A Study Of Effective Channel Utilization Using Cognitive Radio

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Abstract— Cognitive Radio Networks are a promising technology likely to be deployed in the very near future as a feasible solution to the spectrum shortage problems faced by traditional wireless systems. Due to marvelous growth in the wireless communication systems, it is generally supposed that there is a crisis of availability of spectrum. In actuality, there is no problem of shortage of radio spectrum, but only a lack of affordable communications infrastructure. This paper provides an overview of major problems that are faced by wireless communication system with regard to spectrum use and the working scenario of Cognitive Radio. There is need to make significantly improved usage of the available radio spectrum. It has been observed that there is many radio spectrum area which are not completely utilized. Cognitive radio has been projected a approach to reuse spectrum in an opportunistic way.

Keywords— cognitive radio; dynamic spectrum access software-defined radio; spectrum utilization; spectrum sensing

I. INTRODUCTION

In wireless communication system Cognitive Radio is a perfect model which involves changes either in a wireless node or in a network parameters of transmission or reception for communicating efficiently and avoiding interference with certified or uncertified users. This variation of parameters is based on the active monitoring of several factors in the internal and external radio environment, such as radio frequency spectrum, network state and user behavior. The Cognitive Radio proposal was initiated by Gerald Q. Maguire and Joseph Mitola III. It was consideration of as an perfect objective a Software-Defined reconfigurable wireless black-box having capability of automatically changing its parameters of transmission or reception in response to user demand and network. Software Defined Radio is currently reached at that stage where each radio is able to perform user favorable tasks and minimizes spectral congestion. Adaptive Digital European Cordless Telephone (DECT) wireless phone a straightforward example is the, which discovers and uses a frequency within its allocate plan with the least noise and interference on that channel and time slot. There are three most important applications that increase capabilities of SDR and making it a cognitive radio [1].

1. Spectrum management and optimizations.
2. Interface with a broad variety of networks and optimization of network resources.
3. Interface with a human and providing electromagnetic resources to aid the human in his or her activities.

Hence, in such a challenging environment, mechanisms such as cooperation, learning, and negotiation help

Cognitive radios make the necessary decisions to ensure reliable communications

We hereby investigate a novel architectural solution for Cognitive Radio Networks that uses network coding for fast control information exchange among cognitive Radios, enabling them to maintain coherent and reliable information regarding the status of the wireless environment. This control information is used by cognitive radios to perform cooperative primary users detection and efficient reuse of the available spectrum resources while guaranteeing robust communication and a prompt reaction to wireless environmental changes.

The cognitive radio introduces a very worthwhile research field area. Unproductive utilization of spectrum is the driving force behind cognitive radio and by adopting it can be able to a reduction of spectrum insufficiency and better spectrum resources utilization. Spectrum Sensing which is frequency spectrum checking for vacant bands forms the primary part of the cognitive radio. There are many schemes for sensing of spectrum like matched filter and energy detector. But the earlier functions suitably for higher signal to noise ratio (SNR) value while the later complexity is very high. These constraints lead to implement a detector which is able performed good under low conditions of SNR as well and having intricacy not as high as the matched filter

II. SPECTRUM MANAGEMNENT

One of the main requirement aimed with cognitive radio is utilization of the existing radio resources in the most efficient way. To make sure the optimum utilization, cognitive radio needs a number of conditions to be satisfied. The primary needs of cognitive radio are-

(a) Negligible interfering with licensed systems,
(b) Ability to adjust itself to various link behavior,
(c) Ability to sense and measure critical parameters about the environment, channel, etc.
(d) Ability to utilize variety of spectral opportunity,
(e) Flexible bandwidth and pulse shape

(f) Adaptive power transmission, information security, Adjustable data rate and limited cost.

