ABSTRACT

Efficient spectrum utilization has emerged as a vital approach to address the underutilization of licensed radio frequency (RF) spectrum in modern wireless communication systems. Cognitive radio networks (CRNs), which enable dynamic spectrum sharing between primary users (PUs) and secondary users (SUs), play a pivotal role in enhancing spectral efficiency. This thesis presents a progressive exploration of multiple CRN architectures, beginning with half-duplex (HD) relay-based systems and advancing toward full-duplex (FD) relay-enabled networks. Each architecture is systematically developed to address evolving communication challenges, focusing on outage performance, throughput analysis, and energy efficiency under various practical constraints.

The investigation begins with an HD-based CRN framework employing a multi-antenna proactive decode-and-forward (DF) relay selection scheme.The architecture employs adaptive spectrum sharing through a hybrid underlay/overlay protocol, where the SU transmitter (SU-Tx) continuously monitors PU activity using energy detection. Based on the sensing outcome, SU-Tx dynamically switches between underlay and overlay modes, allowing maximization of transmission rate while protecting PU transmissions. A comparative analysis demonstrates that, under the same diversity order, increasing the number of relays yields better outage performance than increasing the number of antennas.

Expanding upon this foundation, the next development introduces energy harvesting (EH) and co-channel interference (CCI) into a multi-HD relay CRN. In this model, SU-Tx and secondary relays harvest energy from PU transmissions and ambient interference. An adaptive hybrid relay (AHR) protocol is proposed to switch between amplify-and-forward (AF) and DF relaying based on signal-to-interference-plus-noise ratio (SINR) thresholds. The impact of relay count, energy harvesting efficiency, and decoding thresholds on secondary outage probability is analyzed, showcasing the superiority of the AHR strategy over conventional AF and DF modes.

The thesis subsequently makes a transition to more advanced FD-based CRN architectures. The system model introduces a joint underlay/overlay protocol into an EH-assisted FD CRN. SU transmitters, equipped with RF energy detectors, dynamically switch transmission modes based on PU presence. Power allocation is optimized across all transmitting nodes to enhance end-to-end throughput. The model accounts for SI and PU-induced interference, and demonstrates significant throughput improvement through the integration of FD relays and joint-mode transmission.

Continuing the exploration of FD systems, a complementary scenario is investigated involving an EH-assisted FD multi-relay network within a multi-user spectrum sharing environment. Analytical expressions for outage probability are derived, incorporating the effects of self-interference (SI) at FD relays and aggregate interference at all receivers. Power control policies are formulated for SU sources and relays. A comparative study confirms the performance gains of FD relaying over traditional HD relaying, particularly in scenarios involving multiple destinations.

Advancing further, the analysis introduces a nonlinear EH model to better mirror real-world energy harvesting behavior. Multiple FD relays support hybrid-mode communication, with SU transmitters dynamically selecting underlay or overlay modes based on sensing results. A closed-form outage analysis is presented, optimizing power allocation under comprehensive interference conditions, thereby enhancing the reliability and energy efficiency of the network.

The next proposed architecture integrates non-orthogonal multiple access (NOMA) into the hybrid FD CRN framework. A base station assisted by FD relays transmits to multiple SU destinations using NOMA principles. SU transmitters, equipped with RF energy harvesting and detection circuitry, operate adaptively in underlay or overlay modes. An analytical model is developed to derive closed-form outage probabilities under SI and imperfect successive interference cancellation (i-SIC), highlighting improvements in spectral efficiency and system throughput.

Finally, the architecture introduces an intelligent reflecting surface (IRS) to assist FD relaying in an m-Nakagami fading environment. Information is transmitted from the SU source to the destination via both an IRS and FD relay using the DF protocol. The IRS supports interference management to ensure PU protection while enhancing the received signal strength at the SU receiver. Performance comparisons reveal that IRS-assisted FD relaying provides significant gains over conventional FD setups.

This thesis presents rigorous mathematical analyses and closed-form derivations to evaluate outage probability and throughput. The progression from HD to FD relaying, integration of energy harvesting, dynamic modes, and the use of NOMA and IRS together reflect a holistic approach to improving cognitive radio performance in complex, resource-limited environments.