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광대역 통신망에서 Forward Error Correction을 이용한 셀손실 회복의 성능 개선

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Performance Improvement In Broadband Networks Using Forward Error Correction For Cell Loss Recovery

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요 약

ATM 망과 같은 초고속 네트워크에서 전송 에러의 주요 원인은 과잉밀집 상태에 있어서의 버퍼 오버플로우이며 이로 인해 셀손실을 야기한다. 본 논문은 이러한 문제를 줄이기 위해 연속적인 셀손실을 회복할 수 있는 방법을 제안하며 이 방법은 18개의 연속적인 셀손실을 회복할 수 있다. 또한 인터리빙 기법을 이용한 FEC 기법의 수치적인 성능 분석을 하였으며 이 결과 셀손실율을 상당히 절감할 수 있었다.

Abstract

We present a method to recover consecutive cell losses using forward error correction(FEC) in ATM networks. Our method recovers up to 18 consecutive cell losses. Also, we present the performance estimation of the FEC technique using the interleaving in ATM networks. Performance estimation shows an outstanding reduction in cell loss rate.

I. Introduction

With increasing attention and demand of a B-ISDN, many researches have been made towards the development and standardization of a B-ISDN recently. Especially, there have been made many researches to recover cell losses in switching nodes due to buffer

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overflows. The packet retransmission method has been used in packet networks such as LAN's to preserve the quality of the packet. However, that is not suitable for ATM networks which handle time-constraint signals such as voice and video. As an alternative, we propose FEC technique to preserve the low cell loss rate. In this technique, a recipient can recover lost or errorneously received data based on parity bits which are added by the source. Recovering lost packets reduces the need for retransmissions of reliable data, and enhances the quality of real-time data that can not rely on retransmissions because of the large delays involved.

Several cell loss recovery methods based on FEC have been proposed for ATM networks. The work in [4] analyzes the reduction in packet loss probabilities due to the parity packet coding and proposes buffer mangement techniques at the intermediate nodes depending on the use of coding. A cell loss recovery method, which is considered to be applied to virtual paths, that uses an FEC technique in ATM networks is proposed in [1]. References [3,9] show how the use of FEC improves the performance of broadband networks. Reference [2] shows that the 4-bit sequence number in segmentation and reassembly(SAR) sublayer provides a powerful capability for detection of cell misordering. In this paper we propose a cell loss recovery method that uses an FEC technique. The crucial point of our study is based on the parity cells as described in [1]. The organization of the paper is as follows. In section II, we review the general overview of ATM networks. In section III, we propose a method to recover lost cells and show two cases of the lost cell recovery based on message size. In section IV, we estimate the performance of the proposed method using parity cells. In section V, we discuss the result of this paper.

II. General overview of ATM networks

The ATM cell consists of 48 octets of payload and 5 octets of header [6]. The virtual path identifier(VPI), an 8-bit field, and the virtual channel identifier(VCI), a 16-bit field, contain the routing information of a cell. The payload type(PT) is used to distingish the user information from the netwoks control information. The cell loss priority(CLP) is a 1-bit field that indicates the loss priority of an individual cell. The header error correction(HEC) is used mainly to discard cells with corrupted headers and for cell delineation.

AAL layer performs the function of mapping user information into ATM cells and is composed of two sublayers: convergence sublayer(CS) and SAR sublayer [7]. Fig. 1 depicts the SAR-PDU for AAL 3/4, which is used for service classes C and D. The SAR-PDU has a 2-octet header and trailer, The header contains three fields as shown in the Fig. 1. The 2-bit segment type(ST) field indicates whether the SAR-PDU is a beginning of message(BOM), a continuation of message (COM), an end of message(EOM), or a single segment message(SSM). The 4-bit sequence number(SN) is incremented by the sender and checked by the receiver. The 10-bit multiplex identification(MID) field allows up to 1024 different CPCS-PDUs to be multiplexed over a single ATM virtual channel connection. The trailer has two fields. The 6-bit length indicator(LI) specifies how many of the octets in the SAR-PDU contain CPCS-PDU data.

