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Cross Layer Analysis And Design With Prescribed Qos using Adaptive Modulation And Coding

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Abstract

In this frame work, a cross layer model which combines Adaptive Modulation and Coding (AMC) at the Physical Layer with admission policy in the Data Link Layer over adaptive wireless links is proposed to maximize the throughput. The proposed cross layer model analysis performance is done by taking into account the QoS parameters such as packet error rate (PER), delay and throughput. The control policy and AMC employed in this analysis possess reduced complexity. By applying admission policy at the Data Link Layer and AMC at the Physical Layer, the throughput is maximized thereby reduce the Packet Error Rate (PER) and delay.

Key Words : Cross-layer design, Adaptive modulation and Coding (AMC), Admission Policy, Quality of Service (QoS).

1. Introduction

Quality of service (QoS) metrics of a connection include data throughput, packet error/loss rate and delay performance. All networks primarily offer two types of services: guaranteed service and best effort service. For QoS guaranteed high-rate multimedia applications, the scarcity of transmission capacity, multi-path fading and Doppler effects are common challenges to most communication networks, military or civilian, when mobile devices communicate a wide range of information over wireless links. The "bottleneck" in such networks is the wireless link, not only because wireless resources (bandwidth and power) are more scarce and expensive than their wired counterparts, but also because the overall system performance degrades due to multi-path fading, Doppler, and time-dispersive effects introduced by the wireless air interface. Unlike wired networks, even if large bandwidth/power is allocated to a certain wireless connection, the loss and delay requirements may not be satisfied when the channel experiences deep fades. Therefore, schemes should be developed to support prioritization and resource reservation in wireless networks, in order to provide guaranteed QoS with efficient resource utilization..

This paper is structured as follows. In Section II the description of the System considered in this model is given. Adaptive Modulation Coding Technique and Admission Policy are explained in Section III. In Section IV the performance analysis of the proposed cross layer model is given. Finally the concluding remarks are given in section V.

2. System Description

The cross layer structure involves communication of information between any two layers. In this work the information transfer between the Physical and Data Link layer is considered. At the Data Link Layer, the processing unit is a packet comprising multiple information bits and at the Physical Layer, the processing unit is a frame consisting of multiple transmitted symbols. The queue

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assumed here has finite-length (capacity) of *K* packets per user. The customers of the queue are packets, served by the AMC module at the Physical Layer.

Details of the packet and frame structure:

i) At the data link layer, each packet contains a fixed number of bits (Nb), which include packet header and payload. After modulation and coding with mode n of rate Rn at the gateway, each packet is mapped to a symbol-block containing Nb/Rn symbols.

ii) At the physical layer, the data are transmitted frame by frame through the wireless link, where each frame contains a fixed number of symbols (Ns). Given a fixed symbol rate, the frame duration (Tf seconds) is constant. With Time Division Multiplexing (TDM), each frame is divided into Nc+Nd time slots, where each time-slot contain a fixed number of Nb/R1 symbols. As a result, each time slot can transmit exactly Rn/R1 packets with transmission mode n. The Nc time slots contain control information and pilots. The Nd time slots convey data, which are scheduled to different users with TDMA dynamically. Each user is allocated a certain number of time slots during each frame. The channel is invariant per frame, but is allowed to vary from frame to frame. Based on the channel estimates obtained at the receiver the modulation-coding (mode) pair is selected, which is sent back to transmitter as feedback. In mobile environment, the channel varies from frame to frame, so a general class of fading channels are adopted. The channel may be a Rayleigh or Nakagami-m model. The Rayleigh distribution is frequently used to model the statistics of signals transmitted through radio channels such as cellular radio. This distribution is closely related to the central chi-square distribution.

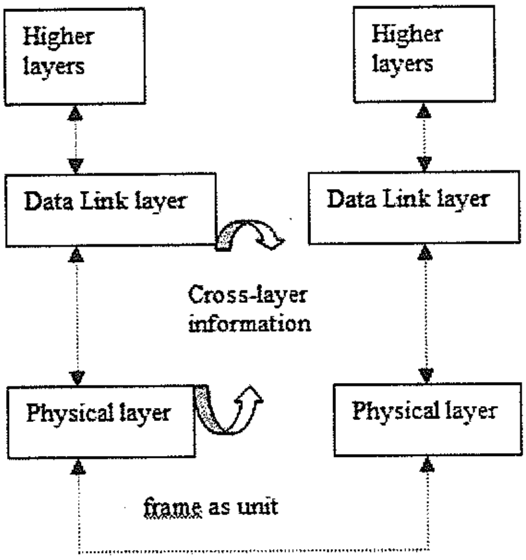

Figure 1 : The Cross-Layer Structure

3. (i) Adaptive Modulation And Coding (Amc)

