Overview of Cognitive Radio Networks

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Abstract. Cognitive radio (CR) allows the best use of dynamic access to spectrum and wide spectrum diversity to mitigate spectrum depletion issues and fulfill huge wireless networking requirements. This paper also illustrates, discusses, and focuses on some essential applications, a proactive spectrum sharing strategy using full-duplex (FD) in the cooperative Cognitive Radio Networks (CRN).

Index Terms: Cognitive Radio (CR), Full-Duplex (FD), Cognitive Radio Networks (CRN).

Introduction

The exponential rise in wireless data traffic has been seen in recent years. The increase in mobile data traffic is expected to rise about 1000 times in the next ten years, with the introduction of new applications and smart terminals [1]. It is well established that due to the amazing development and advancement in communication systems and technology, there is a problem with the available radio spectrum. Therefore, devices and smartphones are fighting hard for bandwidth. Considering all this, it is expected that nearly 50 billion wireless devices will compete in the coming years for wireless access. By 2030, it is estimated that there will be 250 times the wireless connectivity market [2]. Wireless networks of the next generation should provide as far as possible broadband connectivity and allow a variety of services including automotive transport, virtual reality, robotic surgery, and the Internet of Things (IoT). Applications that fuel the appetite for a wider range of coverage, lower delays and greater reliability in the next generation of wireless networks include 1 to 12 Gbps car docks, high-speed trains and data infrastructures. The wireless radio frequency is sadly a finite resource and the wireless spectrum available does not cover the requisite wireless spectrum. To address this inevitable broadband spectrum shortage, it is also necessary, as can be seen, to improve the infrastructure to meet increasing transport and service demands. [3].
The sharing of spectrum between multiple users, in time or space, is the potential and highly probable solution to the spectrum quality (i.e. bandwidth scarcity counter-scarcity) and the anticipated rise in traffic demand. Spectrum participation may therefore be divided into two groups, (i) non-licensed sharing of bands and (ii) licensed sharing of bands. Band signals and simple traffic managed Quality-of-Services (QoS) specifications when lower critical band traffic is downloaded.

More information and coordination should be used for the next generation of radio networks to prevent interference when maximizing spectrum use. Such radio stations should communicate with their colleagues intelligently to use their organizational characteristics and to maximize their valuable resources without previous knowledge. To maximize their hybrid wireless spectrum, the use of both radios should allow integrated smart radios to be linked with other previously unknown radios. This is not only used in congested and difficult conditions to communicate efficiently but is often used to share the available spectrum band with many heterogeneous radios without central coordination or spectral preparedness. [3].

Cognitive radio is described as “A ‘Cognitive Radio’ is a radio which, based on interaction with the environment in which it operates, can change its transmitter parameters”[4].

I. Cognitive Radio Concept
CR is a big instrument for improving the quality of spectrum and potentially reducing problems of spectral scarcity [5]. Cognitive users can adapt the transmitters and secure incoming users by sensing the radio environment. Usually, two stages include sensing and cognitive transmission of the spectrum. The cognitive users sensing the radio atmosphere and collect spectral information at the spectrum sensing level (e.g. occupation status, traffic, electricity, channel gain). For the spectrum data obtained during cognitive transmission, cognitive users pick the best spectrum bands and adjust transmissions.

II. Cognitive Radio Fundamentals
The cognitive radio can perceive and adjust its parameters to use bandwidth effectively. Given the ideal protection of available frequency channels for 90% of the time, this technology focuses on enhancing and maximizing spectral usage. CR detects and transmits a set of frequencies at a given time and location of the unused spectrum. This uses empty strip for secondary use with no mainly approved custom strip intervention. Therefore, a principal user may be separated by the CR method from a secondary user. Higher priority is given to approved users and key users are named. It provides enough bandwidth to improve the content and enhance data rate services. The primary steps for the working of CR include the spectrum sensing, spectrum analysis, spectrum choice and spectrum mobility.

