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무선 ATM에서 터보코딩을 사용한 UEP

정회원 문 병 현 *

Unequal Error Protection for the Wireless ATM with Turbo Coding

Byung-Hyun Moon* ***Regular Member***

요 약

본 논문에서는 무선 ATM 환경에서 터보코딩을 이용한 UEP(Unequal Error Protection)을 제안한다. 일반적으로 ATM셀의 header부분은 payload부분보다 중요시되며 header 부분에 payload보다 부호율이 낮은 터보코드를 무선 ATM적용하여 비트오류확률과 셀손실 확률을 구하였다. 무선ATM 환경에서 터보코드를 사용하고 프레임길이 28바이트의 DLC 셀구조에서 UEP가 가능함을 보였다. 부호율 1/3인 터보 코딩을 이용한 경우 동일한 부호율의 컨벌루션 코드를 이용한 EEP(Equal Error Protection)과 비교하여 비트 오류확률과 셀 손실율에 있어서 최소 1 dB와 2dB 신호대잡음비의 개선을 보였다.

ABSTRACT

In this paper, an UEP(unequal error protection) is proposed for the wireless ATM by using a Turbo code. The header portion is considered more important than the payload. The BER(bit error rate) and CLR(cell loss rate) are obtained for a two level turbo code scheme with smaller code rate on the wireless header than the payload. It is shown that the UEP is possible for the framelength of 28 byte wireless ATM cell. Rate 1/3 turbo code obtained at least 1 and 2 dB performance gain in BER and CLR over the convolutional code with the same rate.

Ⅰ. Introduction

In recent years, wireless ATM has emerged as a solution for mobile multimedia by supporting ATM-based transport in a seamless manner [1]-[2]. Like the wired ATM networks, the Wireless ATM(WATM) is expected to support several different types of traffic stream such as data, voice, and video with different QOS requirements. Due to the effect of fading, multi-path and interference, the wireless link is characterized by a higher and variable error rate and fundamentally limited in bandwidth resource compared with fiber-based wired ATM. Such difference in error characteristics and bandwidth limitation leads to forward error control (FEC) and data link protocol using ARQ(automatic Repeat Request) for wireless ATM network in order to insulate the ATM network layer from wireless channel impairment.

In multimedia wireless ATM interface, the header and various payloads have different importance or error protection needs depending on source significance information(SSI). By using block codes, an UEP(unequal error protection) scheme having two different FEC codes for the header and payload for wireless ATM is proposed [3]-[4]. Also, an adaptive two-level UEP code

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* 대구대학교 정보통신공학부 무선통신연구실(bhmoon@taegu.ac.kr)
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scheme using PCC's(parallel concatenated codes) is proposed and analyzed for Gaussian and fading channel [5]. As shown in [5], the performance of CLR(Cell Loss Rate) of wireless ATM with punctured convolutional code shows that there is no performance gain for small signal-to-noise ratio. However, the turbo code provides sharp coding gain for small signal-to-noise ratio. This motivates the use of turbo code for the wireless ATM. In this paper, we propose a two level UEP code scheme using punctured turbo code for wireless ATM application. The bit error rate and cell loss ratio of the proposed scheme is evaluated and compared with EEP(equal error protection) of convolutional coding with rate 1/3. In section II, DLC(data link control) packet format for wireless ATM cell is given. In section III, the encoding and decoding of two rate turbo codes are given. In section IV, the simulation results for the proposed scheme is presented. Finally. conclusion is given in section V

Ⅱ. WIRELESS ATM CELL

The 8-bit header error check (HEC) is for detecting and an optional correcting a single bit error in the ATM cell header excluding ATM payload [6]. Cell header error control is important to prevent misrouting and minimize the cell loss due to cell header error which can lead to cell dropping or misrouting. One of the issues in wireless ATM is the 10 percent header overhead inherent in ATM. This overhead, if present in every ATM cell, causes a large degree of unnecessary inefficiency. In the media for which ATM is designed, bandwidth is abundant, and 10 percent overhead is not an issue. In the wireless medium, however, this is not tolerable. On the other hand, most of the time the header a mobile host utilizes is fixed or one of a few alternatives. Thus, the information content of a header can easily be represented with a smaller number of bits than the 5 bytes used in conventional ATM [7].

