide high reliability with retransmission.

Besides, the number of receiver terminals affects the efficiency of the mechanism.

D. Groupcast with AL-FEC

The mechanism transmits coded packets through FEC at the application level via Groupcast. In this study, we employ Reed-Solomon, which is a block code. Although the mechanism does not use retransmission or acknowledgment as Groupcast, it can enhance reliability by utilizing redundancy.

Figure 1 shows the packet structure based on the AL-FEC structure in MMT used in [6], although this paper assumes RTP/UDP as the transport protocol. ADU (Application Data Unit) is a transmission unit at the application level. The mechanism divides an ADU into several source blocks. Each source block has FlowID (one byte) and Length (two bytes); they become overhead. FlowID shows the position of the block in the original ADU. Length indicates the padding length. From the several source blocks, the FEC encoder generates repair blocks. An RTP/UDP packet bears each source block or repair block with FEC payload ID (six bytes).

III. SIMULATION

This paper utilizes ns-3 [8] to simulate video and audio transmission over a wireless LAN.

Figure 2 illustrates the network topology. Five wireless nodes STA_1 through STA_5 and media receiver terminals MR_1 through MR_n ($n = 5, 25, 50$) are arranged on the circle with a r [m] radius from AP. They connect AP with an IEEE 802.11a wireless LAN.

Table I shows the EDCA parameter values; they are the default values for IEEE 802.11a. We assign audio, video, and interference traffic to AC_VO, AC_VI, and AC_BE, respectively. The maximum retransmission count in the MAC layer is
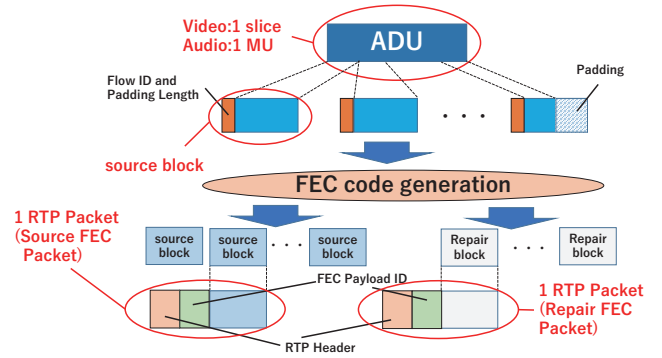

Fig. 1. Packet structure for FEC

MR: media receiver terminal   MS: media sender terminal
AP: wireless access point   R: wired router
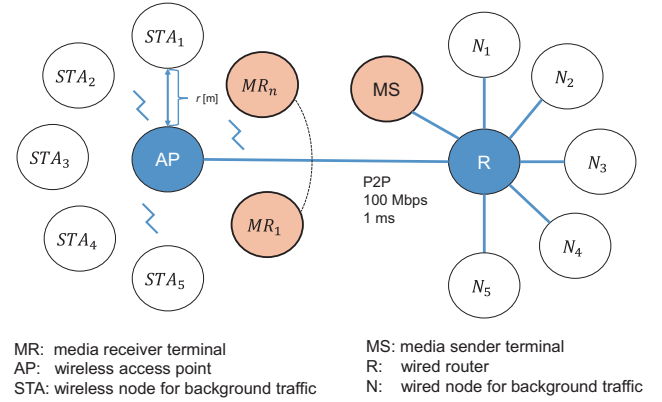STA: wireless node for background traffic   N: wired node for background traffic

Fig. 2. Network topology

four. The transmission rate for the groupcast communications is 24 Mbps.

The router R with AP, R with each of five wired nodes N_1 through N_5, and R with MS (Media Sender) are connected via the P2P link with a transmission speed 100 Mbps, and a propagation delay 1 ms. The buffer size in AP is 100 MAC frames.

