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Spectrum Management Techniques using Cognitive Radios Cognitive Radio Technology

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Abstract - Spectrum has been a very valuable resource in wireless communication systems. The available electromagnetic radio spectrum is getting crowded day by day due to manipulation in wireless devices and applications. Underutilization of Spectrum has become a major source of concern for each network user. The present paper attempts to portray "Spectrum Management Techniques using Cognitive Radios", where the strength and scope of Cognitive Radio Technology are discussed. It also highlights the efficiency and effectiveness of the system when compared to conventional mode of operations. Further, the present paper also lucidly explains the modus operandus of Cognitive Radio Technology Spectrum Management Techniques namely Spectrum Sensing, Spectrum Decision-Making, Spectrum Sharing and Spectrum Mobility. These functionalities make Cognitive Radio Technology an asset to the network domain and easily solves issues like interference, noise and underutilization. The paper also focusses on describing the Transreceiver and network architecture. On the whole, this paper is an overall description about the Spectrum Management Techniques in Cognitive Radio Technology in brief.

I. INTRODUCTION

The growing demand of wireless applications has put a lot of constraints in the usage of available radio spectrum .which is limited and precious resource. Also, it has been found that the allocated spectrum is underutilized due to spectrum static allocation. Moreover the conventional approach to manage spectrum is very inflexible. Present wireless networks are characterized by such a policy, where governmental agencies assign this spectrum on a long term basics to license holders. With most of these sort of allocations it is hard to find vacant bands to either deploy new services or to enhance existing ones. In order to overcome this situation, a new means for improved utilization of the spectrum creating opportunities for dynamic spectrum access is preferred. This issue can be solved using Cognitive Radio (CR) technology.

II. COGNITIVE RADIO TECHNOLOGY

Cognitive Radios are designed such as through provide highly reliable communication to all users of the network, wherever and whenever needed and to facilitate effective Radio spectrum utilization. Cognitive Radio can change it's transmitter parameters based on it's interaction with the environment. CR Networks are envisioned to provide higher bandwidth to mobile users the key enabling technologies of CR Networks are the Cognitive Radio techniques that provide the capability to share the spectrum in an opportunistic manner.

CR enables the wide usage of temporally unused spectrum, referred to as spectrum hold or white space. Consequently, it selects the best spectrum which is shared with other users and exploited without interference from the licensed user. CR as the functionality to be programmed to transmit and receive on a wide variety of frequencies. Through this capability, the best spectrum band the most suitable operating parameters can be selected and can reconfigured.

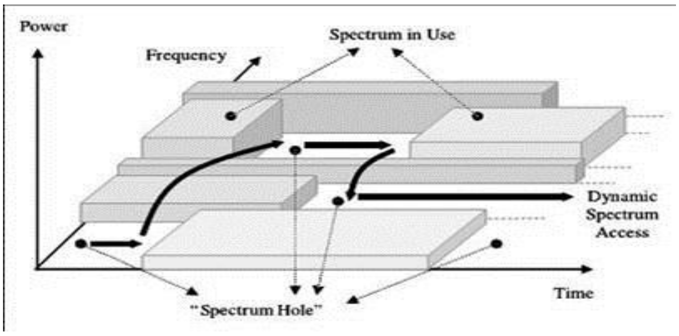

Figure 1: White space or Spectrum hole

III. ARCHITECTURE:

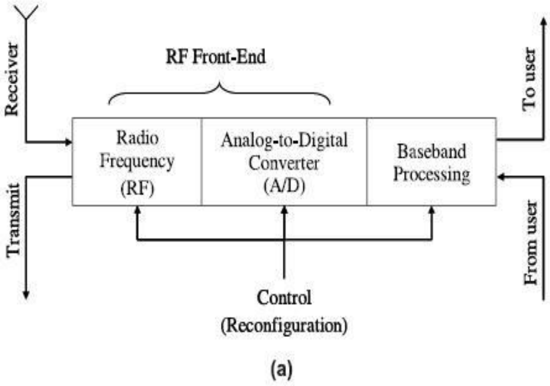

Figure 2: CR Transreceiver Architecture

CR requires a novel Radio Frequency (RF) Transreceiver architecture. The main components of CR Transreceiver or the Radio front-end and the Base-band processing unit. The novel characteristic of the CR Transreceiver is the wideband RF front-end that is capable of simultaneous sensing over a wide frequency range. Here, the received signal is amplified, mixed and analog to digital converter. In the base-band processing unit the signal is either modulated or demodulated.

