A Hybrid Data/Header Interleaving Strategy for Wireless ATM Networks

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ABSTRACT

A header interleaving strategy was proposed to reduce the cell loss probability for wireless ATM networks. Such strategy spreads each header bit over the entire data field. Lots of burst errors on cell will be transformed into single-bit error on header which can be easily corrected by the HEC (Header Error Correction) field. Since each corrected cell may also contain incorrect payload, a data/header interleaving strategy (DIS) was proposed to recognize potentially dirty cells. When congestion occurs, the cell discarding strategy will drop them first to decrease the number of dirty cells received. In this paper, we proposed a new hyper-cells interleaving strategy (HIS) which has a lower payload error ratio than that of DIS. The cell error probability of a corrected cell of HIS is analyzed. Simulation results show that the proposed strategy substantially increase the received clean cell ratio.

Keyword: wireless ATM, CIS, interleaving, HIS.

1. Introduction

Recently, there have been many studies for high speed Asynchronous Transfer Mode (ATM) technology based wireless multimedia services for future broadband multimedia personal communication [1],[2]. In a wireless ATM network, the ATM cells are transmitted in radio environment with high jamming and fading effects. Due to such unpredictable factors, the bit error rate is high and the burst errors may occur abruptly. Since the CRC-8 code in HEC (Header Error Control) filed can not recover the burst errors in cells, these cells with burst errors will be lost or mis-routed. An interleaving method [3] is proposed to solve this problem. This cell interleaving method distributes 40 header bits within in a cell. Based on this technique, burst errors in header are spread out as isolated random errors in header field of a cell. Therefore, the HEC field is able to correct the single-bit header error and then the cell mis-routed probability will be reduced. To obtain a higher survivability, a block cells header interleaving expansion method was proposed in [4],[5]. In this method, each cell has a higher probability to survive when burst length of error is even longer than 10 bits.

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Based on multi-cell interleaving approach, the data/header interleaving strategy (DIS) [6] was proposed to precisely determine which cell is dirty or clean. The DIS spreads all data bits of a cell and locates them on the neighbors of all header bits. Any header bit error implies that this cell has a higher probability to contain incorrect payload. Because of the HEC only correcting the header information, the corrected cell may still contain incorrect payload. For simplicity, the corrected cells are marked as *dirty* cells. As the network becomes congested, these dirty cells should be dropped first. To decrease the number of error cells received in the destination, a cell discarding strategy (CDS) has been proposed in [5]. The ATM network supports QoS (Quality of Service) by managing the Cell Loss Priority (CLP) bit in header. When network is congested, the cells with low priority (CLP=1) will be dropped. Within these low priority cells, some clean cells may be dropped also. In the proposed CDS, the CLP bits of a dirty cell with high priority and a clean cell with low priority will be changed. Besides, it will drop the dirty cells before dropping the clean cells with the same priority.

However, when burst errors occur, the DIS may cause a number of cells become dirty. As a result, the number of error cells received by the destination becomes large. In this paper, we propose another efficient hyper-cell interleaving strategy (HIS) which will reduce the burst errors occur on different cells. The clean cell received ratio will be increased by HIS even when burst errors occur.

The rest of this paper is organized as follows. In Section 2, the hyper-cell interleaving strategy (HIS) is addressed in more details. In Section 3, the cell error probability of HIS is analyzed. In Section 4, the cell discarding strategy is introduced. In Section 5, the simulation model and simulation results are reported. Finally, some conclusion remarks are given.

2. Hyper-cells Interleaving Strategy

In this section, an extended block-cells header interleaving method called hyper-cells interleaving strategy (HIS) is proposed. Such strategy is modified by data/header interleaving strategy (DIS) [6],[7] and changes the data payload arranging method. It has an acceptable cell payload error recognizable ability and it can improve the cell error ratio. Furthermore, this strategy substantially

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increases the received clean cell probability (RCCP).

For simplicity to demonstrate, five consecutive ATM cells are grouped in a block together to perform the hyper-cells interleaving. According to the arrival sequence, we number the cells from C_1 to C_5. After the hyper-cells interleaving is performed, these reallocated cells are numbered as I^1, I^2, I^3, I^4, and I^5. The sum of cell headers in a block is 200 bits ($40 \times 5 = 200$). We spread these 200 cell headers equally into the five cells in this block as the equation defined in (1).

$$C_i(H_a) = I^{\lceil a/8 \rceil}_{\{i+5[(a-1) \bmod 8]\}\times 10} \quad (1)$$

where i is the index of cell in a group ($1 \le i \le 5$), and a is the index of the header bit in a cell ($1 \le a \le 40$).

