COGNITIVE RADIO – AN EMERGING TECHNOLOGY

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Abstract - *In recent times, there are many IoT applications that leads to the increase in network load. For remotely accessing, the IoT connects the heterogeneous devices wirelessly and control them. Most of the devices use licensed wireless spectrum bands. Soon there will be a congestion in the spectrum, thus creating the interference among the users which leads to the spectrum scarcity problem. The spectrum must be used effectively and efficiently to support large deployment of IoT systems. This leads to the raise of emergent technology called Cognitive Radio (CR) [4]. Cognitive Radio is a dynamic spectrum utilization technique where transceiver has the intelligence to detect the channels which are in use and those which are not in use. As the result, it makes the use of available spectrum efficiently and minimize the interference among users. A overview of CR architecture, functions of CR, challenges in each function of CR environment and issues in CR are investigated in this paper. A energy power allocation method is discussed to that facilitates the efficient utilization of the spectrum.*

Key Words: Cognitive Radio Network (CRN), Interference, Whitespace, Reconfigurability, Orthogonal Frequency Decision Multiple Access (OFDMA)

1. INTRODUCTION

Internet of things is defined as a system containing digital objects which are interconnected to each other, thus providing human-to-machine or even sometimes machine-to-machine interaction without the intervention of human beings for transmitting the data collected over a network. A 'thing' in Internet of things can be any device which can be assigned with the IP address and is capable of transferring information over network. IoT technology is quickly being transformed into reality. One can witness the transformation by the devices they use like smart phones, watch etc. New technologies impact the commerce and policies of the world. Cognitive radio is a technology which affects the marketplace for radio devices and service which resulted in the implementation and development of wireless communication policy. Cognitive radio is a set of radio systems which coordinates the usage of radio band. The radio spectrum is recognized when it is unused and is utilized in a most efficient manner. Such unused radio spectrum is referred to as 'spectrum opportunity' or 'white space' [1].
Cognitive radio has the ability to be a disruptive force within a spectrum management. A Cognitive Radio is a radio which can be programmed and configured dynamically in order to use the wireless channels in its locality to avoid the user interface and congestion. Such radio is used to detect the unused or available channels automatically, then changes the transmission like parameters to allow more wireless communication in a specified spectrum at one particular location.

As IoT technology is growing rapidly, there is a need for the spectrum to be located for the packets produced from IoT network, hence Cognitive Radio Network is used to integrate with the IoT concept which is named as Cognitive Radio Internet of things. A Cognitive Radio is a radio that can change its transmitter parameters based on interaction with the environment in which it operates. The first cognitive radio wireless regional area network standard was IEEE 802.22. This was used to identify available channels for the use of cognitive radio network. Spectrum Sensing is the one which monitors the spectrum and identifies the engaged channels. IEEE 802.22 was designed to utilize the frequencies which are unused at one location. These are the white spaces which are unused television channels in a particular areas. Cognitive Radio cannot use the same unused frequency all the time. As the availability of the spectrum changes, the network adapts itself to prevent interface with transmissions which are licensed.

The frame structure of IEEE 802.22 comprises of two main structures i.e. superframe followed by the sub-frames[2]. Superframe has SCH and a preamble as shown in fig 1. These will be sent by base station in every channel which helps to transmit without interference. Once the CPE is turned on it will sense the spectrum to find the available channels and receives all the needed information needed to attach to base station[2]. The MAC layer performs two different types of sensing in either in-band or out-bands measurements. In-band measurement consists of sensing the actual channel used by CPE and out-band measurement deals with sensing the rest of channels. The primary function of MAC is to support the PHY. One of the modifications to the existing MAC is including support for "Ranging" in MAC. This is to support the ranging function of PHY. To ensure the ability to provide guaranteed bandwidth, users are allowed to reserve uplink transmission slots.

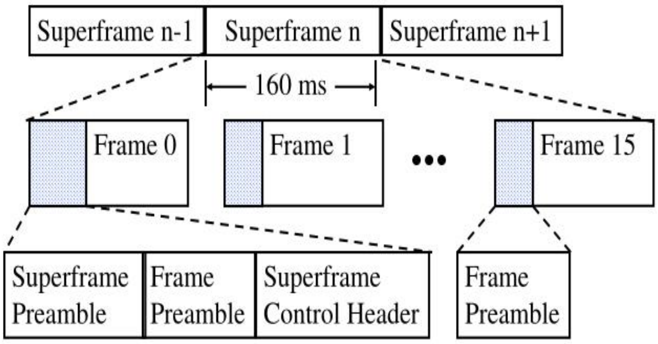

Fig - 1. IEEE 802.22 frame and superframe structures.

