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A SURVEY ON COGNITIVE RADIO, ITS NEED AND PARADIGMS

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Abstract: A network plays an important role in our day to day life. Wireless technologies, for their transportability, flexibility and maintenance are getting widely popular in networks in today's era. The wide use of wireless technologies in turn, leads to spectrum scarcity as licensed users occupies a big part of the spectrum. Cognitive Radio (CR) technology is an ultimate approach to encounter spectrum scarceness issues arising in wireless communications. CR provides spectrum access to secondary users without affecting the activities of primary users and thus ensure smooth communication. In this paper, we discuss some basic terms and recent literature surveys related to it.

Keywords: Cognitive Radio; Underlay; Overlay; interweave; Dynamic Spectrum access

I. INTRODUCTION

Joseph Mitola proposed the first cognitive radio model in late 90s. The wireless systems are having conversion from just telephony to high speed communication employing a large amount of data. The data is not only limited to voice now, but can be audio-visual, live broadcast, large database of an organization or any other form of data also. As new systems are having wireless capabilities, the available spectra are being reduced and the problem of spectrum scarcity arises. CR technology keep the ongoing communication smooth and allows new user to transmit on the existing spectra by means of dynamic spectrum access. Intelligent wireless communication systems have evolved as the recent developments in radio technology allowed much improvements over the existing radio systems which gave birth to cognitive radio technology. These intelligent wireless systems learn the patterns by enabling some action and getting the output, which is compared to the surrounding environment. CR analyses the spectrum usage along with the radio channel. Then it makes the decision to select the band for transmission. It does not cause interference to other wireless system. [1] An action is initiated which helps in getting some result which in turn kept for future performance enhancements. Thus, the system adapts to the surroundings. [6]

II. WHY COGNITIVE RADIO IS NEEDED

Bluetooth, Wi-Fi networks, wireless sensor networks and various ad hoc networks are using the freely available spectra, the 2.4 GHz band which usage is increasing day by day. This leads to the issue of spectrum scarcity in this band. Also, this band is heavily influenced by interference from various radiations from the other communications equipment. There are other bands, on the other side, that are not being utilized properly and the frequencies are not always in operation. TV broadcast bands and military bands are such good examples. Cognitive radio can be an ultimate solution of this issue that can be resolved by allowing the unlicensed users to make use of unused portions of the spectrum which is available to licensed users only.

Cognitive radio intelligently controls the various communication factors like transfer speed, modulation schemes, power, bands etc. by sensing the state of the network and its surrounding users. Cognitive radio technique is going to be newer generation technique that is going to be revolutionary in wireless services. The secondary users are adapted to the available spectrum by using cognitive radio technique. [2]

System learning ways are adapted for the surrounding changes and are added to the database. Based on the data stored in this database, the flexibility is developed towards the variations. [3]

Cognitive radio can be used for dependable, efficient and improved transmission. It allows us to fully utilize the available resource. [4] The newer generation demands higher bandwidth, but the spectra are being used more and the bands are falling short in some frequency ranges. To encounter this issue, the spectra must be managed properly, and cognitive radio is a good approach in spectra management. [5]

III. COGNITIVE RADIO PARADIGMS

Cognitive Radio Paradigms are mainly of three types – Underlay, Overlay and Interweave.

A. Underlay

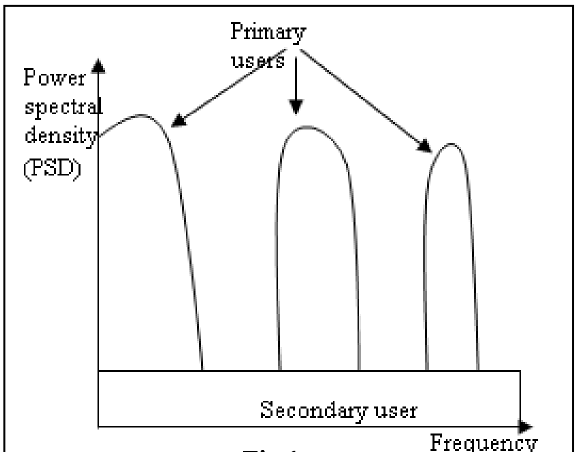

Fig 1

In Spectra Underlay, the level of the interference caused by the cognitive users to the primary users is governed by the cognitive radios. The cognitive users can transmit on the given band of the spectra only if the interference level is under the tolerable limit.