III. A New Cell-Loss Recovery Method

Until now, conventional cell loss recovery methods in ATM networks recover up to 16 cell losses because lost cells are identified based on 4-bit sequence number(SN). For example, Fig. 2 shows that columns 1 and 2 can not be recovered. However, we can recover more consecutive cell losses if we extend the row length of the coding matrix as shown in Fig. 3. Arranging the data in a matrix and adding parity cells as shown in the figure are employed to recover bursts of lost cells [3]. The i-th bit of a parity cell is the modulo 2 sum of the i-th bits of the data cells. That is, if we denote the k-th bit of the packet in the(i,j) position in the array by $c_{i,j,k}$, and consider m-bit cell size, then

$$c_{M+1,j,k} = \left(\sum_{i=1}^{M} c_{i,j,k}\right) \bmod 2,$$
$$1 \le k \le m,\ 1 \le j \le N.$$

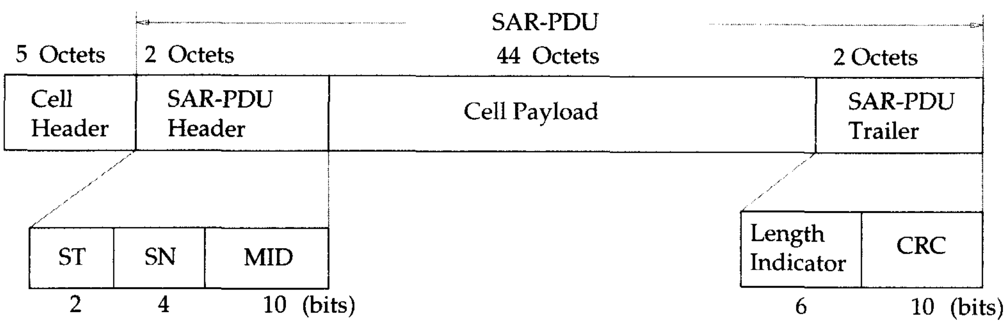

Figure 1 : SAR-PDU format for AAL3/4

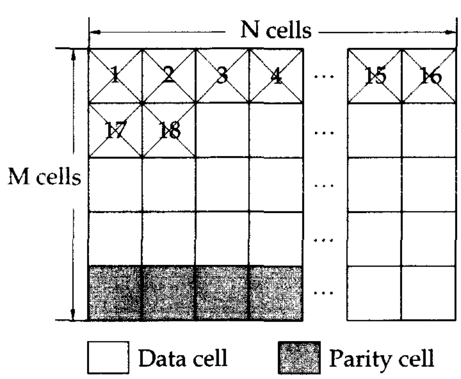

Figure 2 : Coding Matrix(row length : 16)

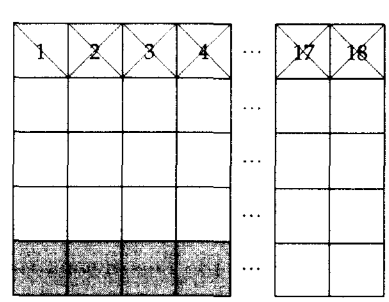

Figure 3 : Coding Matrix(row length : 18)

Parity cells possess an OAM cell attribute so that they can be distinguished from data cells and have high priority. There is no processing delay in encoding because of the multiplicative and additive natures of the encoding operation [1]. The encoding tasks that FEC encoder does are the generation of the parity cell and transfer of the coding matrix to the network.

A. Decoding Procedure

The FEC decoder at the receiving side buffers the cells from network. Note that the decoder waits until the last cell within a coding matrix comes up. The decoder finds lost cells by observing the 4-bit SN and 2-bit segment type(ST) values in the stream of received cells, and recovers the lost cells using parity cells. The SN and ST values in a cell are used to consider a new cell SN(SN*) as shown in Table 1.

