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ANALYSIS AND SIMULATION BASED ON 5G CHANNEL CODING TECHNOLOGY

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Abstract. In wireless communication systems, the noise and electromagnetic interference in the channel can have a significant impact on the transmitted signal. The introduction of channel coding techniques is a very effective way to reduce the bit-error-rate (BER). As mobile communication has entered the 5G era, the data traffic has increased significantly compared to 4G, and as the modulation steps increase, the BER will increase, which makes the importance of channel coding even more significant. In China Mobile's 5G technology, channel coding is usually performed by LDPC (Low Density Parity Check Code), and the application of channel coding technology in China Mobile's 5G technology and how to improve the coding rate will be discussed.

Keywords: 5G channel coding, BER, LDPC.

Introduction

5G is a new generation of wireless mobile communication network that is currently being vigorously studied by China Mobile, and the 100-megabit data transmission will bring unprecedented pressure to the entire network. The reason why channel coding technology is introduced in the digital communication system is that the noise in the channel interferes with the transmission signal and the error code often appears in the received signal. In an environment of extremely high growth of transmitted data, how to ensure a very low bit error rate will be a new challenge for 5G networks. Channel coding is a way to effectively control the BER using forward error correction by adding redundancy to the transmit signal while eliminating these redundant codes in the signal receiver using a decoder. These redundant codes enhance the confidence level of the signal and minimize other effects on the signal such as noise, thus reducing the BER. In the 1960s, LDPC codes, low-density parity-check codes, were first proposed by Dr. Gallager, but limited by the technical conditions at that time, there was a lack of feasible decoding algorithms until the 1990s, when a breakthrough was made based on Turbo codes.

LDPC code, which borrows the circular iteration mechanism from Turbo code, is a linear code generated from a recursive convolutional encoder that uses an iterative decoding process to decode the received information. The recursive convolutional encoder is a group code that converts bits of information into 1 group length, and each group code containing transmitted information can be decoded into the original information. In an iterative receiver, the decoder usually shows the probability of receiving a digital signal "1" or "0", and the probability of receiving a signal can increase with the number of iterations. The iterative receiver is composed of two identical decoders, each of which can also use the result of the other to produce a more accurate signal probability, which is the whole process of iterative decoding. In the channel coding parallel system, the transmitter side usually consists of two encoders and mixers, while the receiver side consists of two decoders and interleavers, and the two structures complement each other В In the encoder part, China Mobile 5G [1–5] system uses convolutional codes for coding, and this paper will also explore LDPC recursive system convolution. This convolutional code can correct transmission errors by adding redundant codes to the transmit information, while helping the decoder to improve the trustworthiness of the received signal. Therefore, adding convolutional codes in communication systems is to convert the transmitted bits into a longer set of strings, and the reason why longer information is used to transmit is to correct the effect of channel noise on the transmitted information. Finally, the final received signal is obtained through the signal "trustworthiness" after several iterations, and when the number of iterations increases, the false bit rate decreases, thus completing the whole channel coding process.

Introduction of LDPC coding technology

LDPC codes, which are mapped from message sequences into sending sequences, code word sequences, by passing a generation matrix *G*. For the generation matrix G , there exists a fully equivalent parity check matrix ugly, and all the code word sequences V constitute the zero space of H, the number of non-zero elements in each row and column of the $H \cdot V = 0$ check matrix twins is very small, which is the reason why LDPC codes are called low density codes. The message to be sent is mapped into a transmit sequence by a specific checksum matrix and decoded in the decoder using the circular iteration principle, and the log-likelihood ratio of the channel output y with respect to the transmitted bits a is calculated as equation (1) below, where L_c – channel confidence.

$$A_c(a) = \lg \frac{p(y \mid a=0)}{p(y \mid a=1)} = L_c y. \tag{6}$$

Figure 1 shows the channel coding schematic, which is widely utilized in existing communication systems. In order to show the channel coding system more systematically and concretely, this paper proposes to use QPSK debugging as the debugging signal, the encoder will utilize LDPC convolutional codes, the interleaver is the most common hybrid coding; the receiver is the corresponding QPSK demodulator, and the de-interleaver. The interleaver and the deinterleaver have opposite functions, in order to disrupt the order of the transmitted bits and thus reduce the adjacent bit interference to a lower level. The channel noise is the most common Gaussian white noise.

