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2016 3rd International Conference on Signal Processing and Integrated Networks (SPIN)

An Efficient Spectrum Hole Utilization for Transmission in Cognitive Radio Networks

Priya Goyal, Avtar Singh Buttar, Mohit Goyal

***Abstract*— Cognitive Radio (CR) seems to be a tempting solution in order to resolve the problem regarding spectrum underutilization and spectrum scarcity. Among the various fundamental functions of CR system, spectrum sensing is the key function where it senses the electromagnetic environment to detect spectrum holes (vacant frequency bands), that can be utilized by Secondary Users (SU) to achieve spectral efficiency. For this, high accuracy and minimal complexity are the main requirements of the system. Spectrum Decision in CR system determines the channel capacity, spectrum hole information along with data rate and bandwidth of the transmission and an appropriate spectrum band is chosen for transmission of the signal. In this paper, an Efficient Approach for Spectrum Utilization is proposed, using Wavelet Packet Transform (WPT) Technique Based on Entropy Estimation for Spectrum Sensing in Cognitive Radio Networks. No need of prior knowledge about Primary User (PU) signal is the most advantageous fact about the sensing technique.**

Keywords: Cognitive Radio, Spectrum Sensing, Spectrum Decision, Primary User Detection, Wavelet Packet Transform, Entropy Estimation, Spectrum Utilization.

I. INTRODUCTION

According to the Federal Communications Commission (FCC) [1] survey, present wireless communication networks, operating in either licensed or unlicensed bands, occupy most of the available spectrum. Still, the demand for free spectrum is constantly increasing with the availability of technological advances in the field of wireless communication. Therefore the need to optimize the utilization of spectrum is the primary task. The conventional method (fixed spectrum assignment) of spectrum allocation to licensed user is very inflexible, where licensed users have supreme rights to operate in that allocated frequency band. With this scheme, most of the useful spectrum is already used and it becomes very hard to accommodate new services or to improve the existing ones. As a large portion of the licensed radio spectrum remains vacant for significant period of time in certain areas, spectrum underutilization come as a more significant problem than the scarcity of spectrum i.e. there are a lots of spectrum holes/white spaces, which are defined as set of frequency bands assigned (licensed) to a Primary User, but, at a particular time and specific geographic location, these spectrum holes are not being utilized by that user. Spectrum utilization can intensely be increased by Cognitive Radio which can co-exist with the existing PUs in the licensed frequency band as it senses the freely available spectrum for spectrum holes and can opportunistically access the detected spectrum holes without causing any harmful interference to the PU [2].

Spectrum sensing is the key function of CR as it involves determining the spectrum characteristics such as time, frequency and the kind of PU signals present. Different spectrum sensing techniques have been reported in the past: Cyclostationary based sensing [3], Energy Detection based sensing [4], Matched Filter based sensing [5], Cooperative spectrum sensing [6], Wavelet based spectrum sensing [7], Multi-user spectrum estimation [8], Waveform-based sensing [9], Entropy based spectrum sensing technique [10] and Spectral Feature spectrum sensing [11] etc. Entropy based spectrum sensing technique is simpler and efficient compared to some of the existing methods as discussed in the literature.

A Spectrum decision Technique using Wavelet Packet Transform (WPT) based on Entropy Estimation is proposed which combines the advantages of WPT Decomposition with efficacy of Entropy Estimation. The WPT method gives accurate information about the decomposed frequency band, depending upon the level of decomposition chosen and the entropy (randomness) of each subband gives the information about its occupancy or freeness. The proposed algorithm is very much robust against noise as the need for accurate estimation of noise is eliminated. Location of spectrum holes in the interested frequency band can be estimated fast by utilizing the wavelet packet probability vector of the decomposed subbands. The choice of appropriate modulation scheme is to modulate secondary user signals and interleave it with primary user signals in the same band. Spectrum decision refers to the decision regarding the data rate, transmission mode, transmission bandwidth etc. and the selection of an appropriate spectrum band according to the spectrum characteristics and user requirements.

This paper is organized as follows: Section II briefly describes WPT and Entropy, and then A WPT technique based on Entropy Estimation is proposed. Section III presents the spectrum decision process for the detected spectrum holes.

II. WAVELET PACKET TRANSFORM BASED ON ENTROPY ESTIMATION

Spectrum Sensing is based on a well known technique called signal detection which is formalized as a hypothesis test [12].

$$H0: x(n)=w(n) \quad (1)$$

$$H1: x(n) = s(n) + w(n) \quad (2)$$

s(n) is the transmitted signal of the PU, x(n) is the received signal by CR receiver, and w(n) is Additive White Gaussian

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Cyclostationary Feature based Detection using Window Method in SIMO Cognitive Radio System

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Abstract— **With some recent developments in the field of wireless communication at rapid pace, users are getting a number of applications which require the precious bandwidth to work on. As the bandwidth is limited, the available spectrum is being congested day by day. Cognitive Radio System (CRS) plays an important role in such scenario. It dynamically adapts its parameters and protocols to provide unused spaces in the total usable spectra. There are a number of ways to detect the unused spectrum/holes/white spaces like Energy Detection, Matched Filter Detection, Cyclostationary Feature Detection (CFD), Wavelet Transform, Filter Bank, Eigenvalue based Detection, Covariance based Method, Multiple antenna method and Multitaper Method. In this paper, a spectrum sensing technique is proposed which is based on the cyclostationary spectrum sensing in multiple antenna cognitive radio by Maximal Ratio Combining (MRC) method. Spectral Correlation Density (SCD) is computed by FFT Accumulation Method (FAM) to perform Cyclic Analysis. Simulation results show that CFD for lower SNRs as the proposed scheme can detect the primary user with a probability of 90 percent approximately at -20dB.**

Keywords—Cognitive Radio; Spectum Sensing; Cyclostationary Feature Detection; Multiple Antenna; Spectral Correlation Density; Maximal Ratio Combining; FFT Accumulation Method.

I. INTRODUCTION

With the advancement in the wireless communication applications, the demand of radio resources is also increasing. To meet this ever increasing demand, there is need to efficiently utilize the available and limited resources. According to a docket of Federal Communications Commission (FCC), the average usage of the available bandwidth is 15-85% [1]. So, need of the hour is to efficiently utilize the available resources. The concept of Cognitive Radio (CR) is introduced to solve the problem. CR is a radio based on Software Defined Radio (SDR) having the capability to adapt its parameters and resources according to the changing environment. It allows the unlicensed users or the Secondary Users (SUs) to opportunistically access the radio spectrum when the licensed users or the Primary Users (PUs) are not utilizing or underutilizing it below some tolerable threshold.

Spectrum sensing plays a major role in the functioning of cognitive radio. A number of techniques are available to sense the spectrum holes like Energy Detection, Matched Filter Detection, Cyclostationary Feature Detection, Wavelet Transform, Eigenvalue based Detection, Filter Bank Method, Multiple Antenna Method, Covariance based Method and Multitaper Method [2]. Among all, commonly used methods of detection are Energy Detection, Matched Filter Detection and Cyclostationary Feature Detection.

Energy Detection method is computationally less complex but lagging accuracy when subjected to the low SNR conditions or noise uncertainty while Matched Filter Method senses in short duration but requires synchronization and prior knowledge of user information such as modulation type, order, bandwidth and operating frequency. Cyclostationary detection is able to detect under low SNR conditions but with high computational complexity. [3]

II. BACKGROUND

Following are some terms needed to understand the proposed algorithm background.

A. Cyclostationarity

According to Gardner [9], the essence of cyclostationarity is the fact that the sinewaves can be generated from random data by applying certain non-linear transformations. A continuous signal $x(t)$ is cyclostationary of order 'n' (in wide sense) if and only if we can find some n^{th} order nonlinear transformation of the signal, $y(t) = f(x(t))$, that will generate finite amplitude additive sine-wave components, which produce spectral lines.