The continuous growth in IoT applications needs huge amount of data to be sent on spectrum which results in the scarcity of spectrum. Spectrum scarcity not only depends on the availability of the channel but also depends on utilization of spectrum and used technologies. The ordinary fixed spectrum assignment policy is an inadequate solution. As a result of dynamic conditions of environment, allocation and utilization of spectrum, cost of purchasing spectrum, it is predicted that it is not possible for IoT technology to grow rapidly without the integration of IoT technology with Cognitive Radio. In order to increase the efficiency of spectrum, IoT objects must be allowed to use licensed unutilized spectrum band. Hence the usage of CRN to establish IoT smart network will be an efficient and economical solution to the problem of IoT spectrum scarcity.

1.1 AN OVERVIEW: COGNITIVE RADIO

An radio spectrum is a natural resource which is licensed and is allocated to the receivers and transmitters (primary users) by the government. A spectrum is nothing but the wavelengths of radio frequency waves which are used for wireless communication services. These wavelengths are broken down into pieces, each piece is called as "bands". Each band is allocated for various purposes like 3G, 4G, TV, WiFi, mobile satellite, etc. Due to the static allocation, there may be over crowded in some bands of spectrum and some bands are free enough as shown in fig 2.

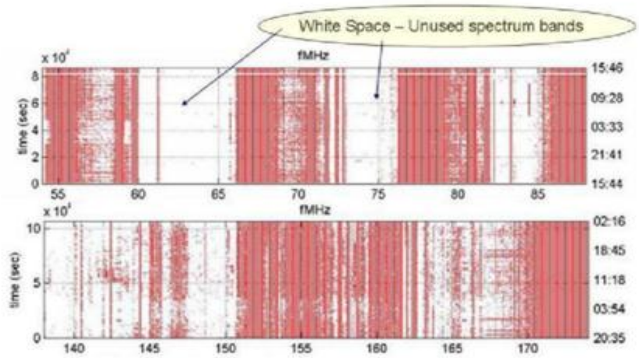

Fig-2. An electromagnetic spectrum band

There will be poor quality of signal in crowded bands whereas remaining bands are gone unused which reflect to the inefficient use of spectrum. The underutilization of the radio spectrum leads to the "Spectrum Holes". In fig 3., the spectrum band is distributed over time scale. Only at certain parts of spectrum, the spectrum usage is concentrated while remaining are left unused [3]. To utilize the spectrum efficiently, the secondary user, who do not have the license to use the spectrum are allowed to access the spectrum holes at right time and right geographic location. This type of dynamic allocation is done by the "Cognitive Radio".

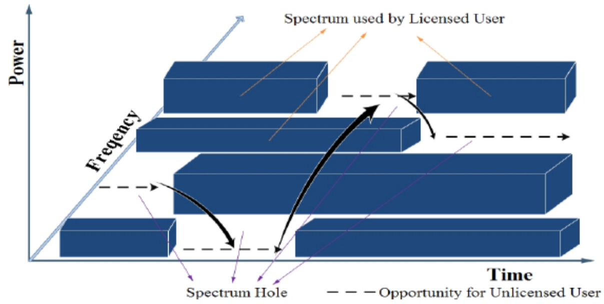

Fig-3. A cognitive radio and whitespace concept

1.2 CR TECHNOLOGY

Cognitive Radio is an intelligent radio which is programmed and configured dynamically. The transceiver present in CR is designed in such a way that it use the best suitable wireless channels in its vicinity. The transceiver has three parts : Radio frequency, Analog to Digital Converter and baseband processing as shown in fig 4. The RF front end is the hardware part of CR which does the functions like down conversion, mixing, reception, filtering etc. Also it is capable of sensing the wide frequency range simultaneously and have a ability to detect the weak signal from a large dynamic range because it has both transmitter and receiver analog functions. The A/D converter converts analog signal into the digital complex baseband representation which is then processes by baseband processing unit. The baseband processing unit is responsible for processing of digital signal like modulation and coding. This part is implemented in software [4].

