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A Comprehensive Study of Cognitive wireless network for Disaster Information Network

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***Abstract*— Cognitive Radio (CR) is an adaptive, intelligent radio and network technology that can automatically detect available channels in a wireless spectrum and change transmission parameters enabling more communications to run concurrently and also improve radio operating behavior In this paper we explain the idea behind cognitive radio systems, their need, the major tasks performed by these systems and focus on their application in disaster management. The flexibility of these systems, specifically, in a disaster relief scenario with complex usage and security requirements, is studied in this paper.**

***Index Terms*— Cognitive radio, Spectrum , Parameters, Disaster management, Dynamic spectrum access, Software-defined radio, Spectrum hole.**

I. INTRODUCTION

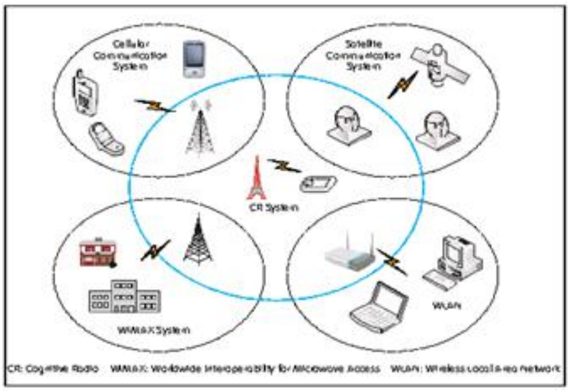

Fig1: Cognitive radio system

The impact of large- scale natural and human disasters are felt by all. In such situations there is an urgent need for information transfer so that the impacted can react appropriately, the victims can coordinate with each other and the authorities- in- charge can manage the situation appropriately to reduce the catastrophic effects of the disaster. In order to handle disasters we need a flexible, secure and robust emergency network that can manage the various network assets that are involved as well as assure access to various critical services and assets. In contrast to many incompatible systems, cognitive radios provide adaptability to myriad radio interference conditions and protocol standards which make them compatible. Cognitive radio (CR) is an intelligent wireless communication system that is aware of its surrounding environment, learns from the environment and adapts its internal states to statistical variations in the incoming RF stimuli by making corresponding changes in certain operating parameters in real time [Haykin 2005][2].The term cognitive radio was first suggested by [Mitola 1999]. He defines the cognitive radio as a radio driven by a large store of a priori knowledge, searching out by reasoning ways to deliver the service the users want [Mitola 1999][2].Spectral efficiency is the need of the hour and will accommodate more and more users and high performance services like broadband in future.

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II. WHY COGNITIVE RADIO NETWORKS WERE DEVELOPED?

Recent "Moore's law" advances in programmable integrated circuits have created an opportunity to develop a new class of intelligent or "cognitive" radios which can adapt to a wide variety of radio interference conditions and multiple protocol standards for collaboration between otherwise incompatible systems. Such a cognitive radio would be capable of very dynamic physical layer adaptation via scanning of available spectrum, selection from a wide range of operating frequencies (possibly non-contiguous), rapid adjustment of modulation waveforms and adaptive power control [5].Current wireless networks are regulated by governmental agencies mainly according to a fixed spectrum assignment policy. Due to the huge success of wireless applications there has been an exponential increase in requests for spectrum allocation. ISM band, has been prolific with a wide range of applications developed in different fields which caused overcrowding in this band. To address this situation, the notion of dynamic spectrum access (DSA) [1] has been proposed. With DSA, unlicensed users may use licensed spectrum bands opportunistically in a dynamic and non-interfering manner. From a technical perspective, this is possible thanks to the recent advancements in the field of software-defined radios (SDRs). SDRs allow the development of spectrum-agile devices that can be programmed to operate on a wide spectrum range and tuned to any frequency band in that range with limited delay [1].The cognitive radio is reconfigurable and built on the software-defined radio (SDR)[1]. As a result Cognitive Radio (CR) transceivers have the capability of completely changing their transmitter parameters (operating spectrum, modulation, transmission power, and communication technology) based on interactions with the surrounding spectral environment. They can sense a wide spectrum range, dynamically identify currently unused spectrum blocks for data communications, and intelligently access the unoccupied spectrum called Spectrum Opportunities (SOP) [1].