A continuous signal $y(t)$ contains a finite-amplitude additive sine-wave component with frequency α, $\alpha \neq 0$, if the Fourier coefficient

$$M_y^\alpha = \langle y(t)e^{-j2\pi\alpha t} \rangle \quad (1)$$

is not zero.

Here, the operation $\langle . \rangle$ is the time averaging operation defined as

$$\langle . \rangle = \lim_{T\to\infty} \frac{1}{T} \int_{-T/2}^{T/2} (.)dt \quad (2)$$

For second order cyclostationarity, the non-linear transformation for the continuous signal $x(t)$ such that $y(t) = f(x(t))$ is given by

$$y_\tau(t) = x\left(t + \frac{\tau}{2}\right) x^*\left(t - \frac{\tau}{2}\right) \quad (3)$$

where the symbol * represents complex conjugate.

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Computational intelligence based metaheuristic for energy-efficient routing in wireless sensor networks

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Abstract: Wireless Sensor Networks (WSNs) open up a new research horizon, with wide range of data oriented applications. Energy efficient routing is one such area of interest, whic... **View more**

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Abstract:

Wireless Sensor Networks (WSNs) open up a new research horizon, with wide range of data oriented applications. Energy efficient routing is one such area of interest, which require non-conventional paradigm for design and development of protocols. Computational Intelligence (CI) based metaheuristic can be used for optimal routing of data, to deliver events in an energy constraint WSNs environment. In this paper, we present BeeSwarm, a CI based, energy-efficient hierarchical routing protocol for WSNs. Our protocol consists of three phases: 1) Set-up Phase-BeeCluster, 2) Route Discovery Phase-BeeSearch and 3) Data Transmission Phase-BeeCarrier. Integration of three phases for node clustering, data routing and transmission, is the key aspect of our proposed protocol, which ultimately contributes to its robustness. Evaluation of simulation results show that BeeSwarm perform better in terms of packet delivery, energy consumption and throughput with increased network life compared to other CI based hierarchical routing protocols.

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Contents

I. Introduction

Wireless Sensor Networks (WSNs) contain self-configured, distributed and autonomous Sensor Nodes (SNs) that monitor physical or environmental activities such as humidity, temperature, sound, vibration or pollutants in a specific area of operation [1]. SNs collect data from their surrounding and forward it to a main location, known as Sink or Base Station (BS) where data can be monitored and analysed for decision making in variety of applications. A WSN may contain hundreds of thousands of such SNs, which can communicate and share data among themselves using radio signals [2]. However, SNs have limited battery life; therefore random deployment of large number of SNs may bring challenges to manage resources for efficient delivery of events in WSNs [3].

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Design of four-pole chebyshev and quasi-elliptic Ka band dielectric resonator filter using higher order mode TE01(δ+1)

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Abstract. This paper describes the development of 4-Pole Chebyshev and Quasi-Elliptic Ka Band Dielectric Resonator Filter using Higher Order Mode TE01δ+1. A microwave filter is a two port network used to control the frequency response at a certain point in a microwave system by providing transmission at frequencies within the passband of the filter and attenuation in the stop-band of the filter. The satellite communication industry created demand for low-mass narrow-band low-loss filters with severe specification on amplitude selectivity and phase linearity. The microwave region of the electromagnetic spectrum has certain unique properties. This enable microwave signals to propagate over long distances through the atmosphere under all the most severe weather conditions. These have both military and civilian applications, including Radar, Navigation and Wireless Communication. Microwave Filters are vital components in a huge variety of electronic systems, including cellular radio, satellite communications and radar. The design of filters uses network synthesis, with which it is possible to apply systematic procedures to work forward from specification to a final theoretical design.

1 INTRODUCTION

AS the Federal Communications Commission (FCC) tightens the frequency allocation bands for satellite communication services providers, the need for "brick wall" filters becomes increasingly large. Adjacent channels cause co-location interference where Provider A's frequency band is almost contiguous to Provider B's frequency band. In other words, the usability of Provider A's pass-band is degraded if the power in Provider B's pass-band is not sufficiently attenuated. Typically the pass-band frequency separations are less than a few 4 MHz (for 36 MHz Transponder Bandwidth).

To sufficiently attenuate Provider B's pass band frequencies while aiming to preserve Provider A's pass band frequencies with minimum loss, a high quality factor filter is needed. Over the years, microwave band-pass filters have been designed in various topologies such as waveguide, combline or cavity structure. In cases where a very sharp roll off is required, transmission zeros are introduced with the use of non-adjacent resonator couplings (cross-couplings). In modern day filter design, for narrow bandwidth band-pass filters; this is often implemented with a dielectric resonator filter with cross-couplings. Dielectric resonators offer compact size, temperature stability and the high quality factor necessary for this type of design. The filter is synthesized with finite transmission zeros placed at Provider B's pass-band frequencies to attenuate unwanted emissions. A microwave dielectric resonator band-pass filter described in this paper deals with the situations mentioned above.

In 1968, S.B. Cohn implemented the first high-Q dielectric resonator band-pass filter and his exploratory studies paved the way for "brick-wall" filters. In the recent past, dielectric resonator filters have been used widely in mobile communication systems, radar and satellite due to their high Q, compact size and temperature stability [1]. They offer high selectivity in narrow bandwidth applications with low insertion loss. Dielectric resonator filters have been developed in multi-mode, mixed-mode and single-mode cavity applications. Despite multi-mode and mixed-mode dielectric resonator cavity filters providing low loss and smaller volume, their inferior spurious transmissions and high-cost manufacturing keeps them a design rarity.

The perfect filter would have zero insertion loss in the pass-band, infinite attenuation in the stop band, and a linear phase response (to avoid signal distortions) in the pass-band. Of course, such filters do not exist in practice, so compromises must be made; herein lies the art of filter design. The insertion loss method allows a high degree of control over the pass-band and stop-band amplitude and phase characteristics, with a systematic way to synthesize a desired response. The insertion loss method allows the performance to be improved in a straightforward manner, at the expense of a higher order filter. The order of the filter is equal to the number of reactive elements used in the filter.

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A Survey on Spectrum Management Techniques in Cognitive Radio Networks

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ABSTRACT
The rapid growth of wireless application leads to increase the demand of proper utilization of the limited and precious spectrum band. Allocated spectrum bands are not fully utilized, because the allocation of spectrum band by *Federal Communications Commission* (FCC) is based on static/fixed assignment policy. So the dynamic allocation of wireless spectrum band is required. Cognitive Radio (CR) technology is based on dynamic allocation of spectrum band. Which allow the secondary user (unlicensed user) to use the licensed spectrum band in an efficient manner using dynamic spectrum access methods.CR offers spectrum sensing techniques which detect the holes/ vacant space (white space) in the frequency band which is not used by primary user (licensed user) can be used by secondary user (unlicensed user) to enhance its spectrum efficiency. Every licensed user/license is generally defined by some parameters- frequency, space, transmitting, power, spectrum owner (i.e. license), types of use and the duration of licensed user or license. In this paper numbers of spectrum management techniques are discussed. The challenges and issues of spectrum management and comparative analysis of different spectrum management techniques are also discussed.

