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A Comparative Framework of Wireless Video Transmission and Correction Techniques

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Abstract
In the current networking world, there is relatively high capacity available for transmission and also the connections are unconstrained. In such an environment, IEEE802.11 Wireless LANs are providing an infrastructure which is indeed ideal for sharing of the video contents and their communications. Also there is an increasing usage of wireless devices like PDAs and laptops or palmtops to get connected to the services of the internet anywhere and anytime. But when the wireless channels are considered, they are prone to severe transmission errors. FEC is the commonly used error recovery mechanism in the transmissions. In this paper, we present a brief analysis of various techniques that were developed as a part of the FEC technique to enhance the QoS performance of the video that is being transmitted over the wireless LANs. Based on the calculation point of FEC rate, the techniques are being classified as Sender-side and Receiver-side FEC schemes. Based on the layer of implementation of the techniques the solutions are classified as Single-layer and Cross-layer solutions. Finally, we conclude that the application and development of techniques for video transmission over WLANs will continue its development in the future.

Keywords
Video Transmission, Forward Error Correction (FEC), QoS, Access Point (AP) Solutions, Redundant Packets

I. Introduction
Currently, the Wireless Local Area Networks (WLANs) are emerging as the de facto specification for various service providers in order to provide a pervasive and unconstrained mobile internet services. They are indeed expected to provide a desired level of Quality of Service (QoS) for delivering video services. Moreover, the IEEE802.11 WLANs are deployed widely in places like office buildings, railway stations, airports, institutions and the home environments. However, these wireless channels are susceptible to several transmission errors like scattering, interference, fading, etc., [2-3]. In order to recover from the packet losses in these wireless environments, strategies like Automatic Repeat reQuest (ARQ) or Forward Error Correction (FEC) are being used. In the case of ARQ, the lost packets are automatically retransmitted when there is a timeout or an explicit request from the receiver. But this scheme results in higher retransmission latency. When the FEC schemes are considered, the packet losses are avoided to a greater extent by transmitting some amount of redundant packets together with the source packets in such a way that the whole block of packets can be successfully reconstructed even when there is some packet loss within the block at the receiver side.So this scheme results in lower retransmission latency. Hence of these two strategies, FEC is widely preferred for wireless video transmissions.
When the FEC mechanisms are considered, there are several ways of implementation like Sender based and AP based. In the Sender based FEC schemes, the FEC redundancy rate is calculated by the sender system according to the feedback information provided by the receiver for the recent packets received pertaining to the desired level of QoS. The traditional Sender based FEC schemes are of two types: Static-Sender based and Dynamic-Sender based. They are characterized based on the calculation of number of redundant packets to be added with the source packets to be transmitted.
In the Static-Sender schemes the redundancy rate is fixed irrespective of the channel conditions and the load on the network. Hence there is an unpredictable recovery performance for this type of schemes. They fail to adjust the redundancy rate according to the condition of the channel. There are several implementations in the Dynamic-Sender techniques. They include the parameters like Packet loss rate, Peak Signal-to-Noise Ratio (PSNR), user feedback parameters, MAC layer feedback parameter and so on. Accordingly, they are classified as single layer and cross layer solutions.
In most cases of Sender solutions the redundancy rate is calculated at the application layer according to the Acknowledgement Messages (ACK). The feedback process and the redundancy rate calculation process takes a finite time. Hence there is no guarantee that this solution accurately reflects the channel condition and the load on the network. This is the reason for moving towards the Access Point based solutions where the AP takes care of rate calculation without the need for feedback information from the receiver system. In the series of implementation strategies in the AP based schemes; Random Early Detection (RED) algorithm is being embedded to improve the performance significantly over the existing scenario.
This work can be preceded in two directions, as one according to the layered solutions and the other based on implementation at the sender or Access point. The video transmission is mainly concerned with the three communication layers of the network: APP layer, MAC layer and PHY layer. The features and working at each of these layers are

A. APP Layer
Storage of pre-coded video or online encoding is done at this layer. This layer also provides convenient video streaming related information like priority structure for video frames, coding parameters of the video content and similar others.

B. MAC Layer
Error recovery parameters and channel access mechanisms are related to this layer and this has direct impact on the performance of the video streams being transmitted.

C. PHY Layer
The time varying channel information and the error information are dealt in this layer. This information can be better used to improve the overall efficiency of the transmission.