III. WORKING OF COGNITIVE RADIO NETWORKS

Most of today's radio systems are not aware of their radio spectrum environment as they are designed to operate in a predefined frequency band using a specific spectrum access system. As elaborated in the introduction, investigations of spectrum utilization indicate that spectrum is not efficiently utilized most of the time. Overall spectrum utilization can be improved significantly by allowing secondary unlicensed users to dynamically access spectrum holes temporally unoccupied by the primary user in the geographical region of interest [7].

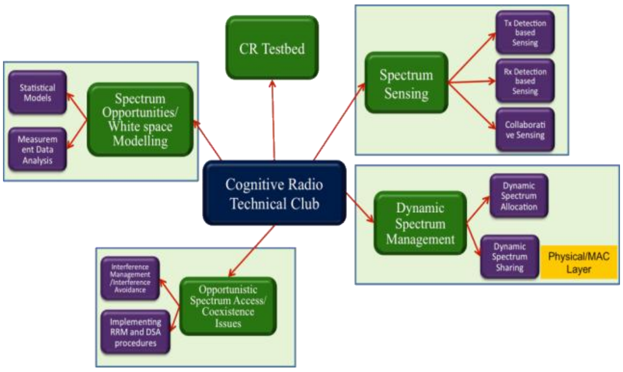

Fig2: Cognitive radio technical club

A spectrum hole [7] or white space is a band of frequencies assigned to a primary user, but however at a particular time and specific geographic location, the band is not being utilized by that user. The spectrum hole concept can be further generalized as the transmission opportunity in radio spectrum space. This spectrum hole can be used to increase the system capacity. Radio spectrum space is a theoretical hyperspace occupied by radio signals which has dimensions of location, angle of arrival, frequency, time, energy and possibly others. A radio built on cognitive radio concept has the ability to sense and understand its local radio spectrum environment, to identify spectrum holes in radio spectrum space, to make autonomous decisions about how it accesses spectrum and to adapt its transmissions accordingly [7].

Spectrum sensing is an active spectrum awareness process where cognitive radio monitors its radio environment and geographical surroundings, detect usage statistics of other primary and secondary users and determine possible spectrum space holes [7].

Spectrum decision: Based on spectrum sensing information cognitive radio selects and decides when to start its operation, operating frequency and its corresponding technical parameters [7].

Spectrum sharing: Since there is number of secondary users participating in usage of available spectrum holes, cognitive radio has to achieve balance between its self-goal of transferring information in efficient way and altruistic goal to share the available resources with other cognitive and non-cognitive users. This is done with policy rules determining cognitive radio behavior in radio environment. Spectrum sharing enables Cognitive radio systems to achieve this balance [7].

Spectrum mobility: If primary user starts to operate, cognitive radio has to stop its operation or to vacate currently used radio spectrum and change radio frequency. In order to avoid interference to primary licensed user this function has to be performed in real time, therefore cognitive radio has to constantly investigate possible alternative spectrum holes [7].

IV. Challenges for Cognitive Radio Networks

The three major tasks of the cognitive radio include:
(1) Radio-scene analysis
(2) Channel identification
(3) Dynamic spectrum management and transmit-power control [2].

The radio-scene analysis includes the detection of spectrum holes by for example sensing the radio frequency spectrum [2].The channel identification includes estimation of the channel state information which is needed at the receiver for coherent detection. Thus, the channel state has to be estimated in the receiver [2]. In addition, the computation of the channel capacity of a cognitive radio link and the power control algorithm in the transmitter require knowledge of channel-state information [Haykin 2005] [2]. The transmitter power control and dynamic spectrum management select the transmission power levels and frequency holes for transmission based on the results of radio scene analysis and channel identification.