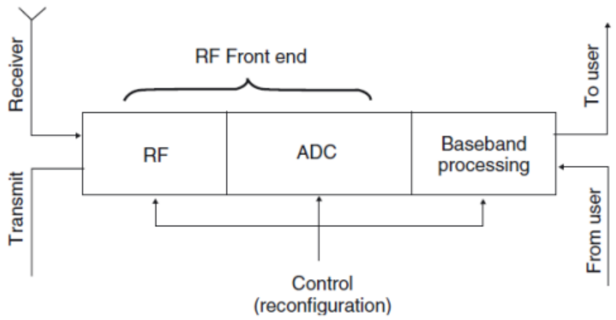

Fig – 4 Basic structure of Cognitive Transceiver

CR detect the available channel and changes its transmission and reception parameters accordingly. This allows more concurrent wireless communication within the given spectrum band. Some of the parameters that CR changes according to radio environment are waveform, protocol, operating frequency, networking etc. The main objectives of CR technology are as follows:

- To provide highly reliable communication whenever needed
- To make efficient utilization of the spectrum

From the above definition, the two main characteristics of CR can be defined.

- Cognitive capability: It simply refers to the ability of the radio technology to sense the information from its radio environment.
- Reconfigurability: It allows the radio to be dynamically programmed according to the radio environment [2].

1.3 CR ARCHITECTURE

Some portions of spectrum are assigned to licensed users for different purposes and some remains unlicensed. The CRNs is split into two main categories i.e, primary network and secondary network (or unlicensed network or CRN network). A primary network is an existing network infrastructure in which spectrum bands are licensed to primary users. TV broadcasts and common cellular networks come under primary networks. It comprises of primary base stations and primary users. A secondary network will share the empty holes of primary network. It consists of cognitive radio base station and secondary user (or CR users). Since CR users does not have license to use some bands, spectrum access is allowed in opportunistic manner. An CRN network can be deployed as both infrastructure network and an ad hoc network as shown in fig 4.

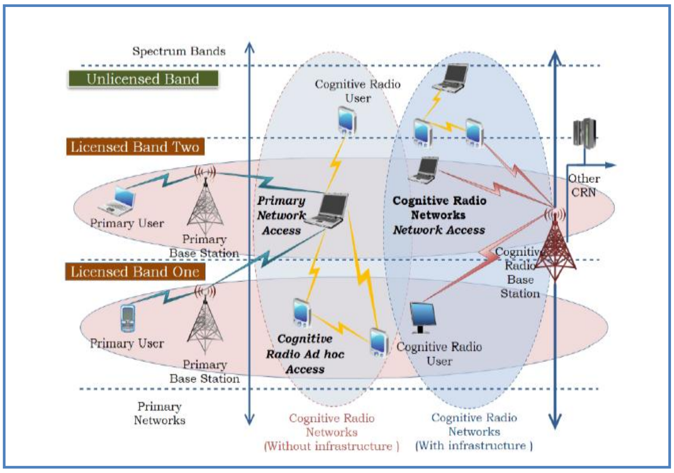

Fig – 4. Cognitive Radio Architecture

In CR network, there are three types of access as follows [3]:

a) CRN network access: A CRN base stations are accessed by CRN users, who belong to that respective CRN base stations, both on unlicensed and licensed spectrum bands.
b) CRN Ad hoc access: Based on the ad hoc connection both on licensed and unlicensed bands, CRN users can communicate with other CRN base stations .
c) Primary network access: Using licensed bands, CRN users can access the primary base stations.

The cognitive and reconfigurability capability are provided by the main components like sensors, radio, knowledge database, learning engine and reasoning engine. Cognitive cycle is established for dynamic spectrum access (DSA) based on these capabilities.

