Data Link Control Scheme for Wireless ATM Transmission

Željko Ilić, Alen Bažant and Mladen Kos
University of Zagreb, Faculty of Electrical Engineering and Computing
Department of Telecommunications, Unska 3, HR-10000, Zagreb, CROATIA
{zeljko.ilic, alen.bazant, mladen.kos}@fer.hr

Abstract

The Asynchronous Transfer Mode (ATM) employs header error control in order to protect cell integrity. However, wireless ATM (wATM) systems require a more powerful error control techniques to offer acceptable cell loss ratio (CLR) and mobile QoS (Quality of Service). This paper describes the data link control (DLC) scheme, used in wireless ATM segment, in order to provide reliable connection services. It analyzes extension of the standard ATM protocol stack by a DLC layer and medium access control (MAC) sublayer. DLC scheme uses TDMA MAC system based on ARQ (Automatic Repeat reQuest) control scheme. The throughput of the system and comparison of the ARQ based approach and the approach based on FEC and interleaving has been performed.

1. Introduction

The Asynchronous Transfer Mode technique is characterized by its flexibility to accommodate a variety of services. It is capable of carrying multimedia traffic such as voice and data at any specified rate by changing the transmission rate of 53-byte ATM cells. Original ATM mechanisms were designed with the assumption that transmission bit errors are rare, which is valid for fiber optic based systems. In recent years there is a high interest in using ATM for wireless transmissions. However, with wireless links the bit error ratio (BER) will be much higher and the bit errors may not be randomly distributed.

The main functionality of the DLC scheme consists in improving the transmission quality by means of error control [7]. The CLR experienced over the air interface can be very high if no error control technique is adopted.

The system architecture used in this paper is composed by base stations (BS) which provide access to a set of mobile terminals (MT). Different multiple access schemes have been proposed for wATM. The most suitable schemes are based on time division multiple access (TDMA) with centralized dynamic slot assignment. Each BS is connected through fiber optic link to an ATM switch (Fig. 1).

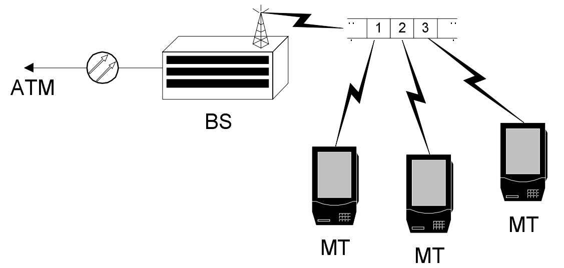

Figure 1: Wireless ATM network architecture

In this paper we evaluate the performance of the proposed scheme and showing how some parameters influence the behavior of the error control mechanism. We present some results based on completely different approaches: FEC and interleaving versus ARQ. Earlier discussions and recent results suggest that ARQ schemes can be an appropriate solution for delay constrained applications and they are performing better than FEC ones. In our scheme, ARQ technique is completely implemented in the base station and schedules transmissions and retransmissions for both uplink and downlink connections.

In this paper we consider Gilbert-Elliot (GE) model for the channel which captures the bursty nature of errors. It is assumed that the channel can be in two states: a good state (ON) and a bad state (OFF). When the state is ON the channel is error free, while when the state is OFF the bit error probability is 0,5.

The paper is organized as follows. The channel model is described in section 2. In section 3, error control schemes are theoretically analyzed. Results of simulation are presented in section 4.

2. The channel model

In this paper radio channel is modeled as Gilbert channel [1]. This model was proposed by Gilbert and Elliot (GE) to characterize the error sequences (burst errors) generated by transmission channels. The model consists of two states: good state (G), where errors occur with low probability, and bad state (B), where errors occur with high probability.

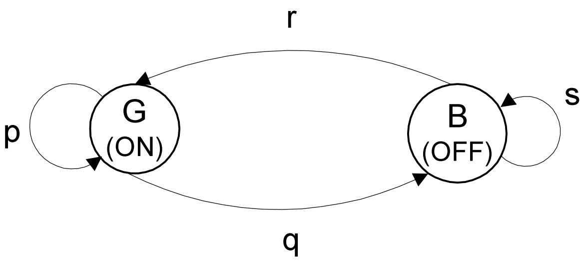

Figure 2: GE model

The state transitions shown in Fig. 2 are summarized by its transition probability matrix

$$P(X)=\begin{bmatrix} p(x) & q(x) \\ r(x) & s(x) \end{bmatrix},\ P(1)=\begin{bmatrix} p & q \\ r & s \end{bmatrix} \tag{1}$$

where $p(x)=1-q(x)$ ($r(x)=1-s(x)$) is the probability that the forward slot i is successful given that the forward slot i-1 was successful (unsuccessful). Note that $1/r$ represent the average length of the bursts of errors.