V. Disaster

Fig3: Cognitive radio technology in larger domain

In order to deal with natural or man-made disaster, restoration of telecommunications is essential. First responders must coordinate their responses, immediate casualties require assistance, and all affected citizens may need to access information and contact friends and relatives. Existing access and core infrastructure may be damaged or destroyed, so to support the required services, new infrastructure must be rapidly developed and integrated with undamaged resources still in place. This new equipment should be flexible enough to interoperate with legacy systems and heterogeneous technologies. The ability to self organize is essential in order to minimize any delays associated with manual configuration.

Finally, it must be robust and reliable enough to support mission-critical applications. Wireless systems can be more easily reconfigured than wired solutions to adapt to the various changes in the operating environment that can occur in a disaster scenario. A cognitive radio is one that can observe its operating environment, make decisions and reconfigure in response to these observations, and learn from experience.A communication path between nodes has multiple links and the suitable links among them is selected based on the distance, power and transmission frequency. By multi-hopping those nodes, user can communicate with other user and send/receive disaster information even though some of information infrastructure are damaged.

5.1. PARAMETERS

Cognitive radios encompass conventional software-defined radio (SDR) while possessing the ”intelligence” to automatically adapt operating parameters based on learning from previous events and current inputs to the system. In developing a cognitive radio control system, several inputs must be defined. The accuracy of the decisions made by an AI method is based upon the quality and quantity of inputs to the system. [3]Cognitive radios should not only be capable of adapting to the frequency spectrum being used around it, but also the channel conditions that could possibly prevent it from effectively communicating in the available bandwidth. A primary feature of cognitive radios is the ability to adapt to the surrounding environment.[3]
This feature defines a critical input to the system - a representation of the environment. In order for the system to make decisions about a certain output, the current wireless environment must be modeled internally. This model is created using environmentally-sensed data received by the system using an external sensor. Another important set of inputs to any AI method are the decision variables. In the cognitive radio case, these variables represent the transmission parameters that can be controlled by the system. Once the virtual channel environment is created, a set of decision variables are applied to the fitness function and an approximation of how well they meet a set of quality of service (QoS) goals is returned based upon the virtual environment. The end result is a quantification of how well a sample set of transmission parameters achieves the set of QoS goals. The AI can use this scalar approximation to evolve the system to an optimal set of transmission parameters.[3]

DECISION VARIABLES-

Cognitive radios become possible when the components within the radio permit the modification of the control parameters. These control parameters are set by the cognitive component once an optimal decision has been formulated using the AI technology.it is used to control the individual radio component[3].

5.1.1. ENVIRONMENTAL PARAMETERS

Environmental variables inform the system of the surrounding environment characteristics. These characteristics include: internal information acquired using sensors within the cognitive radio, and external information from local cognitive radios within the same network. Both types of information can be used to aide the cognitive controller in making decisions. These variables are primarily used as inputs to the fitness function.[3]

5.1.2. FITNESS OBJECTIVES

In a wireless communications environment, there are several desirable objectives that the radio system may want to achieve. This works defines three objectives for the fitness function in order to lead the system to an optimal state.[3]

Parameter Name	Symbol	Description
Transmit Power	P	Raw transmission power
Modulation Type	MT	Type of modulation
Modulation Index	M	Total number of symbols in a constellation

Table 1:TRANSMISSION PARAMETER LIST

Parameter Name	Symbol	Description
Bit-Error-Rate	BER	Percentage of bits that have errors relative to the total number of transmitted bits.
Signal-to-Noise Ratio	SNR	SNR Ratio of the signal power to the noise power.
Noise Power	N	Magnitude in decibels of the noise power

Table 2:ENVIRONMENTALLY SENSED PARAMETER LIST

Objective Name	Description
Minimize Bit-Error-Rate	Improve the overall BER of the transmission environment.
Maximize Throughput	Increase the overall data throughput transmitted by the radio.
Minimize Power Consumption	Decrease the amount of power consumed by the system.

Table 3:COGNITIVE RADIO OBJECTIVES

VI. CONCLUSION

This paper has described the application of cognitive radio systems in a disaster relief scenario and the cognitive networking approach for addressing the challenges of the emergency response environment. In this paper the cognitive radio network has been successfully studied, its working has been analyzed and its challenges and parameters have been discussed. The features and nature of cognitive radio systems that makes these systems the need of the hour have been studied in this paper.

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