II. Video Transmission and Streaming

A wide variety of applications are growing up, to enable multimedia services delivery over WLANs like VoIP, video streaming, video conferencing and so on. Still, video delivery over wireless LANs is a challenging task, where a desired level of QoS needs to be met to its users. The first and foremost reason is, the channel is error-prone. The most videos are compressed and this compressed video is error sensitive and time critical in nature. The algorithms used for video compression aims to reduce the bandwidth which results in complex dependencies among the transmitted video blocks. In such cases when a single packet is lost on transmission, it will affect both the current frame and also the upcoming frames. Also the transmission should be within the threshold level, which is decided by the decoding time at the receiver side. When the delay experienced during the transmission exceeds the threshold, the entire video becomes useless, though they are transmitted reliably. Hence reducing error and delay parameter are the conflicting demands in the video transmission over WLANs.

There are two different scenarios in the video application: real time video transmission and video streaming. In the former scenario, several users of the same WLAN transmit their video data to each other or use the AP to do so for the remote users. This may include video conferencing and other interactive video services which need onboard video coding and perfect delay constraints. In the video streaming, the video server is responsible for the delivery of the video content to several users connected to the WLAN. This include video download, video-on-demand where at the receiver side the video frames are buffered before the play-out. As a result, offline encoding is adopted and hence can tolerate relaxed delay constraints.

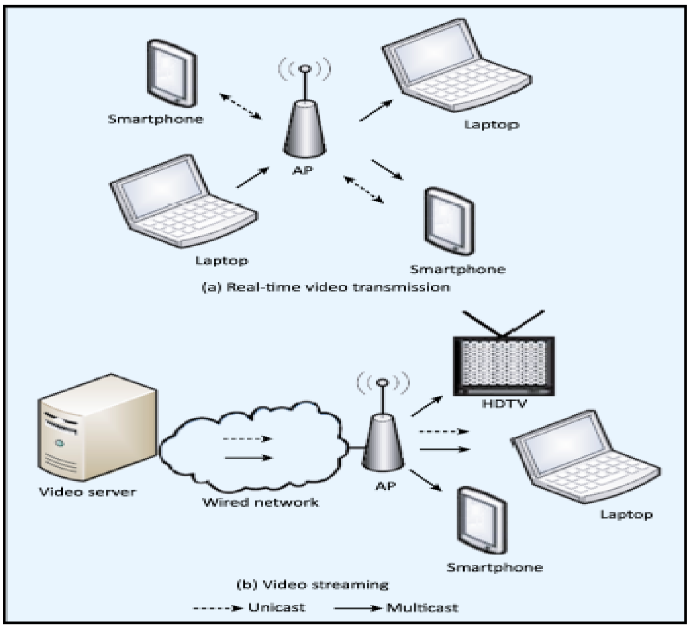

Fig. 1: Video Application Scenarios

III. Various Solutions for Video Transmission

The relevant technologies in video transmission over WLANs are being presented in this paper.

A. Solutions Based on Implementation Layer

There are Single layer and Cross layer solutions available for video delivery over Wireless LANs. The Single layer solutions are concerned with APP layer, MAC layer and PHY layer. But they are generally limited as the interaction between the network layers is absent. The Cross layer solutions are concerned with a combination of these three layerslike MAC-APP cross layer, PHY-APP cross layer, PHY-MAC cross layer and PHY-MAC-APP cross layer solutions.

1. Single Layer Solutions

(i). APP Layer Solutions

This type of implementations are generally related to the generation of video bit streams by using the video coding techniques, which are greatly reliant on the codec algorithm used. This is typically true for the real time video transmission where the QoS performance is highly dependent on the algorithm being used for onboard coding. These types of solutions using a single APP layer are deployable in any wired or wireless network. Preferably the solutions based on APP layer are based on H.264/AVC video coding standard. A few parameters like transmission rate and error probability are the only adaptable parameters by these APP layer solutions. This standard has a wide impact on video transmission due to its error resilience tools and optimization functions for rate distortion. In order to improve the quality of the video being received, channel coding is hosted to fight the errors in transmission. For this to be achieved, JSCC have been to develop the solutions that could consider both source and channel coding rate together. In this case one needs to be careful in allocating the bit budget between both to arrive at an optimal solution. For the reason that this standard, JSCC can efficiently increase the robustness of video bitstreams, this can be well thought-out as application layer FEC.

