초고속 통신망으로 멀티미디어 데이터 전송시 분실한 셀과 데이터의 효율적 복원 방법

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An Efficient Packet Recovery Technique of Lost Cells from Multimedia Traffic on ATM

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요 약

Asynchronous Transfer Mode(ATM) 네트워크로 멀티미디어를 전송하는 방법이 점점 현실 화 되었다. 하지만 많은 양의 멀티미디어 데이터를 ATM 네트워크로 전송시 네트워크 전송 율이 포화상태이면 전송되는 데이터는 버퍼에서 기다리거나 혹은 폐기된다. 특히 영상과 같은 데이터는 보내지는 데이터 셀의 손실이 발생할 경우 재전송 요구 시 셀 지연에 대하여 매우 민감하다. 따라서 디코더에서 그 셀은 즉시 복원이 되거나 Error Concealment가 이루어지어야 하다. 멀티미디어 데이터를 Asynchronous Transfer Mode(ATM) 네트워크로 보낼 때 손상되는 데이터의 복원을 위하여 일반적으로 네트워크 자체에서는 요구하지 않는 별도의 셀 손실 방지를 위한 방법이 필요하다. 따라서 본 논문에서는 셀 전송 시 일어날 셀 손실이나 샐 데이터 내에서 일어날 비트 에러를 효율적으로 복원할 수 있는 방법을 제시한다. 실험 결과는 정지화상 전송 시 전송될 화상을 압축한 후 ATM 셀로 나눈 후 전송시 발생할 셀 손실을 효과적으로 복원한 결과에 대하여 논의한다.

1. Introduction

Most networks so far have been dedicated to a particular or specific service. The public switched telephone network(PSDN) is a circuit switched network primarily designed for voice. Data networks are also optimally designed for supporting data services. However the demands for providing multimedia services, such as voice, data, image and video is increasing rapidly. Therefore in the future all the different network services would be supported over common high speed network using the Asynchronous Transfer Mode(ATM) or other techniques. ATM-based broadband Integrated Services Digital Network (ISDN) is becoming available for multimedia transport.

A major concern in any communication network is the control of transmission errors. Automatic Repeat Request (ARQ) schemes are often preferred to Forward Error Correction (FEC) scheme because they are easy to implement and show superior performance at low bit-error rates. The throughput rate of an ARQ scheme strongly depends on the number of requested retransmissions and this falls rapidly with increasing bit error rate (BER). For applications involving real-time video and voice over very high speed networks, ARQ-based schemes impose an unacceptably long transmission delay. The problem is more acute if the data paths are fairly long, as in wide area networks (WANS). On the other hand, since FEC has no retransmissions, the throughput rate and to a large extent, independent of the need for data retransmissions and enhances the quality of real-time application (video and voice) that cannot rely on acknowledgments (ACKS) and retransmissions because of the large delays involved.

ATM[1] and other WANs, are based on the fiber-optic links with very low bit error rates, typically from 10-10 to 10-14 , over long distance fiber cable. ATM is the choice for high-speed networking. All the data is packed into cells of 53 octets including the necessary overheads, each cell being transmitted independently, but along a fixed path. Multimedia transport over ATM networks is fast becoming a reality[2][3]. However, there are problems associated with transport of such traffic over high-speed links. The networks can become congested and the result can be either delay because data has to wait in the buffers or with worsening of the situations, the buffers may become full and data will be discarded. Unlike in slow-speed networks, error or lost data can not be handled through retransmission. The need arises therefore to look for alternative methods to tackle such situations. While the responsibility of maintaining data integrity may be transferred to the higher layers, this is viable only when the data is not sensitive to delay. If real time transfer is required even this approach will not do.

In the case of voice the problem is usually simple. We may just discard the delayed data or if the network drops cells we may not take any action. This is quite adequate most of the time because of the robustness of speech data, unless we use very low-bit rate encoding. However, in the case of video traffic, we can not afford to lose much data.