The main aim followed by Cognitive Radio is usage of frequency bands that are governed by their licensed users. thus, the most specific considerable requirements of cognitive radio is interference caused by cognitive devices with the licensed users remains at a insignificant level. The main features offered by cognitive radio idea is that the aimed spectrum of frequency is scanned periodically for the order to check its accessibility for usage. According to the outcome of this spectrum scrutinize, determination of the bands that will be utilized for cognitive communication. Since at different locations and time the available bands can fluctuate, cognitive radio is predictable for having a high suppleness in regulating the spectrum occupies by it.

Network topologies: Our analysis begins with grid and circular reference scenarios and then consider random topologies. We ensure that all random topologies used in the simulations are connected. To this end, we do a simple breadth-first-search of the underlying connectivity graph and check if all nodes are visited (a standard procedure to check for connectivity). The topology is valid (i.e., it is used in the simulations) if a single connected cluster exists and is discarded otherwise [2].

Software Defined Radio:

An SDR is a radio into which carrier frequency the properties, network access, modulation ,and signal bandwidth are software defined. SDR is a general-purpose device into which the similar radio tuner and having processors which are used for implementing various waveforms at various frequencies are used. The benefit of this approach is that the equipment is more cost-effective and versatile . Additionally, it can be upgrade with latest software for fresh waveforms and latest applications after delivery, sale and installation [3].

Physical (PHY) layer: An extensive version of the ns2 IEEE 802.11b/g PHY layer is implemented by us, which is having calculations of Packet Error Rate (PER) accounting for channel effects, modulation, and multi-user interference. In aspect, the Signal to Interference plus Noise Ratio (SINR) is figure out for each packet and for each receiving node taking into thought the interference which is generated by close by transmitters. PERs are acquired from the PER curves pre-calculated. For the channel, we use the standard ns2 two ray ground propagation model. More details can be found in [4].

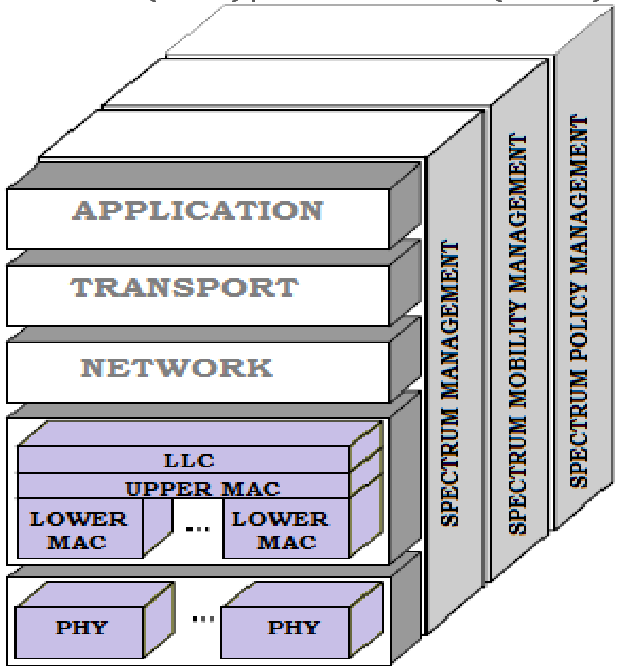

Figure.1 Cognitive Radio Architecture

The architecture of Cognitive Radio is given in Fig.1 The architecture has different layers and the physical layer handles different spectrum sensing algorithms. The layers is liable for characterization of radio environment and management of power. Network layer handles spectrum routing whereas transport layer handles spectrum handoff. The application layer deals with user utility and QoS requirements.

Spectrum Managing Framework for Cognitive Radio Networks:

Cognitive Radio networks introduce only one of its kind challenge which is due to coexistence with diverse QoS requirements as well as primary networks. therefore, new spectrum managing functions required for Cognitive radio networks with the following significant design challenges:

1. Interference Avoidance: Cognitive Radio network should avoid primary networks interference.

2. QoS Awareness: In order to choose an suitable spectrum band, Cognitive radio networks should maintain QoS-aware communication, for considering heterogeneous and dynamic spectrum environment.

3. Seamless Communication: Cognitive Radio networks should offer seamless communication despite of the emergence of the primary users [5].