Table 1: List of Abbreviations

Abbreviations	Expansion
PHY	Physical Layer
MAC	Medium Access Control Layer
APP	Application Layer
AP	Access Point
JSCC	Joint Source and Channel Coding
FEC	Forward Error Correction
MIMO	Multiple Input and Multiple Output
RTT	Round Trip Time
AMC	Adaptive Modulation and Coding
DCF	Distributed Coordination Function
PCF	Point Coordination Function
EDCA	Enhanced Distribution Channel Access
HCCA	HCF-Controlled Channel Access
CW	Contention Window
ARQ	Auto Repeat request
RTS	Request to Send
CTS	Clear to Send
RED	Random Early Detection

(ii). PHY Layer Solutions

The physical layers of IEEE802.11 is said to possess an important characteristic called AMC, where it can provide multiple transmission rates based on diverse modulation and coding schemes. This property helps the mobile devices to pick up the suitable link rate according to the channel conditions at an instance and the QoS needs in order to improve the system performance.

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However, designing the scheme for rate adaptation according to available choices of rate modes to improve the throughput is a difficult task. A series of algorithms based on RTT parameter have been proposed with an intention to pro-actively detect the variations in the channel condition in its incipient stages and these are easily implementable [13-14]. Also, the MIMO technology of the physical layer introduced by IEEE802.11n helps to increase the reliability and throughput at a cost of more complicated signal processing requirement. The MIMO can operate in two modes: spatial multiplexing and diversity to increase throughput and reliability respectively. This is the reason why there is a significant trade-off between the throughput and reliability achieved. However, additional performance gains in throughput will produce QoS improvements for video over these channels.

(iii). MAC Layer Solutions
The aim of the MAC layer is to provide medium access control functions like generating check sequence, retransmitting frames and access coordination. One of the extensions to improve the QoS performance is the development of IEEE802.11e standard. Two MAC functions are defined in original standard:a mandatory DCF and an optional PCF. To regulate access to the shared medium CSMA/CA is used and the significant parameter of DCF is the size of the CW. To support the transmission of the multimedia content PCF is used as a centralized unit of control which is implemented at the Access Point in a WLAN. DCF is meant to provide best effort service and all the users compete with same priority. There is no mechanism for providing priority to real-time video data over other applications. Time-critical applications are being supported by PCF. Later IEEE802.11e replaced DCF and PCF with EDCA and HCCA to provide better QoS performance. Time delay is strictly controlled than in prior case. Contention free access mechanism for providing guaranteed QoS for real-time media transmission has been developed. Retry limit adaptation is a significant improvement. To prevent collision of ACK messages from multiple users of the medium, FEC is often implemented in the multicast mode.

2. Cross Layer Solutions

(i). MAC-APP Cross-Layer Solutions
For channel access mechanism based on contention, this cross-layer type of solution concentrates on mapping the priority frames of video into priority queues. H.264 data partitioning is the technology used to generate the priorities of the video packets and map them into the priority queue of the EDCA [15]. For contention free channel access, the solutions focus on utilize the limited bandwidth to schedule as many videos as possible. In the MAC layer, ARQ and MAC-FEC are the implementations in addition with access mechanism. The Retry limit adaptation algorithm [12] can be combined with the priority of the video streams to produce the MAC-APP cross-layer solutions. ARQ or FEC or their combination can be used to implement MAC-APP cross-layer solutions.

(ii). PHY-APP Cross-Layer Solutions
This PHY-APP category of cross-layer solutions aims to transmission rate adaptation of PHY layer to video characteristics of the APP layer. [16] shown that PHY layer rate adaptation and APP layer error resilient video coding can be combined to enhance the overall performance. Also JSCC and error concealment combined with rate adaptation provides an optimal solution.

(iii). PHY-MAC Cross-Layer Solutions
The main aim of this category of cross-layer solution is to maximize the network throughput. Also there is no need to account the video data characteristics in the process of designing. Accordingly, MIMO of PHY layer and CW size of different traffic categories at MAC layer can be integrated [17]. Two cross-layer mechanisms: link differentiation-distributed queuing MAC protocol and link differentiation-multiple polling MAC protocol. These protocols help to improve the throughput of all types of traffics, especially for video traffic for its volumetric nature.

(iv). PHY-MAC-APP Cross-Layer Solutions
The performance improvement can be further improved by combining more than two layers of the network. The success lies in efficient migration of risk in increase of state parameters for cross-layer interactions. QoS metric of APP layer along with adaptive cross-layer feedback mechanism of PHY layer can be combined with RTS/CTS function of MAC layer to achieve a greater performance over the previous techniques without the need for the feedback information to be provided about the channel state [18]. Optimization architecture for cross-layer for video multicast has been developed recently [19].

B. Solutions Based on FEC Mechanism
The predominant mechanism used for correcting transmission errors in wireless networks is FEC.

