A Review on Spectrum Sharing in Wireless Communication System

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Abstract- *With the rapid development of broadband wireless access and mobile terminal technology, people are eager to obtain information and services from the Internet at anytime, anywhere and even in the process of moving, and the mobile Internet has been developed rapidly in such a background. In this review discuss the different spectrum sensing techniques and challenges in wireless network communications.*

Keywords:- Wireless communication, Orthogonal frequency division multiplexing, International telecommunication union, Cognitive radio, Long term evolution.

INRODUCTION

The cellular communications networks and its technologies have developed by generations starting from the first generation (1G) to the current fourth generation (4G), to fulfill the increasingly continued data demand as a result of the cellular communications industry growing, due to the importance of communications in our life for better world in all of domains. The development was in a gradual manner by increasing the data rate and decreasing the latency also treating with the growing in number of users. So, the generations have been working fine especially with successfully standardization achieved by 3GPP releases for various cellular systems and technologies. Unlike the previous generations and current 4G which are not sufficient for the future, the fifth generation (5G) will be different according to its requirements which have been shaped by the International Telecommunication Union (ITU) [2].

Orthogonal frequency division multiplexing (OFDM) is an easy-to-implement and effective multi-carrier transmission technique, and it has been used in many current wireless communications systems, including IEEE 802.11a/g/n wireless local area networks, Long Term Evolution (LTE), and digital television (DTV) systems. Moreover, OFDM has been recognized as one of the key physical-layer technologies for fifth generation wireless networks [1]. OFDM is also an appealing modulation candidate for CR systems due to its inherent sensing and spectrum shaping capabilities. It should be noted that OFDM has already been adopted by the IEEE 802.22 CR standard for reusing the spectrum allocated for TV channels. Therefore, various aspects of OFDM-based CR (OFDM-CR) networks, ranging from resource allocation to spectrum monitoring, have received considerable research attention.

Next generation wireless networks are expected to provide broadband access wherever needed and also support a diversified range of services including everything from self-driving cars to virtual reality, robotic surgery and Internet of Things (IoT) [10]. Connections in the order of one to dozen of Gbps to vehicles, high speed trains, data-intensive services (e.g., augmented reality, immersive 360^0experiences, etc.) are some of the applications that will drive the demand for larger coverage area, lower latency and higher capacity at reduced cost in next generation wireless networks [4]. Unfortunately, the wireless radio spectrum is a scarce resource, and the available wireless bandwidth does not scale with the needed wireless bandwidth. Hence, as can be seen, the development of technologies that can tackle the ever increasing traffic and service demands while combating the imminent scarcity of spectrum bandwidth is of vital importance for next generation wireless networks.

In recent trend, it has been observed that almost entire wireless technologies adapting OFDM for broadband as one of the potential candidate. Primary reason behind selecting multicarrier transmission approach as OFDM is that it provides highly flexible and adaptive physical layer, which is highly recommended for CR operation. As far as definition of CR concern, radio which is having better observations regarding sensing environment, tendency to adapt operating parameters in dynamic manner and intelligently can reach to a significant goal. Process which makes CR intelligent, can be understand by using cognitive cycle [5] formed by following states such as observe, orient, plan, decide and act.

To improve the performance of underlay spectrum sharing, several approaches have been proposed. Maximum ratio transmission (MRT) was proposed as a transmit diversity scheme for a transmitter deployed with multiple antennas. Recently, MRT has been applied to distributed single carrier transmission systems [9]. However, acquiring exact channel state information at the transmitter side (CSIT) is a challenging task in distributed wireless communications systems, in which transmit diversity heavily relies on CSIT.

II. Related Work

CR technology provides the possibility to improve the spectrum utilization as much as possible under the current spectrum resource allocation policy. SUs cannot only sense the spectrum environment around and access spectrum hole in the opportunity way, but also need to sense the presence of PUs constantly during they occupying the licensed spectrum and to terminate communications immediately when the PU reaccesses due to their priority are lower than the PUs. Hence, spectrum sensing is the key technology in CR and foundation of spectrum sharing. CR technology makes it possible to reuse valuable spectrum resources without changing the existing spectrum allocation policy, thus addressing the problem of low utilization rate. The core idea of CR is to realize spectrum sharing through dynamic spectrum access, and the implication of spectrum sharing is that SUs can use the idle spectrum of PUs, but only if they cannot interfere with the communication of PUs. Typically, spectrum sharing includes four steps, as shown in below figure.

