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A Cross Layer Framework Design for transport of Video over Wireless Networks

A. Dhanalakshmi[1], L. Balaji[2]

[1]Assistant Professor, Dept of EIE, Panimalar Engineering College, Chennai, India
[2]Assistant Professor, Dept of ECE, Velammal Institute of Technology, Chennai, India

[1]dhanalakshmi248@gmail.com

***Abstract*—To maximize end user satisfaction, Wireless multimedia application needs the communication networks to allocate resources dynamically. Cross layer framework design offers a solution to this problem. In this paper, a cross layer framework design strategy optimizes the application, physical and MAC layers jointly for video streaming. An efficient FEC mechanism to combat channel errors is chosen based on the channel condition. The optimization is done to maximize the average PSNR of the received video signal.**

***Keywords*—Multimedia, Group of Pictures, PSNR, Forward Error Correction, Dynamic resource allocation.**

I. INTRODUCTION

Multimedia transmission over wireless medium needs widely varying quality of services in terms of delay, bandwidth requirement, error tolerance, loss tolerance and so on. But existing wireless networks provide only limited time varying quality of services [1-3]. The traditional layered architecture addresses this issue by the implementation of resource management, adaptation and prediction algorithm at the lower layers of the stack, namely PHY, MAC, network and transport layers. They are optimized within the layer concerned without considering the other layers. This leads to simple independent implementation, but is often found to be suboptimal to meet the QoS requirements. This shows the necessity for joint optimization across the layers.

The cross layer design is an evolving paradigm in the design of wireless network architecture that takes into consideration the dependencies and interaction among layers and supports optimization across layers. The cross layer design is not a replacement for layered architecture but it enables information exchange between the layers, thereby making the system more adaptive. 3G wireless networks need to support multimedia application like media streaming, video conferencing and interactive video. The classical layered network architecture struggles to support their QoS requirements such as throughput, delay, PSNR and so on. This issue can be tackled by cross layer design.

There are numerous research works going on in this area. In [3], a cross-layer optimizer for wireless video streaming is designed to operate in three steps: layer abstraction, optimization and layer reconfiguration. To do these steps more side information need to be carried by a video frame which increases the communication cost. In [5], the H.264 wireless video transmission over IEEE802.11 WLAN is proposed using a cross-layer architecture that leverages the H.264 error resilience schemes of data portioning and existing QoS based IEEE802.16 MAC protocol features. In [7], a two phase methodology that resolves the sleep time trade off across the physical and the link layer and schedules nodes at run time with near optimal energy efficient configuration in the solution space has been proposed and applied to MPEG4 video transmission and video delivery with guaranteed QoS over slow fading channels. In [8], an adaptive FEC mechanism is proposed based on the information from the interface queue length and MAC layer retransmissions.

In the present work, a cross layer optimization frame work is proposed including adaptation across application and

MAC layer retransmissions and scheduling information are exchanged among these layers to realize optimized PSNR for video transmission. This paper is organized as follows: a brief explanation for a general cross layer frame work and the MPEG compression standard which allows the adaptation of error resilience mechanism is dealt with in section II, the frame work of the proposed model is dealt with in section III, the simulation results are discussed in section IV and the conclusions with scope for future work is presented in section V.

II. CROSS LAYER DESIGN

There are numerous solutions proposed in each layer for efficient transmission of multimedia traffic over wireless networks, [4]. The adaptation parameters normally considered at different layers are listed below.

Physical	:	Modulation rate (Constellation Size), bandwidth, transmit and receive power, SNR and BER.
MAC/Link	:	Link reliability through FEC (Forward Error Correction) and ARQ (Automatic Repeat Request), medium access protocol to avoid/reduce collisions, Framing of data ensure reliable transmission with minimum overhead.
Network	:	Routing algorithms based on power allocation, bandwidth and distance.
Transport	:	Error protection strategies.
Application	:	Compression ratio, forward error correction mechanism, throughput, delay.

A. Problem Formulation

A Cross layer design problem could be formulated with the objective of selecting an optimum combination that gives the required QoS. The joint cross layer strategy is defined as [3],

$$S=\{P_{1P}...P_{NP},MAC_{1M}...MAC_{NM},LL_{1N}..LL_{NN}\ Net_{1N}...NET_{NN},T_{1T}...T_{NT},A_{1A}...A_{NA}\} \quad (1)$$

leading to,

$$N= NP \times NM \times NN \times NT \times NA \quad (2)$$

possible combinations. The optimal solution is the one represented by the following equation,

$$S_{opt}(x) = \text{Max } Q[S(x)] \quad (3)$$

where $Q[S(x)]$ represents the quality of media communication defined by, Throughput $[S(x)] \geq \text{Throughput}_{max}$

B. Wireless Video Streaming

MPEG compression standard is one of the popularly used scheme for the delivery of video. One of the major features of MPEG is random access capability. The different frames are organized together in a Group of Pictures (GOP). GOP is the smallest random access unit. A GOP consists of I, P and B frames depending on the perceptual content of the video information. The frames which are coded without any reference to the past frames are called I frames and they do not have temporal correlation. So the compression rate is low compared to the frames that make use of the temporal characteristics correlations for prediction. Thus the number of frames between two I frames is a tradeoff between compression efficiency and convenience. In order to improve the compression efficiency MPEG scheme contains two other frames, the Prediction coded frames (P) and Bidirectional Predictive coded frames (B). The P frames are coded using motion compensated prediction from I or P frames. B frames achieve a high level of compression by using motion compensated prediction from the P frame. In the proposed architecture, the application layer sets the FEC mechanism based on channel condition and background traffic of WLAN architecture.

