ABSTRACT

In the swiftly maturing world of wireless communications, meeting the ever-increasing demand for higher data rates, enhanced spectral efficiency (SE), and improved connection is a major concern. The number of machine-type devices (MTDs), which are already an integral part of our daily lives, is projected to increase exponentially over the next few years. The current orthogonal multiple access (OMA) methods, which are extensively implemented in previous generations of wireless networks, are inadequate to handle the stringent demands of future user density and network traffic. Non-orthogonal Multiple Access (NOMA) is emerging as a game-changing technology that promises to revolutionize the way it utilizes the radio spectrum and enable more efficient communication in future wireless networks. NOMA is a cutting-edge multiple-access technique for wireless networks. NOMA, unlike conventional OMA systems such as Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA), and Code Division Multiple Access (CDMA), allows multiple users to simultaneously share the same time and frequency resources. The fundamental basis of NOMA technology is rooted in the use of superposition coding (SC) and successive interference cancellation (SIC) methods, which will be further expounded upon in subsequent chapters. The proliferation of intelligent gadgets, the Internet of Things (IoT) devices, and the forthcoming fifth generation (5G) and beyond networks have created an opportunity for NOMA to facilitate a paradigm shift in connectivity, therefore enabling a more interconnected global society.

Cognitive Radio (CR) is another revolutionary technology that emerged as a result of the scarcity of available radio frequency spectrum and the inefficiency of the traditional fixed frequency allocation method for specific services. Implementing CR requires intelligent spectrum monitoring, effective spectrum management, and dynamic spectrum sharing. Three fundamental types of CR networks include Underlay, Overlay,

and Interweave. In underlay networks, secondary users (SUs) are allowed to share the spectrum with primary users (PUs) by transmitting at lower power levels to avoid interference. Strict interference constraints are followed to prevent the degradation of PU communications. In overlay networks, SUs opportunistically access additional spectrum resources not utilized by licensed PUs during their idle periods. In interweave networks, SUs actively sense and detect unused spectrum (spectrum holes) within PUs frequency bands and opportunistically transmit within these holes without causing interference. Underlay CR enables continuous spectrum utilization and offers lower latency as it does not wait for idle periods, unlike interweave CR, which may experience delays due to spectrum sensing and waiting for unused spectrum holes. Overlay CR might also introduce latency due to complex signal processing and coordination with primary users. This is the motivation to work on underlay CR networks.

Most of the works in the literature deal with downlink and cooperative underlay NOMA networks. This thesis considers multiuser uplink underlay NOMA wireless networks and develops novel power apportioning techniques. The first work develops an intelligent selection of a pair of SUs from the available SUs, using NOMA signalling to maximize throughput. The fixed power apportioning is considered based on the statistical properties of the channels. Careful power control ensures that interference with the primary network (PN) does not exceed the interference temperature limit (ITL). It is shown how primary channel knowledge can be intelligently exploited for even more significant throughput gains in the channel state information (CSI) dependent ITL case. CSI dependent ITL is not explored much in the literature. In underlay networks, the signal-to-noise ratios (SNRs) of each link show large variations since the transmit powers are random and determined by random fading channels to the primary receiver (PR). This inspired our second work, which focuses on CSI based power apportioning among a selected pair of SUs. The study demonstrates the NOMA/OMA mode switching mechanism and develops lower and upper bounds on performance for both static and CSI dependent ITL. These bounds are important and useful to system designers. Till now, only a pair of SUs is selected. The third work considers selecting multiple SUs instead of a single pair and proposes channel-aware ITL apportioning among selected

SUs. Throughput improves significantly when using the proposed power apportioning techniques. The upper bounds for both static and CSI dependent ITL are derived for the considered network. Imperfect SIC occurs due to channel estimation errors and hardware impairments. For this reason, all works derive closed-form analytical expressions for performance, taking imperfect SIC into account.

A new technology called semi-grant-free (SGF) communication is intended to improve 5G and beyond wireless network performance. In order to maximize wireless network performance, SGF communication is a creative strategy that combines the advantages of both grant-based (GB) and grant-free (GF) communication approaches. This hybrid approach aims to address the shortcomings of conventional communication systems, especially in situations where traffic patterns are erratic or unpredictable. Devices using GB communication need to ask to use the communication channel and must wait for permission before sending data. Although this approach guarantees efficient communication, it can cause major delays and increase overhead, particularly in networks with high traffic. On the other hand, GF communication reduces overhead and latency by allowing devices to send data without first obtaining permission. But this can also result in interference and collisions, especially if multiple devices try to transmit simultaneously at the same subcarrier frequency. SGF communication reconciles these two points of view. Under specific circumstances, usually when the GB user is not experiencing an outage, it permits SGF users to send data within the ITL. However, when the GB user is experiencing an outage, SGF users send data with their peak powers. In both conditions, SGF users communication ensures the quality-of-service (QoS) of GB users and leads to interference control and reliable communications.

The majority of research in the literature focused on the peak powers of SGF users in NOMA-assisted SGF wireless networks. The fourth work in this thesis examines multiuser SGF-NOMA networks using underlay CR principles and carefully allocating the ITL among SGF users. It is shown that switching from 3-user NOMA to 2-user NOMA to OMA avoids the entire system outage and improves overall throughput. For the first time, SIC errors are taken into account for the SGF-NOMA networks. The fifth work proposes a novel instantaneous power apportioning scheme for multiple SGF users along with the GB user at the same subcarrier frequency. The closed-form analytical expressions for the SGF-NOMA networks are derived.

The analysis of wireless networks assisted by NOMA and featuring CR and SGF communication systems is substantially advanced by this thesis. As the demand for improved SE increases in tandem with the density of users, the acquired insights become extremely valuable for system designers. Overall, this thesis comprises novel work and significant advancements in the field of wireless communications.