The objective of AMC is to maximize the data rate by adjusting transmission parameters to channel variations, while maintaining a prescribed Packet Error Rate P0. Let N denote the total number of transmission modes available. We assume constant power transmission, and partition the entire SNR $_{N+1}$ range into N + 1 non-overlapping consecutive interval, with boundary points denoted as $\{\gamma_n\}n=0$,

mode n is chosen, when $\gamma \leq \lfloor \gamma_n, \gamma_{n+1} \rfloor$.

To avoid deep channel fades, no data are sent when $\gamma_0 \leq \gamma < \gamma_1$, which corresponds to the mode n = 0 with rate $R_0 = 0$ bits/symbol. For simplicity, the instantaneous Packet Error Rate (PER) in the presence of additive white Gaussian noise(AWGN) is approximated as [1]

$$\mathrm{PER}_n(\gamma) = \begin{cases} 1, & \text{if } 0 < \gamma < \gamma_{pn} \\ a_n \exp(-g_n \gamma), & \text{if } \gamma \geq \gamma_{pn} \end{cases} \qquad (1)$$

where n is the mode index, γ is the received SNR, and the mode-dependent parameters an, gn, and γ_{pn} are obtained by fitting (1) to the exact PER[1]. Based on (2) and (4), the mode n will be chosen with probability given by:

$$\Pr(n) = \int_{\gamma_n}^{\gamma_{n+1}} p_\gamma(\gamma) d\gamma \qquad (2)$$

Let PERn be the average PER corresponding to mode n. In practice, we have �> �$_{pn}$, and thus obtain as

$$\overline{\mathrm{PER}}n = \frac{1}{P_r(n)} \int_{\gamma_n}^{\gamma_{n+1}} \mathrm{PER}_n(\gamma) p_\gamma(\gamma) d\gamma \qquad (3)$$

The average PER of AMC is computed as the ratio of the average number of packets in error over the total average number of transmitted packets

$$\overline{\mathrm{PER}} = \frac{\sum_{n=1}^{N} R_n \Pr(n)\, \overline{\mathrm{PER}}_n}{\sum_{n=1}^{N} R_n \Pr(n)} \qquad (4)$$

Table 1 : Various Transmission Mode With Convlutional Coding

	Mode 1	Mode 2	Mode 3	Mode 4
Modulation	BPSK	QPSK	16-QAM	64-QAM
Coding Rate Rc	1/2	½	¾	3/4
Rn (bits/sym)	0.50	1.00	3.00	4.50
an	274.7229	90.2514	53.3987	35.3508
gn	7.9932	3.4998	0.3756	0.0900

The thresholds can be found out for the regions $\{\gamma_n\}_{n=0}^{N+1}$, so that the prescribed P0 is achieved for each mode. The Packet Loss/Error Rate is obtained from the following equation

$$\xi = 1 - (1 - P_d)(1 - P_0) \qquad (5)$$

where P_d is the packet dropping rate and P_0 is the target Packet Error Rate. The throughput is defined as the number of bits received correctly per second. Using the PER ξ and the Packet Arrival Rate λ, Throughput η is calculated using the formula:

$$\eta = \lambda(1 - \xi)$$

In order to decrease the delay and PER, the Throughput must be maximized.

(ii) Admission Policy

In order to guarantee QoS for all QoS-guaranteed services/users, the following two-step admission control policy is proposed:

1. When the QoS-guaranteed user k requests a certain QoS, the admission control module determines the minimal required *bk* time slots per frame. If the inequality

$$b_k + \sum_{i \in I} b_i \le N_d \qquad (6)$$

holds, then user k is admitted into the set I; otherwise, user k is rejected.

2. No bandwidth is reserved for the best-effort services/ users and the corresponding admission control scheme is up to the designer's choice. This admission control policy guarantees the prescribed QoS for all QoS-guaranteed users in the system, because bi time slots are reserved for each user i d"I , at any time. Thus, determining bi is the key to ensure prescribed QoS guarantees. However, due to the dynamic behavior of the queue and the channel, the bi time slots may not be occupied by each user.

