Abstract

In this digital world, needs of data integrity and confidentiality as well as reliable transmissions are paramount. Error Correcting Codes (ECC) play a vital role in ensuring that transmitted information remains accurate, even in the presence of errors introduced by noise, interference, or malicious activities. In communication systems, ECC are used popularly for detecting and correcting errors. Beside this application, ECC are equally crucial for maintaining data integrity in Solid-State Drives (SSD), where corruption can have serious consequences. With the rise of cyber-security threats, ECC have found applications in physical layer security (PLS) techniques that help to protect data against unauthorized access and manipulation. Advanced ECCs such as Golay and polar codes have demonstrated significant capabilities, where Golay codes are excelling in correcting multiple errors and polar codes are enabling capacity-achieving performance for future communication systems. As communication technologies continue to evolve, the importance of efficient and robust error correction methods will only increase, making the study of these codes essential for future developments in the field.

This thesis explores the decoding techniques and performance of Cyclic Redundancy Check (CRC)-concatenated polar codes, focusing on their application in SSD and Binary Deletion Channels (BDC). It demonstrates that integrating CRC codes with polar coding significantly improves error recovery, even in deletion-prone environments, while maintaining computational efficiency. Through simulations, the research provides insights into optimizing CRC length and list size configurations, contributing to advancements in error correction for communication and data storage systems. This thesis also investigates the Genetic Algorithm (GA) based optimized polar code construction technique for communication systems over Additive White Gaussian Noise (AWGN) and Rayleigh Fading Channel (RFC). Proposed method enhances error-correction performance without relying on CRC. The results show that GA-optimized designs, using Successive Cancellation List (SCL) and Belief Propagation (BP) decoding, achieve lower Block Error Rates (BLER) at reduced Energy per Bit to Noise Power Spectral Density (E_b/N_o) ratios, improving efficiency and performance. Further, this thesis explores advanced coding techniques to improve security and reliability in wireless communication, including the development of efficient Golay encoders and decoders for the McEliece cryptosystem and Physical Layer Security (PLS) scheme based on polar coding method. The proposed McEliece system, leveraging extended Golay codes, addresses vulnerabilities in traditional cryptosystems against quantum threats. Also, the proposed polar coding scheme uses artificial noise to enhance secrecy at physical layer by weakening eavesdropper channels. These contributions provide some solutions for secure and reliable data transmission in wireless networks. Lastly, this thesis examines the optimization of polar codes for 5G New Radio (NR) control channels and Wireless Sensor Networks (WSNs) in the Internet of Things (IoT) applications, focusing on enhancing error correction capability by applying concatenated polar codes with interleaving blindly (I_B). This work highlights the performance improvements of Distributed CRC Aided (DCA-polar) and CRC Aided (CA-polar) polar codes, particularly for short block lengths and low Signal-to-Noise Ratio (SNR) conditions. The results also demonstrate that concatenated BCH-Polar codes with I_B outperform traditional methods in terms of Bit Error Rate (BER) and computational complexity. All these findings provide a robust framework for reliable and secure communication in modern wireless systems showcasing the potential of these techniques to meet the stringent demands of 5G and beyond.