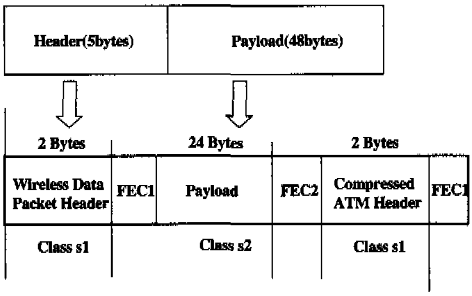

Fig. 1. DLC packet format of wireless ATM cell.

The data link control(DLC) packet format of wireless ATM cell is adapted from [5]. As shown in Fig. 1, the wireless ATM packets have 4 byte of header consists of 2 bytes of compressed ATM header and 2 bytes of wireless data link header. FEC1 represents the redundant parity bits of the code used in the header with code rate $R_{s1}=1/3$ and FEC2 represents the parity bits of the code used in the payload with code rate $R_{s1}=1/2$. In order to ensure a low loss rate and correct delivery, $R_{s1}=1/3$ is used for the header.

Ⅲ. ENCODING AND DECODING OF TWO RATE TURBO CODES

A. Turbo Encoding

A general diagram for the turbo encoder is given in Fig. 2. The turbo encoder is composed of two identical recursive systematic coder(RSC) encoders. The two encoders receives the same information bits, but the lower encoder receives the randomly interleaved information bits. However, in order to achieve the unequal error protection, the interleaver is no longer random.

The interleaver block is denoted by Π and its output is $\overline{m_i}$. The function Π specifies the interleaver according to

$$\overline{m}_{\Pi(i)} = m_i \tag{1}$$

where $i\in(0,\cdots,L-1)$ and L is the length of the input block length. The interleaving operation is the inverse of the interleaving operation and can be defined as

$$m_{\pi^{-1}}(i)=\overline{m_i} \qquad (2)$$

As shown in Fig. 2, $x_i^{(0)}$ is the systematic output of the turbo encoder. The parity outputs, $x_i^{(1)}$ and $x_i^{(2)}$ are obtained from the upper and lower RSC encoder's parity outputs corresponds to the input data bit m_i. The codeword $x=(x_0^{(0)},x_0^{(1)},x_0^{(2)},\cdots,x_{L-1}^{(0)},x_{L-1}^{(1)},x_{L-1}^{(2)})$ is obtained by multiplexing the three ouput from the turbo encoder. The overall rate of the code is 1/3.

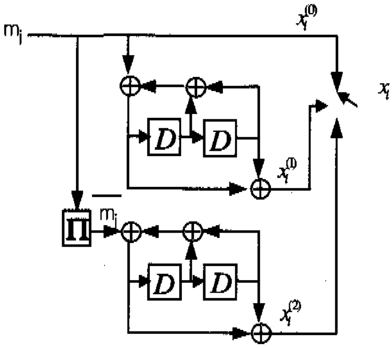

Fig. 2. Turbo encoder with rate 1/3

B. Rate Compatible Turbo Codes

The rate compatible punctured convolutional (RCPC) codes presented in [8] give different levels of protection to different blocks of data bits by utilizing the same structure of encoder and decoder.

As with the convolutional code, the rate can be increased by puncturing the codeword x in appropriately [9-10]. For example, a rate 1/2 turbo code can be obtained from the rate 1/3 turbo code using the following puncturing matrix

$$P=\begin{bmatrix}11\\10\\01\end{bmatrix} \qquad (3)$$

where bits that are transmitted are specified by a "1" and bits are punctured are specified by a "0". In this paper, the rate 1/3 turbo code is considered. If the rate is less than 1/3, the redundancy produced by the FEC is very severe for wireless ATM application. If the rate is 1/2, there are no redundancy is present to give error protection when parity bits are punctured to obtain higher rate turbo code.