The assigned position ($C_i(H_a)$) denotes the a-th header bit in cell C_i and I^x_y stands for the y-th bit location in the I^x cell after performing hybrid-cells interleaving.

For analyzing the cell error probability of HIS, each of the data bits in the block is also interleaved by specific method. The arrangement of data interleaving is to avoid burst errors on data bits that are belonged to different cells. In this method, the data bits of each cell are arranged around their own cell header and there are 9 data bits between the two adjacent cell headers. For instance, the data bits of cell C_1 must be distributed around the headers of cell C_1. Therefore, five data bits are placed at the left side of a header bit and four data bits are placed at its right side. The residual 24 ($384 - 40 \times 9 = 24$) data bits of cell C_1 are located as the neighbors of I^1. Let $C_i(D_b)$ denote the assigned position of the b-th data bit ($1 \le b \le 384$) in cell C_i. For cells C_1, C_2, C_3, C_4 and C_5, the assigned position $C_i(D_b)$ can be determined by the following equation (2) :

$$Ci(Db) = \begin{cases} I^{\lceil b/72 \rceil}_{\left\{i+5\left[\left(\left\lceil \frac{(b-1) \bmod 72+1}{9} \right\rceil - 1\right) \bmod 8\right]\right\}\times 10+(-1)^b \left\lceil \frac{[(b-1) \bmod 72] \bmod 9+1}{2} \right\rceil} & ,1 \le b \le 360 \\ I^i_{b-360} & ,361 \le b \le 364 \\ I^i_{b+40} & ,365 \le b \le 384 \end{cases} \quad (2)$$

According to the formulas that have been described above, we can know the assigned position of each bit after hyper-cells interleaving. Therefore, the five consecutive ATM cells can be interleaved easily before transmitting data to the wireless ATM networks. The cell format is illustrated in detail by Figure 1.

3. Analysis of Cell Error Probability

In this section, the cell error probability (CEP) of HIS is analyzed. It is well known that burst errors may occur in wireless ATM networks when cells are transmitted from user radio station to central radio station. We consider the case of error, which can be detected and corrected by the HEC field. Figure 2 shows that only when the burst error bits are more than 5 bits, the case of burst errors covering the data of other cells may happen in HIS method. However, in DIS method, when burst length is more than 2 bits, the data of other cells will be incorrect. It means that HIS avoids burst errors spreading on too many cells in a block. Therefore, when the cell header is error, the error of data only occurs in its own cell.

Let BER and P_i denote as the single error bit probability and the i-bit burst error occurrence probability. To keep the bit error rate the same, the 2-bit burst error occurrence rate is assume to be one half of single error probability ($P_2 = BER/2$). Similarly, the n-bit burst error occurrence rate is BER/n ($P_n = BER/n$). The analyzed cell error probability (CEP) is the data error probability of each cell in a block. Hence, the CEP can be derived by the following equation (3).

$$CEP = C_1^{40} \cdot \left\{ \sum_{i=2}^{5} p_i^{\,i} \cdot q_i^{39} \cdot i + \sum_{i=6}^{10} p_i^{\,i} \cdot q_i^{39} \cdot (11-i) \right\} \quad (3)$$

4. Cell Discarding Strategy

The dirty cells can be recognized by the analysis of CEP and then they will be marked. To perform the cell discarding strategy (CDS), the dirty cells with high priority and the clean cells with low priority need to be taken into considerations. To obtain a better performance, the cell discarding mechanism will swap their priority to each other. The state transition diagram is shown in Figure 4. For example, initially ATM switch states in the HHPDC (hunting high priority dirty cell) state. As soon as a high priority dirty cell is found, it enters into the HLPCC (hunting low priority clean cell) state and keeps looking for the low priority clean cell. When it is detected, the CLP bit of these two cells will be changed immediately. After then, it will return to HHPDC state as usual.

5. Simulation Model and Results

In this paper, the modeling of the wireless channel is represented by a two state Markov process as shown in Figure 5 [8]. In the 'good' state, the bit error probability is considered very low. In the 'bad' state, the bit error rate becomes high and the burst errors are generated. There are four parameters to define this model.

