Coding Scheme for Various Service Types in AAL2 of ATM-PON

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Abstract— **A coding scheme according to service types in AAL2 of ATM-PON are proposed in this paper. The service types and corresponding error correcting codes are indicated by two of six reserved bits in SSTED of AAL2. Several coding schemes such as BCH and convolutional codes are considered under various circumstances. As a result, (127,120) and (127,106) BCH codes may be the best choice among all the possible schemes for voice and data service, respectively.**

I. Introduction

THE voice-based service of subscriber terminal is changed to the data-based service due to the rapid development of communication and semiconductor technologies recently. And the growth of internet service accelerates the need of transmission with wideband information which provides multimedia services such as voice, data and image, etc. High speed and quality of subscriber network is required to accept these data-based traffic. Much cost is needed to construct completely new network satisfying these requirements.

So several new types of network which are combinations of subscriber line, coaxial cable and optic fiber are emerged these days. ATM-PON(asynchronous transfer mode-passive optical network) [1,2] is a new technology suitable for this requirement. AAL2 is the most appropriate type among the several AAL types to provide various multimedia services simultaneously in ATM-PON[3,4].

Use of ECC(error-correcting code) is desirable to provide these services more effectively. In general, the channel of ATM-PON are fairly good, but multimedia communication systems which should provide various types of high quality services may be seriously damaged by small number of errors. Therefore higher quality communications can be possible by using ECC on account of correcting the intermittent errors occurred during transmission [5,6]. ECC can be classified into two main catagories such as block or convolutional code. The latter is usually known to show better error performance than the former because encoding is done by the previous information bits as well as the present ones due to memory element.

The researches on error control in AAL2 are mainly focused on the CRC(cyclic redundancy check) code for just detecting errors up to now. And the coding schemes for various services are not presented. Therefore the proper coding scheme according to service types in AAL2 of ATM-PON is investigated and the error performance is analyzed in this paper.

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II. Discrimination of Service Type in AAL2 of ATM-PON

High speed multimedia services such as VOD(video-on-demand), HDTV(high-definition television), remote medical treatment, remote education and video conference, etc. should be provided in the future communication systems. ATM-PON is considered to be a proper choice for high speed subscriber network considering those services. AAL2 is known to be the most suitable one among several AAL types to provide various multimedia services through ATM-PON[3,4].

AAL2 is composed of two sublayers which are CPS(common part sublayer) and SSCS(service specific convergence sublayer). Constant and variable rate traffic can be transferred in AAL2. Especially low rate packets which are short and variable length can be transferred efficiently in delay sensitive applications. Although AAL1 can also support constant rate traffic, AAL2 can support rt-VBR(real time-variable bit rate) services more efficiently.

Data transmission which requires reliable communication should use SSCS which is possible to control errors occurred during transmission. SSCS is composed of three sublayers such as SSSAR(service specific segmentation and reassembly sublayer) in charge of actual segmentation and retransmission, SSTED(service specific transmission error detection sublayer) perceiving the errors of total frames and SSADT(service specific assured data transfer sublayer) which controls errors by retransmission. The SSTED-PDU(protocol data unit) is depicted in Fig. 1. CI is allocated for protecting congestion and CRC code of 32 bits are used for detecting bit errors. And LP of 1 bit is assigned for transparent transmission. Also 6 bits are reserved for future applications.

Two of six reserved bits in SSTED-PDU is proposed to be used to distinguish service types and the corresponding ECC in this paper. One bit is assigned for discriminating service types and the other bit for whether ECC is used or not. Service types are catagorized as voice and data in this paper.

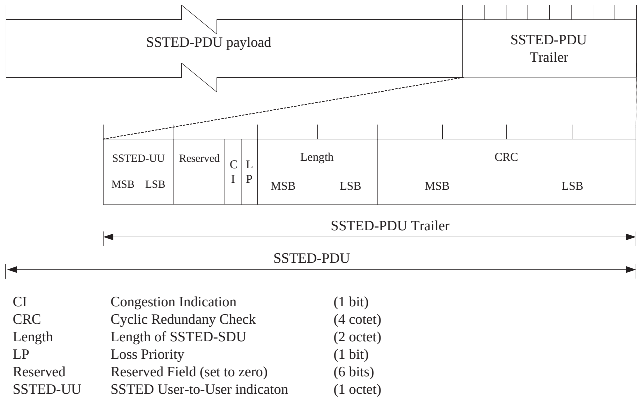

Fig. 1. Structure of SSTED-PDU.