General Terms
Wireless communication, Optimization techniques, Spectrum efficiency

Keywords
Cognitive Radio, Spectrum management, Wireless communication, Genetic algorithm

1. INTRODUCTION
The growing demand of wireless applications has put a lot of constraints on the usage of available radio spectrum which is limited and precious resource. However, a fixed spectrum assignment has lead to under utilization of spectrum as a great portion of licensed spectrum is not effectively utilized. Cognitive radio is a promising technology which provides a novel way to improve utilization efficiency of available Electromagnetic spectrum [1]. Spectrum sensing helps to detect the spectrum holes (underutilized bands of the spectrum) providing high spectral resolution capability. The challenges and issues involved in implementation of spectrum sensing techniques are discussed in detail giving comparative study of various methodologies.

The available electromagnetic radio spectrum is a limited natural resource and getting crowded day by day due to increase in wireless devices and applications. It has been also found that the allocated spectrum is underutilized because of the static allocation of the spectrum [2]. Also, the conventional approach to spectrum management is very inflexible in the sense that each wireless operator is assigned an exclusive license to operate in a certain frequency band. And, with most of the useful radio spectrum already allocated, it is difficult to find vacant bands to either deploy new services or to enhance existing ones. In order to overcome this situation, we need to come up with a means for improved utilization of the spectrum creating opportunities for dynamic spectrum access. The issue of spectrum underutilization in wireless communication can be solved in a better way using Cognitive radio (CR) technology [3].

2. COGNITIVE RADIO
Cognitive radio is a wireless communication system which aims to enhance the utilization of the radio frequency (RF) spectrum. The motivation behind cognitive radio is the scarcity of the available frequency spectrum, increasing demand, caused by the emerging wireless applications for mobile users. Most of the available radio spectrum has already been allocated to existing wireless systems, however, and only small parts of it can be licensed to new wireless applications. A study by the Spectrum Policy Task Force (SPTF) of the Federal Communications Commission (FCC) has showed that some frequency bands are heavily used by licensed systems in particular locations and at particular times, but that there are also many frequency bands which are only partly occupied or largely unoccupied [4]. For example, spectrum bands allocated to cellular networks in the USA [5] reach the highest utilization during working hours, but remain largely unoccupied from midnight until early morning.

The major factor that leads to inefficient use of the radio spectrum is the spectrum licensing scheme itself. In traditional spectrum allocation based on the command-and control model, where the radio spectrum allocated to licensed users is not used, it cannot be utilized by unlicensed users and applications [6]. Due to this static and inflexible allocation, legacy wireless systems have to operate only on a dedicated spectrum band, and cannot adapt the transmission band according to the changing environment. For example, if one spectrum band is heavily used, the wireless system cannot change to operate on another more lightly used band.

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A Survey on Various Clustering Techniques in Wireless Sensor Network

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ABSTRACT

Wireless Sensor Network (WSN) is the type of Ad hoc network. WSN is a self-configuring network; any sensor node can join or leave the network when they want. WSN has gained increasing importance in a variety of military and civilian applications. With recent advances in wireless communication technologies, WSN is a great leap forward over traditional sensor network. WSN consists of a large number of heterogeneous/homogeneous nodes which communicates through wireless medium and works cooperatively to sense or monitor the environment In WSN no central controller is present, nodes are responsible for data routing in the network. The sensor nodes are equipped with a cpu, small memory and low power battery.These devices sense physical quantities and are used in various applications. The main challenge in WSN operation is efficient use of energy to increase the life time of network.But while maximizing the lifetime, energy efficient and scalable sensor network remains a challenge. One of the techniques that can be used is 'clustering'.The clustering technique with data aggregation on cluster heads provides an efficient scalability in WSNs, favoring a better network lifetime. In this paper a survey of different clustering algorithms and their comparisons is briefed based on the cluster formation parameters and cluster head(CH) election criteria.

General Terms

Wireless Sensor Network, Clustering, Network Lifetime

Keywords

Cluster, Cluster Head, LEACH, HEED, Energy efficiency, Wireless Sensor Network

1. INTRODUCTION

In recent days, WSN are emerging as promising and interesting area. WSN consist of a large number of heterogeneous/homogeneous nodes (usually called as sensor nodes) which communicates through wireless medium and works cooperatively to sense or monitor the environment. The number of sensor nodes in a network can vary from hundreds to thousands. The nodes senses data from environment and send these data cooperatively to the sink/gateway node [1]. These tiny sensor nodes consist of sensing, data processing and communication components. Mostly WSN are used for applications such as military surveillance and disaster monitoring. Generally WSN is deployed in hostile environment where it is unattended. A wireless sensor network is composed of large number of sensor nodes that are densely deployed either inside the phenomenon or close to it and communicates wirelessly. Sensor field usually consist of scattered sensor nodes [1]. Each of these scattered sensor nodes has the capabilities to collect data and route data back to the sink. By using multi hop infrastructureless architecture, data is routed back to the sink which further communicates with task manager node via Internet or satellite.The important feature of WSN is that when hundreds or thousands of sensor nodes are deployed in inaccessible area many sensors connect to controllers and processing stations directly (e.g., using local area networks), and communicate the collected data wirelessly to a centralized processing station. So, a sensor node has not only a sensing component but also has on-board processing, communication and storage capabilities. Instead of sending raw data to the nodes responsible for the fusion, they use their processing capabilities to compute and transmit only required and partially processed data. Sensors should be chosen for an application depends on the physical property to be monitored. For example, such properties include temperature, pressure, light, or humidity.

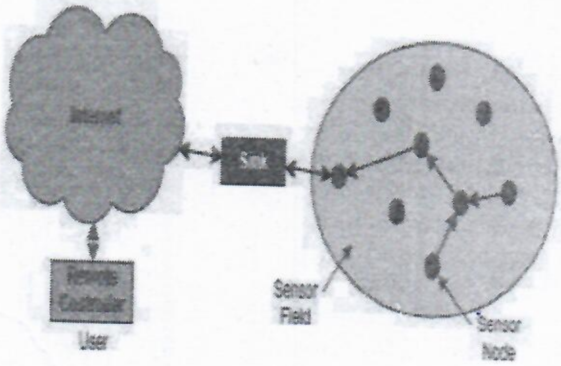

Figure 1: Architecture of wireless sensor network [1]

With these enhancements, a sensor node is not responsible only for data collection purpose. It sense the observed area, collect data in the form of physical quantity and process it after converting sensed analog data into digital form by using ADC(analog to digital converter)and then combines its own data with other sensor nodes data and transmit wirelessly to the sink or base station [2]. The capabilities of sensor nodes in

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A Survey on Routing Protocols in Wireless Sensor Network

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ABSTRACT
Recent advances in wireless communications and electronics has led to the development of tiny sensors. These tiny sensors consume less power, small in size, having low cost and are more energy efficient. Wireless Sensor Network (WSN) is the collection of these tiny sensor nodes which are commonly used to collect information and data from different target areas. WSN consist of small nodes with sensing, computation, and wireless communications capabilities. In WSNs, energy is crucial challenge for sensor node for sensing and transferring the data to the nearest node or to the sink. Different energy efficient approaches have been given by different researchers and each energy efficient approach available in lifetime has its own advantages and disadvantages over the other energy efficient approaches. In this survey, various routing protocols have been described which are energy efficient and hence enhance the network lifetime.

General Terms
Wireless Communication, Data Collection Approaches, Lifetime Enhancement.

Keywords
Wireless Sensor Network (WSN), Routing Protocols, Energy Efficiency.

