IJIREEICE

ISSN (Online) 2321-2004
ISSN (Print) 2321-5526

International Journal of Innovative Research in
Electrical, Electronics, Instrumentation and Control Engineering

Vol. 8, Issue 8, August 2020

DOI 10.17148/IJIREEICE.2020.8807

Review on Designing ADSL with RS Encoding

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Abstract: Digital communication systems are used for transferring information data between separate remote points, which are connected by appropriate communication channels. The data being sent is usually affected by different channel errors (e.g., noise or interference) that worsen the quality of transmission link. The communication system performance and quality of transmissions can be increased by applying the Forward Error Correction (FEC) technique, which is used in almost all digital communication systems to improve performance with regards to Bit Error Rate (BER). Theoretically, FEC allows the maximum level of information in any channel. In practice, it reduces the cost for designing the communication system. This is also the case for Asymmetric Digital Subscriber Line (ADSL), which uses both Trellis coding and Reed-Solomon FEC to perform error corrections. In ADSL, the error correction algorithms used (especially decoding) are computationally complex and demanding compared to the other algorithms.

Keywords: DSL, ADSL, FEC, BER.

I. INTRODUCTION OF ADSL

In recent years, Digital Subscriber Line (DSL) technology has been gaining popularity as a high speed network access technology, capable of the delivery of multimedia services over the existing telephone infrastructure. A major impairment for DSL is *impulse noise* in the telephone line. Lightning and switching equipment transients are common causes of impulse noise. However, current DSL services make use of Forward Error Correction (FEC) techniques for improved resistance to noise interference in the data transmission. Digital Subscriber Line (DSL) is a family of technologies that are used to transmit digital data over telephone lines. In telecommunications marketing, the term DSL is widely understood to mean Asymmetric Digital Subscriber Line (ADSL), the most commonly installed DSL technology, for Internet access. DSL service can be delivered simultaneously with wired telephone service on the same telephone line since DSL uses higher frequency bands for data. On the customer premises, a DSL filter on each non-DSL outlet blocks any high-frequency interference to enable simultaneous use of the voice and DSL services[5].
The bit rate of consumer DSL services typically ranges from 256 kbit/s to over 100 Mbit/s in the direction to the customer (downstream), depending on DSL technology, line conditions, and service-level implementation. Bit rates of 1 Gbit/s have been reached. In ADSL, the data throughput in the upstream direction (the direction to the service provider) is lower, hence the designation of asymmetric service. In Symmetric Digital Subscriber Line (SDSL) services, the downstream and upstream data rates are equal. Researchers at Bell Labs have reached speeds over 1 Gbit/s for symmetrical broadband access services using traditional copper telephone lines, though such speeds have not yet been deployed elsewhere[9].

II. FORWARD ERROR CORRECTION

Forward Error Correction (FEC) in transceiver (transmitter/receiver pair) is used to deliver information from a source (transmitter) to a destination (receiver) through a noisy communication channel with a minimum of errors. FEC allows a receiver in the system to perform Error Detection and Correction (EDAC) without requesting a retransmission of the corrupted data. FEC offers a number of benefits:

- FEC enables a system to achieve high data reliability;
- FEC results in greater effective throughput of user data, because valuable bandwidth is not being used to retransmit corrupted data;
- FEC yields performance gains and low error rates for systems in which other options, such as increasing the transmitted power or installing noise-limiting components, are too expensive or impractical;
- System costs can be reduced by eliminating an expensive or sensitive component and compensating for the lost performance by a suitable FEC scheme.

Source encoder: In the source encoder of the transmitter, the message to be transmitted is transformed into a sequence of bits that represents the original message. These bits are then fed to the channel encoder.

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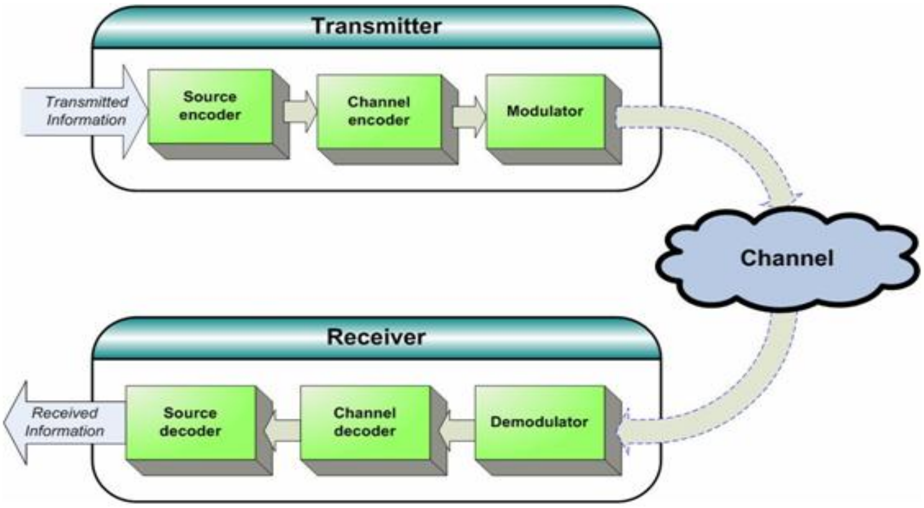

Figure 1. FEC Communication System.