2 Bytes Wireless Data Packet Header	**24 Bytes Payload**	**2 Bytes Compressed ATM Header**

Fig. 3. Block structure for two level UEP turbo codes.

C. Data Frame And Interleaver Structure For The Two Level Uep

In order to obtain UEP, more puncture is needed on the redundant symbols corresponding to less important input symbols and less puncture on the symbols corresponding to more important input symbols. However, UEP cannot be achieved by puncturing alone. If the information symbols corresponding to different error protection are spread over the input data frame $m=(m_0,\cdots,m_{L-1})$, the performance of the turbo code is close to that of an equal error protection. Therefore, UEP is achieved by choosing the appropriate interleaver according to the support set [9] . In this paper, the input data block structure is chosen as shown in Fig. 3. Since the information at the beginning and at the end of a information block is better protected, the 2 bytes of wireless header is placed in front of the data frame and 2 bytes of compressed header is placed at the data frame, 24 bytes of the payload are placed in the middle of the data frame [10].

The encoder input frame m as shown in Fig. 1 is partitioned into 2 classes s_1 and s_2 of size K_1(=4bytes) and K_2(=24bytes). It is assumed that the class s_1 where the header information is located is more important than the class s_2. Thus, the 4 bytes header information is positioned in class s_1 and the 24 bytes payload is in class s_2. As explained in [9], we need a permutation Π that maps support set onto the same set of positions in the interleaved frame. The permuted position of the class s_1 stays in the class s_1 and

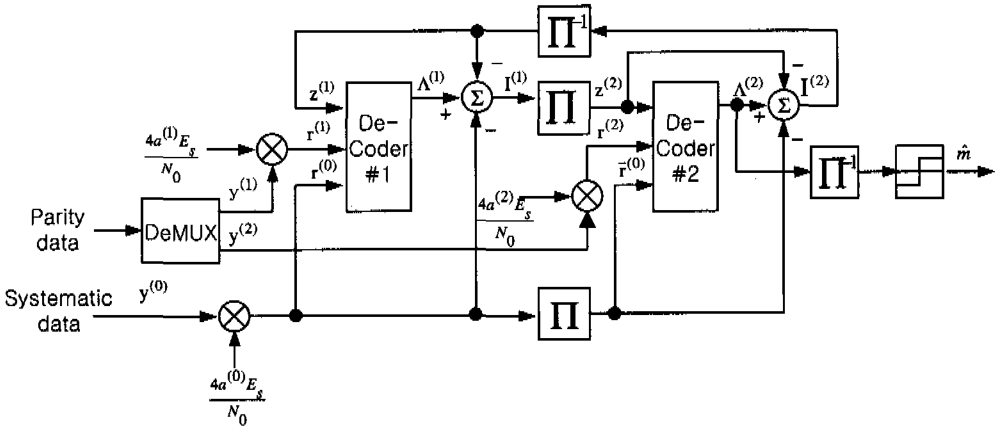

Fig. 4. Turbo decoder schematic.

the same applies to the class s_2. In the simulations, a new random interleaver is generated for each simulation frame.

D. Turbo Decoding

The problem of decoding turbo codes involves the joint estimation of the two Markov processes, one for each constituent code. Turbo decoding proceeds by independently estimating the individual Markov processes. Since the two Markov processes are driven by the same data, the estimate can be improved by sharing the information between the two decoders in an iterative fashion. The output of one decoder is used as a priori information by the other decoder. The soft-bit decisions made by the individual decoders are represented as log-likelihood ratios (LLRs) of the form shown in Eq. (4)

$$\Lambda_i = \ln\frac{P[m_i=1|y]}{P[m_i=0|y]} \tag{4}$$

where y is the received sequence. The log-likelihood at the output of a SISO(soft input soft output) decoder can be factored into the three terms [11]

$$\Lambda_i = \frac{4a_i^{(s)}}{N_0}y_i^{(s)} + z_i + l_i \tag{5}$$

where the terms $y_i^{(s)}$ and z_i represent systematic channel observation and information derived by the other decoder. And, the term l_i is called the extrinsic information.

