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A LDPC Coding Scheme for Improving the Satellite ATM Links Performance

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Abstract

Satellite ATM networks is a new-type broadband satellite communication networks and plays an important role in the global communication networks. However, a major problem encountered for using satellite links to transport ATM cells is the high bit-error ratio of satellite links, which severely impact the application of ATM over satellite. Therefore, in order to achieve a fiber-like quality on the satellite links, forward-error-correction codes are important for ATM cells. Considering the error characteristic of satellite links and ATM cell format, a novel LDPC coding scheme that four standard ATM cells being encoded as a whole is presented, which can achieve good performance and do not require to modifying standard ATM protocol. This scheme also makes use of the unequal error protection property of irregular LDPC codes, suitable for stressing protection to ATM cell header. Experiments show that the scheme proposed can distinctly improve bit-error ratio of satellite links and achieve good coding gain.

1. Introduction

Satellite Asynchronous transfer mode (SATM) networks is a new-type broadband satellite communication networks and plays an important role in the global communication networks. However, a major problem encountered for using satellite links to transport ATM cells is the high bit-error ratio of satellite links, which severely impact the application of ATM over satellite. Since ATM, the basic switching and multiplexing mechanism for broadband integrated services digital network (B-ISDN), has been proposed for highly reliable links (fiber links) with very low bit-error ratio (BER). In contrast with fiber links, satellite links are energy limited and relatively unreliable due to subjecting to a large number of random and burst channel errors[1,2]. Therefore, in order to achieve a fiber-like quality on the satellite links, forward-error-correction codes are important for ATM cells.

Low density parity check （LDPC） codes, originally proposed by Gallager in 1962 and rediscovered by MacKay in 1993, are linear block codes with a sparse parity-check matrix that can be conveniently described through a graph commonly called Tanner graph. Such a graphical representation facilitates a decoding algorithm known as the belief propagation (BP) iterative decoding algorithm. The sparse matrix plus BP decoding algorithm makes LDPC codes achieve astonishing error-correcting performance of approaching the Shannon limit. LDPC codes are viewed as serious competitors to other powerful error correcting codes and have been adopted as a forward-error-correction (FEC) standard by many communication systems. LDPC codes are also suitable for application on the SATM links, since irregular LDPC codes have intrinsic unequal error protection (UEP) property[3] and can give emphasis protection to cells header.

In this paper, we propose a LDPC coding scheme instead of the popular concatenated RS and convolutional codes[2] in the satellite ATM communication systems. The paper is organized as follows. In section two，the property of LDPC codes is given. Section three describes an efficient LDPC-FEC coding scheme for SATM. Finally, we give simulation results and conclude the paper.

2. The Property of LDPC Codes

The excellent near Shannon limit performance of LDPC codes mostly depends on its randomly created sparse parity-check matrix. Due to the characteristic of sparseness and random, LDPC codes take on a important inherent property — self-interleaving, which

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implicates using LDPC codes as FEC codes do not bring additional time-delay and complexity due to using interleaver/deinterleaver.

In addition, LDPC codes have another intrinsic property — different degree bit nodes have different UEP. As we known, the degrees of irregular LDPC codes' bit nodes are different. For explaining our design scheme, it is good to provide some insight how irregular LDPC codes have UEP property for different bits. It is known that it is best to have high degrees for bit nodes due to the error protection ability of bit nodes is improved with the degree's increasing. This is because in the process of iterative decoding, the more information a variable node receives from its adjacent check nodes, the more accurately it can judge about its correct value, so the errors of high degree variable nodes are corrected faster than low degree ones, which leads to the UEP property of irregular LDPC codes. Those bit nodes with highest degree are named as 'elite' bits.

3. LDPC-FEC Coding Scheme

A broadband satellite ATM communication system composes of satellite and earth stations, shown in Fig.1. At the originating earth station, the ATM cells are extracted and encapsulated into cell packets for routing, then encoded by LDPC code and modulated for uplink transmission. At the destination earth station, received downlink data are demodulated and decoded, ATM cells are recovered. The space segment is the on-board processor, consisting of an ATM switch and LDPC encoder/decoder and modulation/demodulation and so on.