Table II shows the specifications of video and audio. The content is a scene of a football game. Here, MU is a unit for media synchronization. In audio, an MU is an audio ADU. A video frame is a video MU, and a video slice is a video ADU. Each MR outputs video and audio after the playout buffering control. When MR drops several slices consisting of a video

TABLE I
EDCA PARAMETER

AC	CWmin	CWmax	AIFSN	TXOPlimit[ms]
AC_BK	15	1023	7	0
AC_BE	15	1023	3	0
AC_VI	7	15	2	3.008
AC_VO	3	7	2	1.504

TABLE II
SPECIFICATIONS OF VIDEO AND AUDIO

item	audio	video
codec	MPEG-4 AAC-LC	H.264 (JM 18.5) GOP IPPPP
image size [pixels]	-	640×480
slices per frame	-	10
average MU size [bytes]	343	I:16706, P:6240
MU rate [MU/s]	46.875	30.0
average bit rate [kb/s]	128.0	2001.9
duration [sec]	120.0	120.0

TABLE III
ABSOLUTE CATEGORY RATING SCALE

score	category
5	Excellent
4	Good
3	Fair
2	Poor
1	Bad

MU (i.e., video frame), MR performs error concealment and outputs the MU as in [6].

MS transmits video and audio streams to MRs with RTP/UDP. Except for Groupcast with AL-FEC, an RTP/UDP packet bears an ADU. Groupcast with AL-FEC transmits each source or repair FEC packet by an RTP/UDP packet.

Wireless nodes STA_1 through STA_5 and wired nodes N_1 through N_5 handle background traffic flows for the audio and video streams. The nodes generate fixed-size IP datagrams of 1500 bytes at exponentially distributed intervals. By changing the average of the interval, we adjust the amount of traffic. We refer to the average traffic for each downlink load terminal N as the *average load*. In this study, we set that the average load of each uplink load terminal STA is half of each downlink load terminal N.

We refer to Groupcast as "group," GCR Unsolicited Retry as "GCR-UR2," GCR Block Ack as "GCR-BA," and Groupcast with AL-FEC as "group-FEC-n." Here, n in group-FEC-n represents the code rate for the video stream in FEC, whereas the code rate of the audio stream is 1/2.

In the simulation, we consider three distances of r (50 m, 52 m, and 54 m), three values of the number of receiver terminals (5, 25, and 50), and two average load values (200 kbps and 700 kbps). We apply three values of the code rate in FEC (1/2, 2/3, and 5/6). We perform 15 simulation runs for each combination. The number of simulation runs in this study is based on the number of assessors in the subjective experiment.

IV. QOE ASSESSMENT

For QoE assessment, we first made test samples (stimuli) for subjective evaluation by actually outputting the audio and video MUs with the output timing obtained from the simulation. Each stimulus is 10 seconds, which is the output audio and video streams from time 90 to 100 after starting the transmission in the simulation.

We put the stimuli in random order and presented them to 15 assessors. The assessors are male students in their twenties. The total time for an assessor is about 30 minutes.

The assessors score each stimulus with the *five-point absolute category rating scale* shown in Table III. The integer value is regarded as a subjective score. We then calculate *MOS (Mean Opinion Score)* as the quantitative measure of perceptual quality.
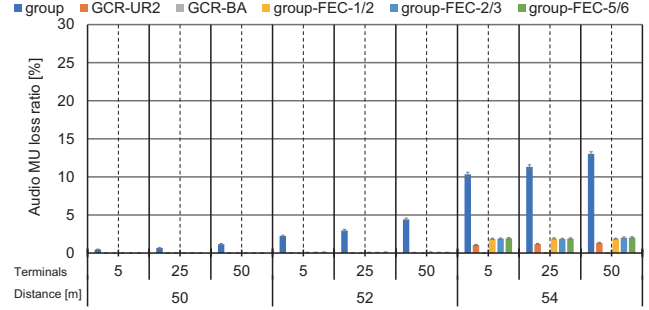

Fig. 3. Audio MU loss ratio (average load 200kbps)

V. RESULTS

A. Application-level QoS

We employ MU loss ratio, video error concealment ratio, and PSNR (Peak Signal-to-Noise Ratio) of video luminance as application-level QoS parameters. The MU loss ratio is the ratio of lost MUs in the network or discarded MUs due to delayed arrival to the total number of transmitted MUs from the sender. The error concealment ratio is the average percentage of error concealed slices in the picture frame. The PSNR of video luminance shows the difference between the output video and the original one before encoding.