The interference limitations can be exploited by:

- ***By using wideband signaling:*** Wideband signaling can be used so that the interference level can be minimized. This can be done by using ultra-wideband or spread spectrum. Ultra-wideband does not consume high energy for limited range, large bandwidth transmission over big part of the radio spectrum. The transmission takes place in a way that there is no interference with existing narrowband and carrier in the existing spectrum. There is no need of the carrier to be essentially present. Very high bandwidth is used, and the data rate is also of a high amount that can be as high as 500Mbps.

- ***By using multiple antennas and spatial filtering*** We can use several antennas and spatial filtering in which shaping of the beam takes place.

We face two types of challenges in spectra underlay:

- ***Measurement Challenges*:** The interference measurement at primary node is a challenge because of non-activity of the primary user. Also, direction measurement of the primary user is another challenge due to the same reason. Both challenges can be rectified easily if the primary receiver is also transmitting.

- ***Policy Challenges*:** There are challenges regarding to the policies because the CR users cohabit with the primary users which have purchased the license for a large amount of the money. Primary users don't want interference and hence they don't like underlays. The interference limits must be precise and thus, accurate interference constraints must be considered. This bounds the spectra underlay proficiencies and its applications.

B. Overlay

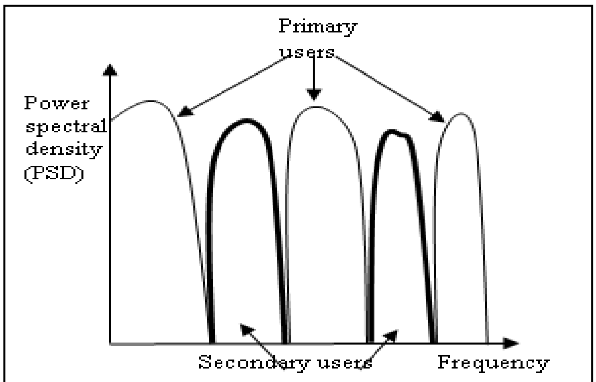

Fig 2

In spectra overlay, a CR user has information about message and/ or the encrypting strategy of other users. The non-cognitive data transmission is assisted by this information and the interference with primary users is avoided by pre-subtraction. CR overhear the primary nodes communication and improves the communication. Spectra overlay provides better transmission with flexible control compared to spectra underlay. [7]

Challenges faced in spectra overlay are:

- ***Complex System:*** It is essential to know about the transmission status of the nodes and recognition of the nodes which, in turn, makes the system more complex.
- ***Getting Information:*** The knowledge about channel, primary users' and CR users' messages is very crucial and essential. Getting this knowledge is not a cakewalk.
- ***Transmission Modes:*** Sometimes, it becomes difficult to have the right transmission mode whether to have between full-duplex or half-duplex mode.
- ***Synchronization:*** Synchronization issue may be faced in spectra overlay which makes it difficult for the communication.

C. Interweave

Interweave approach was the main motivation for cognitive radios for Mitola. Recent researches show that even spectra packed with users are not utilized across entire frequency, space and time. Some frequencies are free for temporary basis which are unused by the primary users. These are known as spectrum holes. Opportunistic transmission is the basic idea behind this approach. Spectrum sensing is done intelligently which finds out whether the parts of the spectrum are occupied. And finally, the spectrum holes are distinguished, and opportunistic transmission is done. Interweave systems keep on watching the spectrum for the spectrum holes after an interval. The spectrum hole is taken over and the agreement between transmitter and the receiver takes place for communication. The transmission of the data takes place avoiding the interference with the primary users. [7]

Challenges faced in interweave are:

- ***Change of places of holes:*** The holes in the spectrum changes their position due to activity of licensed users. This can be overcome by using wideband quick receivers with rapid sensing. There is need to sense the spectrum after each interval of the given time. The transmitter and the receiver need to co-ordinate to search for the spectrum holes which are common. Also, there is no assurance of getting high bandwidth.
- ***Detecting the active users*:** Incorrect holes may be detected due to effect of fading and shadowing. False active node may be detected because of random interference.
- ***Policy challenges:*** Licensed users don't want to share their network and hence they hardly allow interweave. The nodes must be fast and agile enough to takeover.

IV. LITERATURE SURVEY ON COGNITIVE RADIO

In [8], we studied the cross-layer pattern for crowding, disagreement and power control in multi-hop type cognitive radio ad-hoc network. A model is designed between the energy efficiency and maximum utilization of network that is two cross layer algorithms is designed which includes efficient power-controlled MAC protocols for cognitive radio ad-hoc network. First algorithm permits cognitive sources and cognitive link to align their transmission capabilities based on law of diminishing returns. Second algorithm controls the persistence probability and transmit power so that it can compensate the offered load. At last these algorithms are then verified and compared with original MAC schemes.

