Research on Communication Coding of Ultra High Speed Fiber Transmission

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Abstract: In ultra-long-haul, high-capacity optical fiber communication systems, there are factors such as fiber loss, dispersion, and nonlinear effects, which greatly degrade system performance. Forward Error Correction (FEC) is the key technology to solve these problems. At present, the FEC code used in the fiber system has a fixed code rate, and the channel state change is not considered. The system throughput is restricted by the worst channel state, and it is difficult to ensure the optimal transmission efficiency of the network. This paper applies a Fountain code with no fixed rate to a fiber optic system.

1. Introduction

The study of communication is a technical issue from the source of a message to the entire process of information destination. Information is one of the three basic elements of the objective world, juxtaposed with matter and energy. Information is generated by sources and always exists in a specific form, which can be speech, images, text, etc. Information is what is delivered through the communication system. The basic characteristic of any source that produces information, that is, its output is described by a probability parameter, that is, the output of the source is indeterminate, otherwise there is no need to transmit information. The communication process first uses a transducer to transform the output of the source into a suitably transmitted signal in the form of electrical coding, electromagnetic coding, optical coding, such as a camera turning an image signal into an electrical signal. The electrical signal is then transformed by the transmitter into a form suitable for transmission by a physical channel or other transmission medium, which typically achieves the matching of the information signal to the channel by a so-called modulation process. A channel is a physical medium used to transmit signals from a transmitter to a receiver, such as the atmosphere (free space), wires, fiber optic cables, and wireless microwaves. Regardless of the medium used, the transmitted signal is damaged in a random manner by various possible factors, causing deterioration of signal quality, that is, noise. Noise can be generally classified into additive noise and non-additive noise. For example, additive noise generated by receiver front-end amplifiers or other user interference on the channel and non-additive noise generated by multipath fading of wireless communication, which causes the amplitude of the signal itself to change with time. Both additive and non-additive signal distortions are random and are often described using statistical parameters. The effects of these signal distortions must be carefully considered when designing a communication system. In the communication system design simulation, the mathematical model of the signal distortion generated on the physical channel established from the perspective of statistical analysis is also used, and the statistical description used by the model should be as close as possible to the actual, such model simulation will have significance. The receiver recovers the information signal contained in the received signal. If the message signal is transmitted by carrier modulation, the receiver must extract the message from the sinusoidal carrier by carrier demodulation. The demodulated information signal usually deteriorates due to the influence of noise in the channel.

2. LT code encoding and decoding principle

The Fountain code concept, the fountain code, was introduced in the 1990s to generate an

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infinite stream of output symbols based on finite input symbols, making it ideal for transmitting information over computer networks and broadcast channels. As the name suggests, the digital fountain code is like a fountain (encoder), which can continuously rush water droplets (output information), each of which has equal information value. Therefore, the receiving end only needs to fill the water cup (decoder) with a sufficient number of water drops to meet the requirements (decoding success). The practical application of the Fountain code must be conditional on the fast encoding and decoding algorithm, and the decoder can recover the original data from a subset of any output symbols with high probability. The size of the subset is close to the optimal value, that is, the size of the input data K. . In 2002, the LT code was proposed, which is approximating for various deleting channels with different erasure probabilities. The coding and decoding method is simple, and the decoding overhead and coding complexity are relatively small, which is the first true meaning. Variable rate fountain code on. Digital fountain code is an ideal solution for large-scale data distribution and reliable broadcast application characteristics. It can generate unlimited output symbols and flexible rate control on the line, so it is called codeless code. In theory, the original file information can generate an infinite output symbol stream containing input information dispersed in each code packet by a specific coding strategy by means of fountain code technology, and the data receiving end can receive the data packet from one or more servers once After receiving enough encoded data packets, the receiving end can decode and reconstruct the original file information without knowing which server the received data packet comes from, specifically what data packet. The price paid is only that the number of encoded packets required for decoding is increased compared to the original number of information units, but a certain design can make a good compromise between overhead and performance. The main application areas of fountain code are high-speed large file transmission in wide area network, international Internet and satellite network, second, providing quality streaming on-demand or broadcast in wireless network and mobile network, and third in 3G mobile network and digital. Television broadcast networks, telecommunications multicast networks, and satellite broadcast systems provide reliable data broadcasts that do not require a feedback channel.

According to the above analysis, we can know that the fountain code can generate an infinite output symbol stream through the exclusive OR of a number of randomly selected input symbols. In this way, the input information is dispersed in each code package, and only need to receive more subsequent information units if the original information is to be restored, without feedback retransmission. The price paid is that the number of encoded packets required for decoding is increased compared to the original number of information units, but it is possible to make a good compromise between overhead and performance through some design. Assume that the coding cost of the fountain code is the parameter ε, defined as $\varepsilon=m/k-1$, ie $m=k(1+\varepsilon)$, and m is slightly larger than the number of k. With this encoding method, if k raw data packets generate an arbitrary number of encoded packets, the receiver can successfully recover all the original data by decoding with a high probability by receiving any of the m encoded packets. From the above analysis, it is known that there are two problems to be paid in designing the fountain code: First, the decoding overhead ε should be minimized, so that we can accept the decoding with as few coding packets as possible, thereby improving the decoding efficiency; secondly, The complexity of the encoding and decoding algorithm should be minimized to make the encoding process as fast as possible.