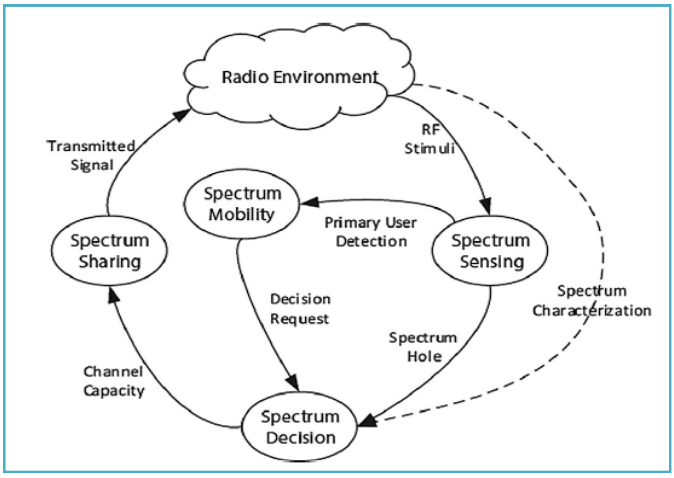

Fig – 5. Cognitive Radio Cycle

Dynamic spectrum access comprises of four main functions as shown in fig 5. This function make the cycle to include the identification of holes, selection of the best radio spectrum, coordination among multiple users for accessing spectrum and vacation of the spectrum band when a PU appears [5].

a) **Spectrum Sensing**: This is the first and most important step in the CR system. Without any interference to primary users, there should be a reliability of transmission as it further dependent on the presence of primary users. The absence or presence of the primary users will leads to the identification of holes in the spectrum. There are three main objectives of spectrum sensing.
   - There should be continuous monitoring of the radio channel that is occupied by PU.
   - There should be continuous sensing of spectrum holes to allocate the spectrum to SU.
   - Estimate the transmission parameters required for spectrum management [1].

   In this process, it senses the surrounding radio frequency spectrum to detect the presence of PU and determine the spectrum holes. Detecting the presence of PU is nothing but finding whether PU is using its allocated spectrum or not. Using various spectrum sensing approaches, white spaces in the spectrum is identified. The three categories of spectrum sensing are Transmitter detection, Cooperative detection and Interference based detection. In Non-Cooperative sensing, the CR will sense the data and use the data independently to identify whether the channel is idle or busy. But in cooperative technique, CR will share the data with other users and take the output from them to decide the availability of channel. In Interference method, the interfernce will occur at the receiver and then controlled by the transmitter through the radiated power and location of individual transmitter. All these types are sub divided into number of types which is shown in fig 6.

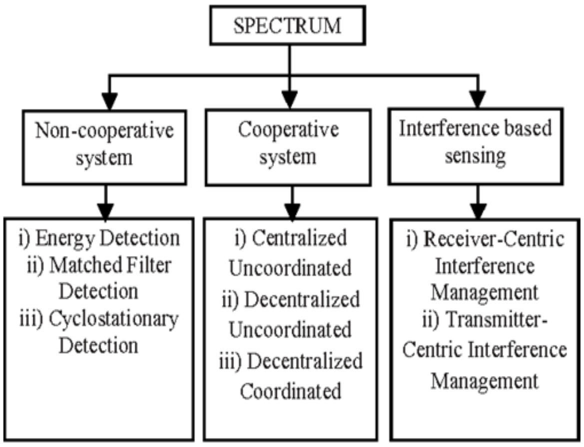

Fig – 6 Classification of Spectrum Sensing Tecniques

Challenges: Some of the challenges are [3],

- Interference temperature measurement.
- Spectrum sensing in multi-user networks.
- Spectrum - efficient sensing.

b) **Spectrum Management**: After the spectrum sensing, the spectrum is managed. This process will predict how long the spectrum holes are going remain open for the use of SU. In this process, the quality of service of the holes which are detected in the spectrum sensing process is estimated and choosing the best spectrum that meets the communication requirements of the secondary users. The two primary steps in spectrum management is as follows [6] :

- Spectrum Analysis: The results of spectrum sensing is analysed to estimate the spectrum standard.

  One has to measure the quality of spectrum which is accessed by the secondary users. Signal to Noise ratio, white space availability and average correlation are the characteristics of the quality. Here, the detected holes are compared.
- Spectrum Decision: It chooses the best available spectrum to meet the secondary user's requirements, without creating the interference to the PU. Spectrum Decision is related to the operations of PU and channel characteristics.

Challenges :

- Decision model.
- Cooperation with reconfiguration.
- Spectrum decision over heterogeneous spectrum bands.

c) **Spectrum Sharing**: The spectrum holes are shared among the CR users which in turn require the coordination of the transmission between the CR users. Since there are many secondary users to use the available spectrum holes, cognitive radio have to maintain the balance between the allocation of bands among cognitive users and non-cognitive users. By considering the behaviour of cognitive radio in the radio environment, the policy rules can do this job [6].

