An Access Point-based FEC Mechanism for Video Transmission over Wireless LANs

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Abstract:- **Forward Error Correction (FEC) is one of the most common means of performing packet error recovery in data trans-missions. FEC schemes typically tune the FEC rate in accordance with feedback information provided by the receiver. However, the feedback and FEC rate calculation processes inevitably have a finite duration, and thus the FEC rate implemented at the sender may not accurately reflect the current state of the network. Thus, this paper proposes an Enhanced Random Early Detection For-ward Error Correction (ERED-FEC) mechanism to improve the quality of video transmissions over Wireless Local Area Networks (WLANs). In contrast to most FEC schemes, the FEC redundancy rate is calculated directly at the Access Point (AP). Moreover, the redundancy rate is tuned in accordance with both the wireless channel condition (as indicated by the number of packet retransmissions) and the network traffic load (as indicated by the AP queue length). The experimental results show that the proposed ERED-FEC mechanism achieves a significant improvement in the video quality compared to existing FEC schemes without introducing an excessive number of redundant packets into the network.**

Index Terms— FEC, video quality, wireless access point.

I. INTRODUCTION

The use of wireless devices such as laptop computers and PDAs to connect to Internet services is becoming increasingly common nowadays. However, wireless communication channels are prone to serious transmission errors due to attenuation, fading, scattering or interference. Packet losses in wireless environments are generally recovered using either Automatic Repeat request (ARQ) or Forward Error Correction (FEC) methods. ARQ schemes automatically retransmit the lost packets during timeouts, or in response to explicit receiver requests. By contrast, in FEC schemes, the effects of potential packet losses are mitigated in advance by transmitting redundant packets together with the source packets such that a block of packets can be successfully reconstructed at the receiver end even if some of the packets within the block are lost during transmission. Of the two approaches, FEC schemes result in a lower retransmission latency, and are therefore widely preferred for the delivery of video streams over wireless networks.

Conventional FEC mechanisms are sender -based, i.e., the redundant packets are generated and encoded at the sender end. Broadly speaking, sender -based FEC schemes can be categorized as either Static FEC (SFEC) or Dynamic FEC (DFEC). In SFEC schemes, the number of redundant packets added to the source packets remains constant irrespective of changes in the network condition. The recovery performance of SFEC schemes is therefore somewhat unpredictable because they fail to capture the real- time network conditions and adjust the FEC redundancy rate accordingly. Thus, various DFEC schemes have been proposed in recent years. In those schemes, the FEC rate is tuned dynamically in accordance with changes in the channel condition or network load. In most DFEC schemes, the FEC rate is tuned at the sender based on information provided by the receiver. For example, in [1], the packet error rate is measured periodically at the receiver side and fed back to the sender, which then calculates the FEC rate required to maintain a constant packet error rate at the receiver end. In the FEC mechanism proposed in [2], the FEC rate is adjusted incrementally in such a way as to preserve a pre-determined value of the Peak Signal-to-Noise Ratio (PSNR) at the receiver end. Meanwhile, in [3], the FEC scheme modifies the FEC rate in accordance with changes in the network delay.

The FEC redundancy rate is traditionally calculated at the application layer based on feedback information such as that provided by acknowledgement messages (ACKs). However, the feedback and FEC rate calculation processes have a finite duration, and thus there is no guarantee that the FEC rate implemented at the sender end accurately reflects the current network condition.Accordingly, the FEC mechanism has been implemented at the wireless Access Point (AP) and the FEC redundancy rate is calculated directly without feedback information from the receiver. In [4], Lin et al. proposed an AP-based FEC mechanism designated as Enhanced Adaptive FEC (EAFEC), in which the FEC rate was determined dynamically in accordance with both the network traffic load (as indicated by the queue length at the AP) and the wireless channel state (as indicated by the number of packet re-transmissions). In a later study [5], the same group proposed an alternative AP-based FEC mechanism designated as Random Early Detection Forward Error

Correction (RED- FEC) based on a random early detection algorithm. In the proposed approach, the redundancy rate was gradually reduced as the AP queue length increased. However, in determining the FEC rate, the network loss rate was ignored. In practice, it is crucial for FEC mechanisms to have the ability to accurately detect channel fluctuations and to manipulate the FEC redundancy rate accordingly. Consequently, Han et al. [6] proposed an Adaptive Cross-layer FEC mechanism (ACFEC) in which loss information was retrieved from the ARQ function of the MAC layer and the redundancy rate was controlled adaptively in accordance with changes in the network condition. However, ACFEC does not take the effect of the network traffic load into consideration. As a result, packets may be lost at the wireless AP under heavy network loads due to a self-induced congestion problem.