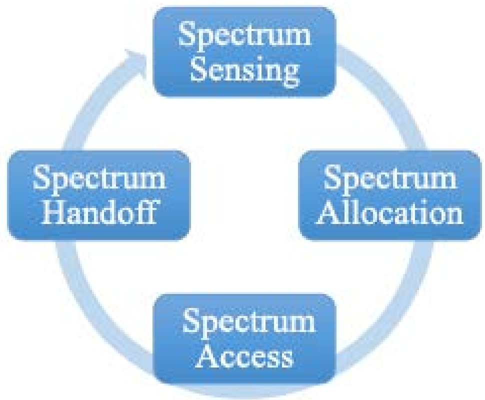

Fig 1: The spectrum sharing process.

Radio spectrum is a precious natural resource, and it is traditionally allocated by governments to specific licensees for exclusive use. Although this simple spectrum allocation approach limits the interference between different wireless systems, it leads to two contradictory consequences. On one hand, the remaining unallocated frequency bands become increasingly scarce. On the other hand, there are still substantial unused resources in frequency, time, and space of the licensed spectrum. In this paper [1] a novel opportunistic spectrum sharing scheme, based on orthogonal frequency division multiplexing with index modulation (OFDM-IM), is proposed for cognitive radio (CR) networks. In the considered OFDM-IM based CR (OFDM-IM-CR) model, the primary transmitter (PT) communicates with the primary receiver with the aid of an amplified and forward (AF) relay by transmitting OFDM-IM signals.

In order to overcome the spectrum scarcity in 5G networks, spectrum sharing is being studied relying on Cognitive Radio (CR) technology. Even with the new spectrum resources (millimeter-wave) for future networks, sharing the spectrum below 6 GHz and above will be necessary. The four stages as processes to achieve spectrum sharing were classified using a novel taxonomy for the latest techniques with their applicability. The proposed algorithms [2] and studies in the literature on spectrum sharing techniques were summarized on the basis of an analytical study. According to 5G requirements several challenges need to be defeated such as large capacity, ultra-low latency, full coverage, and numerous connectivity. This paper presents a comprehensive survey on the sharing techniques which may be applicable to 5G networks.

Index Modulation is applied to cluster-based wireless sensor networks (WSNs) in this study. The aim is to design an efficient decision gathering scheme for target-detection cluster based WSNs. The proposed scheme [3] implies that only a single node reports all the local decisions from cluster-members toward the central entity. Unlike conventional clustering, the reporting node is not fixed as it varies based on the obtained local decisions. Consequently, the local decisions of all cluster members are divided into two groups. The first one is modulated and the other one determines the index of the reporting node. The decision error rate of the proposed scheme is analyzed and an upper bound is derived. The derived bound is shown to precisely matches simulation results at pragmatic signal to noise ratio values.

The unprecedented surge of mobile data traffic requires future wireless networks to support both high spectral efficiency and energy efficiency. To this end, index modulation (IM) emerges as a revolutionary modulation concept. As a realization of IM in frequency domain, subcarrier IM (SIM) has been receiving significant interest. In this article [4] they introduce the generic framework of SIM and its specific representatives. The potential applications of SIM are then investigated in a variety of scenarios, including cognitive radio, relay networks, downlink multiuser communications, and physical layer security. We finally discuss the challenges and possible research directions in SIM and its applications.

In context of effective resource utilization using spectrum sensing and dynamic spectrum access (DSA), Cognitive Radio (CR) has been proposed as versatile and an emerging technology. In order to understand, how OFDM is consider as suitable candidate for cognitive radio, this paper [5] presents various aspects of Orthogonal Frequency Division Multiplexing (OFDM) based cognitive radio. As total transmission rate of CR user is maximized in interference constraint scenario, this paper also formulate problem for optimal transmit power control in OFDM based CR under various spectrum sharing approaches such as underlay, overlay and interweave. Apart from existing works in the literature here we presented mathematical formula for power-allocation schemes for interweave as well as joint underlay and overlay approach. MATLAB simulation shows that with optimal power transmission by CR users, capacity can be improved significantly.

