"Electronics, Information, Communication" Field

Achievement : Pioneering contribution to information and coding theory

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Error correction schemes in digital information communication

To realize remote surgeries and autonomous driving, it is indispensable to use low-latency error-free data transmission. In digital data transmission, however, errors may occur in both wired and wireless communications due to noises caused by problems in communication equipment or radio noise interference. Since most of these noises cannot be removed, it is necessary to devise a framework to detect and correct these errors.

One of the easiest ways to achieve this is to send duplicate data. If the data "01" is repeated three times and sent as "01 01 01", even if an error occurs and becomes "11 01 01" at the receiving end, the correct data "01" can be recovered by the majority rule. The process of adding extra data in such circumstances is called "coding", and the process of correcting errors and recovering the original data is called "decoding".

Principle and features of LDPC codes

This approach is, however, very wasteful of data and not very reliable. A better approach, familiar to communication engineers in the 1950's, was to arrange a block of data into rows and columns. A parity check digit is added to each row and to each column, as illustrated in Fig. 2. The parity check digit is 1 if the number of ones in that row or column is odd and is 0 otherwise. Then if an error occurs in transmission in a particular row and column, the check digit for that column and row would indicate the location of the error, and it could be corrected.

Much research in the 1950's was devoted to improving this approach, including the Hamming codes, the BCH codes, the RS codes, and LDPC codes. All these schemes replace the rows and columns of data above with an arbitrary collection of subsets of data. A parity check is then appended to each subset and errors are corrected according to the parity check digits which have the wrong parity after transmission.

In the LDPC codes invented by Prof. Gallager, the overall block of data was chosen to be very large, but each of the above subsets were chosen to be quite small, a choice made to simplify the implementation of error correction. He showed that these subsets could be kept at a fixed small size while increasing the length of the overall block so as to approach channel capacity with highly reliable transmission.

LDPC codes became mainstream after 2000

LDPC codes were proposed by Prof. Gallager during the 1960s. However, because processing capability of computers were limited at that time, his ideas were neglected for the next 30 years.

From the 1990s, computer processing capability rapidly enhanced, and research into its practical implementation became active. In 1998, it was proven to be the most theoretically superior scheme, and its adoption into the large-capacity information communication systems advanced drastically.

Since the 2000s, LDPC codes have been rapidly adopted in digital communication systems and digital storage systems. These include digital TV satellite broadcasting, 10 Gigabit Ethernet, WiMAX high-speed data communication, and the 5th generation mobile communication system (5G), as well as hard disks and solid-state drives. It has become an extremely important basic technology that supports our modern digital society.

Figure 1 Error correction schemes in digital information communication

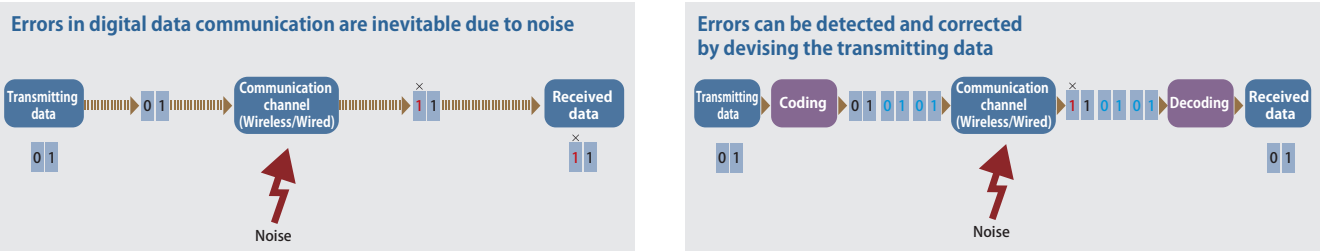
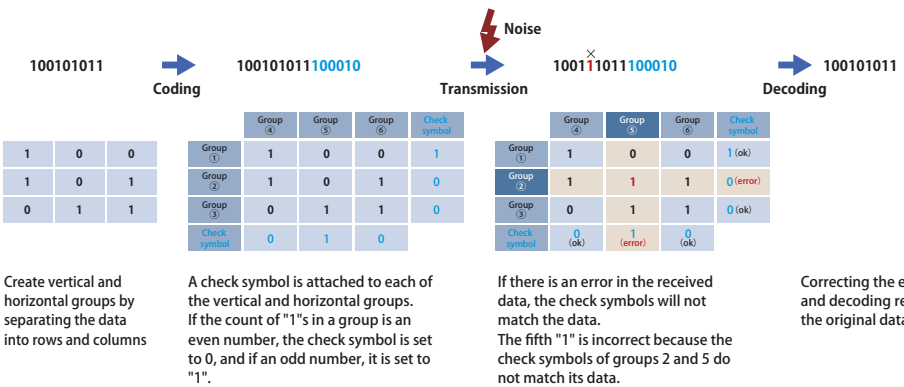


Figure 2 A simple example of using parity checks to correct errors

Using the method of grouping and checking data



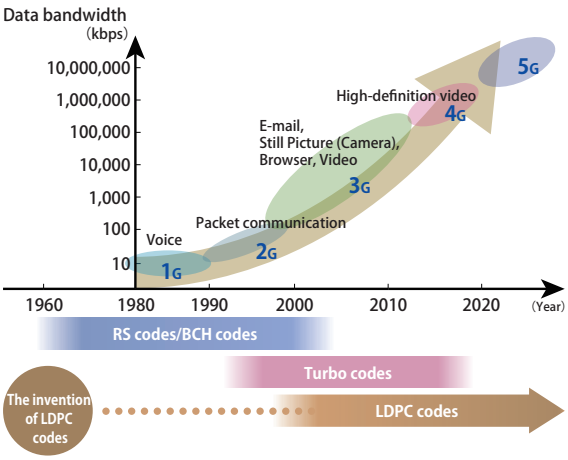
Realizing both high reliability and efficiency

(1) Use a large overall block length with randomly chosen groups in place of horizontal and vertical groups

(2) Achieve simple decoding by using groups of small size (low density)

Figure 3 LDPC codes became mainstream after 2000

The dramatic increase in wireless communication speed and the advancement of communication equipment



Technologies that contribute to the realization of a Super Smart Society (Society 5.0)

Currently, there are no other practical codes that can outperform LDPC codes. As computer processing capability continues to rapidly improve in the future, the application of LDPC codes is expected to further expand in scope.

Super Smart Society (Society 5.0), which is envisioned to be the future of our society, will require the cyberspace and the real world to be highly integrated. LDPC codes are expected to contribute significantly to this goal by playing an essential and fundamental role in solving the various challenges of information communication, such as demands for higher speeds, capacity, and reliability, and lower power consumption.

Figure 4 Technologies that contribute to the realization of a Super Smart Society (Society 5.0)

LDPC codes is a key technology that supports high speed, high capacity, high reliable, and low power data communication