This paper proposes an Enhanced Random Early Detection Forward Error Correction (ERED-FEC) mechanism for improving the quality of video transmissions over wireless LANs (WLANs). In the proposed approach, redundant FEC packets are generated dynamically at the AP in accordance with both the condition of the wireless channel and the current network traffic load. The channel condition is evaluated by monitoring the wireless channel condition. As the condition of the wireless channel deteriorates, a greater number of redundant FEC packets are generated. Conversely, as the channel condition improves, the number of FEC packets is reduced. The network traffic load is evaluated by monitoring the queue length at the wireless AP. If the queue is almost empty, i.e., the network is only lightly loaded, the number of redundant FEC packets is increased. By contrast, if the queue is nearly full, i.e., the network is heavily loaded, the number of FEC packets is reduced. By adopting this approach, the ERED-FEC algorithm significantly improves the video quality without overloading the network with an excessive number of redundant packets. An analytical model is proposed for predicting the quality of MPEG -4 video streams delivered over WLANs with FEC protection in terms of the effective packet loss rate and the Decodable Frame Rate (DFR) . It is shown that the model provides the ERED-FEC mechanism with the means to determine the FEC redundancy rate required to guarantee the QoS requirements of video transmissions over lossy wireless networks.

II. EXISTING MECHANISMS

A. Forward Error Correction (FEC)

The basic principle of FEC entails injecting redundant packets (h) into the video stream together with the source

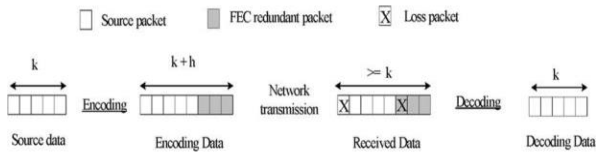

Fig. 1. FEC encoding and decoding.

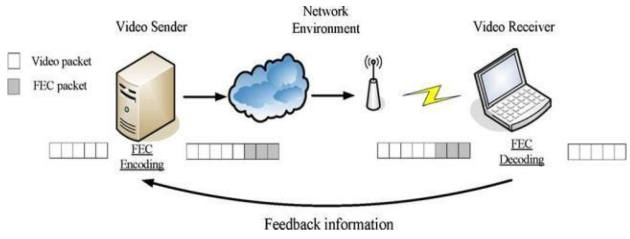

Fig. 2. Sender-based FEC scheme.

transmission packets such that packet losses can be recovered at the receiver end without the need for retransmission. In other words, as shown in Fig. 1, the original block is encoded as packets, where is the summation of source packets and redundant packets. Thus, provided that no more packets are lost in transmission, the source transmission packets can be successfully recovered at the receiver. Since FEC schemes enable the recovery of source packets which would otherwise be lost, the effective loss rate in the transmission network is lower than the actual loss rate.

In FEC codec, redundant packets are derived from the original packet using conventional coding theory techniques. Of the various traditional error correcting codes available for this purpose, Reed-Solomon (RS) code has attracted particular interest. RS code provides an ideal error protection capability against packet losses since it is a maximum distance separable code, i.e., no other coding scheme exists capable of recovering lost source data symbols from a lesser number of received code symbols.

B. Sender-Based FEC Mechanisms

1) Constant Error Rate FEC (CER-FEC): Takahata et al. [1] proposed a sender-based Constant Error Rate FEC (CER-FEC) scheme for enabling the dynamic QoS control of real-time multimedia streams over heterogeneous environments comprising wired and wireless connections. As shown in Fig. 2. In the proposed scheme, the packet error rate is periodically observed at the receiver side and any change in the error rate is fed back to the sender. Upon receiving this information, the sender calculates the number of redundant packets required to restore the error rate to its original value. In other words, the FEC redundancy rate is dynamically controlled in such a way as to maintain a constant packet error rate at the receiver end.