4. PERFORMANCE ANALYSIS

The performance of the system is analyzed in terms Packet Error Rate (PER) and delay. The PER is calculated for the data frame being transmitted for two cases: without applying admission policy and by applying admission policy. It is observed from the figures 2&3, the PER is reducing with minimum SNR in the case with admission policy than the other one.

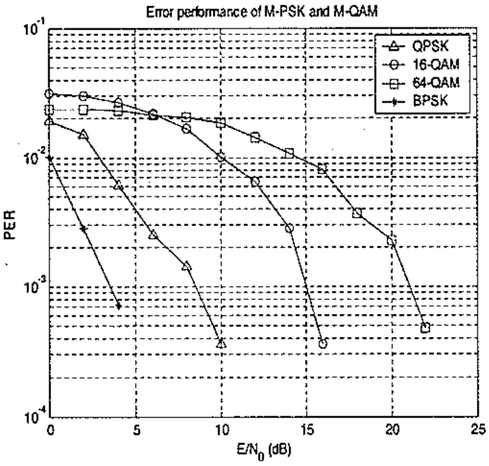

Figure 2 : Packet Error Rate without admission policy

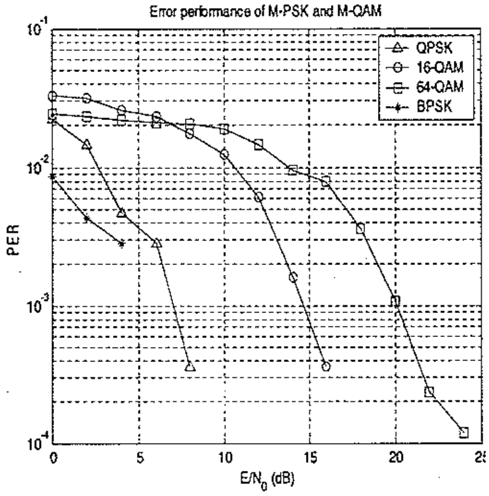

Figure 3 : Packet Error Rate with admission policy

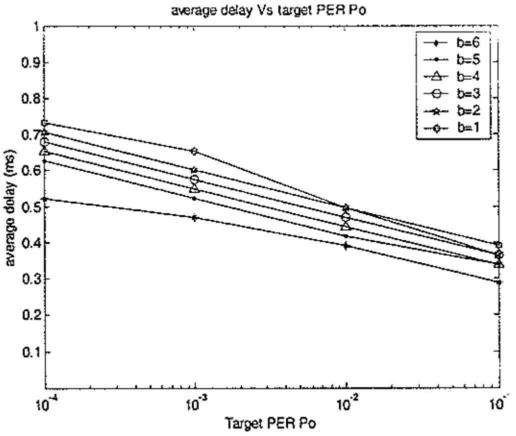

Figure 4 : Average Delay vs Target Packet Error

Rate

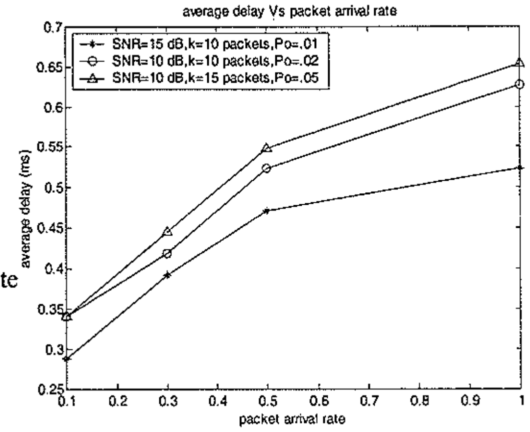

Figure 5 : Average Delay vs Packet Arrival Rate

The average delay is plotted against target PER as in Fig.4. The average number of packets in the queue is varied and the average delay under each condition is plotted as shown in Fig.5.

From the Fig.4 it is inferred that, when the average number of packets is 30, the delay is minimum for lower target PER. If the average number of packets is increased to 60, the delay gets increased.

Thus the delay depends on the average number of packets in the queue. The average delay is plotted for different packet arrival rates as in Fig.5. With minimum target PER, when the SNR value is increased and the number of packets being sent is decreased when the average delay is minimum.

5. CONCLUSION

In this paper, we developed a cross-layer model for multimedia applications in adaptive wireless networks, where the QoS-guaranteed multiuser at the data Link Layer is coupled with Adaptive Modulation and Coding (AMC) at the Physical Layer. We introduced novel admission policy and analyzed QoS of a wireless connection in terms of packet loss rate and average delay, given a certain reserved bandwidth.

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