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An introduction to various error detection and correction schemes used in communication

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Abstract
Wireless communication systems are more prone to errors during transmission of messages. But reliable and efficient data transmission is a main topic of interest. Since long time, researchers are working for various error detection and correction (EDAC) technique for error free data transmission. This paper is an attempt to provide basic information about various error detection and correction schemes developed. There are mainly two types of EDAC techniques namely Automatic repeat request (ARQ) and Forward error correction (FEC). Stop & wait ARQ and Continuous ARQ have been discussed in this paper. Further, this paper provides basic information about different types of block codes namely cyclic redundancy check codes (CRC) and Hamming codes. Convolutional code has also been discussed.

Keywords: EDAC, ARQ, FEC, CRC

1. Introduction

Growth in technology has led to the demand of error free signals. Today's communication system consists of both wired and wireless communication [1]. Wireless communication networks are more sensitive to bit errors than wired communication systems. Due to advancement in data transmission techniques, chances of error introduction and noise have also increased. Received data is more likely to be damaged by noisy channels used for communication. So, for a reliable data transmission, it is necessary to find that whether data is error free or not. Now a days, various error detection and correction techniques are in practice. These EDAC [2] are used to reduce the interference in electronic medium and to reduce the level of noise. These techniques first detect the error in the received data and then try to produce an error free version of received data. Recently, Error correction codes (ECC) are used for reliable data transmission in digital communication [3]. In this, the data is encoded before storage in memory. ECC take data bits to be transmitted and form a set of redundant bits. These redundant bits are sent to original data bits. At the receiver side, error correction information is used to check whether received data is error free or not and then bit error can be corrected [5]. It is to be mentioned here that the performance of transmission is increased at the cost of additional redundant bits. Many applications do not work due to errors present in the data. First of all, we must know the type of error present so that it can be removed. The commonly used EDAC techniques are: - Automatic Repeat Request (ARQ) and Forward Error correction (FEC). The rest of the paper is organized as: Section II consists of different types of error present in data transmission, section III discusses the automatic repeat request (ARQ) scheme, section IV explains Forward error correction scheme and its different types namely block coding and Convolutional coding. Finally, section V concludes the paper.

2. Types of Errors

Errors may be classified into three types [6]:-

i) Single bit error: - If during transmission, only one bit is damaged then error is said to be single bit error.
ii) Multiple bit rror: - If during transmission, more than one bit is damaged then error is said to be multiple bit error.
iii) Burst Error: - If during transmission, more than one consecutive bit is damaged then error is said to be burst error.

3. Methods of EDAC

3.1 Automatic repeat request (ARQ)

ARQ is a simpler way of sending and receiving information. As the name suggests, the receiver sends back a message regarding the information received. If correct information is received then receiver resends positive acknowledgement [7]. While if an error is received, then receiver resends a negative acknowledgement. To check whether received data is error free or not, CRC bits are also sent along with the original information. CRC bits are checked in the received data, if CRC bits match then data is error free otherwise negative acknowledgement is send.

A) 'Stop and wait ARQ'

In this method, the transmitter sends the information and waits for the acknowledgement respond of receiver. If positive acknowledgement is received then next information message is send. Otherwise same message is retransmitted. The retransmission of message is done until positive acknowledgement is received or the number of retransmissions increases a certain limit of transmissions.

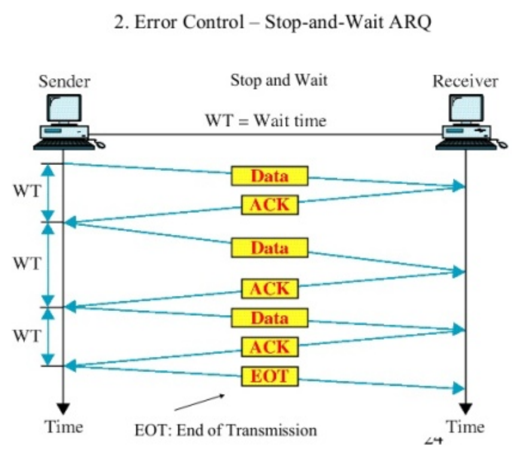

Fig 1: Stop and wait ARQ scheme

B) 'Continuous ARQ'

As the name suggests, the transmitter keep on sending the information message continuously, until it receives negative response from receiver. The negative response can be considered in two ways:

a) 'Go back N -ARQ'

In this method, transmitter keeps on sending information message continuously without waiting for the receiver respond. The acknowledgement of receiver is received at the transmitter end after a certain period of time (Round trip delay). A certain number of messages have been sent in round trip delay time (say N). If negative acknowledgement is received then transmitter sends N-1 messages again. Hence, at the transmitting end there must be memory storage device that store the data. This method is moderately efficient. Although, if channel is too noisy and transmitting rate is high then this method is not a appropriate choice for transmission.

b) 'Selective repeat ARQ'

In this method, the only those messages for which negative respond is received are retransmitted. Hence, sender needs not to resend other messages that have been sent before the receiving of negative response. All such messages are stored in memory and are used when incorrect message is received correctly. Hence, this method requires a large memory and more memory storage equipments. But this method reduces delays and more information can be sent in lesser time.