A comprehensive description of CR Network architecture is essential for developing communication protocols that address the dynamic spectrum variation. The components of the CR Network architecture can be classified as two group's namely primary network and CR Network the primary network (or licensed network) is refer to as an existing network. Here, the primary users pertain a license to operate in a specific spectrum band. If primary networks possess an infrastructure, their activities or controlled through primary base stations. The CR Network (dynamic spectrum access network/secondary network/unlicensed network) does not have a license to operate in a desire band. Thus, additional functionality is required these users to share the licensed spectrum band. CR Networks may include spectrum brokers that distribute spectrum resources among secondary networks.

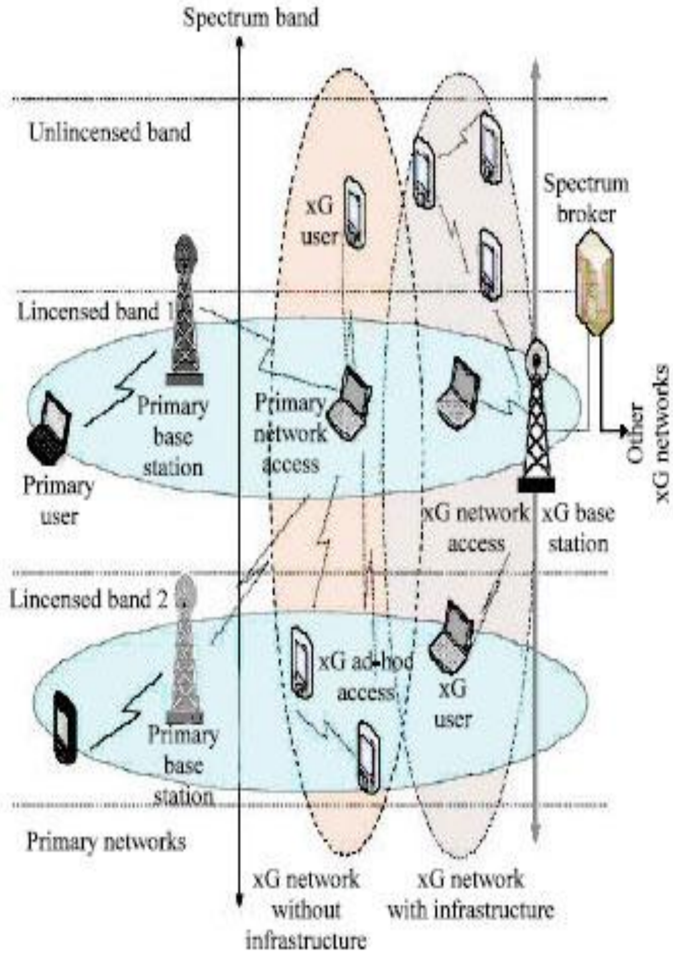

Figure 3: CR Network Architecture

IV. ADVANTAGES OVER TRADITIONAL NETWORKS

Overcome radio spectrum scarcity
By sensing spectrum utilization (irrespective of channel allocation), cognitive radios can broadcast on unused radio spectrum, while still avoiding interference with the operation of the primary licensee.
Avoid intentional radio jamming scenarios
By sensing channel availability and even predicting the jammer's tactics , cognitive radios can evade jamming by dynamically and preemptively switching to higher quality channels.
Switch to power saving protocol
By switching to protocols that trade off lower power consumption for lower bandwidth, cognitive radios conserve power when slower data rates suffice.
Improve satellite communications
By predicting rain fade and reconfiguring transmitters/receivers for optimum bandwidth, cognitive radios improve communication quality when and where the information is needed most.
Improves quality of service
By sensing environmental and inadvertent man-made radio interferences, cognitive radios can select frequency channels with a higher Signal to Noise Ratio (SNR).