In [9], proposed an adaptive cognitive positioning system with the cognition capabilities for indoor as well as outdoor environments that consider the important characteristic of location awareness of cognitive radio technology. This positioning system must measure components that are bandwidth decision and hybrid overlay and underlay enhanced dynamic spectrum management (H-EDSM). H-EDSM offers the optimum available bandwidth and switching mechanism for changeover between overlay and underlay modes.

In [10], optimal power allocation methods have been studied to accomplish the delay restricted capacity and the blocking capacity for fading channels in CR networks. To obtain delay limited capacity using optimal power allocation method is analogous to channel inversion. Outage capacity is obtained using optimal power allocation method and considering the topmost interference power limitations and average interference power limitations, smallest outage probability is calculated for each fading state.

In [11], spectral sharing concept is studied where cognitive radio (CR) uses the same bandwidth as that allocated to the active primary radio (PR) connection considering that CR transmitter possess ideal channel state information (CSI) regarding the channels PR as well as CR receivers. They studied optimal power control for secondary radio fading channels and found that that power control policy is better than the old one but depends on the typical PR receiver interference power constraint.

In [12], suggested a location awareness engine architecture to give actualization to the concept of location awareness in cognitive networks which comprises location estimation, mobility management, security, statistical learning and tracking seamless positioning and location based application. This paper mainly focusses on location based application in which location information is used in cognitive network by using a few location-aided applications for network optimization such as network planning, handover etc. along with optimization of network performance.

In [13], proposed software defined radio based cognitive radio which is an intelligent communication system which is cognizant to its surroundings and learns from the situation and adapt to the dissimilarities in the input. The intelligent wireless communication system has mainly two objectives: 1) highly reliable communication. 2) optimum utilization of radio spectrum. This paper discusses three main cognitive tasks 1) analysis of radio environment. 2) estimation of state of the channel and predictive modeling. 3) control of power transmission and dynamic spectrum management.

In [14], this paper discussed the problem of multi-hop relay selection as already existing research concentrated on single-hop relay selection that might not be able to completely utilize the benefits of cooperative transmissions. This paper suggested a cooperative framework FTCO in which spectrum sharing in frequency as well as time domain are considered then multi-hop relay path is calculated via considering the multi-hop relay selection issue as network formation gain. Also proposed PRADA, a distributed dynamic algorithm for comprehensive path stable network. Also found results showing that cooperative multi-hop relaying can help the primary and secondary network both and provide global path stability form PRADA algorithm.

In [15], considered secondary user (SU) as positive cooperators for the primary users (PU) rather than assuming SU as interference to PU which is in many existing works. In this paper PU select SU as relay nodes for their transmission but here is the challenge to select a relay node efficiently as there are large number of SU and it is not possible to first scan all of them and select the best one. So it proposed an optimal stocking theory which will help PU to make a decision whether to stop observing the SU nodes and use the current one or to skip it and move to the next one. Also discussed optimal observation order of the SU examine the probability of collision. This paper also evaluated the performance of the suggested scheme by comparing the proposed scheme and the random selection policy.

In [16], proposed power control and admission control algorithm for ultra-wideband cognitive radio network so that secondary user (SU) can get quality of service without interfering primary user (PU). Using quasi-convex optimization problems, a power control algorithm is developed in which data rate of all SU is maximum. By using channel gain ratio, admission control algorithm is developed which will neglect SU having low some data rate. The channel gains are based on the ranging capability of ultra-wideband radio. Also examined the performance of power and admission control strategies.

In [17], proposed a power control algorithm using iteratively reweighted least square (IRLS) for the cognitive radio networks so that it ensures less interference to the primary users (PU) and provide SINRs for the secondary user (SU). To converge the optimum power vector, this algorithm will update the transmission powers and also will maintain the total interference in a tolerable limit.

In [18], considered the robust distributed power control issue as the already distributed power control algorithms assumes the perfect channel that degrades the performance of the cognitive radio network. In this paper main objective is to minimize the total power consumption providing quality of service to the secondary user (SU) and avoiding interference to the primary user (PU). The robust power control issue is considered as a semi-infinite programming (SIP) issue. In worst case of the constraints this issue can be changed to second order cone programming (SOCP) issue. An asynchronous iterative algorithm is then used to decrease the message overhead being passed among the nodes.