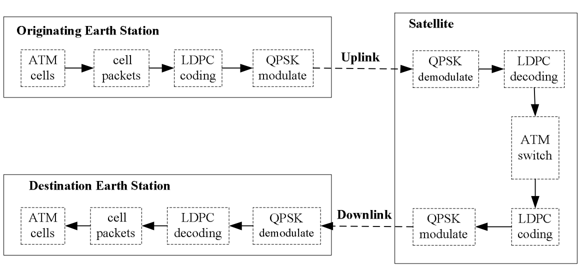

Fig.1. Satellite ATM networks with LDPC-FEC

To provide fiber-like BER while keeping earth station and space segment costs to a minimum, a high performance coding scheme is required. For the uplink, where relatively high EIRP can be provided by the earth station, then higher code rates such as R=4/5 or even higher are appropriate to maximize information rate and provide adequate coding gain, but at the cost of more Eb/N0. For the downlink, due to limited available transmit power, then lower code rates provide more coding gain, the R=1/2 codes are appropriate, or perhaps even lower. In selecting the final code parameters the implementation complexity must be evaluated relative to the desired data rate and error correction capability.

Since LDPC codes are block codes with selectable block length, the actual block size employed depends on the packet size used. Considering several factors, such as the characteristic of channel and delivery delay of ATM cells over links and the performance of LDPC codes, a small number of cells are encoded as a packet and then framed. As a recommend, four standard ATM cells constitute a packet as information bits of LDPC code being encoded, code rate R=4/5 uplink frame format and code rate R=1/2 downlink frame format are shown in Fig.2 and Fig.3.

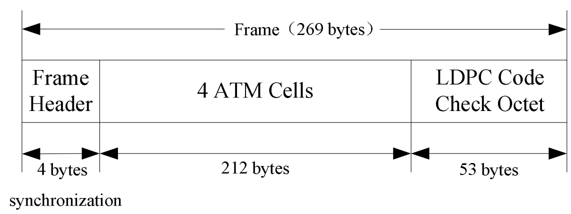

Fig.2. Uplink Frame Format

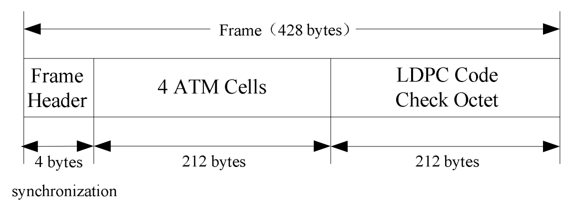

Fig.3. Downlink Frame Format

The standard ATM cell consists of a 5-byte header and a 48-byte information field. Since the cell header carries the information necessary for routing the cell to its destination and any errors in the header will result in discarding the cell, therefore, protecting the integrity of the cell header is very important. Taking advantage of UEP property of irregular LDPC codes, map cell header bits to higher degree elite bits of irregular LDPC code, so as to cell header gets a higher protection level. In order to achieving low complexity encoding and mapping between cell header and elite bits, a simple subclass of LDPC codes — extended irregular repeat-accumulate (eIRA) codes[4] are selected as UEP-LDPC-FEC codes over satellite ATM, progressive-edge- growth (PEG) arithmetic[5] is used to distribution degree of nodes.

4. Simulation

The channel model used in the analysis of the satellite channel is the additive white Gaussian noise (AWGN) channel model. Uplink frame and downlink frame are simulated. Degree distribution of nodes is similar to reference[4]. The simulation result is shown in Fig.4, comparing with the conventional scheme of the concatenated code with a （2,1,7）convolutional inner code and a（244, 212）RS outer code[2], proposed LDPC coding scheme can provide much better performance, a 10^{-6} BER can be achieved with only $E_b/N_0 \approx 1.6$dB which is about 1 dB less than the conventional concatenated code scheme. For higher code rate, LDPC code scheme can also provide good performance. Besides, the proposed scheme does not need an interleaver/deinterleaver, which can reduce not only the complexity of on-board processing but also the delay of encoding/decoding.

5. Conclusion

A novel LDPC coding scheme of four standard ATM cells being encoded as a whole for improving the satellite ATM links is proposed, which can achieve good performance and do not require to modifying standard ATM protocol. This scheme also makes use of the UEP property of irregular LDPC codes, suitable for stressing protection to ATM cell header. Experiments show that the scheme proposed can distinctly improve BER of satellite ATM links and achieve good coding gain.

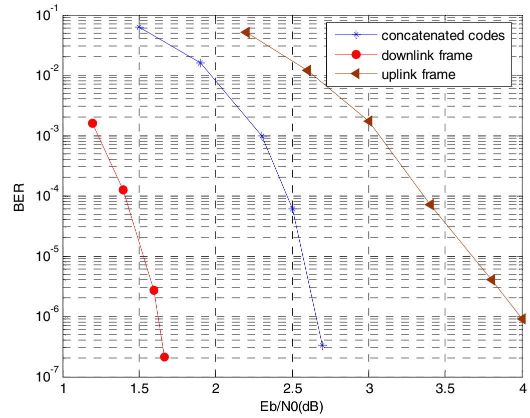

Fig.4 Performance of uplink frame and downlink frame

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