In ATM networks, low priority cells are dropped first in the event of congestion. Since a lost cell is just a block of bits in error, essentially some form of FEC is needed. Park and Lee[4] suggest an error concealment techniques. The basic idea is the following. Let the pixels in odd numbered lines be labelled 0 and 1 alternately and labelled 2 and 3 in even numbered lines. All pixels with the same label are collected as a sub-block 0-SB, 1-SB, 2-SB and 3-SB. Each sub-block may be transmitted as a cell. In the event a cell, (say 0-SB) is lost, we have missing pixel in every 2×2 segment. Using interpolation techniques we can estimate these lost pixels. There must be some encoding delay as well as reconstruction delay. The authors suggest methods for random cell loss as well as burst loss. There is a forward error correction technique for MPEG encoded data transmission over ATM. Lei[5] advocated the technique. The 188 Byte MPEG transport layer data is encoded using a shortened(255, 253) Reed-Solomon code to generate a (192, 188) code. This code word is broken into 4 groups, each with 47 bytes of data and one of the parity bytes as shown in Figure 2. Each group is an ATM cell payload. However this can handle only random errors and will not be able to recover data if a cell is lost. Shacham and later Ohta and Kitami[6][7] have suggested methods which will recover cells if they are lost. We have adapted this approach in order to recover lost ATM cells and also to address those situations where a cell may not be lost but may just contain random errors.

Ⅱ. Packetization of Subbands

The division of images into subbands is accomplished by the use of a single stage of low/high-pass operation in each direction resulting into a total of four subbands. That is, the 512×512-pixel image is divided into 4 subbands, each with a size 256×256 shown in Fig.1. After the subbands are encoded by using some compressed technqiues, they are packetized for the use in an ATM network.

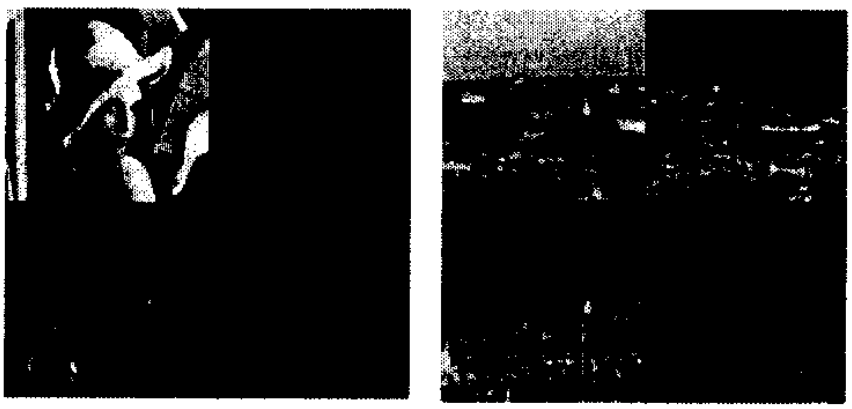

Fig. 1. Four Separated Subbands

Since an ATM cell contains 53 octets, with 48 of these being data, we break up digitized data into the appropriate number of 48 octet units for transmission as shown in Fig.2.

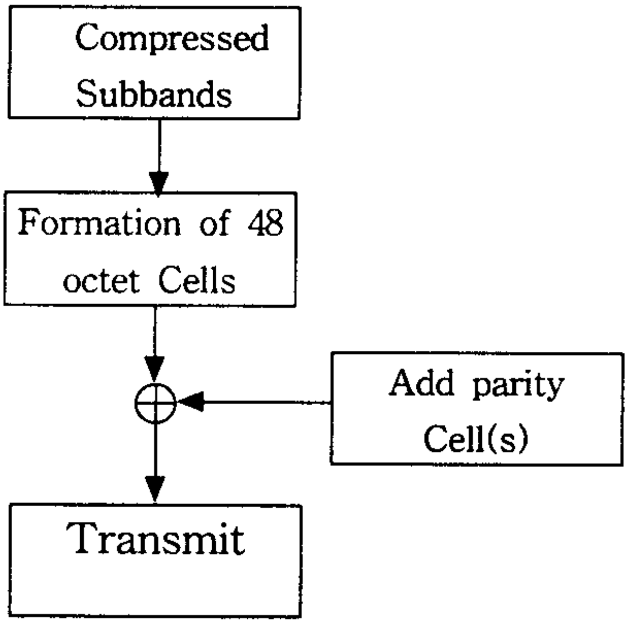

Fig. 2. Packetization of Subbands

Ⅲ. Packet Loss Recovery

In this paper, a method for recovering lost cells in a telecommunication infrastructure is provided. By "telecommunication infrastructure" it is meant to include, but is not limited to, all packet networks, ATM networks, wireless networks and ISDN and other conventional network.

