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A Perspective of Cognitive Radio in Wireless Sensor Networks – A Survey

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Abstract*— In this Modernistic World folks want everything compact and mobile. As the wireless devices dominate the market, the necessity of wireless network and wireless communication has been increased. The Regulations of FCC (Federal Communications Commission) allocates 2.4 GHz to ISM band. It is used by major part of the population because technologies like Zigbee, Bluetooth, Wi-Fi/802.11 and etc use this unlicensed band. As a result we are running out of spectrum. Shortage in the unlicensed band must be alleviated. The promising solution is Cognitive Radio (CR). In this paper, CR and its features are reviewed in detail. Basics of Software Defined Radio (SDR) and related technologies were discussed. This paper gives the overview about SDR and describes the functions and importance of cognitive Radio. Also the key research areas and innovative works on Dynamic Spectrum Access (DSA) have been analyzed. A new idea of integrating the existing strategies to effectively utilize the spectrum is proposed.

Keywords*—Spectrum, Cognitive Radio, Software Defined Radio, Spectrum Sensing and Dynamic Spectrum Access.

I. INTRODUCTION

According to IEEE P1900.1 group, SDR is defined as "*Radio in which some or the entire physical layer functions are software defined".* SDR is flexible; it provides low cost, increase in capacity, Ubiquitous Connectivity, Interoperability and many other benefits to service providers (quasi-future proof their networks) and end users. SDR paved the fundamental ways for the efficient use of spectrum. It facilitates re-programming or reconfiguration to operate with different protocols. Incompatible problems in wireless technology due to evolution of link-layer protocol standards (2.5G, 3G, and 4G) are solved by SDR [1], as it incorporates radio functionality in software.

Cognitive Radio [2], a hot research area in wireless technology made a revolution in radio spectrum usage. Without affecting the rules of FCC, it provides the efficient and effective access of spectrum for both licensed and unlicensed users. Various protocols (like Dynamic Spectrum access) are employed to solve the spectrum scarcity. Based on CR a network has been developed, by name CRAMNET (Cognitive Radio Assisted Mobile Ad Hoc Network). Recently, all the innovations in Wireless communications are highly focused on CR and CR based sensor networks (CRSN). The reason is CR can provide interference free channels even to unlicensed users.

Synthetic (Cooperative) MIMO, Cognitive spectrum management, Cognitive routing are recently proposed applications enabled by CR. Some other applications of CR networks are cellular network, multimedia, military network and leased network. Spectrum sensing, an important characteristic in CR networks to identify the temporary holes in spectrum without causing interference to the primary users (PU). The cognitive radio devices generally access spectrum as secondary users.

In some technologies like adaptive radio, intelligent radio and cognitive radio, a versatile software defined radio plays a vital role in increasing performance and better quality of service in a communications link. Brief note on such radios; a) Adaptive Radio- an emerging new paradigm in wireless and the innovation to unlock the shortage by enabling the good use of spectrum; b) Intelligent Radio- Intelligent radio is cognitive radio that allows machine learning. When CR is used along with intelligent radio, it can adapt to changes in the environment; c) Cognitive Radio- enabled by SDR, a technology to afford interference-free spectrum to unlicensed users.

II. OVERVIEW OF COGNITIVE RADIO

A. *CR DEFINTION*

Many researchers give their own definition for CR. Let us analyse different definitions and try to confine what is CR exactly. Generally it senses the environmental changes and act spontaneously. According to FCC it is adaptive spectrum awareness. CR is a SDR, but not a software or program. CR is considered as agile technology to overcome spectrum scarcity. It provides fastest and interference-free spectrum utilization for enhanced performance and efficiency without violating FCC rules and regulations.

We can summarize that Cognitive Radio is a radio or sensible technology, as it can adapt to the dynamically changing environment facilitating efficient usage of spectrum and spectrum holes. Spectrum holes are underutilized or temporarily unused portions of the licensed bands which are accessed by the Secondary Users (SUs) through spectrum sensing.

B. *CR FEATURES*

The unlicensed user leaves the spectrum at once the licensed users of that spectrum access it. A spectrum sensing is a key feature in CR technology. To identify the unused bands two methods are used, one is database oriented sensing and spectrum sensing oriented method [3]. Generally first method is widely used in TVWS (Television White Space), in which the database contains the information about the primary user's location adopted by FCC, as this is used to detect the spectrum usage of licensed users by accessing database.