Figures 3 and 4 depict the audio MU loss ratio. Figures 5 and 6 show the video MU loss ratio. Figures 7 and 8 represent the video error concealment ratio. We display the PSNR of video luminance in Figs. 9 and 10. Each result is an average of 15 simulation runs. We also depict 95 % confidence intervals.
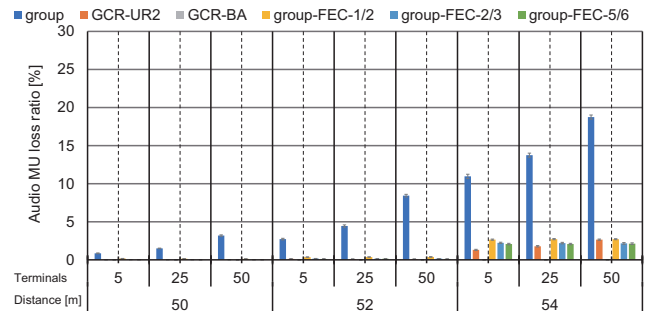

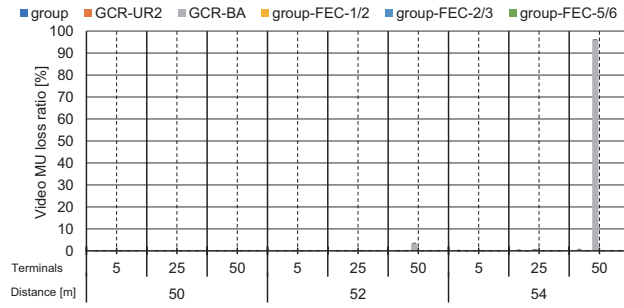Fig. 4. Audio MU loss ratio (average load 700kbps)

Fig. 5. Video MU loss ratio (average load 200kbps)
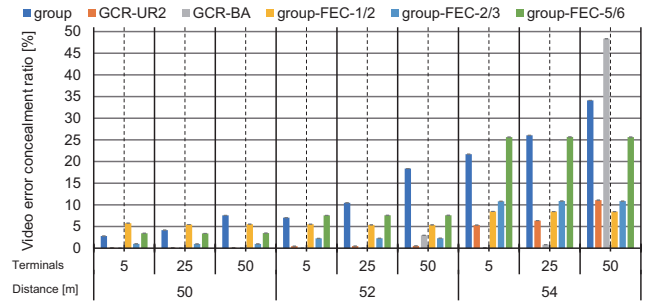

Fig. 8. Video error concealment ratio (average load 700kbps)
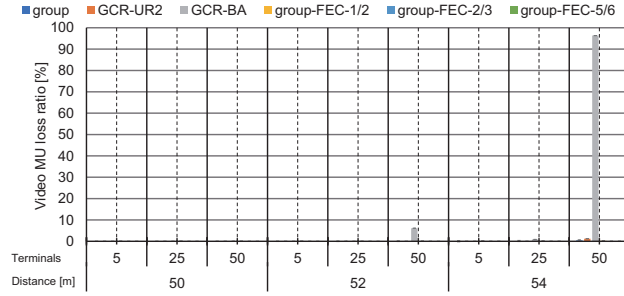

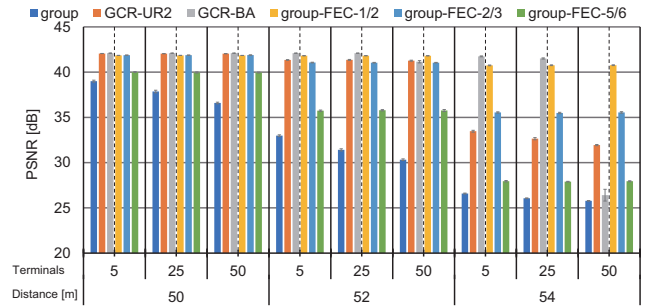
Fig. 6. Video MU loss ratio (average load 700kbps)

Fig. 9. Video PSNR (average load 200kbps)

The abscissa combines the number of receiver terminals and the distance between the terminal and AP.