1. INTRODUCTION
Recent advances in wireless communication and electronics have enabled the development of low cost, low-power, multifunctional sensor nodes that are small in size and communicate untethered in short distances. These tiny sensor nodes, which consist of sensing, data processing and communicating components, leverage the idea of sensor networks. Sensing is a technique used to gather information about a physical object or process, including the occurrence of events (i.e., changes in state such as a drop in temperature or pressure). An object performing such a sensing task is called a sensor. When many sensors cooperatively monitor large physical environments, they form a wireless sensor network (WSN) [1] [2].
Basically, each sensor node comprises sensing, processing, transmission, mobilizer, position finding system and power units. Sensor nodes are usually scattered in a sensor field, which is an area where the sensor nodes are deployed. Sensor nodes coordinate among themselves to produce high-quality information about the physical environment. Each sensor node bases its decision on its mission, the information it currently has and its computing knowledge, communication and energy resources [2]. Integrated into numerous devices, machines and environments sensors provide a tremendous societal benefit. Data collected by sensor nodes in a WSN is typically propagated toward a base station that links the WSN with other networks where the data can be visualized, analyzed and acted upon. Wireless sensor networks consist of small nodes with sensing, computation and wireless communication capabilities. A large number of these sensors can be networked in many applications that require unattended operations, hence producing a wireless sensor network [3].
For example, WSNs have profound effects on military and civil applications such as target field imaging, intrusion detection, weather monitoring, security surveillance, distributed computing, detecting ambient conditions such as temperature, movement, sound, light, or the presence of certain objects, inventory control and disaster management.

While many sensors connect to controllers and processing stations directly (e.g., using local area networks) an increasing number of sensors communicate the collected data wirelessly to a centralized processing station. This is important since many network applications require hundreds or thousands of sensor nodes, often deployed in remote and inaccessible areas. Therefore, a wireless sensor has not only a sensing component but also on-board processing, communication and storage capabilities. Sensor nodes communicate not only with each other but also with a base station (BS) using their Storage Mining, Processing, Analysis, Internet wireless radios, allowing them to disseminate their sensor data to remote processing, visualization, analysis and storage systems.

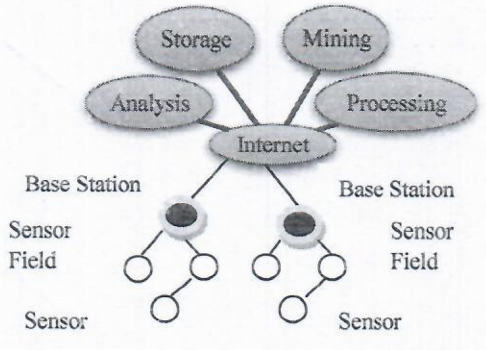

Figure 1: Wireless Sensor Network [3]

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Microwave Attenuation of Cobalt-Tin Substituted Barium-Strontium Hexagonal Ferrite

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Jasbir Singh ; Charanjeet Singh ; Rajat Joshi ; S. Bindra Narang **All Authors**

Abstract: This paper focus on microwave attenuation characteristics of M-type Ba 0.5 Sr 0.5 Co x Sn x Fe (12-2x) O 19 hexagonal ferrite (x varies from 0 to 1 in steps of 0.2) Netw... **View more**

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Abstract:
This paper focus on microwave attenuation characteristics of M-type $Ba_{0.5}Sr_{0.5}Co_xSn_xFe_{(12-2x)}O_{19}$ hexagonal ferrite (x varies from 0 to 1 in steps of 0.2) Network analyzer has been used to measure microwave parameters. Co^{2+} and Sn^{4+} ions substitution leads to enhancement in attenuation, which is maximum at composition x=0.4 with magnetic field of 45.04 dB and at frequency 12.4 GHz. Similar trend is observed for increase in magnetic loss at same frequency for composition x=0.4.

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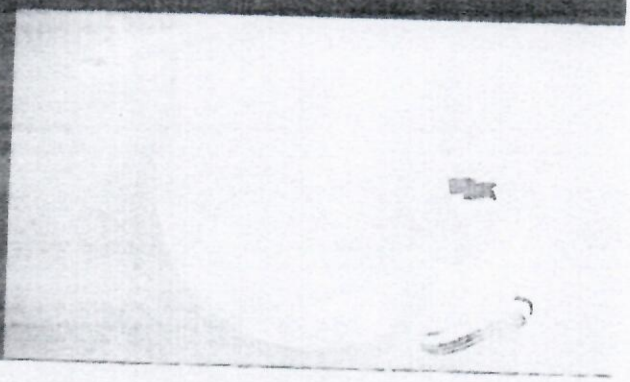

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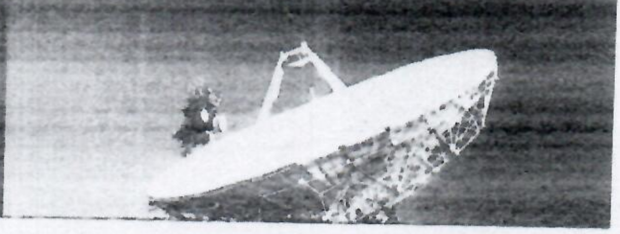

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Methods of Hybrid Cognitive Radio Network: A Survey

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***Abstract*— In advanced radio communication systems, most of the radio spectrum remains underutilized. To fully utilize the radio spectrum, an efficient allocation of the scarce and expensive radio resources is most important and challenging. As a solution of this problem, cognitive radio network (CRN) can make better use of the radio spectrum by allowing the secondary users (SU) to opportunistically access and share the licensed spectrum using dynamic spectrum access (DSA) technology. There are two main sharing techniques in CRN based on the access technology: 1) over-lay; 2) under-lay. In over-lay mode, secondary user can access only vacant spectrum in the absence of primary user (PU) but in under-lay mode, the SUs can coexist with the PUs in the same channel under the SINR (signal to interference plus noise ratio) constraints. To further improve the spectrum scarcity, both over-lay and under-lay approaches gets combined under SINR constraints to make a hybrid cognitive radio. In this paper, we provide a survey for different methods of hybrid cognitive radio in which under-lay and over-lay modes are merged using different techniques to efficiently utilize the scarce radio spectrum.**

Keywords—under-lay, over-lay, interference temperature, hybrid cognitive radio network.

I. Introduction

THE FIXED spectrum allocation and access strategies results in increasing the inefficient utilization of the radio spectrum. The growing bandwidth demand due to the numerous wireless applications leads to the failure of this fixed spectrum allocation policies [3]. Also, according to the FCC (Federal Communications Commission) recent report, only 6% part of the expensive radio spectrum is utilized properly, the other remains underutilized [1]-[2]. As a solution of this spectrum scarcity problem, a new communication technology is introduced known as dynamic spectrum access (DSA) to exploit the existing wireless spectrum opportunistically [4]. DSA allows secondary users (SUs) to access the licensed spectrum bands opportunistically without harming the performance of primary users (PUs) [5].

The cognitive radio network (CRN) is a promising key technology of the DSA. According to Joseph Mitola III [6], who has first introduced the cognitive radio network, a CRN is defined as intelligent software defined radio that senses the radio environment for detecting available channels and accordingly changes its transmitter or receiver parameters such as operating frequency, bandwidth, modulation, transmitting power [7]. CRN consists of two main users: 1) primary users (PUs); 2) secondary users (SUs) where primary users are the licensed users to whom governments issue license for accessing the radio spectrum, but the secondary users are unlicensed ones which access the available vacant radio spectrum bands only in the absence of the primary user. The secondary users must adapt and reconfigure their transmission parameters to share the licensed channel in to preserve the performance of primary users [8].