TABLE I

REQUIRED ERROR RATE AND DELAY TIME OF VARIOUS SERVICE TYPES.

Type	Error rate	delay time(ms)
Voice	$\leq 10^{-3}$ or 10^{-4}	≤ 40
Data	$\leq 10^{-6}$ or 10^{-7}	≤ 100

The BER and delay time specification for these two types is shown in Table 1. The requirement of voice service which is very sensitive to delay and durable somewhat higher error rate may be set as BER below 10^{-3} or 10^{-4} and delay time within 40ms. The requirement of data services such as short message, electronic mail, tele-fax, remote control service, video telephony, tele-shopping and moving picture, etc. demanding high quality even though a little bit longer delay may be chosen as BER below 10^{-6} or 10^{-7} and delay time within 100ms.

A discrimination scheme using the two of six reserved bits is shown in Fig. 2.

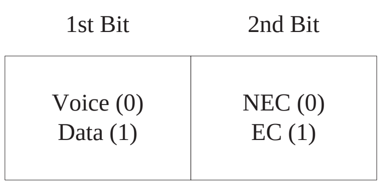

Fig. 2. Discrimination of service type.

Here, EC means ECC is adoped and NEC means that ECC is not adoped. The first bit is for discriminating service types and the second bit for whether ECC is used or not as shown in the figure. For example, 00 means voice service and ECC is not used. And 11 means data service and ECC is used.

III. CODING SCHEMES AND THEIR PERFORMANCE

Reliable communications are possible by using ECC which can correct errors occurred in the transmission channels. ECC is usually classified into two main catagories such as BC(block code) or CC(convolutional code). CC which has memory shows better error performance than BC in general because the previous information bits as well as the present one are used for encoding and decoding.

There are three widely used codes in BC. Hamming code which has single error correcting capability is the simplest one. And there is BCH(Bose-Chaudhuri-Hocquenghem) code that is characterized as linear and cyclic. Finally, there is RS(Reed-Solomon) code that is extension of BCH code to non-binary code showing good performance against burst errors.

It is expected that the errors caused by ATM-PON is mainly occurred by the noise of peripheral systems rather than the channel itself. So the dominant types of errors are expected to be random rather than bursty. Hamming code has only single error correcting capability and RS code has relatively complex structure even though it has strong capability to correct burst errors. Therefore BCH code which shows various error correcting capabilities and good error performance at random errors may be the best choice among block codes.

The length of payload in ATM-PON is 48 bytes or 384 bits. And it is desirable that the decoding for error correcting is completely finished within one ATM cell. The number of frames that can be accommodated in one ATM cell and the utility ratio of payload of ATM cell is represented according to the codeword length of BCH code in Table 2. If the length of codeword is 127, maximum of three frames can be used, which corresponds to 381 bits. In other words, only 3 bits are unused, so the utility ratio is 99.22%. Therefore, the codeword length of 127 may be the most appropriate one among various BCH codes in terms of utility ratio.

TABLE II

UTILITY RATIO OF PAYLOAD ACCORDING TO THE LENGTH OF CODEWORD OF BCH CODE.

Length of codeword	Acceptable number of frames	Number of used bit	Utility ratio
15	25	375	97.66%
31	12	372	96.88%
63	6	378	98.43%
127	3	381	99.22%

BER(bit error rate) of BCH code whose length of 127 is analyzed by both computer simulations and approximated equation. The decoding algorithm used for computer simulation is Berlekamp-Massey algorithm[7,8] which is widely used for BCH code. The approximated equation of BER is shown as follows[9,10].

$$P_B \approx \frac{1}{n} \sum_{j=t+1}^{n} j \binom{n}{j} p^j (1-p)^{n-j} \qquad (1)$$

where P_B means bit error probability, that is BER and n is the length of codeword. And p is channel symbol error probability of BSC(binary symmetric channel). And t is the number of correctable bits, that is, error correcting capability.

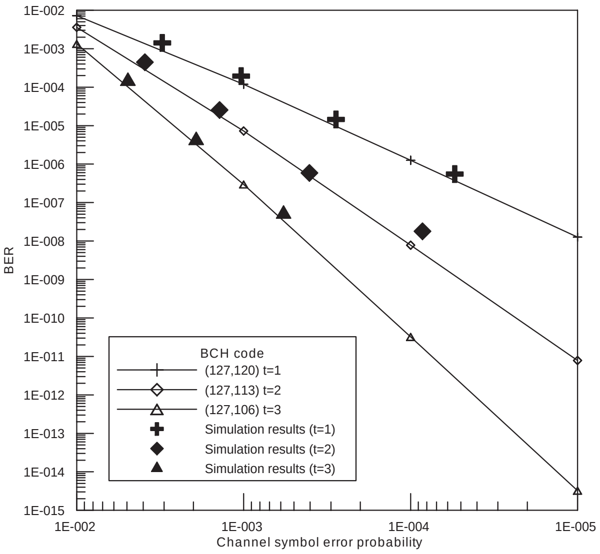

Fig. 3. BER of BCH codes whose length is 127.