For example, in one embodiment, an ATM network is provided wherein the ATM adaptation layer is capable of selectively implementing an error recovery scheme. The method uses a set of parity data that is determined based upon user data. User data as well as parity data is formed into ATM cells of appropriate size. Whenever one or more of these cells becomes lost, the ATM adaptation layer can selectively implement the error recovery scheme to recovery lost data. In addition, a technique for identifying errors in the cell can be incorporated for use in correction of a cell that is received but with errors. With this technique, a cell with errors can be identified, discarded and recovered with the correct information as though it had been lost. Error identifying techniques are well known to those of skill in the art.

Ⅲ-Ⅰ. Single packet Recovery

In accordance with the error recovery technique, a data packet is grouped into blocks of predetermined, size. Parity packets that contain the error-control bits are then added to each block. The number of parity packets and their construction determines the maximum number of data packets that can be recovered. One packet can be recovered from the block protected by a single vertical parity packet. To recover more packets in a block, more control data must be added. To create a block with two-packet recovery capability, the vertical and diagonal parity must be added to each block. The number of lost packets recovered and the marginal increase in a data rate must be considered in making the determination of the number of parity packets and their construction.

As an example, the transmission of image data over ATM networks using a method like subband coding[8] has now been performed. After the subbands are encoded by using some coding technique, they are packetized for the use in an ATM network. Since an ATM cell contains 53 octets, with 48 of these being data, the subband frame is broken into the appropriate number of 48 octet units for transmission.

The encoded data is packetized into ATM cells of 48 octets for transmission. Appropriate parity bits are computed and these are also grouped into ATM cells for transmission. In order to recover a single packet, a vertical parity cell must be added to each block of k cells. The vertical parity packet P_{pi} is generated by the following rule :

$$P_{\pi} = \left(\sum_{j=1}^{k} dji\right) \mathrm{mod}(2), i = 1, 2, ..., m$$

where dji is the i-th bit of the j-th packet and Ppi is the sum modulo 2 of the bits in the i-th column.

A method of recovering one lost packet is shown in Fig.3. If the vertical parity is formed as the bit by bit in each position, the vertical parity packet (Pp) can be determined as

$$Pp = D1 \oplus D2 \oplus D3 \oplus D4$$

such that

$$Ppj = d1j \oplus d2j \oplus d3j \oplus d4j \quad j = 1, 2, ..5$$

Therefore, if packet D3 is missing from a block, it can be recovered as :

$$D3 = Pp \oplus D1 \oplus D2 \oplus D4$$

When a block protected by a single vertical parity packet is received with two or more packets missing, none of those packets can be recovered.