II. Operations of Cognitive Radio Network

CRN performs four main operations such as spectrum sensing, spectrum decision, spectrum sharing and spectrum mobility which are illustrated as follows in CRN operation cycle:

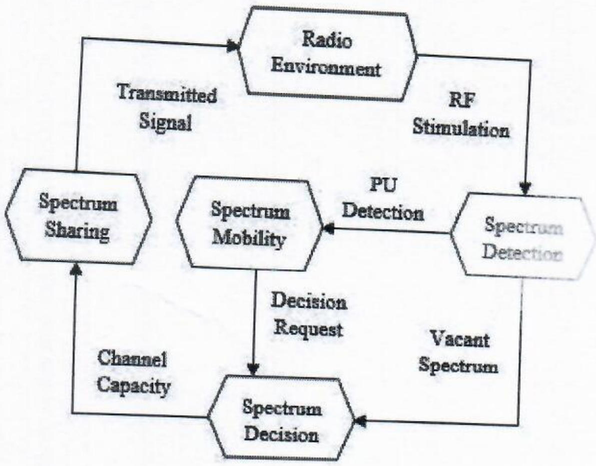

Fig. 1. CRN operation cycle

- *Spectrum Detection:* First operation is spectrum sensing in which CRN senses the radio environment for detecting the available vacant spectrum bands which are free while primary user is inactive [9].
- *Spectrum Decision:* After detection of available channels, CR network needs to decide that which available vacant bands are best suitable for use according to the QOS (quality of service) requirements of the secondary user [10].
- *Spectrum Sharing:* Next, the sharing of spectrum bands is performed, in which the fair spectrum scheduling is provided between the PUs and SUs or among the coexisting secondary users [11].

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Spectrum Sharing Schemes in Cognitive Radio Network: A Survey

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***Abstract*—With the rapid advancements in wireless communication, the problem of scarce radio resources and the low spectral efficiency caused by the stationary spectrum sharing strategies restricts the evolution of the future mobile communication. For this purpose, cognitive radio (CR) emerges as one of the most promising inventions which can overcome the spectrum shortage and spectrum underutilization. As the primary objective of CR, spectrum sharing can make efficient use of the limited spectrum, eliminate the scarcity of frequency resources and improve the system utilization, hence playing an important role in improving the system performance of cognitive radio networks (CRNs). In this survey paper, the spectrum sharing in CR network is discussed in terms of sharing process and different sharing schemes. Furthermore, the comparison of different spectrum sharing strategies is concluded. Moreover, some applications of the spectrum sharing schemes in CR network, like smart grid, public safety, cellular network and medical area are also introduced. In addition, the research issues in the field of spectrum sharing are discussed as well.**

Keywords—Cognitive radio network (CRN), spectrum sharing, dynamic spectrum access, under-lay, over-lay.

I. Introduction

The electromagnetic *radio spectrum* is a natural resource, which is used by transmitters and receivers and licensed by governments. According to the Federal Communications Commission (FCC) report given by the Spectrum-Policy Task Force, only 6% of the entire spectrum is being used by the different agencies and the other part remains free or underutilized [1]. The traditional static spectrum allocation of the radio resources results in spectrum scarcity. This problem of scarce spectrum can be improved by making it possible for a secondary user (SU) to access a vacant spectrum space unoccupied by the primary user (PU) at the right location and the time [3]. For this purpose, a new technology called Cognitive Radio (CR) is introduced by Joseph Mitola III in 1999 seminar at the Royal Institute of Technology in Stockholm, Sweden [2], [4] that uses the concept of dynamic spectrum access (DSA) which renders the capability to share wireless channels with licensed users in an opportunistic way [5]. In dynamic spectrum allocation, the unlicensed secondary users can share the same spectrum band in an opportunistic manner without interfering the transmission of the existing licensed primary user when licensed primary user is not occupying that spectrum channel.

II. Cognitive Radio Network

Cognitive radio (CR) is a new paradigm of wireless communication in which a transceiver can intelligently detect the radio environment that which spectrum bands are busy (occupied by PU) and which are vacant (spectrum hole), and abruptly move into these free channels while avoiding occupied ones. A "Cognitive Radio" is a software defined radio that can adapt and reconfigure its transmitter or receiver parameters (modulation, operating frequency, bandwidth, allocated power etc.) according to interaction with the environment in which it operates [7].

A. *Functionality of cognitive radio network*

The cognitive radio operation is based upon the four main functions, namely the spectrum sensing, spectrum decision, spectrum sharing and spectrum mobility which are illustrated as:

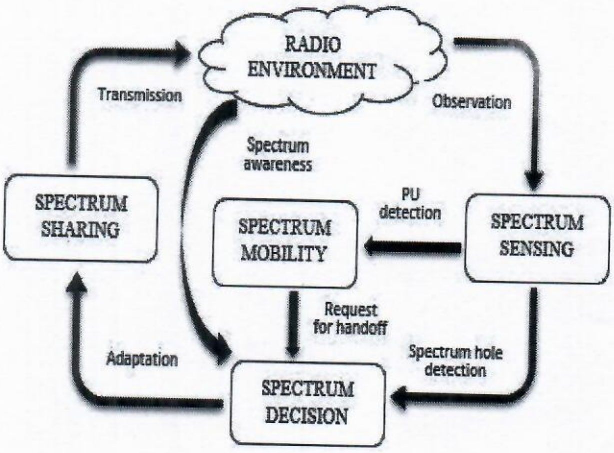

Fig. 1. Cognition function cycle.

1) Spectrum sensing: The first step is sensing of the spectrum in which CR senses the radio environment whether PU is active or not by checking the characteristics of the RF received signals [8]. Let PU transmitter transmits the signal $x(t)$ through a channel having channel gain h and noise $w(t)$. There are two hypotheses assumed for received signal $y(t)$ which decide whether PU is present or not.

$$H_0: y(t) = w(t) \quad (1)$$
$$H_1: y(t) = h * x(t) + w(t) \quad (2)$$

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Fuzzy Logic based Spectrum Handover Approach in Cognitive Radio Network: A Survey

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Abstract—**The demand of wireless application is increasing day by day but there is crunch in availability of spectrum band as spectrum bands are in limited amount. Cognitive Radio Network (CRN) is an advanced technique that utilize licensed spectrum bands that are available. Cognitive function cycle has mainly four functions such as, sensing of spectrum, spectrum decision, sharing of spectrum and spectrum mobility. Here the emphasis is on spectrum handover which is performed when licensed user returns to its channel or if channel condition become worst then SU will have to vacate the channel for the primary users having higher priority. In this survey paper, the utility of fuzzy logic in spectrum handover is discussed. Furthermore, the spectrum handover techniques using fuzzy logic in cognitive radio network have been discussed such as; spectrum handover based on fuzzy logic controller, spectrum handover based on power control, channel reservation based spectrum handover, spectrum handover based on underlay power sharing, hierarchical FLS based handover, handover decision based on SU priority, spectrum handover based on negotiation approach are described briefly. The decision making is the main challenge for CRN, so concept of fuzzy logic is introduced in spectrum handover for efficient decision making to reduce handover delay, optimizing power consumption, unwanted handover is reduced.**

Keywords—Cognitive Radio Network (CRN), Spectrum handover, fuzzy logic controller (FLC), Membership Function.

I. INTRODUCTION

The numbers of traffic currently carried by network in wireless communication is expanding constantly because of the growth in number of users and through the increase in wireless based applications. The frequency fixed allocation policy, has produced scarcity of available bands of frequency.

The Cognitive Radio is described by International Telecommunications Union, as "a radio or system that detects and is aware of its environment and can be adjusted dynamically according to its radio operating parameters", it acts as a key for, the dynamic access of spectrum, for an opportunistic and efficient utilization. The Secondary user (SU) is permitted to utilize channel of an accessible licensed band, but when the primary user arrives back to occupy channel, to proceed further transmission the secondary user must leave the channel and search for a new approachable channel, this can be termed as spectrum mobility or handover of spectrum in Cognitive Radio [3-4].