In order to deal with these challenges, we present a directory for different functionalities essential for CR networks spectrum management. The process of spectrum management consists of four major steps:

1. Spectrum Sensing: A Cognitive Radio user can only assign an unused spectrum portion. thus, the Cognitive radio user should observe the spectrum bands which are available, obtain their information, and identify the spectrum holes.

2. Spectrum Decision: On the basis of spectrum availability, Cognitive radio users can assign a channel. This channel assign not only depends on availability of spectrum, but also based on the internal and external policies.

3. Spectrum Sharing: As there may be various Cognitive Radio users that trying for spectrum accessing, access of Cognitive Radio network be supposed to be synchronized in order to avoid various users colliding into the overlapping spectrum portions.

4. Spectrum Mobility: If the requirement of particular spectrum portion which is in use by any primary user, the communication desires to be continued in a further spectrum portion which is vacant. The framework of spectrum management for Cognitive Radio network communication is illustrated.

It is clear from the considerable amount of interactions that spectrum management functions requires a cross-layer design approach. therefore, every spectrum management function collaborates with, transport, application routing, physical and medium access layer functionalities with taking into thought the underlying spectrum's dynamic nature

III. SPECTRUM OPPORTUNITIES

The cognitive radio network architecture, as given in the figure may classified into the two groups as cognitive network and the primary network. Primary network is the legacy network that have an exclusive right of assured spectrum band. Whereas, to operate or work in the desired band cognitive radio network does not have any license. The primary elements of the unlicensed and primary networks defined as follows:

1. Primary User: Primary user has a license to work in a assured spectrum band. The controllability of this spectrum access can be only done by its base-station and should not any affect cause by the operations of any other unauthorized user [6].

2.Primary Infrastructure: Primary base-station is a preset infrastructure network module which has a license of spectrum. In standard, the primary base-station is not having any cognitive radio facility for sharing the spectrum with other cognitive radio users. but, primary base-station might be has necessarily to have both cognitive radio protocols and legacy for the access of primary network of cognitive radio users.

3. Cognitive Radio User: There is not any spectrum license for Cognitive radio user. thus, the spectrum access is permissible only in an politic manner. Abilities of the cognitive radio user consist of sensing of spectrum handoff, , spectrum decision and MAC/routing/transport protocols of cognitive radio. The user of cognitive radio is assumed for having the capability for communicating with not only the other cognitive radio users but with base-station as well.

4. Cognitive Radio Base-Station: Base-station of Cognitive radio is a preset infrastructure module with abilities of cognitive radio. Base-station of Cognitive radio offers particular hop connection to users of cognitive radio with no spectrum access license [7].

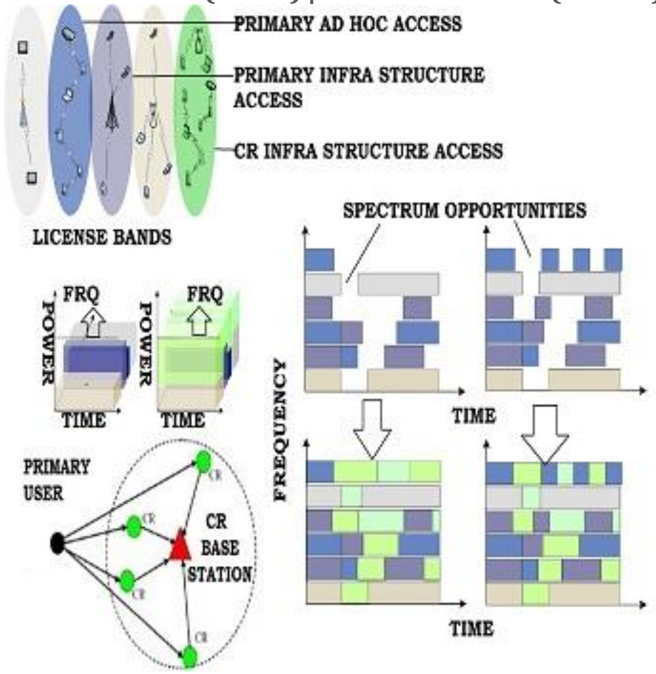

Figure. 2 Cognitive radio network architecture.