The relationship between PUs and SUs would bring more spectral efficiency benefits. Such mutual networks are also characterized by Cooperative Cognitive Radio Networks (CCRNs). As SUs function as relays for PUs, the spectral effectiveness of CRNs is increased, as SUs are more likely to use the spectrum [6].
a. Spectrum Detection System

To create, improve and enforce various transmission strategies for the build of an efficient CR network\cite{3}, the propagation environment of these networks must be understood. The faster and stronger the CR system is the less damage it can do to other users since it knows the current radio environment and other users.

Spectrum sensing takes place during silent cycles of intra- and interframe data transmission. To locate the previously used networks, frequency hopping or multiplex scers and communication protocols are used to transmit the next channel \cite{7}.

For spectrum sensing, the following techniques are commonly used.

1) **Energy sense:** Because of its technical simplicity and quick implementation of the simplest technological technique. In this method, compared the measured energy to a suitable threshold to determine that a spectral hole exists.

2) **Coherent Sensing:** In this technology, the detector has an accurate knowledge of primary user signals such as the form of modulation, order, pulse duration, data rate and bandwidth. The signal obtained is connected to a new copy and a limit value contrasts the effect.

3) **Cyclo-stational sensing:** If (x) function not fully understood, but other characteristics are known, the data can be used to create test statistics that are closely associated with the signal. This includes a cyclical auto-relation function for a generated data signal that is regular but stopped for noise or wide range.

4) **Autocorrelation sensor:** To distinguish white noises and the principal data signals by autocorrelation, the main data signal station is used.

b. Sharing of spectrum Types

The CR activity can be graded as follows according to the spectrum use scenario:

1) **Underlay Systems:** This device is forwarded to the primary user at the same time by subsequent users. However, secondary users' involvement is under a certain amount.

2) **Overlay Systems**: Secondary users in this system communicate at the same frequency with primary users. But it revises key user knowledge to boost the performance of primary users and uses complicated signals and encoding schemes. The secondary radio station knows the advantage of the channel, coding systems and sequence of data that are passed on by primary users. To increase secondary as well as primary device output, the secondary transmitter can use sequence information in a variety of ways. This information knowledge can be used to delete primary signal interference or secondary users can assign themselves their power or better encoding methods can be used to remove interference from the secondary transmitter.
3) **Interweave Systems:** In this process, even though during the primary user data transmission a spectral void (white space) is detected, the secondary consumer transmits data in parallel with the primary user. The receptor for this system must be regularly reconfigurable and have a long front end. Such applications of spectrum hole can be accessed by secondary applications in orthogonal space, which improves the use of bandwidth through opportunistic reuse of spectrum hole.

**Technology of work**

The CR devices listen to high-frequency waves either with a broadband signal to keep distortion below the sound level or with multiple antennas and beamer-forming antennas. The waves are viewed at a high-frequency level. The sensing signal is a very tiny UWB signal with much bandwidth. The CR provides information on present and past roles and conduct as well as potential future roles, possible user behaviour, the sensitivity of waveform, including modulation, labelling, rates of power, control systems, synchronization, etc. This knowledge allows the behaviour and consequences of cognitive customers to be intelligently judged. The selection of the best transmitting parameters for frequency bands and power, modulation, coding, beam designs, etc., will optimize their ability for transmission and minimize interference with other spectrum users. For this CR system, it is important to locate a suitable transmission site. When a vacant channel is identified, the secondary user sends data through a reconfigurable antenna. The integrated frequency reconfiguration properties allow data transmission to be restarted in a different empty path if the primary receiver wants to re-use the network.

**A Strategic Approach for Spectrum Sharing using a Full-Duplex in cooperative Cognitive Radio Networks**

The term "duplex" refers to the ability of two devices to communicate within a wireless network. However, communication can be carried out simultaneously or not depending on a device's data flow capabilities like half-duplex (HD) or full-duplex (FD). Due to its simplicity in implementation, the HD is the most frequently used data flow mode in wireless networks. Unable to transmit and receive HD systems simultaneously [8].