The spectrum sensing is lending the un/underutilized portion of radio spectrum from the licensed users without causing interference to PUs. The idle frequency bands can be detected by spectrum sensing.

C. *FUNCTIONS OF CR*

i) Spectrum Management- As per the needs of the secondary users the best communication channel is provided to them. This scenario shows the improper usage of spectrum. Many licensed bands are not utilized properly, so the resources are wasted at one side and other side lack of resources for unlicensed users. Both the conditions must be balanced without interference and with higher performance in their channel.

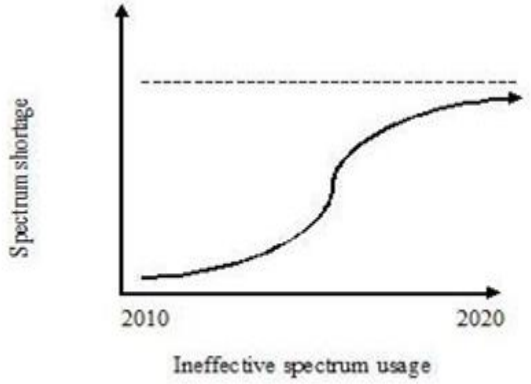

Fig. 1 Inefficient Management of spectrum

ii) Spectrum Mobility - concept says when SU accessing the licensed spectrum, if it detects the primary users is back to their channel, it must immediately leaves the channel without creating any disturbance or interference to the PU. Pre-empting the SUs access to the licensed channel may affect their performance, so the SU must be dynamically switched on to another available spectrum hole. This is achieved thorough spectrum handoff. In some cases unlicensed bands may lose its quality.

iii) Spectrum Sharing – several users can share or co-ordinate the same channel, also for selecting the required channel and power allocation. Sometime co-existence between licensed users occurs; this remains a challenge in sharing spectrum.

iv) Spectrum Decision – Based on the user requirement the decision is taken to select the particular band which provides better communication channel from available unused channels. Selection of channel is based on current transmission, also on Quality of Service requirements.

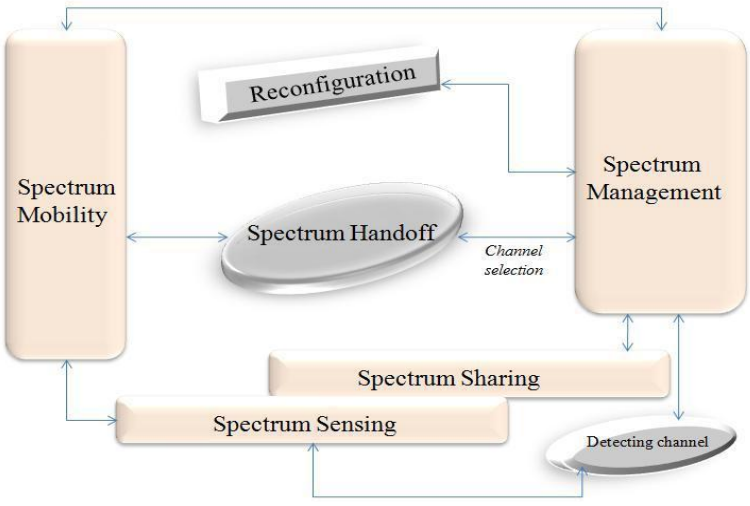

Fig. 2 CR Functionality

D. **PRIMARY AND SECONDARY USERS**

Primary users probably have no problem in accessing the spectrum. They have freedom to access the particular channels allocated to them. But it is more expensive to own licensed band, also resources are limited.

SU can use the underutilize bands of PU. Is that possible to access PU without affecting FCC regulations? Even though we are utilizing licensed bands without causing interference to PU; some questions are remaining unaddressed. Such as if costly licensed bands can accessed by secondary users, is the security of the PU is assured? They may claim for the legal rights and privacy. Some may waste the resources but not ready to share the spectrum.

