ABSTRACT

The next-generation of wireless networks is essential to meet the requirements of high data rates and massive connectivity. These networks are fundamentally important for improving various aspects of our daily lives through Internet of Things (IoT) applications such as smart homes, wearable devices, advanced power grids, industry 4.0 technologies, smart education, and multimedia applications like voice over internet protocol (VoIP) and video streaming. Machine-type devices (MTDs) are already playing a significant role in our everyday lives, and their number is expected to explode in the coming years. Due to their sheer number, the existing orthogonal multiple access (OMA) techniques (widely used in older generations of wireless networks) are unfit to meet the uncompromising future requirements on user density and network traffic. Numerous multiple access technologies have been extensively studied over the past decade for this reason. Among these, non-orthogonal multiple access (NOMA) has emerged as a highly promising option due to its exceptional spectral efficiency (SE), low latency, and capacity to support extensive connectivity. Technologies like relayed NOMA (R-NOMA), Cooperative NOMA (C-NOMA), and coordinated direct and relay transmission (CDRT) NOMA have recently been proposed to enhance reliability, quality of service (QoS), and coverage area. Due to acute spectrum shortage, the use of cognitive radio (CR), especially of the underlay type, is advantageous. The performance of NOMA signalling in such underlay networks is therefore of considerable interest.

CDRT-NOMA and C-NOMA techniques presented in literature attempt to improve performance at a distant far-user (FU) at the expense of a near-user (NU) by signalling to both users together. Without use of incremental signalling techniques, a diversity of two can be achieved by the FU with CDRT-NOMA, but not by the NU. In this thesis, we attempt to improve the performance of the NU too. This motivates it to participate in NOMA signalling to assist a distant FU. Note however that the power allocated to the NU symbols can alternatively be reduced, and that of the FU increased (thereby enhancing FU performance). In this thesis, we develop a technique for combining along with successive interference cancellation (SIC) to allow the NU also to attain a diversity

of two, and analyze the performance. Performance of the suggested scheme is shown to be markedly superior in terms of both SE and energy efficiency (EE). Analysis of performance for the underlay CDRT-NOMA network is also presented. It is further shown that use of incremental signalling can further improve both SE and EE. Important insights are drawn on performance.

CR is another promising technology that attempts to overcome the problem of limited radio resources by allowing spectrum sharing. In the underlay type of CR that has shown the most promise, the transmit powers are constrained by the interference temperature limit (ITL), and are random due to the peak interference type of power control. The performance of NOMA in such scenarios can therefore be poor. It is shown in this thesis that network adaptation by switching between NOMA and OMA, along with user selection, is the key to achieving good performance despite the power constraints. It is shown that by leveraging limited knowledge of the primary channel through a channel state information (CSI) dependent ITL, very significant gains in throughput can be achieved over the case of static ITL. Closed-form expressions for power allocation are presented, along with insights into selecting optimal parameters to maximize performance.

In a multiple access network, it is shown in this thesis that due to the fading nature of channels, network adaptation by mode switching between OMA, NOMA and C-NOMA is the key to attaining good performance. It is further shown that when a simple user selection scheme is used along with mode switching, very good performance can be obtained at the distant users. In the statistical fixed power allocation (FPA) scheme, it is shown how the power allocation can be chosen based on statistical properties of the channels alone to maximize the throughput performance. It is then shown that when channel knowledge is available, it can be used to determine the NOMA power allocations to further improve performance with intelligent user selection and mode switching. This channel-aware scheme is referred to as the dynamic power allocation (DPA) scheme. It is further shown that the DPA scheme can lead to energy savings. Closed-form expressions for the outage probability, throughput, and EE are derived for both the FPA and the DPA schemes. This thesis shows that despite strict constraints on the transmit power of the secondary transmitter, high throughput can be achieved in underlay CRNs using intelligent user selection and switching strategies. Furthermore, this thesis emphasizes the importance of intelligent channel-aware techniques for achieving performance goals.

In a downlink multiuser NOMA network, it is shown in this thesis that exploiting channel knowledge at the source can lead to dramatic improvements in SE as well as EE. An optimal user subset selection mechanism is developed. The optimum NOMA power allocation parameters are expressed in closed-form using channel knowledge, and the throughput performance is analyzed. It is shown how the transmit power can be optimally chosen based on this knowledge to maximize EE.

This thesis makes significant contributions to the analysis and optimization of co-operative and cognitive communication systems based on NOMA signalling. Due to increasing user density and the need for enhanced SE and EE, the insights obtained are extremely valuable for system designers.