According to current research the spectrum handover technique is the essential element for empowering the transmission of secondary user information continuously [4-5], Since these techniques can reduce handover delay during channel switching for the transmission of a secondary user and can limit channel degradation. During the spectrum handover it is inevitable that the communication will be temporarily broken, because it is necessary to carry out a process for discovery of new available frequency bands, therefore a spectrum handover technique is required, to change the current transmission of the secondary user to a new spectrum band with the minimum degradation of quality by reconfiguring its communication parameters [5].

There are currently several spectrum handover techniques, however, the technique using fuzzy logic system is most successful as it is more efficient as compared to other techniques having complex mathematical models. Fuzzy logic system analyses network during spectrum handover before taking decision for selecting and utilizing the license spectrum band more efficiently. Upon the Primary user activity spectrum handover technique depends completely.

II. DYNAMIC SPECTRUM ACCESS

In Cognitive Radio dynamic spectrum access is provided by enabling unlicensed users the access of using the spectrum that are licensed. Spectrum dynamic allocation policy for CR network (DSA) is proposed where unlicensed secondary user (SU) can utilize the unused spectrum bands opportunistically, which are generally called as "spectrum gaps", without meddling with the existing primary users (PU) [3]. The licensed band underutilization has propelled the evolution of CRN. The CRN can sense wide channels of spectrum efficiently, identify spectrum gaps and utilize these gaps for communication when required, without interfering to PU. In this scenario cognitive radio is also termed as a secondary user. In CRN, dynamic spectrum access depends on the four principle steps of cognitive function cycle such as Spectrum Sensing, Spectrum Decision, Spectrum Sharing and Spectrum Mobility are as follows:

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Handover Triggering based Spectrum Handover Approach in Cognitive Radio Network: A Survey

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***Abstract*—Rapid developments in wireless communication technology has increased huge demand for spectrum bands. This has raised the problem of spectrum scarcity, to meet such demands we require dynamic allocation of the spectrum which can be provided by cognitive radio networks (CRNs). Cognitive radio network is an evolving network which empowers secondary users (SU) to opportunistically utilize the spectrum band allotted to a primary user (PU) and it also has capability to solve spectrum inefficiency and spectrum scarcity issues. Spectrum handover approaches can reduce the handover delay, avoid unwanted interference, reduce collision and utilize the channel optimally to enhance the overall performance of SU communication. Hence, these approaches play an important role in enhancing the system performance of cognitive radio networks (CRNs). In this survey paper, various approaches of spectrum handover in the CR network has been discussed. Furthermore, the comparison of spectrum handover approaches has been carried out on various parameters. Moreover, some applications of the reactive and proactive handover in the CR network and research challenges related to spectrum handover has also been discussed in this paper. The parameter for analyzing the performances of spectrum handover approaches are listed which determine the efficiency of these approaches. Finally, through graphical representation, handover delay and complexity of various handover approaches is compared.**

Keywords—Cognitive Radio network(CRN); Dynamic Allocation of spectrum policy(DSA); Reactive Handover Approach; Proactive handover Approach.

I. INTRODUCTION

With the increase in the requirement of new wireless devices and its applications the number of wireless users has increased, due to which problem of spectrum scarcity has increased to a large extent. So, to tackle this issue the federal communications commission (FCC) decided to explore better approaches. Cognitive radio network (CRN) is an advanced radio network that targets to enhance radio spectrum use by dynamically utilizing the underutilized and unused spectrum by utilizing it opportunistically [1]. CRN promises to be the main solution for prevalent problems in wireless networks arising out of the restricted spectrum accessibility and the inability in the opportunistic use of frequency bands which are not fully utilized by the licensed user [2]. The first notion of cognitive radio was brought in by Joseph Mitola III in the seminar held in 1998 at the Royal Institute of Technology in Stockholm [4]. In the CR network, the spectrum is dynamically allocated by enabling the unlicensed users to utilize the vacant spectrum of licensed user as shown in fig1, for solving the issue of insufficient utilization of the spectrum in the wireless communications. In the CR network, through policy of dynamic allocation of the spectrum (DSA) the secondary (unlicensed) user can utilize the vacant spectrum bands of PU opportunistically, which are generally known as "vacant spectrum holes". But there must be no conflict with the primary (licensed) users while utilizing the vacant spectrum bands [5].

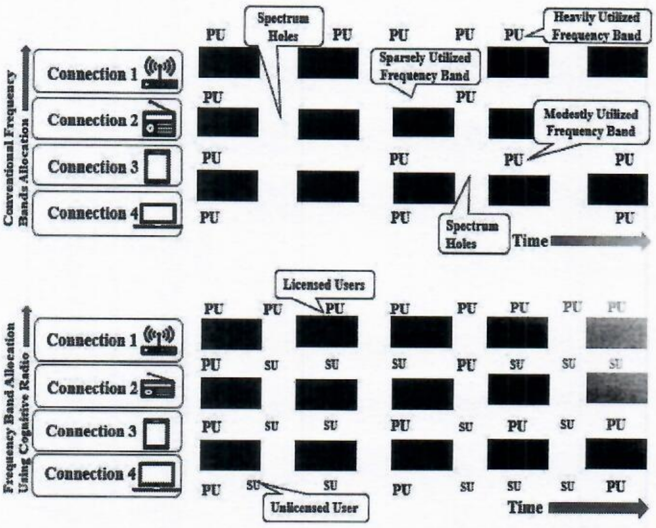

Fig. 1. Dynamic allocation of the spectrum in CRN

II. COGNITIVE RADIO NETWORK

For the SU network, CR is a key technology where the spectrum is utilized in the dynamic manner. CR is defined as follows "A 'Cognitive Radio' is an intelligent wireless communication system which is evolved by software defined radio that can analyse, sense, adapt, decide and communicate through interaction with the environment in which it works" [7]. According to the above description, the two main qualities of CR are; (a) *Cognitive capability*: Through interaction in real-time with the radio environment, the unused spectrum is identified (i.e. Spectrum gaps/white

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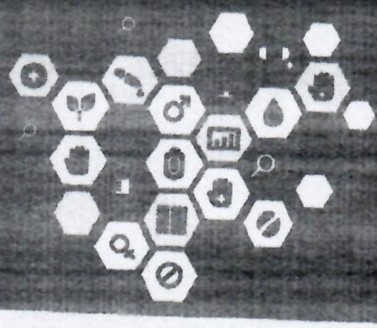

Ziyaur Rahman
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Spectrum Management in Cognitive Radio

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Size-based performance analysis of haar-features for detection of facial images from low resolution surveillance videos

Publisher: IEEE

Vikram Mutneja ; Satvir Singh All Authors

Abstract

Abstract: Face detection has been a very prominent research field since past two decades. In most of the works done so far, haar-features have been the key components in the task o... View more

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Abstract:
Face detection has been a very prominent research field since past two decades. In most of the works done so far, haar-features have been the key components in the task of object detection and have been very instrumental owing to their simplicity, efficient computation, scalability and ability in the encoding of structural contents of facial images in the form of compact binary representation. The selection of the size of example images for the training of the haar-features decides the base size of the detector which consequently influences the overall performance of the face detection system. In this work, we have done the performance analysis of modified version of face detection algorithm with respect to the size of the haar-features based trained detectors and applied the concept to process facial images from low-resolution surveillance videos. It has been empirically concluded that hybridization of the classifiers from different base size results in better detection rate as compared to using haar-features trained from the single base size in detecting low-resolution faces.

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Contents

I. Introduction

Features are an important part of realizing any classification task. The haar-features have been used vastly in the job of object and face detection and have proven to be the key components in the breakthrough development in the area of face detection with the introduction of viola-jones [1] algorithm. Innumerable works have targeted modification and improvement in the viola-jones [1] haar-features and boosting based framework for face detection. In the detection task, the number of haar-features generated is usually very high depending upon the size of detector window to be used. Haar-features encode the structural contents of facial images based on their location and size, as illustrated in Figure. 2 showing the geometrical representation of features applications on different types of input facial images.