With the development of wireless communication technology, the need for bandwidth is increasing continuously, and the growing need makes wireless spectrum resources more and more scarce. Cognitive radio (CR) has been identified as a promising solution for the spectrum scarcity, and its core idea is the dynamic spectrum access. It can dynamically utilize the idle spectrum without affecting the rights of primary users, so that multiple services or users can share a part of the spectrum, thus achieving the goal of avoiding the high cost of spectrum resetting and improving the utilization of spectrum resources. In order to meet the critical requirements of the fifth generation

(5G) mobile network, especially the Wider-Coverage, Massive-Capacity, Massive-Connectivity, and Low-Latency four application scenarios, the spectrum range used in 5G will be further expanded into the full spectrum era, possibly from 1 GHz to 100 GHz. In this paper [6] they conduct a comprehensive survey of CR technology and focus on the current significant research progress in the full spectrum sharing towards the four scenarios. In addition, the key enabling technologies that may be closely related to the study of 5G in the near future are presented in terms of full-duplex spectrum sensing, spectrum-database based spectrum sensing, auction based spectrum allocation, carrier aggregation based spectrum access. Subsequently, other issues that play a positive role for the development research and practical application of CR, such as common control channel, energy harvesting, non-orthogonal multiple access, and CR based aeronautical communication are discussed.

Spectrum sharing is an important aspect of 5G new radio, as it plays a complementary role for fulfilling diversified service requirements. This paper [7] studies unlicensed spectrum sharing, namely, local thermal equilibrium (LTE) over unlicensed bands (LTE-U), for providing a better quality of experience (QoE) in 5G networks. Specifically, unlicensed band selection and resource allocation (time, licensed, and unlicensed) are jointly designed, and an optimization problem is formulated with the objective of maximizing LTE users' QoE [measured in mean opinion score (MOS)] while protecting incumbent wireless systems such as Wi-Fi in the unlicensed spectrum. To solve the multi-player interaction in this spectrum space fairly, they employ a game-theoretic approach. A virtual coalition formation game (VCFG) is used to solve the unlicensed band selection problem. The outcome of the VCFG defines the optimization problem within each coalition. This optimization problem is then decomposed into two sub-problems: 1) time-sharing problem between the LTE-U and Wi-Fi systems and 2) a resource allocation problem for the LTE-U system.

In this work [8] author present an optimal mapper for OFDM with index modulation (OFDM-IM). By optimal we mean the mapper achieves the lowest possible asymptotic computational complexity (CC) when the spectral efficiency (SE) gain over OFDM maximizes. They propose the spectro-computational (SC) analysis to capture the trade-off between CC and SE and to demonstrate that an N-subcarrier OFDM-IM mapper must run in exact 2(N) time complexity. We show that an OFDM-IM mapper running faster than such complexity cannot reach the maximal SE whereas one running slower nullifies the mapping throughput for arbitrarily large N. They demonstrate our theoretical findings by implementing an open-source library that supports all DSP steps to map/demap an N-subcarrier complex frequency-domain OFDM-IM symbol.

In this paper [9] a distributed cognitive underlay single carrier system is investigated. A secondary users' network consists of a control unit (CU) and a group of secondary user remote radio heads (S-RRHs). To effectively access the radio spectrum licensed to the primary users, a distributed cyclic delay diversity (dCDD) scheme is employed between the CU and S-RRHs as the transmit diversity scheme. Multiple primary user transmitters (PTXs) are assumed to be located isotropically within the secondary users' network, so that a mixture of line-of-sight (LoS) and non-line-of-sight (nLoS) paths from the PTXs to the secondary user receiver is considered. In addition, a mixture of LoS and nLoS paths is considered in the secondary users' network. For a new transmit diversity scheme and channel model, the performance of the secondary users' network achieved by dCDD in the presence of isotropically distributed multiple PTXs is investigated. dCDD enables the CU to use multiple S-RRHs at the same time, so that determining the effects of a different number of S-RRHs in the presence of a new channel model is an open research issue.

