EVALUATION OF FLDPC CODING SCHEME FOR ADAPTIVE CODING IN AERONAUTICAL TELEMETRY

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ABSTRACT

The aeronautical telemeter channel is characterized by Multipath interference, Doppler shift and rapid changes in channel behavior. In addition to transmission error during aeronautical telemeter, transmission losing also exists. In this paper, we investigate the correction of transmission error and processing of telemetry transmission losing, and propose an adaptive coding scheme, which organic combines Fountain code and low density parity check (LDPC) code. We call it fountain LDPC (FLDPC) coding. In the coding scheme, The LDPC code is explored to perform transmission error correction, while, the problem of transmission losing is resorted to fountain code. So FLDPC is robust for transmission losing and transmission error. Moreover, without knowing any of these the channel information, FLDPC can adapt the data link and avoid the interference through adjusting the transmission rate. Experimental results illustrated that a signification improvement in transmission reliability and transmitting efficiency can be achieved by using the FLDPC coding.

KEY WORDS

LPDC, FLDPC, FOUNTAIN CODING, RATELESS

1. INTRODUCTION

The aeronautical telemeter channel provides communication between aircrafts and ground stations. However, it also presents severe challenges for communication with high reliability and high speed.

(1) **Multi-path interference**: due to surrounding buildings when aircraft taxiing, take-off and landing [1], and reception scenarios in low elevation angle [2], the multi-path interference may lead to distortion of communication signals and telemetry link outrages [1-2].

(2) **Doppler spread**: as high relative speed between aircraft and ground station when take-off and landing, the Doppler frequency shift is 600Hz in general case [1], and up to 1.2kHz when severe case.

(3) **Time-varying characteristics of channel**: as fading, severe interference and distortion, the aeronautical telemetry wireless communication channel tend to time-varying characteristics, and lead to loss of data packages [3].

So the telemetry channel is characterized by Multipath interference, Doppler shift and rapid changes in channel behavior. In addition to transmission error during aeronautical telemeter, transmission losing also exists. These challenges and uncertain factors lead to transmission error and transmission losing when we conduct flight test of aircraft. For the challenges and problems, many researchers present different schedules and methods to improve the telemetry communication performance. For example, Turbo [4], LDPC coding [5], serial concatenated convolutional code [6] and other forward error correction coding are presented to correct transmission error data. However, these methods mainly focus on the correction of transmission errors. Few research works focus on the processing of data packet transmission lost. As a matter of fact, wireless transmission losing is one of main outrage of the communication link.

In this paper, we investigate the correction of telemetry data and processing method of the telemetry data packet missing, and propose an adaptive coding scheme, which organic combines Fountain code and low density parity check (LDPC) code. We call it fountain LDPC (FLDPC) coding and show the framework of FLDPC coding. In the coding scheme, The LDPC code is explored to perform error correction, while, the problem of data packet missing is resorted to fountain code, which is rate less erasure correcting coding. So FLDPC is robust for data packet missing and data error. Moreover, without knowing the channel information, FLDPC can adapt the data link and avoid the interference through adjusting the transmission rate. We make technical contributions as follows.

1). Different other research works, we not only consider the transmission error problem, but also we take the transmission losing into account, and propose an adaptive coding scheme called FLDPC, which can overcome the problem of transmission error and losing.

2). For the transmission losing problem, in the FLDPC scheme, we utilized Fountain code to realize adaptive transmission strategy, so as to transmission efficiency.

3). For the transmission error problem, we consider the processing of random error and burst error. Different from Raptor codes, we utilized interleaver to transform burst error into random error. Then we employ LDPC to correct transmission random error, so as to improve transmission reliability of telemetry.

4). During the evaluation stage, we first perform modeling the dynamic aeronautical radio telemetry channel, which gets multiple path, Doppler shift, transmission error and losing characteristics. Then we evaluate the performance of FLDCP coding in term of average bit error rates (BER) and average transmitting efficiency.