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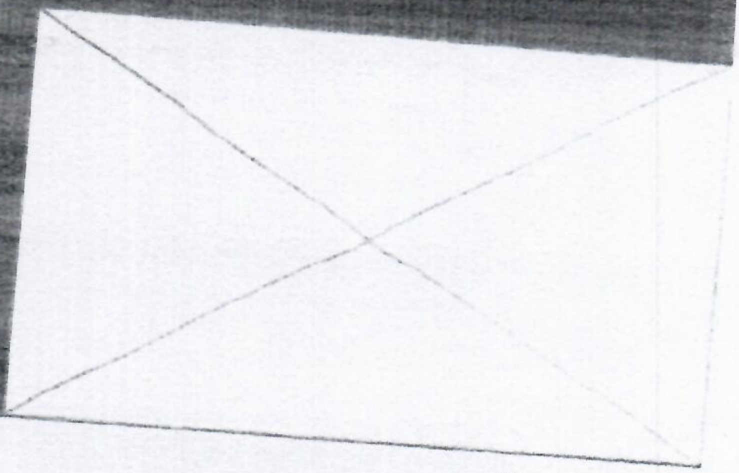

Dr Rakesh Kumar is working as Assistant Professor in the department of Electronics and Communication Engineering at IKG Punjab Technical University,Kapurthala,Punjab and have a total teaching experience of about 17 years and his research interest areas are mobile ad hoc networks and evolutionary algorithms.

Rakesh Kumar
Ankur Sharma

Implementation of OLSR protocol using NS-2 Tool

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2

Fundamental Operations of Cognitive Radio: A Survey

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***Abstract*— Cognitive Radio (CR) has evolved as a smart technology in bridging the disparity between the availability and allocation of the radio frequency spectrum amongst multiple users. With a Software Defined Radio (SDR) framework, Cognitive Radio aims to target high spectrum utilization efficiency via opportunistic spectrum access through autonomous adaptation of its communication parameters according to the network and the demands of the users. This paper presents an overview of the spectrum holes in the licensed bands, the concepts of Cognitive Radio, its features and the transceiver details. The functionality of the Cognitive Radio Cycle is explained along with the description of methodologies for spectrum sensing, spectrum decision, spectrum sharing and spectrum mobility.**

Keywords*— *Cognitive Radio (CR), Dynamic Spectrum Access (DSA), Radio Spectrum (RF), Interference Threshold, Over-lay, Under-lay.

I. Introduction

Federal Communications Commission (FCC) is a regulatory body that allocates fixed radio spectrum to licensed holders for various applications as military, television, cellular etc. However, by reports of Spectrum Policy Task Force, only 6% of the fixed allocated RF spectrum is fully utilized while rest of the spectrum remains underutilized and goes in vain [1]. Expediently growing users of multimedia applications with high data rate and Quality of Service (QoS) requirements have resulted in insatiable demand of the scarce radio spectrum. This issue of scarce and underutilized radio spectrum can be mitigated by the concept of Dynamic Spectrum Access (DSA) [2] that enables unlicensed users to opportunistically access the un-used spectrum of the legitimate users without harming the existing users. The NeXt Generation (xG) wireless networks [3] having heterogeneous architectures with Cognitive Radio (CR) [4] technology has emerged as new paradigm to dynamically exploit the existing underutilized spectrum. The key feature of CR technology is to identify which portion of spectrum is vacant and certainly the update the operating parameters to efficiently use the spectrum. The incumbent legitimate users which hold license for the spectrum are known as Primary Users (PUs) whereas the low priority un-licensed users that access the resources of PUs are known as Secondary Users (SUs).

The paper in explains the concept of spectrum holes, then description of Cognitive Radio followed by the operation of Cognitive Radio Network and the CR cycle is given.

II. Concept of Spectrum Holes

"Spectrum holes" are the temporal and spatial opportunities in the licensed spectrum that can be effectively exploited by the Cognitive Radio users [5]. There can be "white space" i.e. temporal spectrum holes wherein legitimate user is not using the spectrum allocated to it at certain time, so, SUs can access the spectrum opportunistically or the "gray space" i.e. spatial spectrum holes wherein PUs operate only in restricted band while the SUs can transmit simultaneously outside the coverage area of PUs without intruding the services of PUs [6]. Fig.1. shows the temporal and spatial spectrum holes.

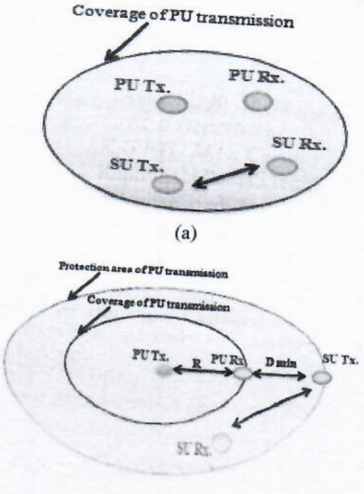

Fig.1. (a) Temporal and (b) Spatial Spectrum Holes

For digital TV in Japan although in the UHF band, 13-52ch are allocated but only 13-15ch and 17-20ch are used at certain location while rest of the channels remain unused [7]. Thus, TV white spaces could be used for Wireless Local Area Network (WLAN) services. Fig.2. shows the availability of channels that can be opportunistically harvested.

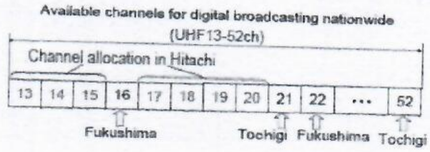

Fig.2. Channel Allocation for TV in Japan [7]

III. Cognitive Radio and Its Features

The term "Cognition" means gathering information through sensing and experiences. The concept of Cognitive Radio was propounded by Joseph Mitola III at Royal Institute of Stockholm; Sweden in 1999 [8].

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Proficient Resource Allocation to Secondary User Using Nature Inspired Technique in Cognitive Radio Network

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Abstract: In this paper, a new resource allocation paradigm is designed whereby a new SU is allowed to gain access to the spectrum of licensed PU. Appropriate bandwidth and power a... **View more**

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Abstract:

In this paper, a new resource allocation paradigm is designed whereby a new SU is allowed to gain access to the spectrum of licensed PU. Appropriate bandwidth and power are the resources allocated to the SU during the inactivity of PU if the interference is below the maximum allowable IT limit of the channel. An efficient algorithm is developed for reconfiguration of SU's parameters using nature inspired computational intelligence technique named ADALINE i.e. Adaptive Linear Neuron. A demand supply based feedback mechanism is proposed to meet the data rate requirements of new unlicensed user. A scenario is considered wherein a single SU transmitter is able to initially coexist with the PU and then, is able to adapt its transmission parameters (bandwidth and signal strength) dynamically as per spectral availability and the demand of its receiving unit. The feedback system developed reduces difference from allowable IT limit and difference from the achievable capacity during each iteration, rendering efficient channel utilization and achieves user's data rate satisfaction.

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Contents

I. Introduction

Wireless Communication is an emerging trend for the worldwide connectivity that has revolutionized the human lifestyle. Electromagnetic radio spectra ranging from 3 kHz to 300 GHz is a natural hub for the wireless connectivity in various fields as military, health, transportation, education, marketing etc. Static frequency allocation (SFA) of electromagnetic spectrum by the regulatory body FCC has exacerbated the problem of spectrum inefficiency [1]. Exponential growth of wireless users has resulted in spectral congestion. An opportunistic SU can alleviate the problem of spectrum [illegible]. For this purpose, Cognitive Radio (CR) is envisaged as a vital technology, a concept propounded by Dr. Joseph Mitola III at the Royal Institute of Technology in Stockholm which incorporates software based dynamic transceiver operability [2]. The key feature of CR technology is to firstly identify spectrum holes [3] i.e. when portion of spectrum is vacant (spectrum sensing) [4] and determine the suitable frequency band as per the requirement of the non-legitimate user (spectrum decision) [5], then to update the operating parameters to enable concurrent usage of the spectrum (spectrum sharing) [6] and...