V. SPECTRUM MANAGEMENT

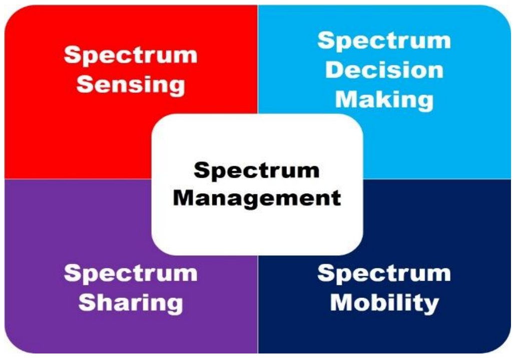

Figure 4: Process of Spectrum Management

The Spectrum Management Process consists of four major steps. They are

- Spectrum Sensing
- Spectrum Decision-Making
- Spectrum Sharing
- Spectrum Mobility

Spectrum Sensing: A CR User can allocate only an unused portion of the spectrum. Therefore, a CR User should monitor the available spectrum bands, capture their information, and then detect spectrum holes.
Spectrum Decision-Making: Based on the spectrum availability, CR Users can allocate a channel. This allocation not only depends upon Spectrum availability, but also based on internal policies.
Spectrum Sharing: Because there maybe multiple CR Users trying to access the spectrum, CR Network should be coordinated to prevent collision of multiple users.
Spectrum Mobility: CR Users are regarded as visitors to the Spectrum. Hence, if the specific portion of the spectrum is a primary network, communication must be continued in another vacant portion of the Spectrum.

VI. SPECTRUM SENSING

We can categorize Spectrum Sensing technique into:
Frequency Domain Approach, Time Domain Approach
Frequency Domain Approach: In this approach, the estimation is carries out directly from the signal. It is also known as Direct Spectrum Sensing technique.
Time Domain Approach: The estimation is performed using auto-correlation the signal. It is also known as Indirect Spectrum Sensing technique. Another way of classification is done as follows:
Non-Cooperative System: It is based on detection of the weak signal from a primary transmitter through the local observation of CR Users. Three schemes are generally used for transmitter

detection. Matched filter detection, Energy detection, Cyclostationary feature detection

Matched filter detection: Matched filter is a linear filter designed to maximize the output signal to noise ratio for the given input signal. Matched filter operation is equivalent to correlation in which the unknown signal is convolved with the filter whose impulse response is the mirror and time shifted version of reference signal. The operation of Matched filter detection is expressed as Where x is the unknown signal (vector) and h is the impulse response of the matched filter.

Energy detection: It is a non-coherent detection method that detect the primary signal based on the sensed energy. Due to it's simplicity and no requirement, it is the most popular sensing technique is con-cooperative sensing.

Cyclostationary feature detection: Cyclostationary feature detection is robust to noise uncertainties and performs better than energy detection in low signal to noise ratio regions. Although it requires a prior knowledge of the signal characteristics, cyclostationary feature detection is capable of distinguishing the CR Transmissions from various types of primary user signals.

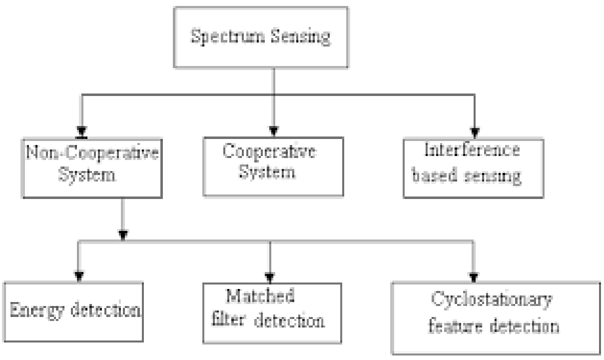

Figure 5: Spectrum Sensing Techniques

Cooperative System: Although Cooperative System reduces the probability of interference, the most efficient way to detect spectrum holes is to detect the primary users who are receiving data within the communication range of CR Users. Currently, this method is only feasible in the detection of TV Receivers and various topologies are currently used and are broadly classified into three regions according to their level of cooperation. Decentralized uncoordinated technique, Centralized coordinated technique, Decentralized coordinated technique

Decentralized uncoordinated technique: The Cognitive Users in the network do not have any kind of cooperation, which means that each CR user will independently detect the channels.