Solving equations:

$$\begin{gathered} \pi\cdot P=\pi \\ \pi_B+\pi_G=1 \end{gathered} \tag{2}$$

the system leads to the steady state probabilities of being in states B and G, respectively, $\pi=[\pi_B \quad \pi_G]$ i.e.:

$$\pi_B=\frac{r}{r+q} \quad \text{and} \quad \pi_G=\frac{q}{r+q} \tag{3}$$

3. DLC architecture

3.1. MAC sublayer

The MAC sublayer has to organize the multiplexing of different traffic streams as well as the separation between uplink and downlink traffic in a dynamic TDMA manner [7].

In TDMA protocol the time is divided in constant length frames and each frame is further subdivided into request subframe and a data subframe. The request subframe is accessed by MTs through a simple protocol in order to declare their transmission needs, while the data subframe is used for the data transmission.

The allocation of data slots is performed by the BS based on a scheduling algorithm, which assigns time slots to different connections, and MTs are informed through broadcast messages. A number of scheduling algorithms that try to separate real-time and non-real time connections have been proposed recently.

3.2. The FEC and interleaving

In wireless ATM, HEC (header error control) is not strong enough and a more powerful error scheme is needed. The method of interleaving can be used to reduce the memory of channel and CLR.

The error control codes used in paper belong to the BCH family. The information stream is segmented into codewords of k symbols, and $n-k$ redundant symbols are added to each codeword.

The interleaver consists of a matrix with d rows and n columns. The codewords are written as rows of the matrix and read out by column to generate a bit sequence transmitted onto the channel.

For each connection, d consecutive codewords are bit interleaved and transmitted in the assigned time slots. The interleaving introduces a transmission delay that increases linearly with d and must not exceed D (lifetime). The wATM cell must be received within its lifetime, or otherwise it is dropped.

In the presence of a delay D, the maximum interleaving size which can be used with BCH codes with codeword size n is $d=\lfloor D/2n\tau \rfloor$, where τ is the channel symbol duration [8].

Table 1 shows the maximum number of wATM cells (each cell is 54 octets length) that can be bit interleaved for different speeds and different D.

Table 1: maximum number of cells within the lifetime *D*

	max. D			
speed	5ms	10ms	25ms	50ms
2 Mbit/s	13	26	65	130
200 kbit/s	1	2	6	13

As can be see in the table, short D and a small connection speed negatively affect the code performance since the deinterleaving process spreads errors among fewer cells.

3.3. Selective repeat ARQ scheme

In the following we consider a generalization of the standard version of the selective repeat (SR) ARQ strategy. The transmitter transmits blocks, whose reception is acknowledged by the receiver by means of a feedback message that can be positive (correct transmission) or negative (wrong transmission). Blocks are kept in a buffer at the transmitter and removed from it when positive acknowledgement is received for corresponding block. Under the correct conditions, the transmitter receives acknowledgements (ACKs) N slots after the block transmission has started due to RTD (RTD–round trip delay). Also, a time-out counter is assigned to each block, and activated when the block is transmitted. When the counter reaches *N* slots, the time-out expires, and retransmission of block will be done in the next slot. In the classic SR version, the absence of feedback is equivalent to a negative acknowledgement.

It may be observed that SR ARQ mode requires some buffer capacity at the receiver side. Once a block is in error, all other successive blocks must be retained in memory, until the block is correctly received. This is the only way to ensure that blocks are correctly delivered to the upper layers. Therefore, the ordering of packets is achieved at the price of large memory and possibly long delays. To reduce this effect some modified schemes have been proposed [6].

In this paper we have used the SR ARQ scheme, its efficiency is higher than Multiple Stop and Wait ARQ protocol used in [2]. Also, we proposed that transmission and retransmission of cells should be controlled by BS scheduling mechanism described in [2]. Each wATM cell is 54 octets long. First four octets of the header and the payload are the same as in wired ATM. Two octets of CRC code are added at the end of cell as parity bits used only on wireless link. These two CRC octets are used to determine errors in received wATM cells. In order to avoid excessive delays, acknowledgements are immediately transmitted in a dedicated portion of the downlink. It is assumed that downlink, from MT to BS, is error free.