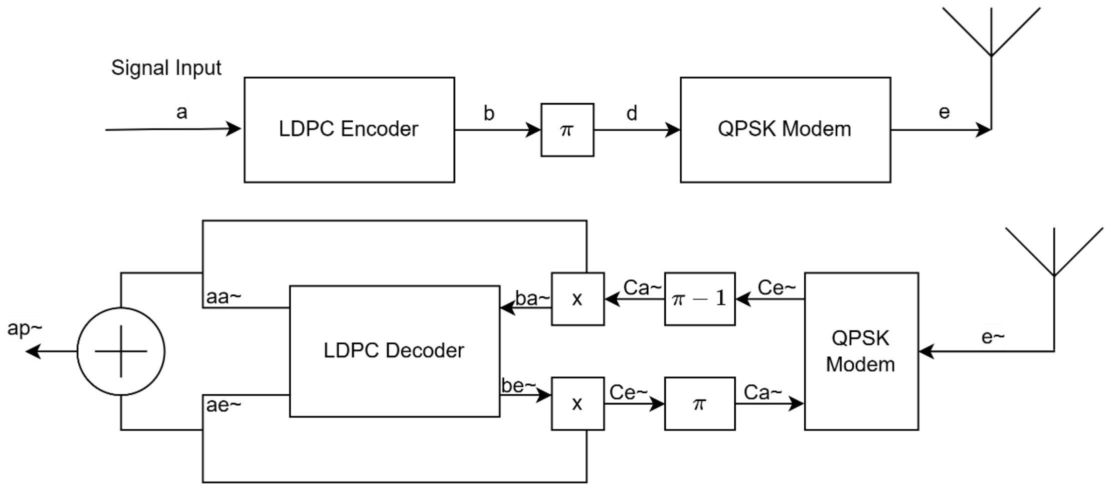

Figure 2. Schematic diagram of LDPC recursive convolutional coding system

LDPC-Conv codes can be regarded as a generalization of LDPC codes in the time domain, which can provide a certain degree of coding gain. The decoding algorithm of LDPC-Conv codes is also based on a probabilistic transfer algorithm. Specifically, the decoding algorithm of LDPC-Conv codes can be regarded as a convolutional version of LDPC codes, and its decoding algorithm is similar to that of LDPC codes, which is also an iterative algorithm based on message passing.

The iterative algorithm is a computational method that approximates the solution to a problem systematically through a series of repeated computations. It is an algorithm that decomposes a problem into small subproblems, solves each subproblem individually, and combines the solutions of the subproblems to obtain a solution to the original problem. Iterative algorithms are particularly suitable for situations where the problem is too complex to be solved by analytical methods, or where an exact solution is not available. In such cases, iterative algorithms provide a useful approximation to the solution.

The transmitted bits pass through the convolutional encoder and the interleaver in the transmitter, respectively, and then modulated into the channel, this time the transmitted information is a coded QPSK signal with Gaussian white noise; at the receiver side, the demodulator will generate a possibility of receiving the information (as "1" or "0"), and the received signal will be iterated between the interleaver and the decoder demodulator. Through the iterative algorithm, each demodulation signal C_e is based on the received signal $\hat{e}$ as well as the previous received signal C_a. When several iterations are completed, the system can judge by itself whether the current $ap\sim$ is the best output and the output result is not after optimization, then $ap\sim$ is the last received signal, so the final received signal will be the result after several iterations of error correction. In the LDPC channel coding system, iterative decoding will be used for both decoder and demodulator. In each iterative decoding process, the accuracy of output bits will increase with the end of each iteration process, and after several iterations, the system can output the best result. The number of iterations can be determined by the parameters of the system noise and the signal-to-noise ratio (SNR). The channel coding system with iterative decoding can approach the theoretical limit of the Shannon capability, which is the main reason for introducing the channel coding technique.

The top line shows the theoretical bit error rate plot for the QPSK system, i.e., the system without channel coding, and the middle and bottom lines show the bit error rate plots for the LDPC channel coding technique after 1 iteration and 8 iterations, respectively.

Simulation of cyclic iterative coding

In the above discussion, the LDPC decoder is a buffered decoder, and only one data can be processed in each iteration, because the decoder or demodulator cannot work at the same time, and the demodulator or decoder needs to wait for the data from the other side during the loop iteration, so there is always an "idle" part in the whole system. The purpose of bufferless decoder is to eliminate this idle state, so that the decoder and demodulator can work at the same time and get the received signal faster.

The decoder can work at any time as long as the receiver is working. The use of cacheless decoders will greatly improve the decoding efficiency, and it has been found through extensive experiments that cacheless decoders can use fewer iterations to complete demodulation than conventional demodulators for the same channel, due to the fact that the decoding process and demodulation process are carried out simultaneously, so that the best results can be achieved earlier.

The comparison of the simulation results in Figure 2 shows that the cacheless decoder stops working after two iterations, while the regular decoder performs eight iterations and obtains essentially the same results.

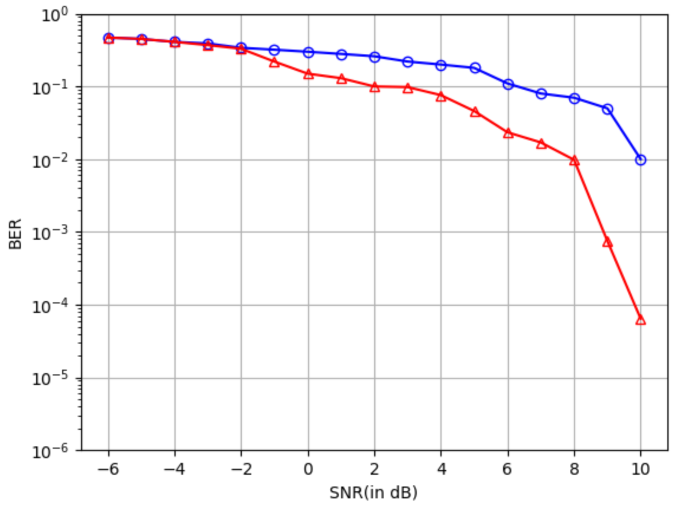

Figure 3. Comparison of the simulation results of LDP C cacheless decoders and cacheless decoders:
Red – cacheless decoders; Blue – cacheless decoders

Conclusion

The introduction of channel coding is effective in reducing the false bit rate in the context of the increasingly aggressive electromagnetic environment and the large capacity transmission of 5G by China Mobile. LDPC's loop iterative coding can be effectively applied to 5G communication networks. According to the BER graphs obtained for different number of iterations, the lower iteration system requires higher SNR for the same FER, while the higher iteration system has lower BER for the same SNR. However, when the number of iterations is increased to a certain number, the BER of the system does not decrease indefinitely, because the system is already close to the Shannon Limit Theory. In the decoder part, the conventional decoder can be optimized to a cacheless decoder, which can obtain almost the same result faster under the same conditions, greatly improving the efficiency of channel coding, and will have a profound impact on the future development of 5G channel coding.

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