2) Cross-Layer FEC (CL-FEC): Bajic et al. [2] proposed an efficient Cross-Layer FEC (CL-FEC) scheme for wireless video multicasting designed to maintain the received video quality for all the users above a certain pre-specified level. In the proposed scheme, each user periodically reports the number of

packets received out of the previously transmitted packets. The sender then calculates the number of packets which each user has lost

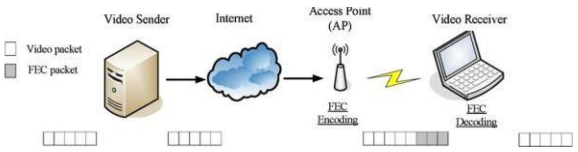

Fig. 3. AP-based FEC scheme.

and determines the maximum number of packets which can be decoded by all the users (i.e., the number of decodable packets for the user with the greatest number of packet losses).

3) Adaptive FEC (AFEC): Park et al. [3] presented an adaptive FEC (AFEC) protocol for facilitating the end-to-end trans-port of real-time traffic whose timing constraints rule out the use of retransmission-based congestion control or QoS provisioning schemes. In the proposed approach, the degree of FEC redundancy is tuned in accordance with the current network delay. Specifically, the number of redundant packets is increased as the network delay decreases, but is reduced as the delay increases.

C. AP-Based FEC Mechanisms

1) Random Early Detection FEC (RED-FEC): In heavily-congested networks, traditional FEC-based error recovery schemes increase the redundancy rate in order to compensate for the greater number of packet losses. However, the redundant packets worsen the network congestion, and therefore further degraded the network performance. To ad- dress this problem, Lin et al. [5] proposed a Random Early Detection FEC (RED-FEC) scheme in which the redundant FEC packets are generated dynamically at the wireless AP in accordance with the current network traffic load, as indicated by the AP queue length (see Fig. 3). Specifically, the number of redundant packets is increased as the queue length shortens, but is reduced as the queue length grows. Importantly, when the queue is near to full, no FEC packets are generated in order to avoid overloading the network. By adopting this approach, the RED-FEC mechanism improves the quality of the delivered video stream without injecting an excessive number of redundant packets into the network.

2) Adaptive Cross-Layer FEC (ACFEC): Han et al. [6] pro-posed an Adaptive Cross-layer FEC (ACFEC) scheme for enhancing the quality of video transmissions over IEEE 802.11 WLANs. The cross-layer design enables the ACFEC mechanism to leverage the functionalities of the different network layers. For example, packet loss information is retrieved using the ARQ function of the MAC layer, while the FEC redundancy rate is controlled adaptively at the application layer utilizing the UDP protocol. Specifically, as the source packets are trans-mitted through the wireless AP, the ACFEC mechanism monitors the transmission performance continuously via the failure information from the MAC layer. After transmitting one block of video packets, the failure counter is used to adjust the FEC redundancy rate accordingly.

D. Contribution of Present Study

The major contribution of the present study is to propose a new AP-based FEC mechanism (ERED-FEC) for improving the quality of video transmissions over wireless LANs (WLANs). The literature contains many proposals for sender-based FEC schemes [1]–[3], which have a finite duration to feedback in-formation from the receiver. Thus, the FEC rate determined at the sender end may not accurately reflect the current network condition. The proposed ERED-FEC mechanism is AP- based and the FEC rate is calculated at the AP directly without feed-back information from the receiver. Moreover, while the literature also contains various proposals for AP-based FEC schemes [5], [6], these schemes consider only single metric, such as the wireless error rate or only the traffic load to determine the FEC rate. By contrast, in the ERED- FEC mechanism proposed in this study, the FEC rate is controlled adaptively in accordance with both the wireless channel condition and the network traffic load. By adopting this approach, the ERED-FEC mechanism significantly improves the video quality and avoids overloading the network with an exc essive number of redundant packets.

III. TECHNOLOGIES USED

The technologies used in this algorithm are as follows:

ERED-FEC Mechanism:

The evaluating the impact of packets losses on the percentage of successfully decoded frames at the receiver end to calculate the error propagation due to packet losses, the interdependencies of the coded frames must be considered. The MPEG-4 standard

defines three frame types for compressed video streaming, namely I frame P frame (Predictive- coded) and B frame. I frames are encoded and decoded independently of any other frames in the sequence. The number of FEC redundant packets generated by the four schemes under light and heavy traffic loads, respectively. In the case of a light load, the number of FEC redundant packets generated by the SFEC and RED-FEC schemes remains approximately constant as the packet loss rate increases since neither scheme considers the channel condition when evaluating the FEC redundancy rate by contrast, the ACFEC and ERED-FEC schemes.