SN	ST	SN *
0	BOM	0
1	COM	1
0	LOM	16
1	EOM	17
2-15	COM	2-15

B. Example

For the case when the message is less than or equal to 16 cells, all random permutations of lost cells at the receiver can be identified and recovered by the 4-bit cell SN since the SN incremented modulo 16. Let's consider the case when the message size consists of 18 cells. The sequence of 18-cell message at the sending side is shown below.

(B : BOM, C : COM, E : EOM, PC : Parity Cell)

SN :	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0	1
ST :	B	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	E
PC :	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		*																*

In this case, all positions of lost cells are not determined by 4-bit SN. For example, consider the case when the cells of which SN value is 1(*) are lost. Then the decoder uses ST field to distinguish whether which cell(second or 18th) is lost.

Thus, the row length of coding matrix can be extended to $N = 18$. This means that the proposed method improves the recoverability of lost cells.

IV. Performance Estimation

In this Section the Gilbert channel is reviewed, and then the effect of the channel in which interleaving is considered is presented.

A. Gilbert channel

The cell discard process is expressed as a

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서울대학교(전기공학 학사), 한국과학원(전기전자공학 석사), University of California at Berkeley(컴퓨터과학 박사)를 졸업하였다. 한국전자통신연구소에서 근무하면서 KD-4 PCM channel bank의 개발에 성공하여 전송장비의 국산화와 외화 절약에 일익을 담당하였다. California주 Monterey 소재 미해군 대학원(Naval Postgraduate School)의 Information System Department에서 조교수로 근무하였으며 현재 연세대학교 컴퓨터과학과 부교수이다. 동경대학 생산기술 연구소 객원연구원, University of California at Berkeley 교환교수 등을 역임하였다. 결혼하였으며 슬하에 일남일녀를 두고 있다. 취미는 바둑, 좋아하는 스포츠는 테니스이다.

※ 주관심 분야 : Protocol Engineering, ATM Network, Network Security 등

two-state Markov model(Gilbert channel) as shown in Fig. 4[1,8] and summarized by its transition matrix

$$P = \begin{bmatrix} \beta & 1-\beta \\ 1-\alpha & \alpha \end{bmatrix}. \quad (1)$$

The cell losses occur with probability $P_G=0$ in the good state(G) while they occur with probability $P_B=1$ in the bad state(B). The average cell loss rate produced by the Gilbert channel is

$$p = \frac{1-\beta}{1-\alpha+1-\beta}. \quad (2)$$

The variance of lost cell X is $\sigma^2 = E(X-p)^2 = p(1-p)$. The correlation of two consecutive lost cells X_1 and X_2 is

$$\rho = \frac{E((X_1-p)\ (X_2-p))}{\sigma^2} = \alpha+\beta-1. \quad (3)$$

Finally, we express the two parameters of the model(α and β) in terms of p and ρ by solving (2) and (3). This yields

$$\alpha = p+\rho(1-p),$$
$$\beta = (1-p)+\rho p.$$

Then the state transition matrix, P, becomes

$$\begin{bmatrix} 1-p(1-\rho) & p(1-\rho) \\ (1-p)(1-\rho) & 1-(1-p)(1-\rho) \end{bmatrix}.$$

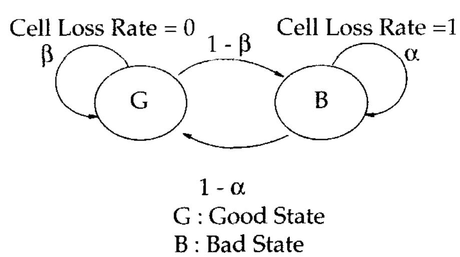

Figure 4 : Cell Discard Process Model

B. Effect of Interleaving

The effect of interleaving is to randomize the consecutive cell losses for the cell stream arriving at the receiving side. Consequently it makes them more amenable to correction with FEC[5]. The source can arrange its cell stream in I interleaved streams, by assigning to each stream every I-th cell. However, monitoring interleaved streams requires more effort by the decoder than is needed for a single stream. Without interleaving($I=1$), the transmission probabilities associated with the transmission of two consecutive cells are given by P as in(1). When the cells are interleaved to degree $I > 1$, two consecutive cells of each cell stream are spaced apart by I cells. Then the corresponding transition probabilities for these two cells is given by P^I

$$P^I = \begin{bmatrix} 1-p(1-\rho^I) & p(1-\rho^I) \\ (1-p)(1-\rho^I) & 1-(1-p)(1-\rho^I) \end{bmatrix}. \quad (4)$$