1. Forward Error Correction (FEC)
The basic idea behind the FEC mechanism is adding redundant packets to the source packets of the video stream in such a way that the original block of video packets can be reconstructed at the receiver end even if there is a loss in transmitted block. This avoids the need for retransmission of the video data to a major extent and hence the retransmission latency is less. Since there are possibilities to recover the packets which would otherwise be lost, the effective loss rate is lower than the actual loss rate. The coding theory techniques are used to derive the redundant packets and the widely used code is Reed-Solomon code [11]. This code proves to be ideal in protection against error caused by packet losses. Also, this scheme is able to recover the symbols of lost source data from relatively lesser number of received symbols when compared to other existing coding schemes.

2. Sender-Based FEC Mechanisms

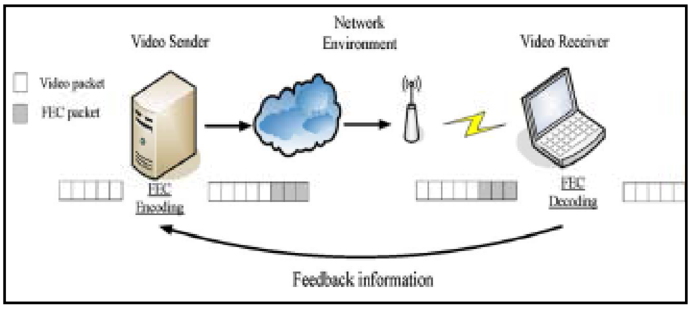

Fig. 2: Sender Based FEC

(i). Constant Error Rate FEC
This mechanism is based on the feedback information provided by the receiver end system using the packet error rate, which is

periodically estimated at the receiver side. This scheme allows having a dynamic control over the QoS of real-time multimedia traffic over a heterogeneous environment. As the receiver sends the feedback, the sender system tries to restore the error rate to its original value by calculating the redundancy rate [5]. Hence maintaining a constant packet error rate is the main theme of this class of FEC scheme.

(ii). Cross-Layer FEC
The ultimate aim of this class of FEC mechanism is to maintain the quality of the video data above a pre-specified level for all the users of the multicasting wireless network. It is the task of every user to report the number of packets received periodically out of the source packets that were originally sent. Then the sender calculates the number of packets that were lost during the transmission and accordingly estimates the decodable level of all users on an average. This estimation is used to adjust the FEC redundancy rate [6].

(iii). Adaptive FEC
An adaptive FEC scheme is basically designed to facilitate end-to-end transmission of real-time traffic where the timing constraints dominate the retransmission based congestion control. The idea behind the protocol is to adjust the redundancy rate according to the current delay in the network. When the network delay is more, the redundancy rate is decreased and if the delay on the network is less, the rate is increased. This is how the QoS is achieved using adaptive FEC schemes.

3. AP Based FEC Mechanisms
In this class of mechanisms, the redundancy rate is calculated at the AP. This idea avoids the need for feedback information to be received from the receiver system as in the case of
Sender based FEC schemes. Hence the retransmission delay is reduced and the video quality can be improved.

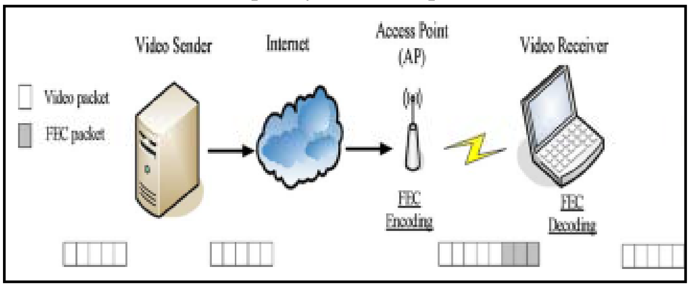

Fig. 3: AP Based FEC

(i). Random Early Detection FEC
Previous strategies result in increased redundancy rate in order to cope up with increasing packet losses. This in turn degrades the network performance by increasing the network congestion. The RED FEC [9] is the scheme that was proposed to generate the FEC packets at the Access Point that considers the current traffic load into account. This traffic load is measured by the queue length at the AP. The idea is to increase the redundant packets as the queue length decreases and reduce in the other case. The most important point is that, no redundant packets introduced when the queue is almost full. This is to ensure that the network is not overloaded due to redundancy. This improves the quality parameters by avoiding excessive redundant packets in the network. Anyhow the packet loss rate is not considered in calculation of the redundancy rate.