Channel encoder: The channel encoder (or FEC encoder) is designed to perform error correction with the aim of converting an unreliable communication channel into a reliable one. The encoder adds redundancy to the data produced by the source encoder in the form of parity information. Then at the receiver, a channel decoder is able to exploit the redundancy in such a way that a reasonable number of errors introduced by the channel can be corrected. Without redundancy, the code would not allow us to detect the presence of errors and therefore would not have any error controlling properties.
Modulator: The coded data produced by the channel encoder is then mapped into analogue signal (waveforms) in the digital modulator, and fed to the channel.
Channel: The channel provides the communication link between the transmitter and receiver, and introduces various forms of corruption to the transmitted signal, like environment noise, attenuation, etc. The errors introduced by the communication channel are classified into two main categories:
Random errors. The probability of error is independent from one transmitting symbol to the next. Random errors occur in the Additive White Gaussian Noise (AWGN) channel in which the transmitted signal suffers the addition of wide-band noise whose amplitude is a normally (Gaussian) distributed random variable;
Burst errors. The bit errors occur sequentially in very short time as groups. For example, impulse noise can cause a burst of errors. Impulse noise is a short burst of relatively high energy noise. Thus, the task of the receiver is to capture the transmitted signal, and remove the effects of the channel.
Demodulator: The demodulator converts the waveforms received from the channel into a binary sequence, which is fed to the channel decoder.
Channel decoder: The job of the channel decoder (or FEC decoder) is to decide what the transmitted information was. The channel decoder removes the redundancy introduced by the channel encoder in the transmitter, and attempts to detect and correct possible bit errors using the knowledge of the code used by the channel encoder and the redundancy contained in the received data. The frequency at which bit errors occur at the output of the channel decoder is a measure of the demodulator-decoder performance. Typically the bit error rate (BER) at this point is kept at a desired level so as to have acceptable quality of communication with minimum resource usage.
Source decoder: Finally, the source decoder tries to reconstruct the original message from the decoded data. This will be an estimation of the original message due to the possible corruption introduced to the data along its way through the communication link.

III. REED SOLOMON CODING SCHEME

RS codes are error detection and correction (EDAC) scheme used in different forward error correction (FEC) techniques. These codes provide powerful correction, have high channel efficiency, and thus have a wide range of applications in digital communications and storage, e.g.:

- Storage devices: Compact Disk (CD), DVD, etc;
- Wireless or mobile communications: cellular phones, microwave links, etc;
- Satellite communications;
- Digital television / DVB;
- High-speed modems: ADSL, VDSL, etc.

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Properties of Reed-Solomon Codes

RS codes are linear block codes. A RS code is specified as RS(n, k) with m-bit symbols. RS(n, k) codes on m-bit symbols exist for all n and k for which $0 < k < n < 2^m + 2$

where k is the number of data symbols being encoded, and n is the total number of code symbols in the encoded block, called codeword. This means that the RS encoder takes k data symbols of m-bits each and adds parity symbols (redundancy) to make an n symbol codeword. There are (n – k) parity symbols of m-bits each. For the most conventional RS(n, k) code,

$$(n, k) = (2^m - 1, (2^m - 1) - 2t)$$

where t is the symbol-error correcting capability of the code, and (n – k) = 2t is the number of parity symbols. It means that the RS decoder can correct up to t symbols that contain errors in a codeword, that is, the code is capable of correcting any combination of t or fewer errors. When a received codeword is fed to the RS decoder at the receiver for processing, the decoder first tries to verify whether this codeword appears in the dictionary of valid codewords. If it does not, errors must have occurred during transmission over a communication channel. This part of the decoder processing is called error detection. If errors are detected, the decoder attempts a reconstruction. This is called error correction.

IV. CONCLUSION

The integral part of each ADSL modem is the Forward Error Correction (FEC) technique, which is used to deliver information from a source (transmitter) to a destination (receiver) through a noisy communication channel with a minimum of errors. FEC allows a receiver in the system to perform error detection and correction without requesting a retransmission of the corrupted data. Reed-Solomon (RS) codes have been chosen for the FEC technique in ADSL. Here, a RS code is specified as RS(n, k) with 8-bit (byte) symbols: the RS encoder in the transmitter takes k data symbols of 8 bits each and adds parity symbols (redundancy) to make an n symbol data block, called codeword. The maximum length (starting from n = 1) of a codeword with 8-bit symbols in ADSL is 255 bytes. There are (n – k) redundant bytes. The ADSL standard requires support of all even numbers from 0 to 16 of redundancy bytes per codeword. This would allow for up to 8 bytes to be in error for every RS codeword. The RS decoder at the receiver removes the redundancy introduced by the RS encoder at the transmitter, and attempts to detect and correct possible bit errors using the knowledge of the code used by the channel encoder and the redundancy contained in the received data.

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