We consider the packet loss rate when determining the FEC redundancy rate, and thus for both algorithms, the

number of redundant packets increases with an increasing packet loss rate. In the case of a heavy load, the number of FEC redundant packets generated by the SFEC and ACFEC algorithms is the same as that generated for a light traffic load since both algorithms ignore the effects of congestion when determining the FEC redundancy rate. Fig. 4 illustrates the basic architecture of the AP-based ERED-FEC mechanism proposed in this study. (Note that an assumption is made that the wired segment of the video delivery path is loss free.) As shown, the ERED-FEC mechanism consists of five components, namely (1) a packet type classifier, (2) a packet loss monitor, (3) a video quality model,
(4) a network load monitor and (5) a FEC packet generator. During video streaming, the streaming server encapsulates the video data in Real-time Transport Protocol (RTP) packets, and delivers them to the receiver through the wireless AP. When a packet arrives at the AP, the ERED- FEC controller retrieves the packet header from the UDP, and identifies the packet type by checking the RTP header. Once a complete block of video packets has arrived, the packet loss monitor estimates the packet loss rate by examining the number of packet retransmissions associated with the block. An appropriate FEC redundancy rate is then

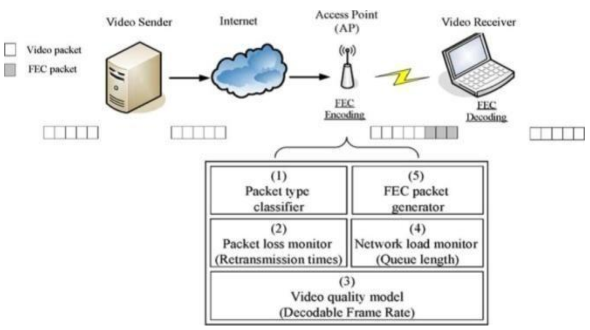

Fig. 4 Architecture of ERED-FEC controller.

MD5 Message Digest Algorithm:

MD5 algorithm was developed by Professor Ronald L. Rivest in 1991. According to RFC 1321, “MD5 message-digest algorithm takes as input a message of arbitrary length and produces as output a 128-bit *fingerprint* or *message digest* of the input.

The MD5 algorithm is intended for digital signature applications, where a large file must be compressed in a secure manner before being encrypted with a private (secret) key under a public-key cryptosystem such as RSA.”

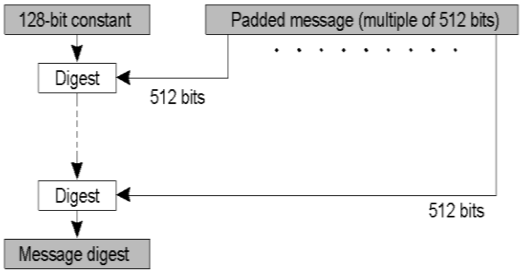

Fig. 5 MD5 Algorithm structure

Step1: Append padding bits

The input message is "padded" (extended) so that its length (in bits) equals to 448 mod 512. Padding is always performed, even if the length of the message is already 448 mod 512.

Padding is performed as follows: a single "1" bit is appended to the message, and then "0" bits are appended so that the length in bits of the padded message becomes congruent to 448 mod
512. At least one bit and at most 512 bits are appended.

Step2: Append length

A 64-bit representation of the length of the message is appended to the result of step1. If the length of the message is greater than 2^64, only the low-order 64 bits will be used.

The resulting message (after padding with bits and with b) has a length that is an exact multiple of 512 bits. The input message will have a length that is an exact multiple of 16 (32-bit) words.

Step3: Initialize MD buffer

A four-word buffer (A, B, C, D) is used to compute the message digest. Each of A, B, C, D is a 32-bit register. These registers are initialized to the following values in hexadecimal, low-order bytes first:

word A: 01 23 45 67

word B: 89 ab cd ef word

C: fe dc ba 98 word D:

76 54 32 10

Step4: Process message in 16-word blocks

Four functions will be defined such that each function takes an input of three 32-bit words and produces a 32-bit word output.