As revealed in Figure 2, users of cognitive radio can either be able to access the base-station or can communicate in a multi hop manner with each other. therefore, in our network architecture of cognitive radio, there are three types of diverse access over heterogeneous networks, which demonstrate different performance requirements as follows:

1. Cognitive Radio Network Access: Users of Cognitive radio can access their individual cognitive radio base-station equally in unlicensed and licensed spectrum bands. As all communications take place within the cognitive radio network, their medium access design is self-regulating of that of primary network.

2. Cognitive Radio Ad Hoc Access: Users of Cognitive radio can establish communicate with other users of cognitive radio through ad hoc connection on mutually in unlicensed and licensed spectrum bands. moreover users of cognitive radio can have their personal medium access technology [7].

IV SPECTRUM SENSING TECHNIQUES

1.Energy Detector:

This spectrum sensing method is simple to implement and does not need any prior information about the primary user signal[7]. However, it needs information about noise variance. It is a non- coherent detection method. From the received signal energy is computed and compares it with a predetermined threshold to decide the presence or absence of the primary user signal. If the test statistic is exceeded, it is decided that primary user signal is present otherwise it is absent. Energy detection can be built up both in time and frequency domain using Fast Fourier Transform (FFT).

Energy Detector simply needs a band-pass filter, square law device and an integrator. By using band pass filter, the received signal's bandwidth is limited to a band of interest. This filtered signal is then squared and integrated. Finally the output of the integrator checks with a predetermined threshold.

In order to decide whether a primary signal exists or not. The threshold value of energy detection can be fixed or variable based on the channel conditions and it also depends on SNR ratio. The energy detection is also called as blind signal detector because it ignores the structure and properties of the signal.[8]

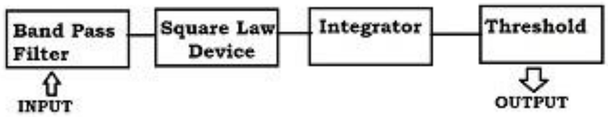

Figure. 3 Block diagram of Energy detector

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$$E = \frac{1}{N}\sum_{N=1}^{N}|Y(n)|^{2}$$

where y(n) is received signal, N is the number of observations, E denotes the energy of received signal. This

$$P_f = Q\left[\frac{U - N\sigma_w^2}{\sqrt{2N(\sigma_w^4)}}\right]$$

$$P_d = Q\left[\frac{U - N(\sigma_x^2 + \sigma_w^2)}{\sqrt{2N(\sigma_x^2 + \sigma_w^2)^2}}\right]$$

where, σ_w^2 and σ_x^2 are the noise variance and signal variance, respectively. Q denotes the Gaussian tail probability Q-function and U denotes the threshold used in the energy detector. In energy detector, threshold can be determined as,

$$U = Q^{-1}(P_f)\sqrt{2N\sigma_w^4 + N\sigma_w^2}$$

where Q^{-1} denotes the inverse Gaussian tail probability Q function. Threshold used in this standard detector depends upon incoming noise variance. So a small variation in noise variance estimation causes performance degradation. Energy detection is simpler than matched filtering and cyclo-stationary feature detection but it has some disadvantages like poor performance under low SNR conditions and no proper distinction between the primary user and noise.