Centralized coordinated technique: In this technique, it cooperated only in sensing the channel. CR Users independently detect the channel and inform the CR Controller, which then notifies all CR Users.

Decentralized coordinated technique: This type of coordination implies building up a network of Cognitive Radios without having the need of a controller.

Interference Based Detection: Primary Receiver emits the local oscillator and leakage power from it's RF front-end while receiving the data from Primary Transmitter. Within the communication range of CR system users, the local sensor then reports the sensed information to the CR Users so that they can identify the Spectrum occupancy status.

VII. SPECRUM DECISION-MAKING

CR Networks require the capacity to decide the best spectrum band among the available bands this notion is called spectrum decision-making. It is closely related to channel characteristics and operations of primary users because available spectrum holes show variations overtime, each spectrum hole is characteristics considering few parameters.

- *Interference:* from the amount of interference at the primary receiver, the permissible power of a CR can be derived.
- *Path loss:* the path loss is closely related to distance and frequency as frequency increases, path loss increases which results in transmission range.
- *Wireless link errors:* Depending on modulating schemes an interference, error rate changes.
- *Link layer delay:* different types of link layer protocols are required at different spectrum bands.

After characterization, appropriate bands are selected. To describe the nature of CR Networks, primary user activity is defined, which is the probability of appearance of primary users during CR transmission. It is important to consider how often the primary users appears on the spectrum band.

VIII. SPECTRUM SHARING

The share nature of wireless channels require the coordination of attempts between CR users. Spectrum sharing can be classified by four aspects namely architecture, spectrum allocation behavior, spectrum access technique, and scope.

The first classification based on architecture

Centralized spectrum sharing: The spectrum allocation and access procedures are controlled by a central entity. The central entity can lease spectrum two users in a limited geographical region for a specific amount of time.

Distributed spectral sharing: Spectrum allocation and access are based on local policies performed by each node distributively. They are also used between different networks.

The second classification is based on allocation behavior

Cooperative system sharing: Cooperative or collaborative solutions exploit the interference measurement of each node such that the effect of communication of one node on others is considered.

Non-cooperative system sharing: Only a single node is considered this selfish or non –collaborative technique results in a certain degree of fairness, as well as improved throughput.

The third classification is based on access technology:

Overlay spectrum sharing: Nodes access the network using a portion of a spectrum that has not been used by primary users.

Underlay spectrum sharing: The spread spectrum techniques are exploited such that the transmission of a CR node is regarded as a noise by primary users.

The fourth classification is based on scope:

Intranetwork spectrum sharing: Spectrum is allocated between the entities of a CR network.

Internetwork spectrum sharing: It enables multiple system to be deployed in overlapping locations and spectrum.

IX. SPECTRUM MOBILITY

After a CR captures the best available spectrum, Primary User activity on the selected spectrum may necessitate that the users change it's operating spectrum bands, which is referred to as Spectrum Mobility. It gives rise to a new type of handoff in CR Networks, called as Spectrum Handoffs. Each time a CR user changes it's frequency of operation, a network protocol may require modifications to the operation parameters. The purpose of Spectrum Mobility in CR Networks is to ensure smooth and fast transition leaving through minimum performance degradation during a spectrum handoff.

X. CONCLUSION

Cognitive Radios are a promising source for usage of underutilized network spectrum. As discussed, we saw how Spectrum Sensing, Spectrum Decision-Making, Spectrum Sharing and Spectrum Mobility manage spectrum in an effective manner. It may be called as an asset to the modern world in the future generations. Since it has an edge over conventional methods in terms on interference, scarcity and quality of service provided, it will create an impact not only in the fields of networks, but also in the minds of network users.

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