The schematic for a standard turbo decoder is shown in Fig. 4. The decoder #1 receives the systematic channel obeservation $r^{(0)}$, the first encoder's parity bits $r^{(1)}$ and a priori information $z^{(1)}$ from the decoder #2. The decoder #2 receives the interleaved systematic channel observation $\overline{r}^{(0)}$, the second encoder's parity bits $r^{(2)}$ and the interleaved extrinsic information from the decoder #1. The decoder #2 produces LLR $\Lambda^{(2)}$ and the extrinsic information $I^{(2)}$. The interleaved extrinsic information is used as the prior information for the decoder #1. After a certain iterations, the estimate of the message $\hat{m}$ is found by deinterleaving and hard-limiting the output of the decoder #2's LLR. If the puncture is used in the decoder, the decoder will not have the complete set of observations of the corresponding encoder's parity bits. In this case, the receiver will assume the value of the punctured parity bits as zero. [11]

Ⅳ. SIMULATION RESULTS

In this section, the performance of a UEP with turbo coding for a given rate and a given block structure is compared with that of convolutional code. The block length of 28 bytes for the wireless ATM application is considered. Since the 4 byte header information uses rate 1/3 turbo encoding and the 24 bytes of payload uses 1/2 turbo encoding, the overall rate

$$\rho = \frac{28}{\frac{4}{1/3} + \frac{24}{1/2}} = 0.5833$$

is used.

The constituents encoders used in the simulations are shown in Fig. 2 and have rate 1/3 systematic recursive convolutional encoders with generators [7,5] in octal notation. There are two level of error protection and the positions of the data bits are shown in Fig. 3. In the simulations, the encoded parity bits for payload are punctured alternatively between the two parity bit stream to get the desired code rate of 1/2. The interleaver is randomly chosen for each block of simulated frames. Thus, the bit error rate (BER) result can be regarded as an average performance over the ensemble of interleavers.

The decoding algorithm used in this study is the logmap algorithm. Decoding is implemented by the iterative decoding with 5 iterations. A small number of iteration is chosen to reduce the latency of iterative decoding. It is known that the performance improves little as the number of iteration is greater than 7. In order to terminate the program, 100 frame error are encountered. The channel is assumed to be AWGN channel with two sided power spectral density of $N_0/2$.

In order to compare the performance of UEP with turbo code to that of EEP with convolutional code, the BER and CLR of wireless ATM with convolutional coding are calculated and plotted. The rate 1/3 convolutional code is generated by generators [7,5] in octal notation with constraint length of 3. If a convolutional code with the minimum free distance d_f is used, the probability of a cell loss is given by

$$P_{CL} = 1 - (1 - P_b)^{32} \qquad (6)$$

where P_b is the bit error probability for BPSK modulation scheme with soft decision decoding. And, it is upper bounded by

$$P_b \leq \sum_{d=d_{free}}^{\infty} \beta_d P(d) \qquad (7)$$

where $\beta_d = a_d f(d)$ and a_d denotes the number of paths of distance d from the all zero path of the Viterbi trellis and $f(d)$ denotes the exponent of N as a function of d. $P(d)$ is the probability that the wrong path at distance d is selected [14].

As shown in Fig. 5, the bit error probability of the two level turbo code is compared with that of convolutional code. To achieve an BER of 10^{-3}, E_b/N_0 of 2 dB and 2.5 dB are required for the header information and payload information, respectively. It is shown that the two level unequal error protection is possible by using Turbo coding for wireless ATM application with a DLC cell block length of 28 bytes. The bit error rate of the turbo code with rate 1/3 obtained at least 1dB gain over the convolutional code.