We organize the structure of this paper as follows: Section 2 introduces the system framework, modeling and detail components. In section 3, we conduct performance evaluation of FLDPC coding in different kinds of channel. Section 4 provides concluding remarks.

2. SYSTEM FRAMEWORK AND MODELING

A. Framework of system

A system framework for evaluation platform is illustrated in Figure 1. It is composed of a transmitter, a wireless communication channel, and a receiver. The transmitter includes a binary data source, a FEC encoder, and a modulator. The receiver consists of a demodulator, a FEC decoder, and a binary data destination.

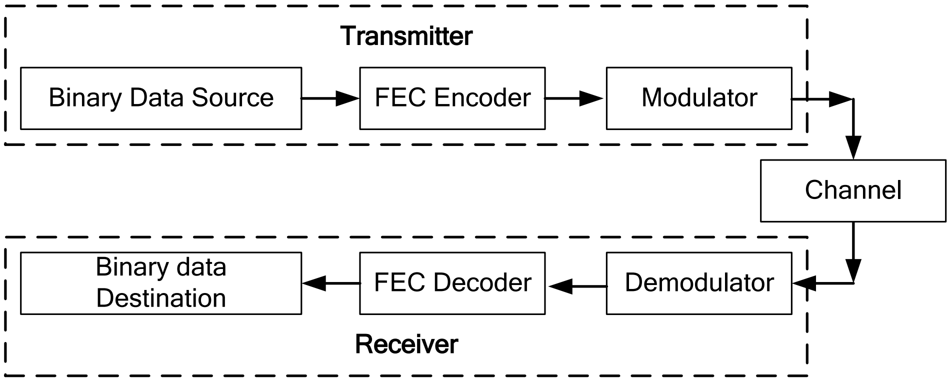

Figure 1. Framework of system

Coding: In Figure 1, the FEC encoder and FEC decoder can be arbitrary coding scheme. In this paper, the FEC encoder is FLDPC scheme, which combines fountain coding and LDPC organically.

Modulation: The modulator and demodulator can be BPSK, QPSK or SOQPSK. As we do not focus on modulation, so we adopt BPSK in this system.

Channel: To make close to real aeronautical telemetry channel environment, the channel is modeled with multi-path, time variance and Doppler frequency shift.

B. FLDPC encoder

The scheme of FLDPC encoder is illustrated in Figure 2. Firstly, telemetry data set is divided into data symbols with the same length. Secondly, we conduct LDPC encoding on each data symbol, and get coded symbols. In this step, we adopt Gaussian elimination encoder algorithm. Thirdly, to convert the burst error to random error, we utilize interleaver to change the sequential number of coded symbols. Fourthly, we apply the LT encoder to interleave symbols, and get the coded frames. And finally, we submit the coded frames to receiver via aeronautical telemetry channels [7].

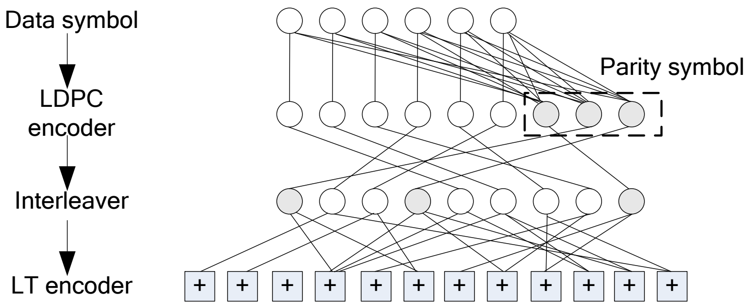

Figure 2. Illustration FLDPC encoder

1) LDPC encoder

We adopt the Gaussian elimination method to obtain a generator matrix G, and then using formula (1) to generate coded bits C from information vector I.

$$C = I.G \tag{1}$$

The code rate can be 1/2，2/3, 3/4 and 4/5. The length of the information vector I takes the value of 512.