4. Simulation results

The system model used for simulation is based on the TDMA frame structure. The frame duration is 0,7 ms which is approximately 35 wATM cells. We have considered and analyzed a raw channel with 2 Mb/s and 0,2 Mb/s rates. The physical channel is modeled as Markov chain with two states as described earlier. We assign the characteristics of the chain by means of the stationary probability $\pi_B = 0{,}01$ and T_{off}, i.e. the average time during which the channel is in the state OFF. These parameters are related by the equation:

$$\pi_B = \frac{T_{off}}{T_{off} + T_{on}} \qquad (4)$$

where T_{on} is the average time during which the channel is in the state ON.

An each cell must be correctly received within lifetime *D*, otherwise it is dropped. The maximum CLR, equal to 10^{-3}, is the QoS that must be satisfied. We supposed that round trip time is negligible in comparison with lifetime *D*.

Figures 3 and 4 show efficiency of the FEC versus T_{off} and lifetime *D* for two different transmission rates, 200 kb/s and 2 Mb/s. Efficiency is measured as ratio of *k*/*n* attained by the lightest code that satisfies the cell loss constraint [2]. Table 2 shows BCH codes used in simulation for different *D* and T_{off}. Very poor performances of this technique, as T_{off} increases is obvious for different speed connections.

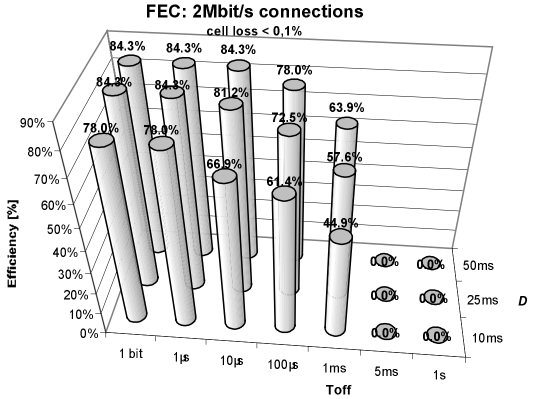

Figure 3: Efficiency of FEC and interleaving with 2 Mb/s connections

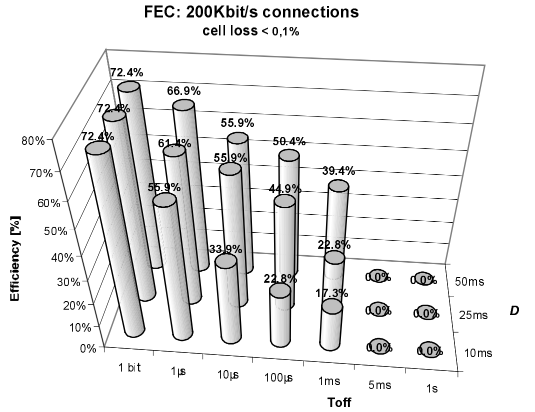

Figure 4: Efficiency of FEC and interleaving with 200 kb/s connections

Table 2. ***k/n*** **ratio for BCH code (connections 2Mbit/s)**

	T_{off}						
D	1 bit	1μs	10μs	100μs	1ms	5ms	1s
10ms	99/127	99/127	85/127	78/127	57/127	0	0
25ms	215/255	215/255	207/255	185/255	147/255	0	0
50ms	215/255	215/255	215/255	199/255	163/255	0	0

Figure 5 indicates that this scheme is suitable for short burst length. Burst errors, it will also, affect codewords because the interleaving is not suitable to make burst errors into single errors which can code correct. It means that technique with FEC and interleaving is suitable only when the bursts of errors are short and connection speed is high in order to achieve interleaving.

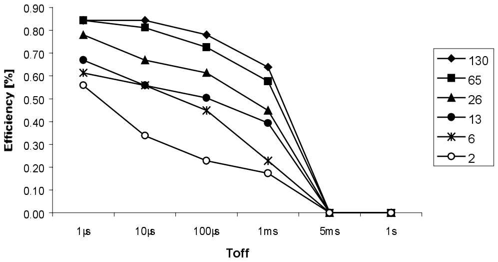

Figure 5: Efficiency of FEC and interleaving versus T_{off} for different values of interleaving degree *d*

4.1. Selective repeat ARQ

We have also developed a simulation model that includes a selective repeat ARQ technique. The transmission scheduler at the BS manages new transmissions and retransmission requests for incorrectly received wATM cells. The results of simulation are presented in Figure 6 and Figure 7 for 200 and 2000 kb/s connection rates. Respectively, the efficiency is measured as the ratio between the number of connections that can be accommodated while still guaranteeing that cell loss probability does not exceeding 0,1 % and the number of connections that can be accommodated in the error free channel [2].