4. Forward Error Correction (FEC)

FEC is a method of error control in which systematically generated additional bits are added to the original data at the transmitting side [8]. The redundant bits may be a function of original information. The redundant bits allow the receiver to detect and correct the error introduced during the transmission of signal. In FEC [9], receiver needs not to ask for retransmission of the signal. Hence, FEC is a better choice where channel is noisy. Because in noisy channel, signal has to be sent a number of times before it can be received accurately. Hence, FEC reduces the complexity and cost of transmission [10]. Further, the channel where retransmission is not possible, FEC is the only choice. Although, all the advantages are attained at the cost of higher channel band width.

The encoded data may or may not contain original information in its original form. Accordingly, there are two types of codes:- Systematic and Non-systematic. In systematic codes, the code has a portion exactly sane as original information while in non-systematic codes, code do not has a portion exactly sane as original information. It is believed that each transmission is incorporated with some noise but Shannon showed that it is not true. According to Shannon [11], if the transmission rate is less than channel capacity, then data can be sent with no error. Hence this theorem puts an upper limit on the transmission rate but opens new doors for communication world. So new codes must be developed that can send data with minimum error probability.

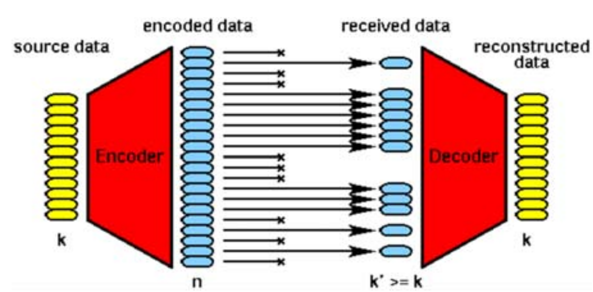

Fig 2: Forward error correction scheme

FEC are mainly classified into two categories:-

a) Block codes
b) Convolutional Codes

a) Block Codes:- Block codes work on block by block basis. Each block code is represented by two integer's m and n. where, m is number of data bits in each codeword and n is number of bits of code-word. There are many types of block codes namely Cyclic redundancy check codes (CRC), Hamming Codes, Turbo codes, Low density parity check code (LDPC), Reed Solomon code etc. all fall in the category of block codes. Some of these are described below:

i) Cyclic redundancy check codes (CRC):- CRC is most widely used cyclic code. In CRC, a generator polynomial is used which is used as divisor in binary division. The original information to be sent is firstly divided by the divisor and remainder is added as redundant bits to the original information [11]. This coded information is sent on the communication channel and at the receiver side, the received data is again divided by the same divisor. If the remainder is same as CRC bits then data is accepted otherwise not. A good selection of generator polynomial will reduce the chances of error transmission. CRC is easy to implement hence, are widely used in storage devices.

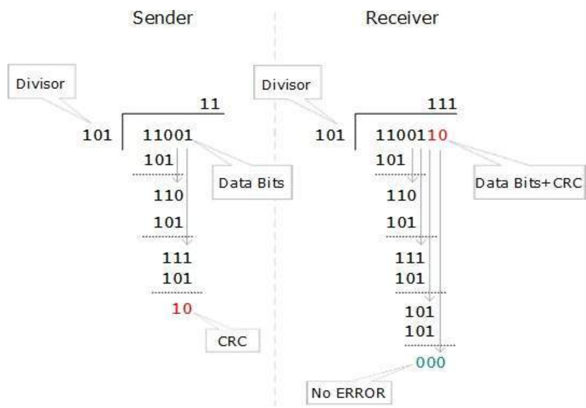

Fig 3: Cyclic redundancy check bit scheme

ii) Hamming Codes: Hamming code [4] is type of linear block coding. Hamming code is identified by two integers (n,k). Where, n is code word length and k is number of data bits. M=n-k is the parity bits that are added. Hence, a number of parity check bits are combined with original data bits. Every check bit consists of number of parity bits. Check bits are sent along with original data bits. At the receiver, check bits are examined. If all the check bits are correct then data is accepted and no error is present but if there is an error then check bits will not be same as original check bits. Then, a unique pattern known as syndrome results that may identify the error bit. Once the error bit is detected it can be corrected.

c) Convolutional codes: Convolutional encoder consists of shift registers and binary adders. In this coding a certain number of bits are stored in the shift register [13]. Once a specified number of bits are stored then the bits are shifted sequentially. For each shifted bit a output is generated which depends upon present input bit as well as on the previous bits. Convolutional codes are represented by three integersn, k and K. Here, n is the number of output bits generated for each shift in the shift register. k is number of input bits for each shift of the register. K denotes the total memory of the encoder. This is known as constraint length. As the Convolutional codes work on sequential basis hence encoder starts it encoding as soon as a few number of bits are sent [14]. Similarly, at the receiver side, decoder starts decoding as soon as encoded data is received. Hence, there is no time delay. Hence, Convolutional coding is best choice when a large data is to be sent.

5. Conclusion

In this paper, various error detection and correction schemes for efficient and reliable transmission of data have been discussed. Automatic repeat request method helps to transmit reliable data to some extent. The equipments used in ARQ are quite simple. But the main limitation of ARQ method is that this method can detect errors but cannot correct them. In case of noisy channels, a large number of retransmissions are required for correct information receiving. The delays are large hence require a lot of time. Forward error correction helps in sending data with less error. Various FEC codes are discussed in this paper. Each code helps in reducing errors in the received data to some extent. Although developing new codes that can send data more efficiently is an open challenge for all the researchers working in this area.

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