The BER calculated by (1) and computer simulation is shown in Fig. 3. The horizontal axis represents channel symbol error probability before decoding and the vertical axis means BER after decoding in this figure. The solid lines are BER's obtained by (1) and the black points near the solid lines are the BER's by the computer simulations.

Single error correcting (127,120) BCH code shows BER of about 10^{-4} and double error correcting (127,113) BCH code shows about 10^{-5} and finally triple error correcting (127,106) BCH code shows about 2×10^{-7} when the channel symbol error probability is 10^{-3}.

BER calculated by the approximated equation and computer simulations shows almost the same performance as shown in the Fig. 3. Therefore, lower BER which is hard to obtain by the computer simulations may be estimated by the equation. For example, it is expected that BER of 10^{-10} or 10^{-11} may be obtained at channel symbol error probability of about 10^{-4} when (127,106) BCH code is used.

The results of the computer simulations are shown to analyze the performance of CC in Fig. 4 and 5. The decoding is done by the Viterbi algorithm[5,11]. The error performance of CC whose code rate is 1/2 with respect to the various number of memories, m is shown in Fig. 4. When the channel symbol error probability is about 4×10^{-2}, the BER's are about $10^{-4}, 10^{-5}, 10^{-6}, 10^{-7}$ when the number of encoder memories are 2, 4, 6, 8, respectively. And BER is decreased as the number of memories is increased.

Fig. 5 represents the error performance according to the code rate when the number of encoder memories is fixed to 8. BER of code rate of 1/2 is about 10^{-3} and that of 1/3 is about 10^{-7} when the channel symbol error probability is about 10^{-1}.

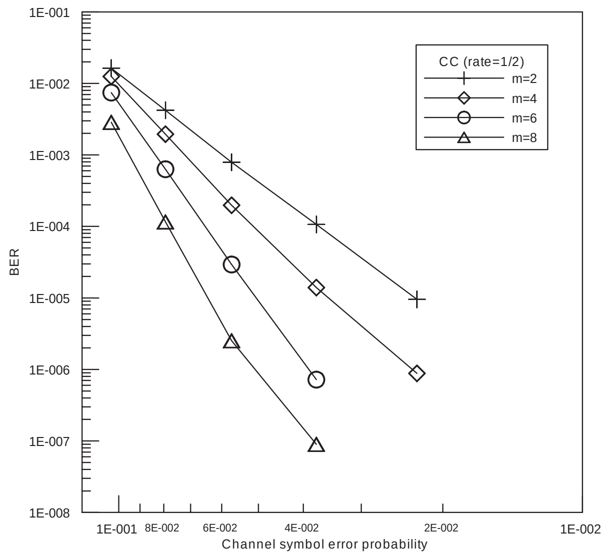

Fig. 4. BER of convolutional code whose code rate is 1/2.

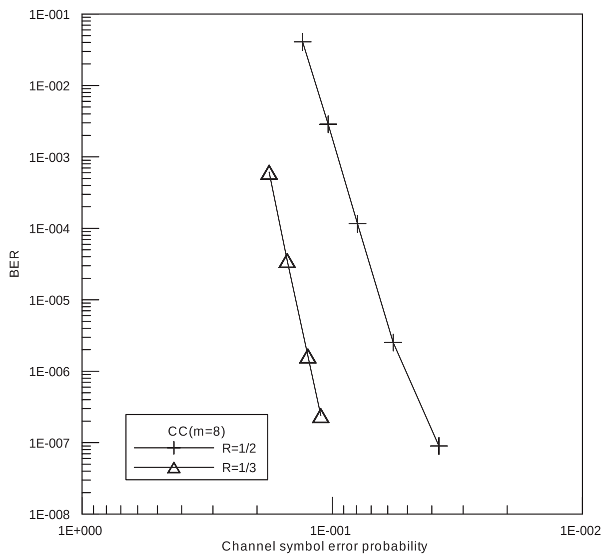

Fig. 5. BER of convolutional code whose number of memories is 8.