The explosive emergence of wireless technologies and standards, covering licensed and unlicensed spectrum bands, has triggered the appearance of a huge amount of wireless technologies, with many of them competing for the same spectrum band instead of harmoniously sharing it. Unfortunately, the wireless spectrum is a scarce resource, and the available frequency bands will not scale with the foreseen
demand for new capacity. Certain parts of the spectrum, in particular the license-free ISM bands, are overcrowded, while other parts, mostly licensed bands, may be significantly underutilized. As such, there is a need to introduce more advanced techniques to access and share the wireless medium, either to improve the coordination within a given band or to explore the possibilities of intelligently using unused spectrum in underutilized (e.g., licensed) bands. Therefore, in this paper [10] they present an open source software-defined radio-based framework that can be employed to devise disruptive techniques to optimize the sub-optimal use of radio spectrum that exists today. They describe three use cases where the framework can be employed along with intelligent algorithms to achieve improved spectrum utilization.

III. OFDM Based Cognitive Radio

OFDM based CR system block diagram as shown in Fig.1, represent interaction of various layers with cognitive engine [5]. Tasks of cognitive engine are allow to sense environment, plan and orient accordingly then act on final decision. In order to perform certain task and make CR so intelligent, cognitive engine consist decision unit, policy engine and local spectrum sensing unit. Based on the information received by policy engine and spectrum sensing unit, decision unit identify opportunity to make it intelligent and configure radio and its physical parameters. Physical layer parameters such as types of modulation, coding techniques, mode of transmission, operating frequency and patterns of interleave can be alter by changing configuration parameter of OFDM as well as also update functionalities of higher layer accordingly.

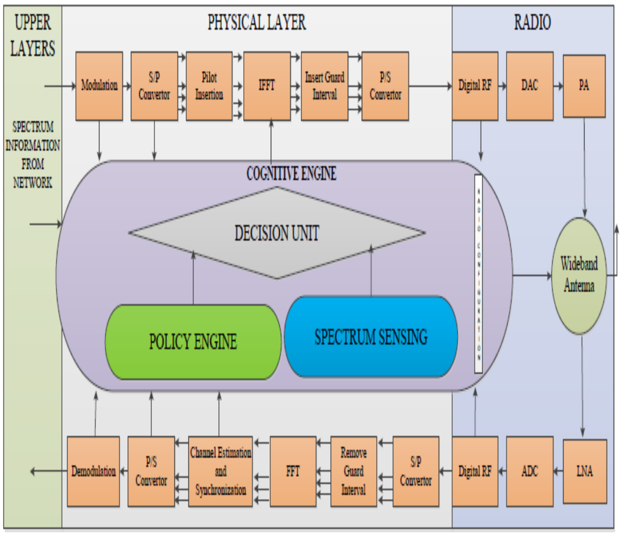

Fig 2: OFDM based CR System.

IV. Problem Statement

Most of today's channel allocations separate wireless systems by splitting the spectrum into fixed and exclusively licensed bands that are assigned over large and geographically defined regions. This approach restricts access to the spectrum in exchange for guaranteed interference-free communications. These allocations of spectrum are human-driven and not adaptive to the dynamics of traffic demand and supply. At any given time, many allocated spectrum bands are unused by their licensees while other bands are completely flooded. For example, a report from the Federal Communications Commission's (FCC) Spectrum Policy Task Force (SPTF) shows that 85 % of current allocated radio frequency bands are either partially or completely unused at different times across geographical areas. This kind of channel allocation scheme tremendously wastes the spectrum capacity and creates unnecessary scarcity [10]. Spectrum sharing, where more than one user shares the spectrum band, either in time and/or space, is one possible and highly viable approach to achieve better spectrum utilization (i.e., combat spectrum bandwidth scarcity) and meet the foreseen increase in traffic demand. Additionally, spectrum sharing can be categorized into two different types: (i) sharing in unlicensed bands; and (ii) sharing in licensed bands.

V. Conclusion

Since the radio frequency spectrum is a scarce natural resource, it needs to be efficiently utilized by all entities that want to use it. To mitigate its inefficient utilization, cognitive radio has been proposed by several authors. Among several approaches of cognitive radios, such as overlay, interweave, and underlay, underlay spectrum sharing is the most promising since unlicensed secondary users can reuse the spectrum licensed to primary users in transmitting their information.

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