The performance of CLR for the turbo code obtained at least 2dB gain over the convolutional

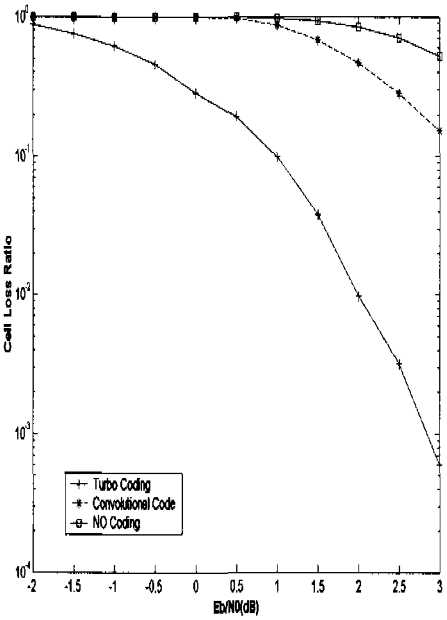

Fig. 5. Cell loss rate of the proposed scheme.

code with the same rate In Fig. 6, the cell loss ratio of the proposed scheme is compared with that of a rate 1/3 conventional code. In the proposed scheme, the cell loss is occurred when at least one bit error is included in the payload whereas the conventional ATM cell is lost when more than 2 bit errors occur. As shown in Fig. 6, The cell loss rate of 10^{-3} is obtained when $E_b/N_0 = 3\text{dB}$. However, the cell error rate of about 0.1 is achieved for the case of a convolutional coding for the same E_b/N_0. The performance of CLR for the turbo code obtained at least 2dB gain over the convolutional code with the same rate.

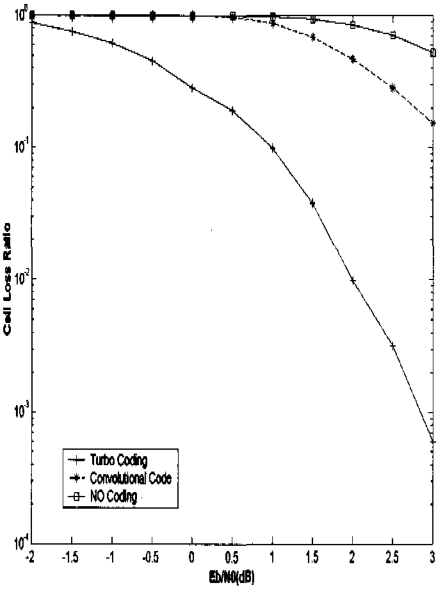

Fig. 6. Cell loss rate of the proposed scheme.

The DLC layer should provide an appropriate error control mechanism to protect against the poor physical level characteristics of the wireless medium. The unsuccessful error recovery mechanism at DLC will require transport level error detection and retransmission of the erroneous cell. By using UEP with turbo coding on the wireless ATM application, the rate of misrouting of the wireless ATM cells will be reduced for small signal-to-noise ratios compare to the one with convolutional code

V. CONCLUSION

In this paper, the two level UEP with turbo coding for wireless ATM application is proposed. Since the header information is considered more important than the payload, the header is encoded with a rate of 1/3 and the payload is encoded with a rate of 1/2 turbo encoder. It is shown that the UEP can be achieved by using turbo code for a short frame length of 28 bytes by appropriately choosing the data frame structure that segregates by the importance of the class and by choosing the corresponding interleaver that guarantees the class invariance. The bit error rate of the turbo code with rate 1/3 obtained at least 1dB gain over the convolutional code. The performance CLR for the turbo code obtained at least 2 dB gain over the same code rate convolutional code.

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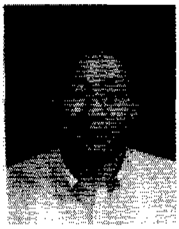
문 병 현(Byung-hyun Moon) 정회원



1985년 6월 : Southern Illinois University 전자공학 학사
1987년 6월 : University of Illinois(Urbana-Champaign) 전자공학 석사
1990년 12월: SMU 전자공학 박사
1991년 9월 ~ 현재 대구대학교 정보통신공학과 부교수
<주관심 분야> 이동통신공학, 통신이론, 부호이론