IV. Coding schemes for various service type in AAL2

Coding schemes of service types such as voice and data may be classified into two cases such as using the same or different coding schemes. When the same coding scheme is used, this can also be classifed into two cases like using CC or BC. If BC is used, the error correcting capability should be different according to the service types. There are two cases when using CC. Changing data rate while maintaining the same number of memories is the one, and keeping the constant data rate and changing the number of memory is the other.

TABLE III

Coding scheme of various service types.

	Same kind of coding scheme			Different kind of coding scheme
	Convolutional code	Convolutional code	BCH code	
Voice	Memory : 8 (Code rate : 1/2)	Code rate : 1/2 (Memory : 2)	(127,120)	Block code (127,120) BCH code
Data	Memory : 8 (Code rate : 1/3)	Code rate : 1/2 (Memory : 8)	(127,106)	Convolutional code (code rate : 1/2 memory : 8)

Several coding schemes according to the performance analysis of the preceding section are shown in Table 3. Code rata of 1/2 may be a proper choice for voice service and relatively low code rate of 1/3 is suitable for data service if the number of memory is fixed to 8 in the case that the same kind of coding scheme of CC is used. The required BER of Table 1 is satisfied for this case at channel symbol error probability of 10^{-1} in Fig. 5. And if the same code rate is used, it may be possible to change the number of memories as keeping the code rate of 1/2. When channel symbol error probability is about 4×10^{-2}, the BER's are about 10^{-4} and 10^{-7} if the number of memories are 2 and 8 respectively as shown in Fig. 4. So, if the service type is voice, the number of memories should be 2 and if it is data, it should be 8.

BCH code with the same codeword length and various error correcting capability is chosen as a proper block code in this paper. If the length of codeword is 127, single error correcting (127,120) BCH code is suitable for voice and triple error correcting (127,106) BCH code is for data service. The required condition is satisfied at channel symbol error probability of 10^{-3} in Fig. 3.

In general, CC shows better error performance than BCH code[5]. On the other hand, more storage elements are required and decoding is very complex. And the length of codeword is variable. On the contrary, BCH code is a cyclic code so it has similar structure as CRC code used for detecting errors in ATM cell and the decoding procedure of BCH code is very simple as compared to CC. Furthermore, the length of BCH code is fixed. So BCH code may be better choice than CC if the same code is used for error correction.

If different coding schemes are used, BCH code whose delay time is relatively short is suitable for voice service and CC for data service because CC shows better error performance than BCH code. In other words, (127,120) BCH code is adequate choice for voice service and CC whose number of memories is 8 and code rate of 1/2 is appropriate for data service.

Using the same coding scheme may be better choice than using different ones due to the complexity and conformity of the system with regard to all the cases mentioned above. Therefore, BCH code with the codeword lenth of 127 whose error correcting capability can be varied according to the service types may be the best choice.

The proposed coding scheme is summarized as shown in Table 4, considering the 2 bits for discrimination as described in section 2. For example, if the two bits are 01, it means that (127,120) BCH code is adopted for voice and if 11, (127,106) BCH code for data service.

TABLE IV

Characteristic of bit type.

Bit	Service	Error correction code
0 0	Voice	None
0 1	Voice	(127,120) BCH code
1 0	Data	None
1 1	Data	(127,106) BCH code

V. Conclusions

A scheme of discriminating service types and adoption of ECC using the two of six reserved bits in SSTED-PDU is proposed in this paper. One bit is assigned for discriminating the service types such as voice and data and the other bit for whether ECC is used or not. And the proper coding schemes are also proposed according to the service types. The coding schemes are classified into two main catagories such as using the same or different types.

First of all, the number of memories of 2 is suitable for voice and 8 for data service with the same coding scheme of CC if the code rate is fixed on 1/2. And if the number of memories are fixed at 8, the code rate of 1/2 is for voice and 1/3 for data service. And (127,120) BCH code is appropriate for voice and (127,106) BCH code for data service, if BCH code is used.

On the other hand, if the different coding schemes are used, BC which has no memory is suitable for voice and CC which shows a good error performance is appropriate for data service. That is, (127,120) BCH code and CC whose code rate of 1/2 and the number of memory of 8 is adequate for voice and data services, respectively.

Using the same coding scheme may be better choice than different ones because of the complexity and conformity of the system considering all the schemes proposed in this paper. So the BCH codes whose length of 127 are suitable in terms of utility ratio and various error correcting capability. Therefore, (127,120) BCH code may be the best choice for voice and (127,106) BCH code for data service.

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