This means that interleaving to degree I has the effect of raising the correlation coefficient of the channel to the I^{th} power. Since a sigle cell loss can be recovered in each column, we first calculate the probability that only one cell is discarded per column[1]. If the discard probability of the ith cell in a column, is D_i, the discard probability of the $(i+1)$th cell, denoted by D_{i+1}, is given by :

$$\begin{bmatrix} 1-D_{i+1} \\ D_{i+1} \end{bmatrix} = \begin{bmatrix} \beta & 1-\alpha \\ 1-\beta & \alpha \end{bmatrix}^N \begin{bmatrix} 1-D_i \\ D_i \end{bmatrix}, \quad (5)$$

where N denotes the row length of the

cell matrix. For convenience, let's express the N-th power of the state transition matrix as:

$$\begin{bmatrix} 1-p(1-\rho^{I}) & (1-p)(1-\rho^{I}) \\ p(1-\rho^{I}) & 1-(1-p)(1-\rho^{I}) \end{bmatrix} = \begin{bmatrix} \beta_N & \bar{\alpha}_N \\ \bar{\beta}_N & \alpha_N \end{bmatrix}.$$

The probability that only one cell is lost in a column, denoted by L_1, is given by

$$L_1 = p\bar{\alpha}_N\beta_N^{M-2} + (1-p)\bar{\beta}_N\bar{\alpha}_N\beta^{M-3} \cdot (M-2) + (1-p)\bar{\beta}_N\beta_N^{M-2}, \quad (6)$$

where M denotes the number of rows in the cell matrix. This means that the average number of cells recovered in a column, is also L_1. So, the improved cell loss rate using the cell loss recovery method with interleaving, denoted by L, is

$$L = p - L_1/M \quad (7)$$

Figs. 5 and 6 show the cell loss rate of the recovery method without and with interleaving when the coding matrix(M = 5, N = 18)is employed. Figure 6 shows the improvement in cell loss rate is large when interleaving to degree $I > 1$ is employed even if ρ is large

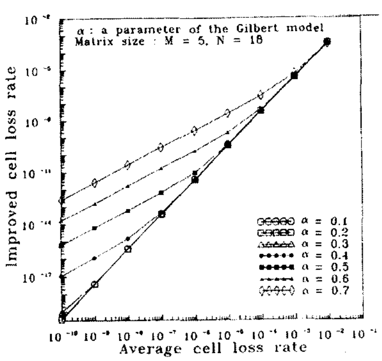

Figure 5 : Improved cell loss rate Without interleaving

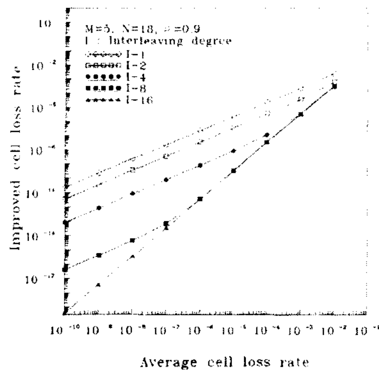

Figure 6 : Improved cell loss rate With interleaving

V. Concluding Remarks

In this paper, we have presented a method to recover the consecutive cell losses due to buffer overflow in high-speed networks such as B-ISDN. The method is based on FEC transmitting parity cells, which is used by the decoder at the receiving side to reconstruct lost cells, together with data cells at the sending side. It recovers up to 18 consecutive cell losses in ATM networks. The missing cells are identified by observing SN and ST values in the stream of received cells and are recovered by parity cells. We showed an example to recover lost cells and presented the performance estimation of the FEC technique using the interleaving in ATM netwoks. The performance estimation showed a substantial reduction in cell loss rate.

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