2) Interleaver

To improve error correction performance, we utilize interleaving to transform burst error into random error. In our paper, we adopt the block interleaver to permute LDPC coded symbols according to corresponding specific mapping. And in the receiver, we need to use the corresponding delinterleaver to map symbols to natural sequence. It should be noted that other kinds of interleaver/deinterleaver pairs can also be adopted in FLDPC coding.

3) LT encoder

The LT encoder is composed three steps:

Firstly, we determine the degree d of an encoding symbol. The degree is selected randomly from a given node degree distribution $p(d)$. We utilize robust Soliton distribution [7].

$$p(d)=\frac{\rho(d)+\tau(d)}{\sum_{d}(\rho(d)+\tau(d))} \tag{2}$$

$$\rho(d)=\begin{cases} 1/K & d=1 \\ 1/d(d-1) & d=2,3,...K \end{cases} \tag{3}$$

$$\tau(d)=\begin{cases} c.\ln(K/\delta)/\sqrt{K}d & d=1,2,...(\sqrt{K}/(c\ln(k/\delta)-1) \\ (c.\ln(K/\delta)\sqrt{K}/K)\log(c.\ln(K/\delta)/\sqrt{K}) & d=\sqrt{K}/(c\ln(k/\delta) \\ 0 & d>\sqrt{K}/(c\ln(k/\delta) \end{cases} \tag{4}$$

Where $\rho(d)$ is the Ideal Soliton distribution.

Secondly, Choose d distinct interleaved LDPC coded symbols uniformly at random. And used as neighbors of the encoding symbol.

Lastly, the LT coded symbol is obtain through XOR operation between encoding symbol and its neighbors symbols.

C. Channel

To evaluate the performance of FLDPC coding, we consider different channel environments, including binary erasure channel (BEC), additional white Gaussian noise channel, fading channel and mixture channel.

1) Binary Erasure Channel (BEC)

The erasure channel is a memory less channels, where symbols are either transmitted perfectly or erased. Suppose the transmission symbols are $x(t)$, and the received symbols are $y(t)$, for a given erasure probability p, the conditional probability of the channel can be expressed as follows [7] .

$$p(y(t)\,|\,x(t))=\begin{cases} 1-p & y(t)=x(t) \\ p & y(t)=? \\ 0 & otherwise \end{cases} \tag{5}$$

2) Additional White Gaussian Noise (AWGN)

In AWGN channel, white Gaussian noise is added to the transmission signal which passes through it. And the noise obeys Gaussian distribution. So the probability density function of noise r can be presented as follows.

$$p(r)=\frac{1}{\sqrt{2\pi}\sigma}\exp(-\frac{(r-u)^2}{2\sigma^2}) \tag{6}$$

Where, u is mean value of r, and σ is standard deviation of r.

3) Fading Channel

In fading channel, the received signal is distorted by multipath propagation and Doppler frequency shift due to high speed between aircraft and ground station. And the received signal $y(t)$ through fading channel can be represented as set of samples at the input to the channel.

$$y(t)=\sum_{n=1}^{N} g_i x(t-T_i) e^{j2\pi(f_o+f_{di})t} \tag{7}$$

Where g_i is the ith path gain, T_i is delay of the ith path, f_o is frequency offset, and f_{di} is the Doppler frequency shift of ith path.

4) Mixture Channel

We consider the transmission error and transmission losing in aeronautical telemeter channel, and model it as a mixture channel of binary erasure, additional white Gaussian noise and fading channel. And it can be present as follows.

$$p(y(t)\,|\,x(t))=\begin{cases} 1-p & y(t)=\sum_{n=1}^{N} g_i x(t-T_i) e^{j2\pi(f_o+f_{di})t}+randn(\mu,\sigma) \\ p & y(t)=? \\ 0 & otherwise \end{cases} \tag{8}$$

C. FLDPC decoder

The scheme of FLDPC decoder is shown in Figure 3. Firstly, the received frame is decoded by LT decoder, if the coded frame is losing during wireless telemetry transmission, more coded frames are needed. Then the decoded symbols are de-interleaved accordingly, and are sent to the LDPC decoder. Thirdly, belief propagation (BP) decoding algorithm is utilized to improve performance. And finally we get the estimation result of telemetry data set.