Challenges:

- Common control channel.
- Spectrum Unit.

d) **Spectrum Mobility**: When the primary users wants to use the bands which is currently used by CR users, then the CR users need to change the transmission to the newly vacant spectrum band. The change in operating frequency band is known as spectrum handoff. Hence spectrum mobility is the function related to the variation of operating frequency band. During the spectrum handoff, to match the new frequency band, the parameters in the protocol stack of different layers must be changed. The handoff must ensure that the CR user continue to transmit the data in new spectrum band [6].

Challenges:

- Spectrum mobility in time domain and in space.

2. ENERGY EFFICIENCY

The wireless communication system may propose high rate of data and quality of service. The system has two types of users. One is Primary User(PU) and other is Secondary User (SU). Primary users are licensed user who has high priority and the secondary users have the access to spectrum in an opportunistic way. Primary Transmitter can transmit signal to primary user and secondary transmitter transmits the signal to secondary user. Single primary transmitter and several secondary transmitters were able to share same spectrum. This method is named as spectrum utilization. A scheme which allocates resource efficiently must be used in CRN and OFDMA[8]. CRN supports secondary transmitter to access primary user spectrum without harming PU, thus it saves energy. The problem here is that the secondary users compete with primary users for their rare resources. This problem can be overcome by determining the threshold value of PU and comparing it with the threshold value of SU, if the threshold value of PU is higher than SU may access the primary user spectrum and viceversa. The better solution for this problem is to allow PU and SU to have wireless communication systems using an array of multiple transmitters (i.e. multiple antenna) at either the antenna or the receiver, this is a concept of OFDMA. This results in providing good efficiency and better channel capacity.

Cognitive Radio networks can be used to establish communication between unauthorized users without affecting other users spectrum. Energy efficient power allocation scheme is required for OFDMA based Cognitive Radio networks in order to achieve maximum rate of energy efficiency and lower level of interface. Energy efficient power allocation can be done using JSPAC strategy[8].

JSPAC Strategy

Let ‘K’ be the subchannel and the range of subchannel is ∞.

Step 1: For each transmitter using separate subchannel n.

Step 2: Set the threshold value of primary user.

Step 3 : If the secondary user value is smaller than the primary user threshold value then the secondary user can access the primary user spectrum.

Step 4: Else the primary user can access their own spectrum without interference of secondary user.

Problem of this method is multiple secondary users competed for single bandwidth. So the bandwidth divided into number of sub channel. Each subchannel can be allocated to every single user.

3. APPLICATIONS

Current fixed spectrum utilization policies result in inefficient spectrum utilization [7]. CR is gaining recognition in order to overcome this problem. CRNs opportunistically search for available spectrum bands by dynamically altering transmitter parameters based on communication with the environment. The following applications depicts on how CR benefits IoT:

Military: Because of the type of spectrum flexibility and agility that the CRs have, it has become most necessary and useful technology. The capability of CR to interoperate in different radio frequency standards along with its ability of sensing interferer’s presence has resulted in wide range of uses. Acknowledging these properties and uses of CR, military has started used this technology. Military community is more interested in secure and secret communications.

Since CR ensures secure transmission and has ability to identify any communication equipments that belongs to the third party, it is being used extensively and has a role in communication equipment used by military.

Public Safety: Public safety agencies need additional spectrum in times of emergency situation. CR has the ability to provide additional spectrum at the time of congestion. This idea is based on sharing of radio spectrum that can help in deciding call main concern and their reaction time. This jurisdiction can take the help of CR in operating others communication equipment and obtaining their information in case of suspicion. CRs provide a channel between two stations irrespective of radio systems. This helps in secrecy.

Broader Impacts and Commercial Use: Spectrum sharing is a important part of dynamic spectrum allocation. The use of CR technologies has resulted in the conversion of conventional approach of static assignment of frequency into dynamic spectrum assignment. With increase in demand for spectrum, it becomes difficult to satisfy this demand. Detection of presence of any device and identification of any interference because of this is required data needed for intelligent sharing of spectrum through its dynamic allocation and reconfiguration of radio. The problem of interference has increased due to addition of wireless local network into ISM band. Although some technologies help in solving this problem but the use of CR results in improving the condition of present system.