III. RELATED WORKS
OVERVIEW OF SPECTRUM ACCESS STRATERGIES IN CR

A. Dynamic Spectrum Access

Researchers calls CR as revolutionary technology because of its Dynamic Spectrum Access capability. DSA facilitates the secondary users to access the spectrum holes dynamically according to the primary user's entry and exit into the licensed bands. It is based on spectrum sharing and spectrum sensing. Some of the existing DSA strategies are discussed.

i) ODSA strategy – Opportunistic DSA will randomly access the spectrum without sensing the currently idle channel. To utilize the spectrum opportunistically without causing interference to the primary user is done by several spectrum sharing schemes; For instance Adaptive Spectrum Sharing. Still many flaws remain in the selecting in ODSA as it time consuming process because it have to search until it finds the idle channel and also unnecessary channel selection leads to energy wastage as the nodes updating frequently.

ii) ***DSARU strategy*** – DSA based on Real-Time Usability [4]. Idle channel is sensed by CR nodes and updated to the database periodically and communication capability is considered to provide the best quality channel. The Spectrum usability values are calculated in the database based on the updates from nodes. This gives enhanced performance and efficiency compared to ODSA strategy. The energy saving updating algorithm saves vast amount of energy and doesn't lose energy by regular updates to the database.

ii) Channel Usage Prediction

Previous works on spectrum decision uses Lezi-update scheme [5] to identify the probability of occurrence of spectrum channel usage. They considered the channel with multiple secondary users, interference caused by each other and error in sensing the state. Even though it is prediction based this channel usage model results with high throughput and performance. This is also random spectrum access strategy.

IV. ON-GOING WORK

We are trying to (initially theoretical) integrate the different existing strategy to facilitate better performance in accessing the spectrum instead of proposing new strategy. Considering the flaws and shortcomings in the previous technology, evolving strategy will guarantee the better utilization of the spectrum.

i) Assign the parameters for spectrum holes SH and Channel Quality CQ; their values can be updated by CR nodes periodically with minimal energy wastage.

ii) Usage predication of that channel is pre-defined or can be updated but these values can be considered as the priority values; Channel prediction Value (CPV).

iii) Instead of the searching the entire database, fast scanning of the spectrum can be done with the help of CPV.

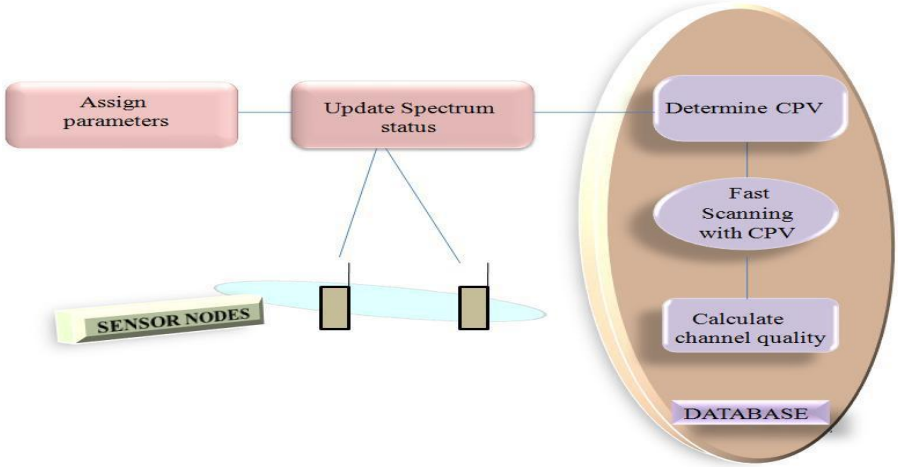

Fig. 3 Block Diagram of proposed concept

iv) Calculating the quality of the communication channel depends on parameter. Best communication channel is calculated with the SH and CQ to determine the Efficient Spectrum usage (ESU).

SH * CQ = ESU. High quality channel facilitates for the effective use of spectrum also interference free access mitigate the errorless spectrum access.

v) CPV is just like cache memory; as it aids in fast scanning of database, thus minimizing time. Worst case is if someone says we don't find the channel by considering CPV, then it may be waste of time.

Main database is maintained in which the spectrum holes are updated periodically by nodes without losing much energy with energy efficient updating algorithm and CPV values are also maintained inside the database. Whenever the need for channel to switch over, it analyses the CPV to get the spectrum hole instead of searching the entire database in the existing strategy which take more time to identify the spectrum holes. With this we can achieve better efficiency in less time interval.

V. CONCLUSION

In this paper the overview about SDR is discussed and functions of cognitive radio is described. Also basic of CR has been reviewed. The research area, Dynamic Spectrum Access (DSA) strategies have been analyzed. A theoretical idea of integrating the existing strategies to minimize the time for switching over unused bands spectrum and also to effectively utilize the spectrum is proposed. Experimental works on going on to achieve the expected results for proposed concept

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