1) Audio MU loss ratio: We notice in Figs. 3 and 4 that group has the largest MU loss ratio among the methods under all the situations considered in this study. This is because group has no reliability control. On the other hand, GCR-BA merely drops MUs. This is because Block Ack and retransmission can recover dropped MUs efficiently. GCR-UR2 and group-FEC also drop few MUs when the distance between the terminal and AP is 50 m or 52 m. Furthermore, for the distance 54 m, the MU loss ratio in GCR-UR2 is from 1% to 2.5%, and that in group-FEC is about 2.5%. GCR-UR2 and group-FEC can recover several MUs owing to twice transmission and FEC, respectively.

As for the relationship between the methods, we see in Figs. 3 and 4 that GCR-UR2, GCR-BA, and group-FEC have almost the same MU loss ratio for the distance 50 m or 52 m. On the other hand, for the distance 54 m, the MU loss ratio of GCR-BA is the lowest.

2) Video MU loss ratio: We notice in Figs. 5 and 6 that the video MU loss ratio of GCR-BA with 50 receivers for the distance 52 m is about 5 %. And the loss ratio for the distance 54 m is about 95 %. As the distance increases, the bit error ratio increases. Under the high bit error situation, MAC frame loss frequently occurs, and then the delay due to retransmission increases especially when many receivers exist. The delay causes the MUs not to arrive by the scheduled
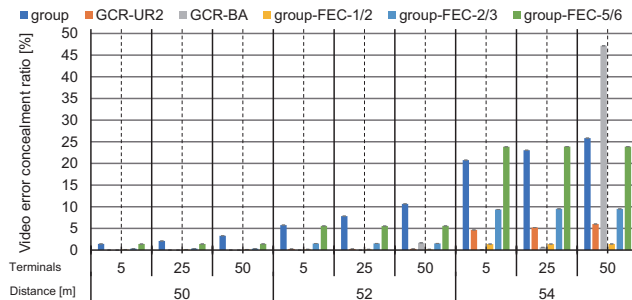

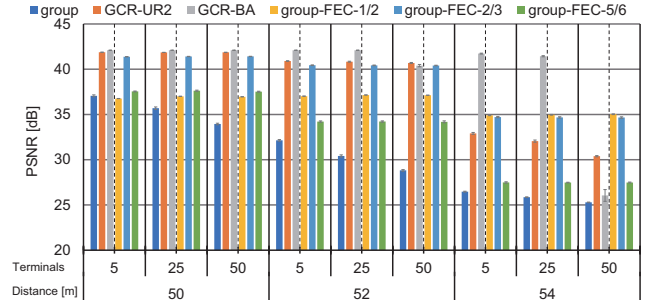Fig. 7. Video error concealment ratio (average load 200kbps)

Fig. 10. Video PSNR (average load 700kbps)

output time. Discarded MUs raise the MU loss ratio in GCR-BA with many receivers.

Figures 5 and 6 show that group, GCR-UR2, and group-FEC hardly collapses video MUs. This is owing to the error concealment; when a part of the MU is lost, the error concealment can conceal the lost part, and then the receiver outputs the MU.

3) Video error concealment ratio: In Fig. 7, we see that group has a larger error concealment ratio than the other methods except for the 50 receivers with 54 m distance when the average load is 200 kbps. This is because groupcast has no recovery mechanism.

The error concealment ratio in GCR-UR2 for the 50 m and 52 m distances is almost 0 %. And the ratio for the 54 m distance is about 5 %. This is because the unsolicited retry mechanism can recover certain MAC frames.

As the number of terminals and the distance increase, the error concealment ratio of GCR-BA increases; it is about 45 % for the 50 terminals with 54 m distance. The overhead for acknowledgment and retransmission disturbs timely arrival.

As for group-FEC, a smaller code rate (larger redundancy) has a lower error concealment ratio. For the 50 terminals with 54 m distance, the error concealment ratio of group-FEC-1/2 is smaller than that of GCR-UR2.

In Figs. 7 and 8, we notice that the error concealment ratio increases as the average load increases. This is because the congestion due to interference traffic causes MAC frame loss. The average load largely affects the error concealment ratio of group-FEC-1/2. For all the conditions of terminals and distances, group-FEC-1/2 has no smaller than 5 % error concealment ratio for the average load 700 kbps. This is because the amount of audiovisual traffic in group-FEC-1/2 is the largest among the methods due to FEC coding overhead.