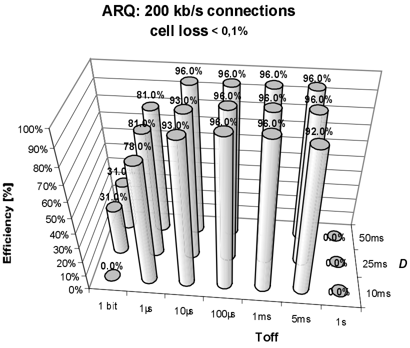

Figure 6: Efficiency of ARQ with 200 kb/s connections

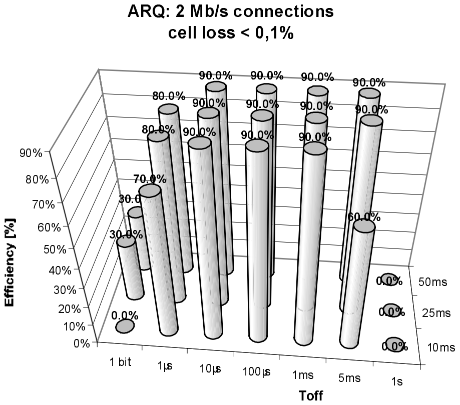

Figure 7: Efficiency of ARQ with 2 Mb/s connection

The last figures show an opposite behavior with respect to FEC. Here, efficiency increases with T_{off} and reaches satisfactory values for typical burst lengths. This behavior is due to the fact that retransmissions are too frequent for very short error bursts. For medium values of T_{off} retransmissions are rare and the efficiency is mainly constant (T_{off} from 10 μs to 5 ms). For high values of T_{off} the efficiency drops to zero since in this case no wATM cells can be successfully retransmitted within the lifetime.

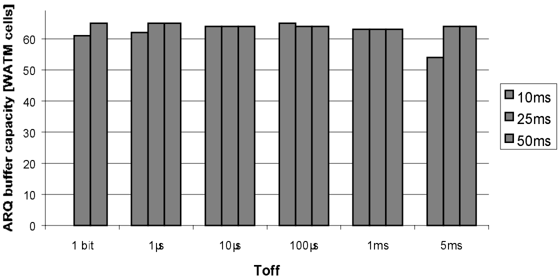

Figure 8: ARQ buffer capacity for different values of T_{off} and lifetime *D* (2 Mb/s connections)

This mode of operation requires some buffer capacity at the receiver side (Fig. 8). In our simulation we suppose maximum of 9 connections and the results show that average buffer capacity is 65 wATM cells for different values of T_{off} and *D*. FEC and interleaving method for this buffer size and 9 connections may use maximum depth of interleaving equal to 7 (9 x 7 = 63). The depth of interleaving shown in Figure 5 presents a maximum efficiency about 60 %. As can be seen, ARQ is much better choice from two reasons. First, its efficiency is higher than FEC one and, second, ARQ requests a smaller buffer size.

This indicates that frame length is very important parameter for ARQ technique (in our simulation frame length is set to 0,7 ms). It means that successful retransmissions are accomplished in very short time.

4.2. Throughput comparation

In the previous two chapters are described the main characteristics for two proposed error control schemes. Now, it is the time to make a choice which technique is better and under which conditions. Figure 9 shows the throughput ratio for ARQ and FEC versus T_{off} and lifetime D.

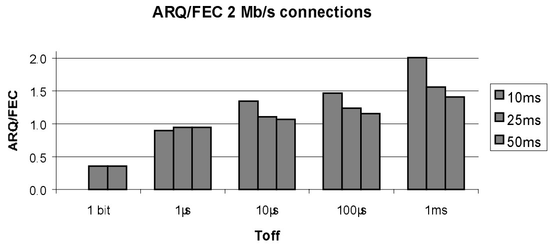

Figure 9: Throughput ratio ARQ/FEC versus T_{off} and lifetime D

Only for very small values of T_{off} FEC and interleaving are better than ARQ. As well, for this values of T_{off} channel is memoryless and does not characterize the wireless channel. For the values of T_{off} higher than 1μs ARQ shows much better results than FEC and interleaving.

5. Conclusion

We have presented protocols to improve the error control performance in networks with wireless links and mobile hosts.

The error control technique includes two different methods, first, ARQ and, second, FEC and interleaving. The efficiency and the throughput are two parameters used for comparation proposed methods.

The FEC and interleaving are not suitable for long bursts because interleaving is not suitable to transform burst errors in to random errors that can be correct by FEC.

The ARQ method provides better performance and sometimes is the only way that appears for reducing the effects of burst errors. Also, SR ARQ appears to be more flexible, as it automatically adapts to the channel quality and provides a required QoS for different speed connections.

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