2.Adaptive Double Threshold:

In basic energy detection spectrum sensing [10], noise uncertainty increases the difficulty in setting the threshold and thus degrades the performance of sensing. Also it is not optimum under low SNR conditions where the performance of single threshold (U) based detector can change from the targeted performance [11]. Adaptive Double Threshold(ADT) scheme is a great solution for this problem. ADT scheme overcomes these difficulties by setting double thresholds UI and U2

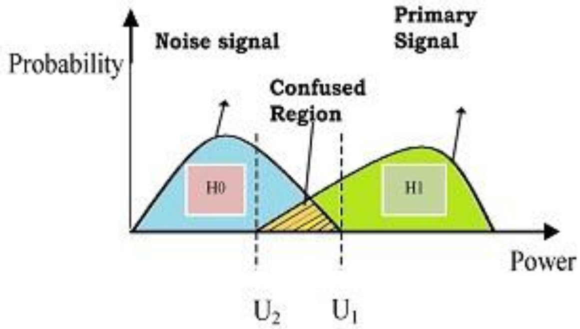

Figure 4 Energy flow of PU signal and noise

The region between upper bound (UI) and lower bound (U2) is known as confused region, which is shown in Fig. In this region, detection of noise and PU signal is difficult using single threshold.[8]

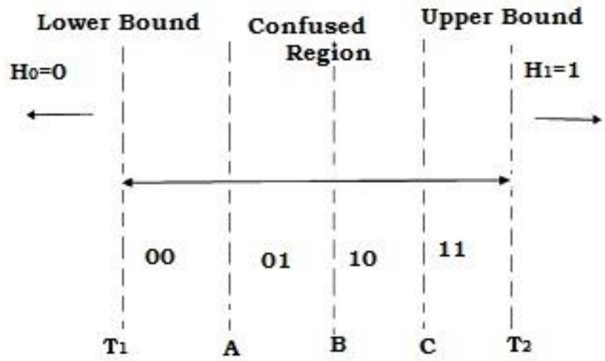

Figure. 5 Diagram of Range of Confusion

The upper threshold *(VI)* of the ADT scheme is selected according to the maximum noise variance, and the lower threshold (U2) is selected according to the minimum noise variance. In this, confused region is divided into four equal levels [10]. If the detected energy values (X) fall inside the confused range, it will generate its corresponding decimal values (DVs). This decimal values are compared with a predetermined threshold *(V)* to take a decision at a fixed probability of false alarm (Pr), i.e. , O. l. If the values lie outside the confused range, it will generate 0 or 1 depending upon the incoming signal. The two bit quantization method divides confused range into four equal intervals.

$$ST = \begin{cases} A = & U_2 + H \\ B = & A + H \\ C = & B + H \\ U_1 = & C + H \end{cases}$$

H is the gap between each quantization levels

$$H = \frac{\text{UPPER BOUND} - \text{LOWER BOUND}}{\text{NUMBER OF QUANTIZATION}}$$

00, $U_2 < X \le A$
01, $A < X \le B$
10, $B < X \le C$
11, $C < X \le U_1$

In adaptive double threshold, upper threshold is selected according to maximum noise variance and lower threshold is selected according to minimum noise variance. Therefore,

$$U_1 = Q^{-1}(P_f)\sqrt{2N\rho\sigma_w^4} + N\rho\sigma_w^2$$
$$U_2 = Q^{-1}(P_f)\sqrt{2N/(\rho\sigma_w^4)} + N/(\rho\sigma_w^4)$$

V.CONCULUTION

Cognitive radio is a young but fast rising technology area. In provisions of regulation of spectrum, the major advantage of Cognitive Radio is more capable to use of spectrum, because Cognitive Radio will allow new systems for sharing spectrum with the existing vacant devices, with control level of interference. There are significant regulatory, technological and application challenges that need to be addressed and CR will not suddenly emerge. The key inspiration for cognitive radio is the presently heavily underutilized spectrum of frequency. The growth is being drive forward by the quick advances in SDR technology enabling a spectrum supple and highly configurable radio transmitter/receiver. A fundamental property of the cognitive radio networks is the highly dynamic relationship between the primary users having an exclusive priority to their respective licensed spectrum and the secondary users representing the cognitive network devices. This creates new challenges for the network design which have been addressed applying varies approaches as has been discussed in the previous sections. The fundamental problems in detecting the spectrum holes are naturally mostly related to signal processing at the physical layer. From the traffic point of view careful attention must be paid in order to guarantee an efficient usage of the wireless medium while simultaneously providing fairness between competing users and respecting the priority of the primary users.

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