In Fig. 8, GCR-UR2, group-FEC-1/2, and group-FEC-2/3 have a smaller error concealment ratio than GCR-BA for the 50 terminals with 54 m distance. The overhead of acknowledgment and retransmission has a larger impact than the redundant transmission under the condition.

4) PSNR: We notice in Figs. 7, 8, 9, and 10 that PSNR decreases as the error concealment ratio increases. This is because error concealment is the only factor of image quality disturbance in our simulation.

In Figs. 7 and 9, when the average load is 200 kbps, we find that group-FEC-2/3 has a larger PSNR than GCR-UR2 for the 54 m distance, while the error concealment ratio of group-FEC-2/3 is larger than that of GCR-UR2. GCR-UR2 transmits each MAC frame twice. On the other hand, in group-FEC, the sender divides a large slice into small blocks, adds redundancy, and then transfers them to the receiver. Therefore, larger slices tend to drop frequently in GCR-UR2 rather than group-FEC. The slice of I frame is larger than that of P frame and impacts image quality. The tendency of slice loss affects the results that group-FEC-2/3 has a larger PSNR than GCR-UR2.
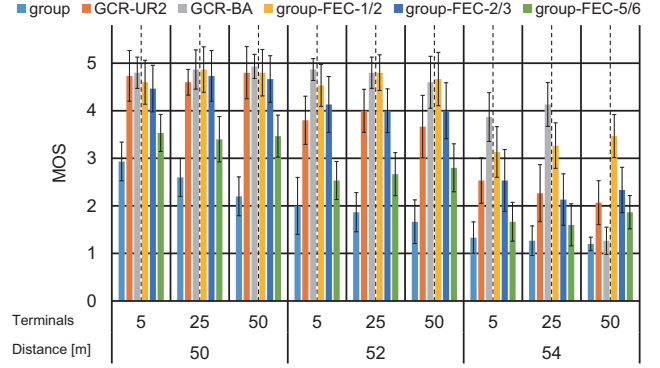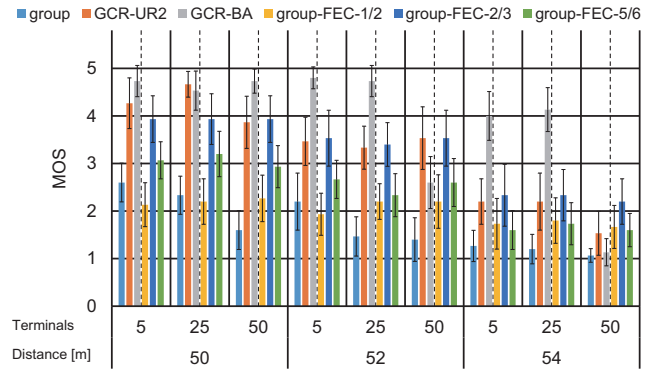

Fig. 11. MOS (average load 200kbps)

Fig. 12. MOS (average load 700kbps)

B. QoE

We depict the MOS values with 95 % confidence intervals in Figs. 11 and 12.

We find in Fig. 11 that GCR-BA has the largest MOS value for the number of receiver terminals 5 or 25, while group-FEC-1/2 is the largest for the 50 receiver terminals with 54 m distance. When the number of terminals is large under bad channel conditions, the overhead of acknowledgment and retransmission disturbs QoE in GCR-BA. The effect of the number of terminals in group-FEC is small, and then the method is effective under the situation.

As we have already found in the application-level QoS assessment, in Figs. 11 and 12, the MOS value also decreases as the average load increases.

In Fig. 12, we see that GCR-BA is the best when the distance is no larger than 50 m or the number of terminals is equal to or smaller than 25. Under the other conditions, GCR-UR2 or group-FEC-2/3 has a larger MOS value.

VI. CONCLUSIONS

This paper performed QoE comparison of reliable transmission methods using retransmission and AL-FEC on audiovisual Groupcast over wireless LANs. As a result, we found that

GCR-BA is the best for the small number of receiver terminals with a small distance from AP. Besides, under many receivers far from AP, group-FEC-1/2 is good under lightly loaded conditions, and group-FEC-2/3 or GCR-UR2 is effective under heavily loaded conditions.

In future work, we need to assess the effect of block size in AL-FEC.

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