- P = state transition probability from good state to bad state.
- Ps = probability of remaining in the bad state.
- e_{good} = bit error rate in the good state.
- e_{bad} = bit error rate in the bad state.

The channel is supposed to generate burst errors only in the bad state. Then the average burst error length (B) can be given by B = 1/(1-Ps). The average Bit Error Rate (BER) is derived as

$$BER = \frac{(1-Ps)e_{good} + Pe_{bad}}{1-Ps+P}$$

The simulation model is shown in Fig. 6. In Fig. 6, sources A and B want to transmit data to station C. The traffic arrival rates in source A (B) is a Poisson distribution with a mean λ_A (λ_B). To investigate the effect of proposed strategy, only source A is mobile station and the transmitted cells from it have a chance to be dirty cells or low priority cells. Contrarily, sources B only generates the clean cells with high priority to cause the network congested. The parameter N is the number of ATM switches from station A to station C and L is the buffer length in ATM switch. For observing the performance, we define an observed variable RCCP (received clean cell probability) as

$$RCCP = \frac{\text{the number of received correct cell}}{\text{the number of total received cell}}$$

The corresponding simulation parameters are listed in Table 1.

Table 1. The simulation parameters.

NUMBER OF ATM SWITCHES (N)	5
The buffer length (L)	150
Mean value of source A (λ_A)	0.5
Mean value of source B (λ_B)	0.2
BER in good state (e_{good})	0.0001
BER in bad state (e_{bad})	0.1

Figure 7 represents the received clean cell probability (RCCP) under different state transition probability from good state to bad state (P). The probability of remaining in the bad state (Ps) is set to a constant value 0.9 and P is considered from 0.99 to 0.0003. It shows that the RCCP of HIS is better than the RCCP of DIS even the value of P is high (which means that the average BER is high). In figure 7, we plot the RCCP of two strategies DIS and HIS under the Ps from 0.05 to 0.8 with a constant P=0.2. We note that a larger Ps is given, a longer burst error length will occur. The result shows that even when burst error length becomes larger, the RCCP of HIS becomes much better than DIS.

7. Conclusions

In this paper, a novel interleaving strategy is proposed to reduce the cell loss rate efficiently in wireless ATM networks. The proposed strategy is based on a header interleaving method that spreads each header bit over the entire data field. In our strategy, the burst errors that occur on header of ATM cell in wireless ATM networks will be transformed into single-bit error on header that can be easily corrected by the HEC field. Intuitively, since each corrected cell may also contain incorrect payload, the cell discarding strategy (CDS) is used to drop these dirty cells first to decrease the number of dirty cells received. We can find that hyper-cells interleaving strategy (HIS) has lower cell payload error ratio in a block. The cell error probability of a corrected cell is analyzed in this paper and the simulation results show that the proposed strategy substantially increase the received clean cell probability. From the simulation results, we can also find that the RCCP of HIS is better than the RCCP of DIS even the BER is high. Moreover, when burst error length is large, the RCCP of HIS is also better than DIS.

