Modulation schemes and error-control coding
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Summary

This course presents a number of examples and applications illustrating the way in which error-control coding, a fundamental outgrowth of Shannon's information theory, has contributed and is still even more contributing to the design of reliable digital transmission and storage systems. Indeed, coding has become an integral part of almost any system involving the transmission or storage of digital information. And as we look to the future and the "digital revolution", it seems assured that the use of coding will become even more pervasive and that error-control coding has moved from being a mathematical curiosity to being a fundamental element in the design of digital communication and storage systems.

Contents

Introduction to information theory. Definition of "information" and fundamental results of Shannon's theorems. Transmission channel models. The spectral efficiency as a fundamental result of Shannon's channel coding theorems.

Introduction to error-control coding.

The fundamental applications of error detection and error correction schemes: space and satellite communications, data transmission, data storage, digital audio and video transmission, mobile communications, file transfer.

Error detection schemes and their applications. Repetition codes in mobile communications (and non-AWGN environments). Horizontal redundancy parity checks, vertical redundancy parity checks, and "double" or "diagonal" parity checks. Cyclic Redundancy Check (CRC) in asynchronous file-transfer systems.

Error correction schemes: Backward Error Correction or ARQ (Automatic Repeat Request) and Forward Error Correction (FEC). Fundamental ARQ protocols, FEC schemes and their applications.

Block codes and their applications. Hamming codes in data storage systems (computer memories (RAM)). BCH codes in communications and data storage systems, including satellite communications, cellular networks, CD Rom, Mass Storage Systems. Reed-Solomon codes in consumer electronics such as CDs, DVDs, Blue-ray Discs, in data transmission technologies such as DSL and WiMAX, in broadcast systems such as DVB and ATSC, and in computer applications such as RAID systems.

Fundamental elements of finite (or Galois) fields theory as a mathematical basis of most common and used block codes. Design guidelines for Hamming, BCH and Reed-Solomon codes and their algebraic decoding.

Convolutional codes, description and application. The coding schemes designed for Pioneer and Voyager space missions adopted in CCSDS (Consultative Committee on Space Data Systems) standard and used in satellite communications and cellular telephony. The coding schemes adopted in earth-orbiting satellite communication systems Globalstar and Iridium. Rate-compatible punctured codes for Digital Audio Broadcasting (DAB). FEC coding in the Global System for Mobile Communications (GSM). Sequential decoding and maximum-likelihood decoding. Viterbi algorithm. "Hard" and "soft" decoding. Performance.

Coded modulation schemes for higher spectral efficiencies. Their application to data transmission. TCM (Trellis Coded Modulation). International Telecommunications Union's ITU-T modem standard V.32 and following standards.

Parallel concatenated convolutional codes through a pseudorandom interleaver (“turbo” codes), description and application. The coding schemes designed for Cassini space mission. Turbo codes for GSM. Performance. The uniform interleaver. Constituent codes design. Iterative decoding algorithm.

LDPC (Low Density Parity Check) codes, description and application. Codes used in recent high-speed communication standards: DVB-S2 (Digital Video Broadcasting), WiMAX, High-Speed Wireless LAN (IEEE 802.11n), 10GBase-T Ethernet (802.3an) and G.hn/G.9960 (ITU-T Standard for networking over power lines, phone lines and coaxial cable). Since 2009, LDPC codes are also part of the Wi-Fi 802.11 standard. Performance. Iterative decoding algorithm.