F (X, Y, Z) = XY or not (X) Z G (X,

Y, Z) = XZ or Y not (Z)

H (X, Y, Z) = X xor Y xor Z

I (X, Y, Z) = Y xor (X or not (Z))

Comparing to other digest algorithms, MD5 is simple to implement, and provides a "fingerprint" or message digest of a message of arbitrary length. It performs very fast on 32-bit machine. MD5 is being used heavily from large corporations, such as IBM, Cisco Systems, to individual programmers. MD5 is considered one of the most efficient algorithms currently available.

IV. PROPOSED MECHANISM

The main disadvantages of the existing mechanisms are that the FEC rate is tuned dynamically in accordance with changes in the channel condition or network load. In most DFEC schemes, the FEC rate is tuned at the sender based on information provided by the receiver. Also the FEC redundancy rate is traditionally calculated at the application layer based on feedback information such as that provided by acknowledgement messages.

The evaluating the impact of packets losses on the percentage of successfully decoded frames at the receiver end to calculate the error propagation due to packet losses, the interdependencies of the coded frames must be considered. The MPEG-4 standard defines three frame types for compressed video streaming, namely I frame P frame (Predictive- coded) and B frame. I frames are encoded and decoded independently of any other frames in the sequence. The number of FEC redundant packets generated by the four schemes under light and heavy traffic loads, respectively. In the case of a light load, the number of FEC redundant packets generated by the SFEC and RED-FEC schemes remains approximately constant as the packet loss rate increases since neither scheme considers the channel condition when evaluating the FEC redundancy rate by contrast, the ACFEC and ERED-FEC schemes.

We consider the packet loss rate when determining the FEC redundancy rate, and thus for both algorithms, the number of redundant packets increases with an increasing packet loss rate. In the case of a heavy load, the number of FEC redundant packets generated by the SFEC and ACFEC algorithms is the same as that generated for a light traffic load since both algorithms ignore the effects of congestion when determining the FEC redundancy rate.

V. SYSTEM ARCHITECTURE

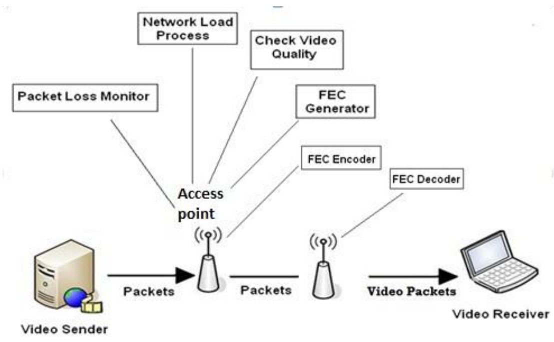

Fig. 6. Architecture of ERED-FEC Controller

The system architecture basically consists of a sender, receiver and an access point at both the ends. The sender sends the video in the form of packets to the access-point near to it. The packets before being sent are provided security using Message Authentication Code. This is taken care by the MD5 algorithm previously mentioned. The access point checks for packet loss, network traffic, video quality. Based on this information, the FEC redundancy rate is calculated. Using this rate, the packets are encoded accordingly. These encoded packets are sent to the access-point near the destination. Here, the encoded packets are decoded using the FEC decoder. These video packets which are ready to be played are sent to the destination system where the video receiver is present

VI. RESULTS AND COMPARISION

The performance of the proposed ERED-FEC scheme is compared with that of three existing AP- based schemes, namely SFEC, RED -FEC [5] and ACFEC [6]. The basic characteristics of the four schemes are compared in Table I. As described previously, the ERED-FEC mechanism determines the number of FEC redundant packets in accordance with both the network loss rate and the traffic load. By contrast, the SFEC scheme ignores both the packet loss rate and the traffic load, while the RED-FEC and ACFEC schemes consider either the packet loss rate or the traffic load, but not both.

Figs. 7 and 8 compare the number of FEC redundant packets generated by the four schemes under light and heavy traffic loads, respectively. In the case of a light load, the number of FEC redundant packets generated by the SFEC and RED- FEC schemes remains approximately constant as the packet loss rate increases since neither scheme considers the channel condition when evaluating the FEC redundancy rate (see Fig. 7). By contrast, the ACFEC and ERED-FEC schemes both consider the packet loss rate when determining the FEC redundancy rate, and thus for both algorithms, the number of redundant packets increases with an increasing packet loss rate. In the case of a heavy load, the number of FEC redundant packets generated by the SFEC and ACFEC algorithms is the same as that generated for a light traffic load since both algorithms ignore the effects of congestion when determining the FEC redundancy rate (see Fig. 8). However, in both the RED-FEC scheme and the ERED-FEC scheme, the number of redundant packets is reduced in order to avoid overloading the network.