There are a variety of strategies for shared spectrum like Full-duplex (FD) communication to achieve the high data levels needed in mobile networks for the new generation. Thanks to its simultaneous transmission and receiving capabilities, the FD transceiver can achieve higher data levels compared to its corresponding half-duplex (HD) [9]. The cognitive radio network, in which the unlicensed secondary consumer (SU) has a shared range of spectrum for the specified primary user (PU) is another common model for optimizing spectral performance [10].

Collaboration between PUs and SUs will bring more advantages to spectral efficiency. These reciprocal networks are often known as Cognitive Radio Cooperative Networks (CCRN). The spectral efficiency of CCRNs improves with the SU’s functioning as PU relays, as SUs are given more opportunities to use the spectrum [6]. Furthermore, the use of FD-conducted relays in CCRNs has been shown to further improve spectral efficiency [11]. Due to these advantages, the
FD transceiver suffers from a simultaneous transmission and reception effect of self-interference (SI).

The network configuration in comprises of a PU (single terminal) and an SU pair, where only the SU pair requires a relay. Therefore, when STs function as FD relays, they increase their spectral efficiency as well as the spectral efficiency of PUs, it is necessary to investigate this sophisticated CCRN pattern. Moreover, this CCRN model is ideally designed to improve spectrum utilization and spectrum efficiency for ultra-dense networks where resources are scarcer. The equality of the FD relay between much opposing PUs remains a major problem in this CCRN model through understanding the implications of SI. SUs is most advantageous in FD mode because they share the whole time they are spending on PUs.

CRN cooperation in the following generation plays an important role by offering high-performance wireless devices that have low power. It uses time and space diversity to increase the performance of CRN. Low energy transfer, increased energy consumption, high performance, low primary network interference, and improved network coverage are cooperative communication advantages in the NRC. Besides, CRN collaboration faces some disadvantages, including increased relay traffic and increased end-to-end latency. The new CRN study included two types of cooperation, i.e. engaged and dynamic cooperation. In dedicated teamwork, there are secondary resources that can only serve as relays. A secondary customer may operate in complex cooperation with a primary or secondary network [12].

Applications
The most common application of CR is the use of white space in television networks that enables secondary cognitive users to use the unused spectrum without being competitive with primary users. A second significant aspect of CR for telecoms systems is also the successful usage of the spectrum with increasing wireless networks and the attempt to improve bandwidth rivalry. Macrocellular traffic spectrum characteristics and opportunistically use the spectroscopic spectrum for high data requirements are expected by the CR technology.

An additional appeal is that CR and NOMA combine high performance, high availability and low latency with 5G. In practice, both CR and NOMA are susceptible to interference and cause NOMA to multiplex within a controlled domain which will eventually lead to substantial interferences between central, secondary and internal interference networks [13].

The gains from an insightful cognitive sharing of the NOMA spectrum can be found below.
- Enhanced spectrum use: NOMA cognitive networks will enable both PUs and SUs at an appropriate level of reception.
- Massive Connectivity: Many smart devices are planned for 5G wireless networks. NOMA cognitive networks, where multiple PU and/or modules are supplied in a single source block at different power levels simultaneously, will satisfy this requirement [14].
Low latency: In cognitive NOMA networks, transmission delays in SUs can be high, resulting in low latency. For example, several SU units can be connected simultaneously by making use of NOMA to support CR networks [15].

Better Justice: NOMA Perceptual Networks will ensure better equality among consumers. This results in a healthy compromise between equity and secondary network efficiency [14].

Conclusions
In reviewing the basic principles of cognitive radio, we found that this is one of the effective methods to solve the problems of a specific frequency spectrum. Additional spectral efficiency benefits would be provided by cooperation between PUs and SUs. These reciprocal networks are also categorized as Cognitive Collaborative Radio Networks (CCRNs) which have different methods of spectrum sharing. Combining NOMA and CR can meet 5G standards for high performance, great connectivity, and low latency, but there are many challenges to this integration that need to study, and analysis and we recommend that the research in this field is advisable. In the future, the wireless spectrum could be used more effectively by NOMA and CR technologies.

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