Health Care: In a health care system, such as telemedicine, wearable body sensors are being used is increasing. Medical data is critical and error sensitive consumption of energy. Wireless Body Area Network for health care systems is suitable for areas where the numbers of health patients are low. The use of CR wearable wireless body sensors can mitigate this problem due to bandwidth, jamming and global operability, which in turn improves reliability.

Real-Time Surveillance Applications: Real-Time Surveillance Applications such as traffic monitoring, biodiversity mapping, and environment conditions that affect crops and livestock, underwater WSNs, vehicle tracking, inventory tracking requires minimum access to channels and communication delay. Some of the applications are sensitive and require high reliability. If the channel is not good delay due to link failure can occur in WSN. WS nodes hop to another channel if it finds a channel idle with better condition in CR-WSNs. To increase bandwidth of channels in CR-WSNs use of multiple channels is possible.

Bandwidth-Intensive Applications: Applications of multimedia, such as video streaming, audio, snap shots over restricted WSNs, are extremely difficult because of large bandwidth requirement. Other packages such as hospital environment, vehicular WSNs, tracking etc, have giant spatial and temporal variations in data density correlated with node density. These applications require huge bandwidth and cannot withstand delay intolerability. Because in CR, SUs can access more than one channel each time needed, CR is appropriate for these forms of applications.

4. CONCLUSION

Internet of things presents a new lifestyle by developing various applications. Many wireless devices are expected to be connected to the internet in future which leads to face the big challenge against the accessing of radio spectrum. This is an urgent problem which must be addressed quickly. Cognitive Radio technology has the capacity to solve the problem related to the spectrum access. In this paper, we discussed about the need of CR technology, architecture of CRN and also the essential properties, challenges and applications of CR are also explored. And also one of the strategy is reviewed to increase the rate of energy efficiency which leads to the efficient utilization of spectrum in current wireless communication. Both CRN and IoT is an emerging and promising technology that will rapidly facilitate the consumers. In future era, CR based IOT will exist will make the world effortless. So there is an need to make this technology more mature in the future for global IoT.

REFERENCES

[1] Dharmendra Kumar Fageria, Rahul Kumar Garg, "A review on cognitive radio based spectrum sensing techniques", International Journal For Technological Research In Engineering, 2018.

[2] Navid Tadayon, Sonia Aıssa, "Modeling and Analysis of Cognitive Radio Based IEEE 802.22 Wireless Regional Area Networks", IEEE transactions on wireless communications, Vol. 12, No. 9, 2013.

[3] Lokesh Chouhan, Aditya Trivediy, "Cognitive Radio Networks: Implementation and Application issues in India", Conference Paper, Available at https://www.researchgate.net/publication/266677162

[4] Shaika Mukhtar, Mehboob ul Amin, "Cognitive Radio Technology— A Smarter Approach ", International Journal of Science, Engineering and Technology Research (IJSETR), Volume 5, Issue 2, February 2016

[5] H. Afzal, W. Aslam and M.R. Mufti3, "A Comprehensive Study on Cognitive Radio Based Internet of Things", The Nucleus 56, No. 2 (2019)

[6] Goutam Ghosh, Prasun Das and Subhajit Chatterjee, "Cognitive Radio And Dynamic Spectrum Access – A Study", International Journal of Next-Generation Networks (IJNGN) Vol.6, No.1, March 2014

[7] A. A. Khan, M. H. Rehmani, and A. Rachedi, "When Cognitive Radio Meets the Internet of Things?," IEEE 12th Int'l. Wireless Commun. & Mobile Computing Conf., Paphos, Cyprus, Sept. 5–9 2016.

[8] A. Thenmozhi, Dr. S. Andrew "Energy Efficiency Pricing Based Multi Resource Allocation in OFDMA Cognitive Radio Networks", International Conference on Computer Communication and Informatics, 2015.

ABBREVATIONS

1. SCH- Superframe Control Header
2. CPE- Customer Premises Environment
3. MAC- Media Access Control
4. RF- Radio Frequency
5. DSA- Dynamic Spectrum Access
6. PU- Primary User
7. SU- Secondary User
8. JSPAC- Joint Subchannel Allocation and Power Control
9. WSN- Wireless Sensor Network
10. CR-WSN- Cognitive Radio Wireless Sensor Network