3. Fountain code advantages

The digital fountain scheme has obvious advantages in data broadcasting: First, the fountain code is a forward error correction coding, and the communication of the encoded code does not require feedback or retransmission at the receiving end, and the receiving end of the digital fountain solution only needs to receive a sufficient amount. The encoded information can be successfully decoded to recover the data, reducing the information processing and transmission time, and avoiding the feedback explosion problem in the broadcast application. Second, the fountain code design has nothing to do with the channel model. In an ideal state, the amount of computation required to generate each code packet is a constant that is independent of the number of packets, and the amount of computation required for successful decoding of the original packet only has linear compilation. The code complexity is very adaptable to complex channel conditions, and the utilization of channel capacity is high, which is beneficial to the simplification and software design of the transceiver codec. Third, the fountain code has a non-fixed code rate characteristic. Not only can any user flexibly determine the length of the received data according to his own receiving condition, the system does not need to affect other users due to the receiving quality of individual users, and thus has a higher heterogeneous user. Good support. Fourth, the fountain code adopts a random coding method, and the coding packets are generated independently of each other and may constitute a very large set, and the probability of repetition between the encoded packets is low, thereby eliminating the efficiency caused by the user receiving the repeated packets. Reduced, thus facilitating applications such as layered multicast and parallel downloads. Based on the digital fountain scheme, the huge technical advantage of large-volume broadcast application, the digital fountain company was established shortly after its introduction to push it to practical application, and it quickly attracted the attention of some scholars, institutions and units. Data distribution and broadcast applications are also gaining more and more support and adoption. Today, with its strong technical appeal and application potential, the digital fountain solution has moved from wired to wireless and is being promoted to more and more applications.

4. LT code encoding code principle

In 002, Luby presented the fountain code LT code with real practical value for the first time in his conference paper “LT codes”. The encoding algorithm of the LT code is simpler. It defines a relationship diagram between the connected source signal and the encoded signal, called the Tanner graph, as shown in Figure 2-1. According to the Tanner diagram, we can understand the relationship between the coded signal and the source signal, and then introduce the coding method. In the figure, u is the source signal and c is the coded signal. The specific coding algorithm of the LT code is as follows:

First, we need to design the degree distribution of the LT code, which indicates the degree of correlation between the coded symbols and the source symbols. 2. Determine the degree of distribution di according to the designed degree distribution ρ(d), and randomly select it in the source signal u. Di different source signals are used as associated symbols of the output symbol ci; 3. di associated symbols are XORed to obtain an encoded signal ci;

Repeat steps 2-3 so that the source signal continuously generates different degrees of worthwhile coded signals, thus establishing a linear relationship between them. The selection of the degree distribution of the LT code is randomly independent, and the selection of the source signal according to the degree is also random and independent, so that the coding symbols of all the outputs of the LT code are independent. Theoretically, the number of times each source signal is associated with the coded symbol can be infinitely repeated, and the number of coded packets is also not fixed, so that the corresponding transmission code rate is also not fixed, so the LT code has a bit error rate. characteristic. From the above analysis, it can be seen that the number and mode of the coding combination of the LT code are directly related to the design of the degree distribution function. The good degree distribution makes the coding more reasonable, which also affects the performance of the decoding performance.

After the encoded signal is transmitted to the receiving end, the source information can be decoded and restored by a code number slightly larger than its own number.

Since the LT code is a new type of code for LDPC-like codes, the decoding method is largely similar. The decoding algorithm of the LDPC code is mainly based on the Tanner graph (MP) massage passing algorithm. The LDPC code proposer Gallager proposed two decoding algorithms based on information transfer, namely the hard decision algorithm of tree decoding and the soft decision algorithm of probability decoding. In the probability decoding algorithm, he also proposed the idea of soft input soft output iterative decoding. In the MP algorithm of infinite order quantization and continuity, it becomes the belief propagation algorithm (BP). The BP algorithm has low decoding complexity and excellent performance. It can be proved that when there is no ring in the Tanner graph, the belief propagation algorithm is equivalent to maximum likelihood decoding and has the best decoding performance. Therefore, this is one of the important differences between LDPC codes and traditional linear block codes and one of the reasons for their good performance. The BP algorithm is based on the probability decoding algorithm proposed by Gallager. Because there are more than one check equation containing a certain source bit, and other bits in these check equations are likely to be included by other more check equations. In order to visually represent this relationship, Gallager introduced the concept of a checksum tree.

5. Conclusion

The LT code is the first practical fountain code. It has no receiving end feedback, strong adaptability to channel conditions, high utilization of channel capacity, low complexity of compiled code, and facilitates hierarchical multicast and parallel download. Etc. The LT code is a non-fixed code rate code that can flexibly control the output code length according to the channel state change. The code rate-free feature eliminates the need for frequent feedback of retransmission information, and the decoder only needs to receive a sufficient number of coded packets. The decoding and reconstruction of the original file can be completed. At present, the application research of LT codes in communication systems is limited to deleting channels and wireless channels, and the related literatures studied in fiber-optic communication systems are rarely seen. This paper focuses on the application of LT codes in the optical fiber environment. The article discusses the coding methods of LT codes, the analysis and application of LT codes in Fibre Channel, and the application of LT codes in optical communication OFDM systems.

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