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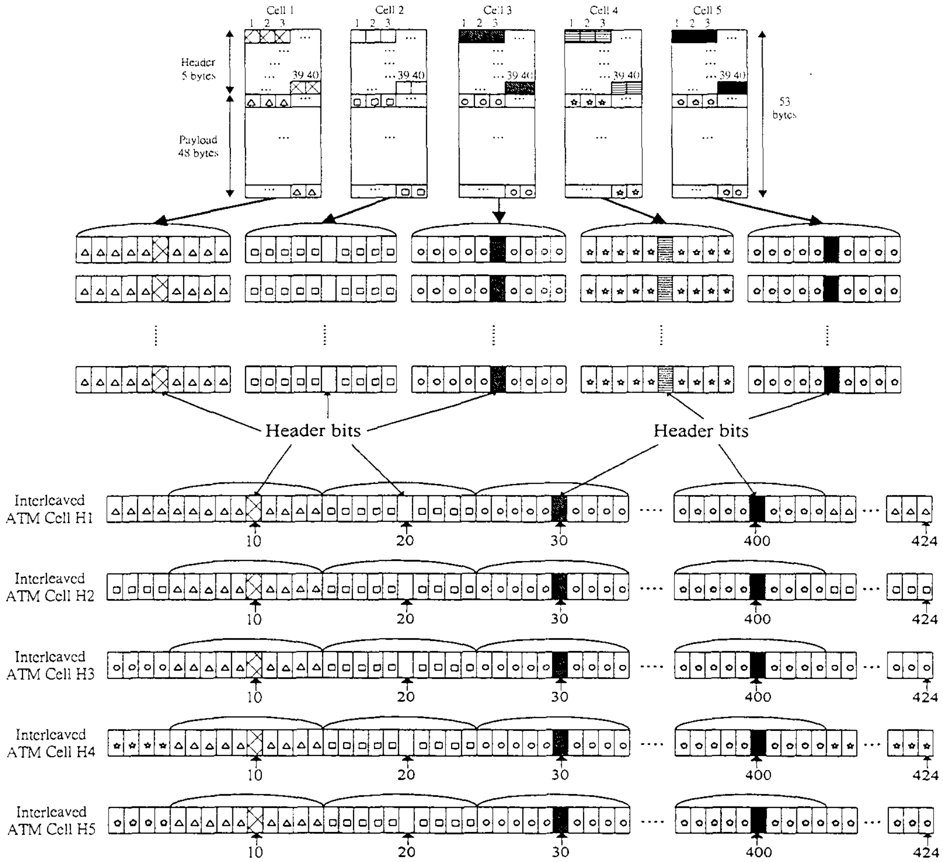

Figure 1. The bit assignment of the hyper-cells interleaving strategy (HIS).

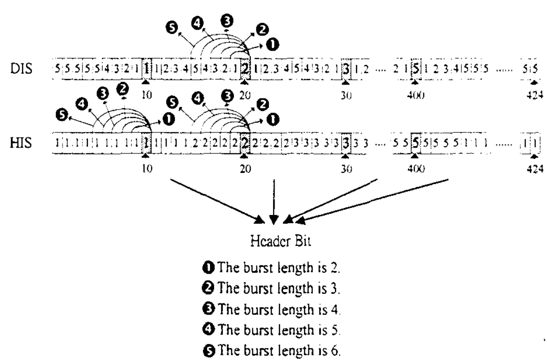

Figure 2. The way of determining the data error probability of each interleaved cell.

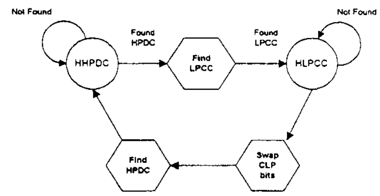

Figure 3. The state transition diagram of the cell discarding strategy.

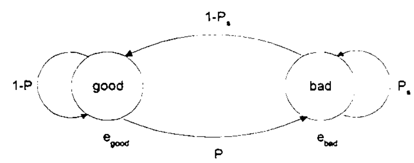

Figure 4. Two-state Markov chain model of the channel condition.

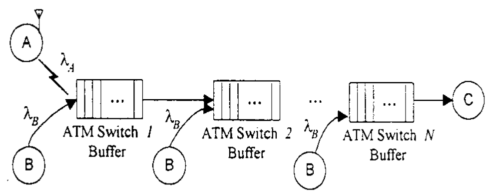

Figure 5. The simulation model.

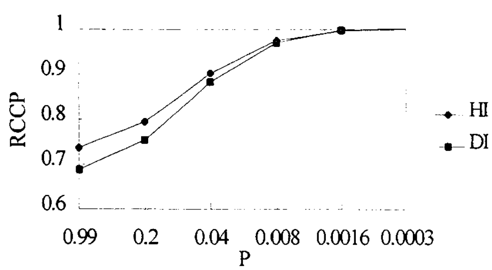

Figure 6. The received clean cell probability (RCCP) under different state transition probability from good to bad (P) when Ps = 0.9.

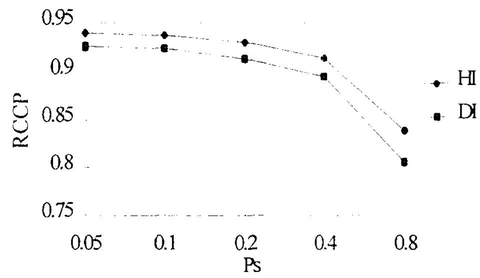

Figure 7. The received clean cell probability (RCCP) under different probability of remaining in the bad state (Ps) when P = 0.2.