(ii). Adaptive Cross-Layer FEC
AC-FEC[10] uses the functionalities of different network layers. The packet loss information is taken from the MAC layer ARQ function. The redundancy rate is controlled using the UDP protocol at the application layer. The failure information of the MAC layer is used to assess the performance of the transmission continuously. When a complete block of video data is sent, the failure counter information is used to manipulate the FEC rate accordingly. This does not consider the network load into account which is a shortcoming in this scheme. This results in self induced congestion in the network.

(iii). Enhanced Adaptive FEC
EAFEC [8]proposes the idea that any node wishing to send data to any other node in the network should send the data to the AP first. This is because AP is the place suitable for adding FEC mechanism. The AP considers the current network condition to estimate rhe FEC redundancy rate. The network traffic load is estimated using the AP queue length. Also the retransmission time taken by a packet indicates the channel status of the wireless network. But the limitation in this system is that the packet loss rate is ignored in calculation of the redundancy rate. This improved the additional packet loss problem encountered in the static FEC schemes. The optimum threshold values can be found out to improve the performance to certain extent.

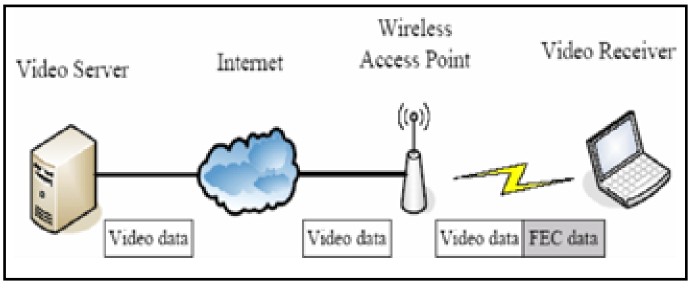

Fig. 4: EA FEC

D. Enhanced Random Early Detection FEC
This ERED-FEC [1] scheme is considered to be superior among the existing FEC schemes as of now. In this scheme the redundancy packets are calculated and introduced at the Access Point. This estimates both the Channel Condition and the network load in order to arrive at a suitable redundancy rate. As mentioned earlier, the network load is evaluated using the AP queue length as the parameter. The number of FEC packets is increased if the queue is nearly empty which indicates that the network is lightly loaded. If the queue length is almost full, then it indicates that there is a heavy load in the network and hence the redundancy rate has to be reduced accordingly. This eliminates the unnecessary overloading of the network thereby increasing the overall quality of the video data to be transmitted.

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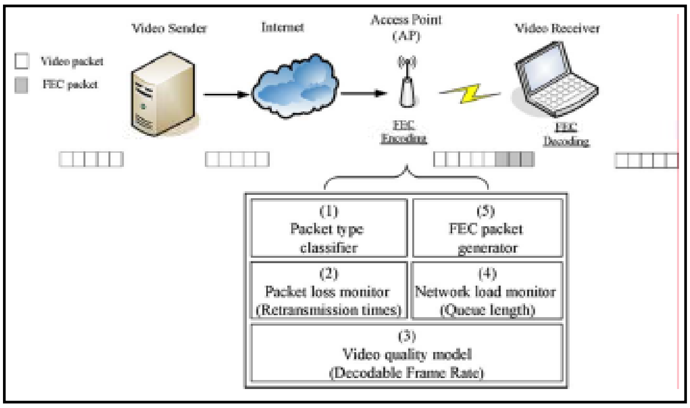

Fig. 5: Architecture of ERED Controller

The steps in video streaming using the ERED-FEC scheme are as follows:

- The controller retrieves the information from the header of the video packet to identify the packet type by checking the RTP header value.
- The packet loss manager estimates the packet loss rate after a complete block of video data is received by calculating the number of packet retransmission for each block of data.
- Using a predefined video quality model, the FEC redundancy rate is calculated.
- The load monitor estimates the current traffic load by using the AP queue length as the parameter.
- Finally, the FEC packet generator adjusts the final FEC rate.

This scheme improves the video transmission quality using the wireless LANs over the previous mechanisms.

IV. Conclusion

This paper has presented the various technologies available for video transmission over a wireless LAN in an efficiently and effectively. One stream of classification is based on the implementation layer of the wireless network. The latter class of solutions is based on the error correction scheme and its variations. The advantages and disadvantages of each such types were discussed. We have focused mainly on the QoS related aspects for discussion which includes energy efficiency, latency, delay parameters and so on. Other important properties to be focused include the security and privacy aspects. As afurther step, the optimization criteria and the cross-layer architecture can be further studied. The solutions are expected to improve and increase for the next generation video data over wireless LANs.

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