TABLE I
COMPARISON OF AP-BASED FEC MECHANISM AND CORRESPONDING PARAMETER SETTINGS

FEC mechanism	Packet loss rate	Network traffic load	Parameter setting
SFEC	Not considered	No congestion avoidance	(n, k) = (11, 8)
RED-FEC [20]	Not considered	Congestion avoidance	(n, k) = (11, 8) Th_{low} = 50%Q_max Th_{high} = 80%Q_max
ACFEC [21]	Considered	No congestion avoidance	k = 8 h = (0, 1, 2, 3, 5, 7, 8)
ERED-FEC	Considered	Congestion avoidance	k = 8 h = (0, 1, 2, 3, 5, 7, 8) Th_{low} = 50%Q_max Th_{high} = 80%Q_max

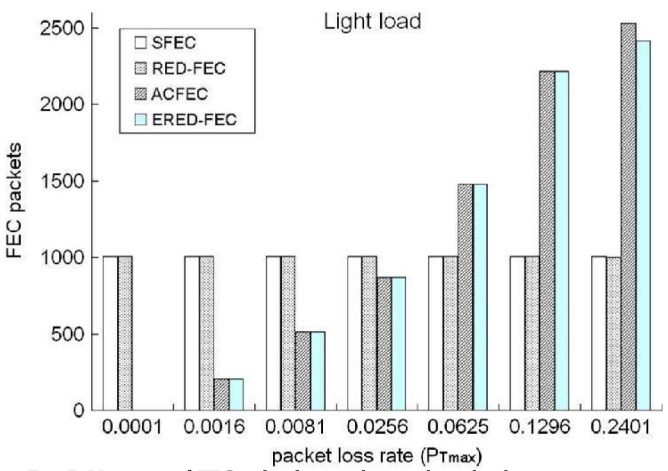

Fig. 7. Variation of FEC redundant packets with packet loss rate in various AP-based FEC mechanisms under light load condition.

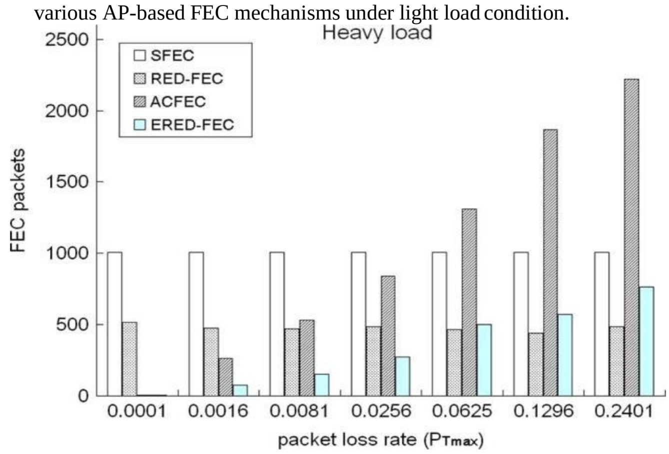

Fig. 8. AP based EC mechanisms under heavy load conditions.

VII. CONCLUSION

This paper has presented an AP-based FEC mechanism (ERED-FEC) for improving the quality of video transmissions over WLANs. In contrast to many FEC schemes, in which the FEC rate is determined at the sender end on the basis of information provided by the receiver, in the FEC mechanism proposed in this study, the FEC redundancy rate is determined at the wireless access point (AP). Moreover, the FEC redundancy rate is calculated in accordance with both the wireless channel condition and the network traffic load. As a result, the ERED-FEC mechanism significantly improves the video quality without overloading the network with redundant packets. The experimental results have shown that the ERED -FEC scheme yields a higher Decodable Frame Rate (DFR) and Peak Signal-to-Noise

Ratio (PSNR) than existing AP-based FEC mechanisms under both light and heavy network traffic loads.

In a future study, the recovery performance of the ERED -FEC mechanism will be further enhanced by utilizing an FEC inter-leaving/de -interleaving strategy. In addition, the feasibility of extending the ERED-FEC scheme to IEEE 802.11e, and IEEE
802.16 (WiMAX), networks will also be addressed.

VIII. REFERENCES

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