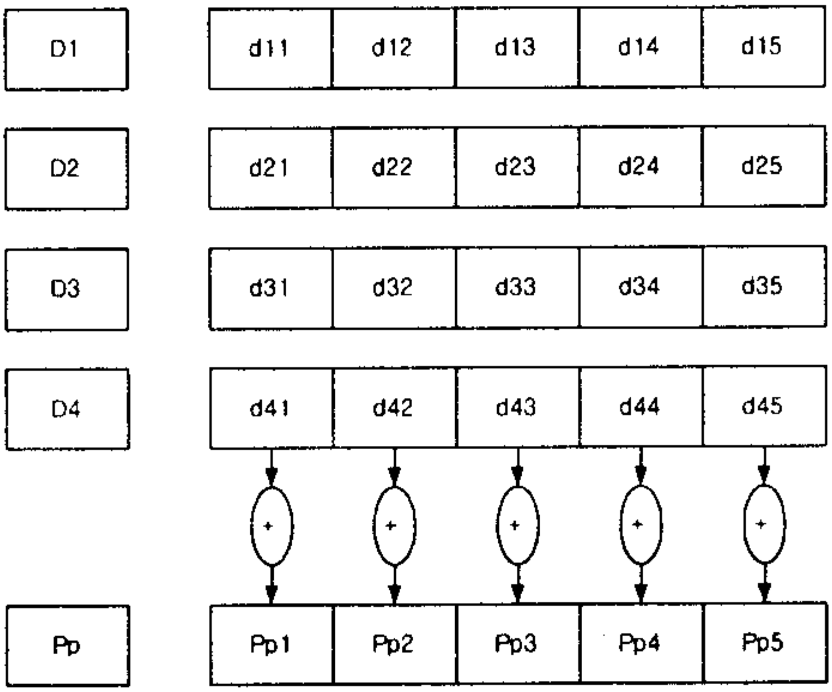

Fig. 3. Vertical Parity Formation Schematic

Ⅲ-Ⅱ. Multiple packet Recovery

In addition to the vertical parity, diagonal parity is formed as shown in Fig.4. To recover two packets in a block, a diagonal parity packet (the bits of which are the modulo-2 sums of bits along block diagonals) is also formed. The diagonal parity packet has m+k bits, compared to m bits in a data or vertical parity packet. One vertical parity cell with m bits and the diagonal cell with m + k bits are used by the receiver to recover two missing cells. The diagonal packet Pd in this case contains 9 elements. The diagonal parities are determined as follows :

$$Pd1 = d11, \; Pd2 = d12 \oplus d21$$
$$Pd3 = d13 \oplus d22 \oplus d31, \quad etc$$

In the paper, the error recovery system is incorporated into the ATM adaptation layer so that error recovery can be performed along the ATM network. The method is suitable for any type of ATM adaptation layer including, but not limited to AAL1 and AAL2. It is applicable either on an end-end basis or on a node to node basis.
In the following example, two missing packets are recovered. Packets 1 and 4 along with the vertical and diagonal parities are received and packets 2 and 3 are missing. The receiver reconstructs the two missing packets in a block by forming new parity packets based on the data received as follows. The new vertical and diagonal parities, Ppr and Pdr, are formed. By forming the modulo 2 sum of the received vertical parity Pp, the new parity Ppr, as well as the modulo 2 sum of the received diagonal parities Pd and the new parity Pdr, syndromes Sp and Sd are generated.

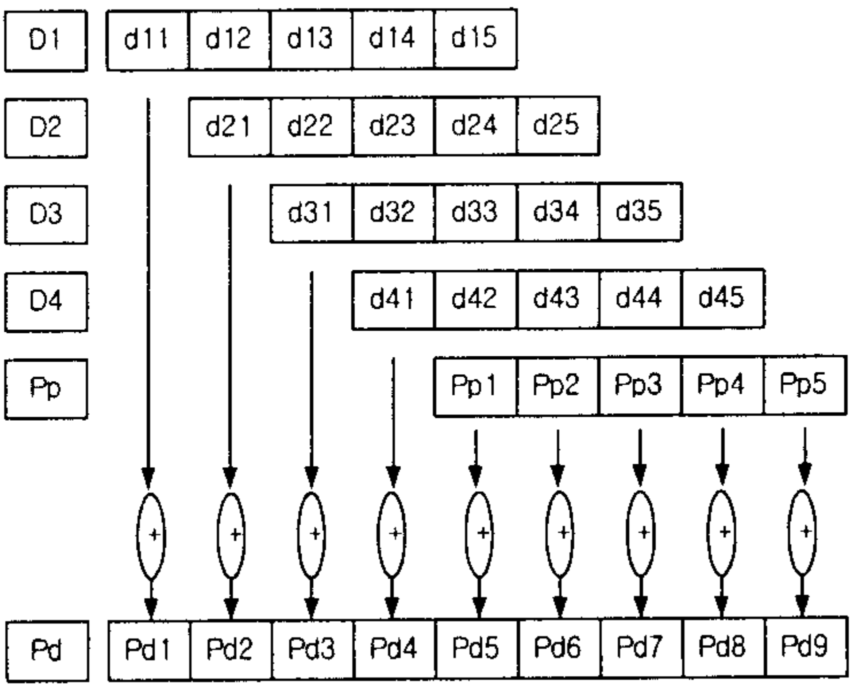

Fig. 4. Diagonal Parity Formation Schematic

The missing data is recovered as follows :

$$d21 = d12 \oplus Pd2,\ d31 = d21 \oplus Sp1$$
$$d22 = d31 \oplus Sd3,\ d32 = d22 \oplus Sp2$$
$$d23 = d32 \oplus Sd4,\ d33 = d23 \oplus Sp3$$
$$d24 = d33 \oplus Sd5,\ d34 = d24 \oplus Sp4$$
$$d25 = d34 \oplus Sd6,\ d35 = d25 \oplus Sp5$$

