Forward Error Correction

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CONTENTS

- Introduction
- Advantages and use
- Types of FEC
- Block Coding
- Convolutional Coding
- How it works?
- Example of working of FEC
- Concatenating FEC codes to reduce errors

CONTENTS

- Turbo codes
- Low density parity check
- Interleaving
- Interleaver Designing

INTRODUCTION

- In telecommunication and information theory, forward error correction (FEC) is a system of error control for data transmission, whereby the sender adds redundant data to its messages, also known as an error correction code.
- This allows the receiver to detect and correct errors (within some bound) without the need to ask the sender for additional data.
- FEC devices are often located close to the receiver of an analog signal, in the first stage of digital processing after a signal has been received.
- FEC circuits are often an integral part of the analog-to-digital conversion process, also involving digital modulation and demodulation, or line coding and decoding.

Advantage and Use

- The advantage of forward error correction is that a black-channel is not required, or that retransmission of data can often be avoided, at the cost of higher bandwidth requirements on average.
- FEC is therefore applied in situations where transmissions are relatively costly or impossible.
- In particular, FEC information is usually added to most mass storage devices to protect against damage to the stored data.

Types of FEC

- There are two types of Forward Error Correction-

A. Block Coding
B. Convolutional Coding

Block Coding

- Block codes work on fixed-size blocks (packets) of bits or symbols of predetermined size. Practical block codes can generally be hard-decoded in polynomial time to their block length.
- There are many types of block codes, but among the classical ones the most notable is Read-Solomon coding because of its widespread use on the compact disc, the DVD, and in hard disk drives.
- Classical block codes are usually decode using hard-decision algorithms, which means that for every input and output signal a hard decision is made whether it corresponds to a one or a zero bit.
- Other example of classical block codes include Golay, BCH, Multidimensional parity, and Hamming codes.

Convolutional Coding

- Convolutional codes works on bit or symbol stream of arbitrary length.
- Convolutional codes are typically decoded using soft-decision algorithms like the Viterbi, MAP or BCJR algorithms, which process analog signals, and which allows for much higher error-correction performance than hard-decision decoding.
- They are most often soft decoded with the Viterbi algorithm, through other algorithms sometimes used.
- Viterbi decoding allows asymptotically optimal decoding efficiency with increasing constraint length of the convolutional code, but at the expense of exponentially increasing complexity.

Convolutional Coding

- A convolutional code that is terminated is also a ‘block code’ in that it encodes a block of input data, but the block size of a convolution code is generally arbitrary, while block codes have a fixed size dictated by their algebraic characteristics.
- Types of termination for convolutional codes include ‘tail-biting’ and ‘ bit-flushing’.

How it Works?

- FEC is accomplished by adding redundancy to the transmitted information using a predetermined algorithm. Each redundant bit is invariably a complex function of many original information bits.
- The original information may or may not appear in the encoded output; codes that include the unmodified input in the output are systematic, while those that do not are non-systematic.

Example of Working of FEC

- An extremely simply example would be an analog to digital converter that samples three bits of signal strength data for every bit of transmitted data.
- If the three samples are mostly zero, the transmitted bit was probably a zero, and if the three samples are mostly one, the transmitted bit was probably a one.
- The simplest example of error correction is for the receiver to assume the correction output is given by the most frequently occurring value in each group of three.

Concatenating FEC codes to reduce Errors

- Block and convolutional codes are frequently combined in concatenated coding schemes in which the convolutional code does most of the work and the block code ‘mops up’ any error made by the convolutional decoder.
- This has been standard practice in satellite and deep space communication since Voyager 2 first used the technique in its 1986 encounter with Uranus.

Turbo Codes

- The most recent development in error correction in turbo coding, a scheme that combined two or more relatively simple convolutional codes and an interleaver to produced a block code that can perform to within a fraction of a decibel of the Shannon limit.
- One of the earliest commercial applications of turbo coding was theCDMA2000 1x digital cellular technology developed by Qualcomm and sold by Verizon wireless, Sprint and the other carriers.
- The evaluation of CDMA2000 1x specifically for internet access, 1xEV-DO, also uses turbo coding.

Low-Density Parity-check (LDPC)

- Low-density parity-check codes are a class of recently re-discovered highly efficient linear block codes made from many single parity check codes.
- They can provide performance very close to the channel capacity using an iterated soft-decision decoding approach, at linear time complexity in terms of their block length. Practical implementation rely heavily on decoding the constituent SPC codes in parallel.
- LDPC codes were first introduced by Robert G. Gallager in his PhD thesis in 1960,but due to the computational effort in implementing encoder and decoder and the introduction of ReedColomon codes, they were mostly ignored until recently.

Low-Density Parity-Check

- LDPC codes are now used in many recent high-speed communication standards, such DVBS2, WiMAX, high speed wireless Lan.

Interleaving

- Interleaving is frequently used in digital communication and storage systems to improve the performance of forward error correction codes.
- Many communication channels are not memoryless: errors typically occur in bursts rather than independently. If the number of errors within a code word exceeds the error-correcting codes capability, it fails to recover the original code word.
- Interleaving ameliorates this problem by shuffling source symbols across several code words, thereby creating a more uniform distribution of errors.

Interleaver Designing

- Interleaving design includes:

A. Rectangular interleaver
B. Convolutional interleaver
C. Random interleaver

- S-random interleaver
- Another possible construction is a contention-free quadratic permutation polynomial. It is used for example in the 3GPP Long Term Evolution mobile telecommunication standard.
- In multi-carrier communication systems, interleaving across carriers may be employed to provide frequency diversity to mitigate frequency-selective fading or narrowband interference.

THANK YOU