Figure 3. Illustration of FLDPC Decoder

3. Performance evaluation

A. Experiment setup

We validate and evaluate the performance of FLDPC coding scheme proposed in this paper, and compared with other related coding schemes. And finally we draw conclusions based on analysis and discussion.

We consider the performance of FLDPC in term of transmission efficiency and transmission reliability.

Transmission Efficiency: For a given data set, we adopt redundancy rate as metric to measure transmission efficiency, i.e. we measure the redundancy rate RR of coding when we could recover all the information symbols rightly as follows:

$$RR = l\_total / l\_\inf or \tag{9}$$

Where, l_total is the length of total coded symbols used to recover all the information symbols, including coded symbols, repeated transmission coded symbols. $l\_inf\, or$ is the length of information symbols, which is to transmit in aeronautical telemetry channel. The lower value of RR is, the higher transmission efficiency is.

Transmission Reliability: We evaluate the transmission reliability in term of bit error rate (BER).

B. Performance evaluation in binary erasure channel (BEC)

We evaluate the erasure performance of FLDPC coding in binary erasure channel, and compare with LT, LDPC coding. The parameter setting is given in Table 1. We conduct LT, LDPC and FLDPC coding in BEC. And transmission performance is illustrated in Figure 4 and Figure 5 in term of Redundancy rate and bit error rate, respectively.

Table 1: Parameters setting for evaluation in BEC

Parameters	Erasure rate	K	N	c	δ	r_mid	r
values	0.1: 0.1:0.5	512	1024	0.2	0.3	1.062	2

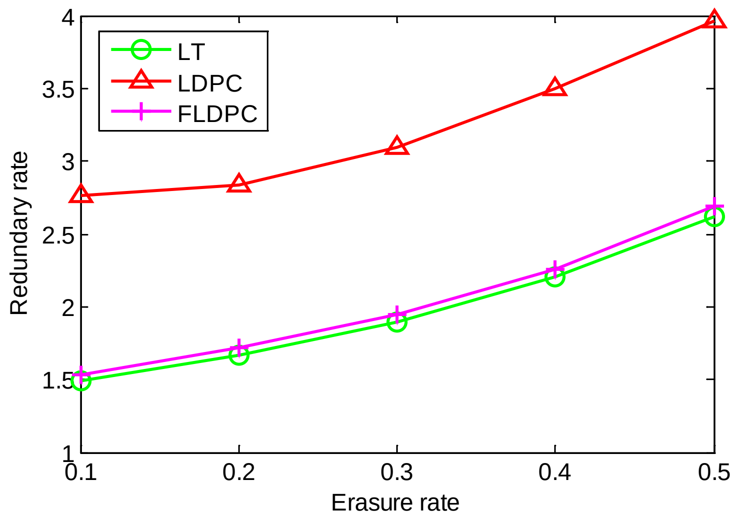

Figure 4. Redundancy rate of different coding scheme in BER

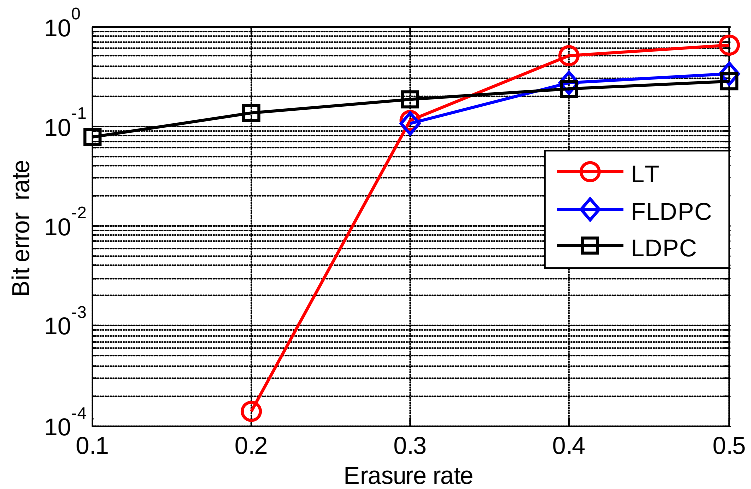

Figure 5. Bite error rate of different coding scheme in BER

Figure 4 illustrates that the redundancy rate of FLDPC and LT coding changes in the same way with the increment of erasure rate. And it is much lower than that of LDPC coding. That is because FLDPC could transmission through adapting the channel. So the transmission efficiency of FLDPC coding is very high.