In [19], considered the problem of cooperative transmission in cognitive radio network as the quality of service of the secondary users get affected sometimes due to bad channel conditions. This paper minimizes the total power consumption by adjusting the transmit power of the cognitive users through geometric programming.

In [20], proposed a combined interaction between on-demand routing and spectrum scheduling by considering the effect of band switching and intra-band back off so that nodes can do transmission effectively on various existing frequency bands. For scheduling based channel assignment, a node analytical model is designed which alleviate the effect of flow time internal interference and regular switching delay. A routing protocol based on cumulative delay is designed using an on-demand interactive. Finally, the results show that this proposed protocol better fits to the multi-flow situation with comparatively less cumulative delay.

In [21], a cognitive radio networks (CRNs) can make the optimum utilization of the spectrum using dynamic spectrum access techniques but due to the wavering nature of spectrum, routing is difficult in cognitive CRNs. A routing model termed as cognitive radio network routing model (CRNRM) for ad-hoc CRNs, to study the routing algorithm and implemented in network simulator 2 (NS2). Also checked the validity of the proposed routing algorithm through experiments.

In [22], considered throughput maximization by suggesting spectrum and energy aware routing protocol (SER) for cognitive radio ad-hoc networks which will provide time slot allotment of channel and efficient route selection. This protocol will maintain the energy consumption, mitigate contention between users and decrease traffic over channels. Finally, this protocol will provide increased network throughput and decreased delays.

In [23], considered cognitive radio network among fading channels and presented power control strategy based on opportunity for secondary user to ensure smooth transmission of primary users and sharing of spectrum between primary and secondary user. The strategy allows secondary user to exploit its attainable transmission rate without affecting the blocking probability of licensed user. It also relieves the secondary user from the burden of system synchronization requirement. It analyzes the achievable rate of secondary user considering the effect of non-ideal channel estimation.

In [24], discuss to maximize the performance of cognitive radio ad-hoc network by adjusting the secondary user rate without affecting the achievable primary rate so that the primary and secondary user can co-exist.

In [25], discussed the mechanism of dynamic spectrum sharing that allows several secondary users to be present in the same channel and use it synchronously for optimum utilization of spectrum along with the protection from interference to the primary user.

In [26], proposed the two strategies: well-organized power control by employing directional transmission to take full advantage of the secondary channel rate and energy control by employing directional transmission to exploit the energy efficiency of secondary user. These strategies are proposed to improve the reuse of spectrum by secondary user without affecting the achievable primary rate. This will increase the probability of concurrent transmission with the lower cost.

In [27], suggested the multiuser resource allocation model based on cognitive radio for wireless ad-hoc network using multicarrier distributed spectrum CDMA modulation. Method of sensing of channel and its estimation is provided to get information like noise power, gain of the channel etc. in pre-existing communication spectrum. Power and frequency spectra are distributed to cognitive radio users in a way to ratify the marked data rate and power constraint of all new users considering no interference to the preexisting users and reduce the power consumption in the network.

In [28], considered the “listen-before-talk” strategy by allowing secondary users (SU) to listen to the primary users (PU) feedback so that they can alter radio power according to the latter’s interference constraints. They evaluated power control algorithms, that is centralized and distributed, and ensured that PU feedback information can be used as an interaction signal among different SU so that they can work simultaneously without affecting PU quality of service.

In [29], considered the concept of efficiently utilization of scarce spectrum by dynamic spectrum access in cognitive radio network. This paper suggested an algorithm for resource distribution for efficient use of resources in dynamic access ad-hoc network. In these networks active cognitive radio network links fulfill their own quality requirements along with no effect on primary user transmission. As cognitive radio (CR) system will operate in heterogeneous network, it requires control of communication rate and power for the active cognitive radio. So, the algorithm provides control of transmission parameters and power to maximize the active CR associations excess function.

In [30], a characteristic of cognitive radio ad-hoc networks called routing is discussed. As previous routing protocol presume the imaginary path between the source and the destination, but this pre-assumption seems to be wrong sometimes due to the features of cognitive network ad-hoc network. This paper proposed a novel routing algorithm for multi-hop cognitive radio networks. By using this routing algorithm, a maximum data rate and minimum delay is provided between the communication of source and destination.

V. CONCLUSION

In this paper, we discussed about cognitive radio, its significance and how it can empower our future networks. Various paradigms of cognitive radio, their techniques and the challenges are discussed. Literature surveys are conducted related to various studies and enhancements in cognitive radios and ideas gained related to how the performance of the conventional networks can be improved.

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