COGNITIVE RADIO IN MODERN TECHNOLOGY

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ABSTRACT

Due to the widespread use of wireless technology, cellular networks are overloaded. Independent measure campaigns found that non-cellular frequency spectrum bands are underutilized. Fixed spectrum radio technology limits effective use of the allocated spectrum; cognitive radio technology allows adaptive changes to the communication channel such that the radio can operate in underutilized spectrum. This paper examines the technology of cognitive radio and analyzes how the technology can be used to optimally reduce current radio spectrum congestion. Techniques such as spectrum sensing, spectrum management, and adaptive power control enable the optimal use of radio spectrum, thus solving limitations in modern communications.

INTRODUCTION

Traditionally, the Federal Communication Commission (FCC) of the United States and other international institutions regulate the use of radio frequency (RF) spectrum. Licensed users, or primary users, are assigned fixed spectrum bands for transmission; to prevent transmission interference on these channels, unlicensed users are not allowed to utilize these bands. In more recent times, the FCC and other independent measure campaigns have found that many frequency bands are largely or partially unoccupied during certain times or at specific locations, while the remaining bands are heavily used [1]. The underutilization of some channels presents a limitation in the RF spectrum architecture as more and more applications require wireless communication. By using the technology of spectrum sensing, spectrum management, and adaptive power control, cognitive radio enables the optimal use of the radio spectrum, thus solving the current limitations in modern communications.

I. WHAT IS COGNITIVE RADIO

Cognitive radio can be defined as emerging RF technology that intelligently analyzes and adapts to the current spectrum environment. The goals of this technology are to increase the reliability of communications when needed and to efficiently utilize the radio spectrum. Cognitive radio changes parameters such as transmit power, carrier frequency, and modulation strategy to optimize its objectives [1]. The key technologies in cognitive radio are spectrum sensing, spectrum management, and adaptive power control.

A. SPECTRUM SENSING

A current inefficiency in the RF spectrum are spectrum holes: frequencies that are reserved for a primary user but are not utilized at specific times and locations [1]. Cognitive radio consists of technology that enables the use of unoccupied channels through spectrum sensing. Spectrum sensing is the process of analyzing bands of the radio spectrum to identify spectrum holes or spectrums that are under-utilized. Observations about the spectrum holes should be made such that the spectrum can be characterized, and the cognitive radio can then operate at the available channel. In addition, if the cognitive radio transmission is modified to operate at the available channel, spectrum sensing should continue to determine if the primary user of the channel returns to transmit [2].

B. SPECTRUM MANAGEMENT

Building on spectrum sensing, another key element of cognitive radio is spectrum management. Spectrum management is the process that modifies radio parameters to fulfill the objectives of cognitive radio. The first state of this process is spectrum sensing to determine spectrum hole information or primary user transmission. If the primary user is detected, then the state of spectrum mobility is initiated, followed by the state of spectrum analysis. If a spectrum hole is detected in the spectrum sensing state, the next state is also spectrum analysis. Spectrum analysis must determine whether to continue spectrum sensing or to change the transmission parameters, by using both the information of spectrum holes and the primary user occupation. The next state is spectrum decision, which then modifies the carrier frequency and modulation depending on the channel capacity [2]. This process surmises cognitive radio functionality to best utilize the RF spectrum.

C. ADAPTIVE POWER CONTROL

A constraint of cognitive radio is that the transmit power of the signal must not cause interference with the primary users' transmission. Furthermore, the cognitive radio must have sufficient transmit power such that the signal can be received by the intended recipient [3]. Spectrum sensing and management are also factors in the output power of cognitive radio. Changing the frequency depending on available channels results in power changes of the output signal. Thus, a key technology of cognitive radio is adaptive power allocation and control.

II. APPLICATION OF COGNITIVE RADIO

A. ADVANTAGES

The main advantage of cognitive radio is providing optimal use of the RF spectrum. Spectrum holes are a considerable deficiency in the current RF network. By transmitting on these under-utilized channels, cognitive radio reduces congestion on channels of fixed-spectrum technology.

Another advantage of cognitive radio stems from the adaptive power control; after determining the appropriate power to follow the constraints in the section above, cognitive radio could operate at the lowest power acceptable. Lower power conserves resources for cognitive radio, but also reduces eavesdropping of the transmission. Low powered signals are difficult to detect at far distances; thus, this reduces unwanted receivers from picking up the transmission.

B. DISADVANTAGES

One disadvantage of cognitive radio is that the FCC has currently allowed cognitive radio operation only in the unused TV spectrum. The FCC has strict guidelines, for example, requiring access to a database of unused channels before transmission, and transmission power limits for a sensing-only device [4]. These current guidelines restrict the possibility of using cognitive radio in other bands to further optimize the RF spectrum. For cognitive radio to reach its full potential, more complex standards and company cooperation will be critical.

Another disadvantage of cognitive radio currently is that spectrum sensing is prone to fault in practice. One fault is a false-alarm event, in which the cognitive radio fails to utilize a channel that is unoccupied. Another fault is a miss-detection event, in which the cognitive radio fails to identify a primary user’s transmission, leading to illegal interference on that channel [5]. These faults result in unwanted operation of the cognitive radio and must be addressed.

C. CURRENT RESEARCH TOPICS

Current research topics on cognitive radio offset the disadvantages above. As research develops further, the FCC is likely to reevaluate the allowable bands for cognitive radio in the interest of the prospective advantages. To address the issue of the above faults in cognitive radio, numerical methods have been developed through research to determine achievable rates and outage probabilities of a cognitive radio with imperfect spectrum sensing [5].

Another area of research is the use of deep learning for automatic modulation classification. Deep learning may allow the cognitive radio to determine the modulation type quickly with a high accuracy, to see if the ideal frequency is allowable to be used. For example, if a licensed frequency was being used at a very low power by a primary user, a cognitive radio that detects usage solely on the power of the signal may not identify the primary user, causing a miss-detection fault. However if the cognitive radio was programmed to determine which modulation classification the low power signal was using, it could detect whether actual data was being transferred over it or not. Current research in deep learning intends to make the classification faster so that a new unused frequency can be detected.

Moreover, research is ongoing to determine how cognitive radio can enable further development of the Internet of Things (IoT). As the IoT evolves, an increasing number of devices require wireless communication [2]. The frequency spectrum is an important resource for wireless communication; however, available frequency spectrum is currently scarce due to FCC allocation. The integration of cognitive radio in this context would alleviate the current strain on the frequency spectrum, and thus is a relevant research topic.

CONCLUSION

Cognitive radio is an emerging communication protocol that consists of spectrum sensing, spectrum management, and adaptive power control. These properties interact to increase the reliability of communications and to efficiently utilize the radio spectrum. The application of cognitive radio is still in its infancy, as more research is required to best use the technology according to FCC standards. As cognitive radio research matures, and the FCC widens the allowable usage, this communication protocol will solve the current limitations of the RF spectrum.

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