The recovery of any pair of missing packets can be done in a similar fashion. By using the vertical and diagonal parities, a maximum of two packets in a block can be recovered. To increase the packet recovering capability, parity packets are added which are linearly independent of the previously constructed parity packets. It is necessary to consider the number of lost packets recovered and the increase in the data rate as part of the process. This error recovery technique can be used in the general framework of ATM transmission. It can also be applied to other model of packetized transmission. In one embodiment, the user can segment the data into 44 octet blocks, form the parity and then send these to the ATM adaptation layer.

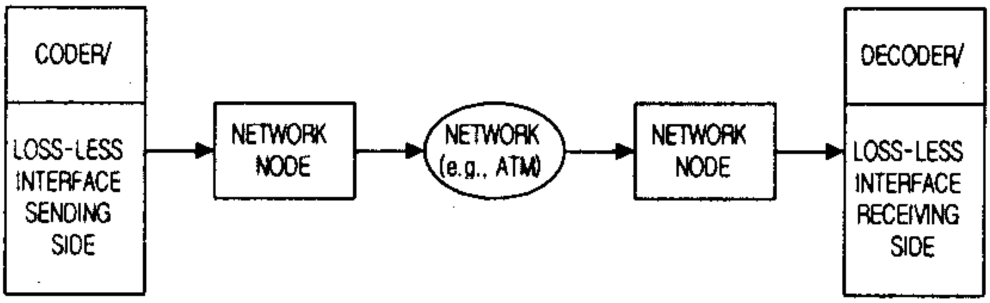

Fig. 5. Endpoint Recovery Diagram

The ATM adaptation layer will then form the cells and transmit them. In this embodiment, any error recovery is end to end only shown in Fig. 5. Alternatively, in another embodiment, the ATM adaptation layer will form the 44 octet blocks, add the 5 byte header to complete the cell. The advantage of this embodiment is that error recovery can be across links so that error accumulation is avoided. By suitably modifying the ATM functions, the facility of either including the error recovery scheme or inhibiting it can be added. The present technique can be used in a wireless environment for recovering missing data without having to request retransmission. It can also be used in digital speech quality or as a means of either improving the speech quality or as a means of accommodating more users without increasing the bandwidth if quality improvement is not required. The method of the technique can be included in a software application or VLSI chip form for ATM networks

Ⅳ. Comparision with the ITU-T recommendation

The ITU-T has a recommendation[9] to recover lost cells using forward error correction and interleaving. A(128, 124) Reed-Solomon code forms 4 bytes of parity for every 124 bytes of data. 47 such blocks are stored and the data is read out in ATM cells as indicated using interleaving. A lost cell means that we have to correct an erasure along one row. This can handle up to 4 lost cells in 128. Unlike the proposed method the ITU-T scheme handles both cell loss as well error cells with the same amount of overheads(about 3%). While our proposed needs a little extra bandwidth, the coding delay of 47 ATM cells is avoided, the decoding is also simpler requiring just modulo-2 operations.

Ⅴ. Simulations and Conclusion

The algorithm has been simulated on a SUN workstation using a 0.75 bpp encoding of 'Lena'[9] as the video data. The program can introduce random errors with a specified average data. We have used cell loss rates of 1 in 1000, 1 in 500, 1 in 250, 1 in 100 and 1 in 50. In all cases we could recover the lost data fully.

Fig. 6. 'Lena' (1 in 100 cell loss rate)

Fig. 7. 'Lena' after lost cells recovered

Fig.6 shows the decoded version of 'Lena' with a cell loss rate of 1 in 100. The fully recovered 'Lena' image data after applying the cell recovery algorithm appears in Fig. 7. The algorithm has also been tested with MPEG encoded video data. The data has been packed in ATM switch programmed to drop cells at specified rates. The switch output is passed on to another workstation running the cell loss recovery algorithm and the MPEG decoder. The algorithms have been only implemented in non-real time. Further work is needed to implement the algorithm on hardware to operate in real time.

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