III. PROPOSED CROSS LAYER SCHEME

The architecture of the proposed cross layer adaptation for video transmission is shown in figure 1. In the current frame work, application layer changes the FEC mechanism for different frames. In the infrastructure mode, when every wired and wireless node wants to send data packets to other wireless nodes, data must first be sent to the Access Point (AP). The AP then forwards packets to the corresponding node. Therefore, AP is a good place for introducing the FEC mechanism for improving quality of video delivered over the network. For efficient adaptive FEC, the AP dynamically determines how many redundant FEC packets should be generated, based on the current network condition. The

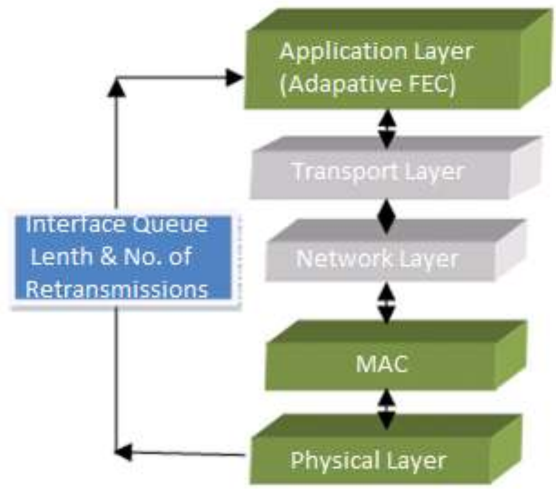

Figure 1 Proposed Cross Layer Architecture

interface queue length is a good indicator for estimating the network traffic load. If network load is high, queue length is long; otherwise, queue length is short. When queue length is small, more redundant information FEC packets can be generated, but when queue length increases, fewer FEC packets are generated to avoid unnecessary network congestion. If the queue length is beyond a threshold level, FEC packets will not be generated, to avoid congestion. The packet retransmission time also indicates wireless channel status. When the wireless channel is good, number of retransmissions is less; otherwise, packet retransmission is more. When the wireless channel is experiencing more lossless, redundant FEC packets will be generated, but when the channel is good, fewer FEC packets will be generated.

IV. SIMULATION SETUP AND RESULTS

Simulation to verify the proposed cross layer scheme is carried out using Network Simulator NS-2.31. NS-2 is an event driven simulator and works with packet level. In this simulation, a wireless network with one access point and four nodes is considered. Out of the four notes one is the source node that has video files to be transmitted to the destination connected to be same access point. The two other nodes are involved in data transmission.

Simulation Parameter	Numerical Value
Threshold 1 Lower Queue Length	10
Threshold 2 Higher Queue Length	40
Threshold 3 Lower No. of Retransmission	4
Threshold 4 Higher No. of Retransmission	15
FEC Packet Size	500 bytes
Max FEC Packets	8

Table 1 Simulation Parameters

Destination node is moving randomly inside the region of the AP. A Foreman video sequence [9] is chosen as the application. This video consists of 420 frames, QCIF format with 176x144 pixels. A random uniform error model is incorporated to introduce errors at the physical layer. Here the decodable frame rate and picture signal to noise ration are considered as the evaluation parameters for the video transmission.

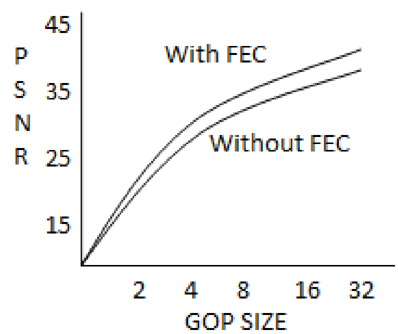

Figure 2 PSNR with and without FEC

The PSNR obtained with FEC mechanism adapted by the application layer is compared with the case of no FEC adaptation in Figure 2. The PSNR value is obtained with the introduction of different error probabilities. The figure clearly shows the improvement in PSNR realized for most of the frames when compared to the case no adaptation. This

With FEC Mechanism (PG= 0.3 Average PSNR = 38.11 dB)

Without FEC Mechanism (PG = 0.3 Average PSNR = 35.88 dB)

Figure 3 Snapshots of Improved Video

is much more evident when the average PSNR obtained with FEC mechanism adapted by the application layer is compared with the case of no FEC adaptation as in figure 3.

V. CONCLUSION AND FUTURE WORK

In this work, an adaptive FEC mechanism with cross layer communication between the application layer, Mac layer and the Physical layer has been carried out. Significant improvement in average PSNR performance have been obtained under cross layer adaptation. The future work aims to tune the network layer depending on the underlying layer performance, that is adaptively route depending on the power level of the nodes and channel condition and hence obtain an optimum cross layer strategy for the delivery of quality video over WLAN.

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