Figure 5 indicates that the FLDPC coding has higher transmission reliability than the other two coding schemes. With the increment of binary erasure rate, the bit error rate is the lowest in the three coding scheme. That's mainly due to FLDPC coding could correct transmission and processing transmission losing. So it could get higher transmission performance.

C. Performance evaluation in mixture channel

The mixture channel combines BEC, Additional White Gaussian noise and fading channel. So transmission error and transmission losing will coexist in mixture channel. The three coding schemes are adopted in mixture channel, and the parameters setting is shown in table 3. The error correction performance is shown in figure 6.

Table 3：Parameters setting for evaluation in Gaussian and fading channel

Parameters	Erasure rate	SNR	K	N	c	δ	r_mid	r
values	0.1	1:5:51	128	1024	0.2	0.3	1.062	2

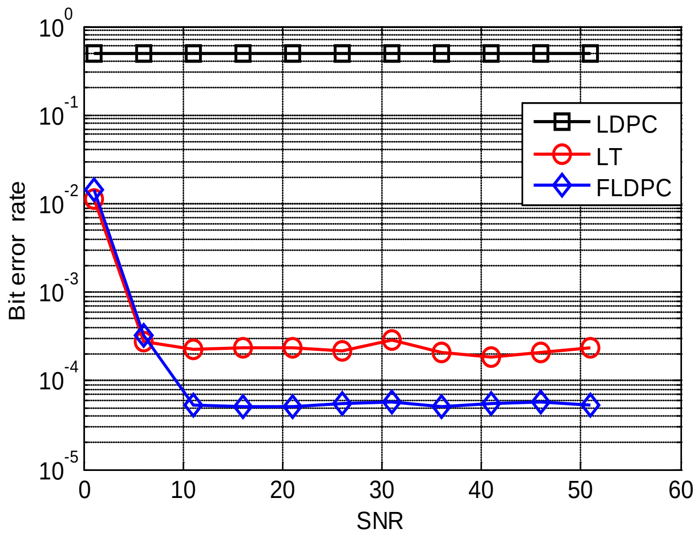

Figure 6. Bite error rate of different coding schemes in mixture Channel

Figure 6 indicates that the transmission error correction and transmission losing erasure performance of FLDPC outperform that of the other coding schemes in mixture channel. In the mixture channel, as the transmission losing and transmission error exist, so the performance of LDPC and LT coding is quite lower. That's mainly due to they cannot process effectively the problem of transmission losing and transmission error, respectively. While, FLDPC coding scheme utilizes LT and LDPC to correction transmission error and process transmission losing, respectively. So it obtains higher communication performance in mixture channel.

D. Discussion

The degree distribution plays an important role in the performance of FLDPC coding. So appropriate degree distribution should be evaluated and determined for aeronautical telemetering environment.

Except for LT, FLDPC coding, Raptor coding is another practical coding scheme in the binary erasure channel. The performance comparison should be conducted to determine more effective coding in aeronautical telemetering channel.

4. Conclusion

For the problem of transmission losing and transmission error in aeronautical telemetry environment, we present a coding scheme called FLDPC. During the evaluation stage, we evaluate erasure recovery and error correction performance of FLDPC through a communication test bed. The experimental result illustrated the validation and feasibility of FLDPC coding scheme in complexity aeronautical telemetry channel. To improve transmission efficiency and credibility, adaptive coding and modulation technique with FLDPC will be our next research works.

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