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to other available vacant band upon the reclamation of PU activity in its licensed band (spectrum mobility) [7].

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Figures

References

A Review and Comparison of AODV, DSR and ZRP Routing Protocols on the basis of Qualitative Metrics

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Abstract – Mobile Adhoc Network is wireless network which is formed without the help of the centralized infrastructure. Any node can be part of this mobile network because of the mobility nature of the wireless network. There are many different routing protocols which are reactive, proactive and hybrid. This paper presents review on AODV, DSR and ZRP and prepared a comparative chart based on the qualitative metrics.

Keywords – Aodv; Dsr; Manet Routing Protocols;Qualitative, Quantative; Zrp.

I. MOBILE ADHOC NETWORKS

Mobile Adhoc Networks are temporary type of networks [1].The formation of these types of networks is required when the emergency arises like earthquake, battlefield, flooding, conference etc. In these types of situations the temporary networks are successful. Mobile Adhoc Network is easy to deploy in less cost.

Nodes in the mobile adhoc network communicate with each other within the radio range. Any node beyond the mobile radio range depends upon multihop transfer policy. Manet network have to face many problems like link failure, information lost due to the mobility nature of nodes. Mobile Adhoc Network is more prone to different types of attacks so more security is required.

Before going into the detail different schemes are used to cast the packets, depending upon how data is transferred from source to destination [1].

II. TYPE OF CASTING

A. Broadcasting

Broadcasting uses the concept of sending the same message at the different locations at the same time. In AODV, if it does not have the path from source to destination same RREQ message is broadcasted to the different locations in search of path from source to destination.

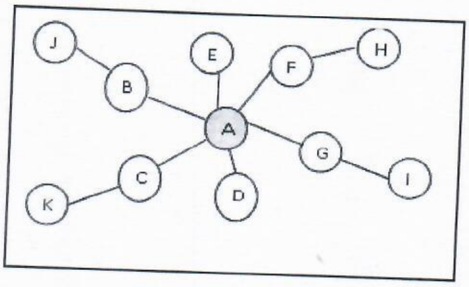

Fig 1. Example of a broadcast.

B. Unicast

Unicast means flow of data to one direction. In AODV if there exists a path from destination to source corresponding to the Route Request. Then RREP is unicast by destination to source.

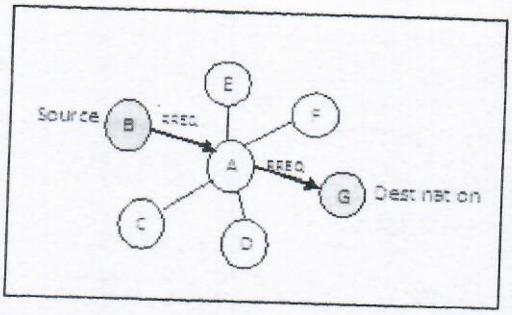

Fig 2. Example of a unicast.

C. Multicast

Multicasting helps us to send the same RREQ to the selected IP Address that is stored in the routing table. Whenever any node receives the RREQ then it can generate the RREP corresponding to that RREQ. The source node may receive multiple RREPs from multiple destinations but the source chooses the shortest path.

Improving Mean Opinion Score (MOS) of VoIP in WiMAX System by Using an Efficient Technique

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Abstract:
VoIP is Voice over Internet Protocol which is a real time application which allows transmitting voice through internet protocol. It provides various services from which one of the important services is phone service over dedicated IP network. The important quality which is perceived by the users of VoIP telephony is speech quality. The quality of speech is degraded by various factors such as packet loss, delay, jitter, etc. This paper concentrate in making better speech quality and to improve the MOS score by using standard PESQ over WIMAX system. Tool used for this purpose is MATLAB R2013b.

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Design and Implementation of Solar Energy Harvesting with Double Booster Circuit in Wireless Sensor Networks

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***Abstract*—Non-conventional sources of energy have gained a lot of interest in the past few decades. Low power applications including embedded systems and wireless sensor network are being explored for energy harvesting from external sources. The abundant source of energy i.e., solar energy is widely used because of its high output and conversion efficiency than other sources like RF energy, piezoelectricity, thermal energy, etc. The harvested power in terms of some microwatts or milliwatts is used to supply in low power applications. In this paper, a solar energy harvesting circuit design is presented with an enhancement of the double booster circuit that increases the output power. The double booster circuit comprises voltage and current booster circuit. The implemented circuit boosts the power to 0.5-1.5 watts depending upon the duration of time. Solar Energy harvesting can be viewed as potential source for extending lifetime of the wireless sensor network.**

Keywords—Wireless Sensor Network, Solar Energy Harvesting, Booster Circuit, Battery Charging.

I. Introduction

Sensor networks work as autonomous units with an arrangement of randomly or uniformly deployed sensor nodes to gather data/transfer in its vicinity. With advancement in wireless communication, new applications are being developed using wireless sensor network (WSN) for detection, monitoring, controlling/actuating parameters in industrial processing, agriculture, war-fields, health services and security. Their working is limited by the battery capacity and its non-replacement due to deployment in remote location. Lifetime of the network is enhanced to certain extent using some energy efficient algorithms like LEACH, DEEC, SEED, HEED, PEGASIS and various nature-inspired techniques. These algorithms do not guarantee life-long operation. Alternative solution for the extended lifetime is harvesting of external energy. Energy sources like solar energy, thermal energy, RF energy, piezoelectric energy, mechanical energy, etc. can be harvested to charge the battery of the sensor node making it economical for unsustainable networks.

Solar energy is the most widely used and abundantly available source of power to energize the sensor node. Solar radiation in the form of photons fall on the surface of the photovoltaic cell to release the energy by creating free charge carriers. Positive and negative charge carriers cause potential difference across the PV junction.[1-2] solar cell, which in some cases is supplying power directly and in other applications acts as a charger for batteries and thereby extend the life of the same.

II. Solar Cell

A Solar cell or a photovoltaic cell is an electrical device that converts the energy of light directly into electricity. The generation of energy from photo cell is based on the photovoltaic effect. The photovoltaic effect consists of a) absorption of light to generate charge carriers b) separation of charge carriers c) collection of charge carriers at the electrodes. The basic principle is to collect a large number of photons through photovoltaic materials such as crystalline silicon, amorphous silicon and cadmium telluride. [1-3] A sufficient number of photons are required to activate the opto-electronic pool to generate electrical energy. Figure 1 shows the structure of solar cell.

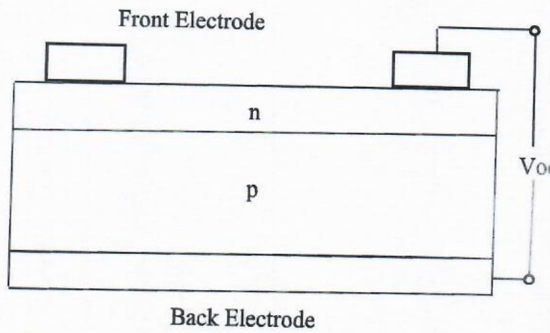

Fig.1. Structure of Solar Cell

The electron-hole pair generated at the electrodes may recombine. Therefore, membranes are used to keep them separate.

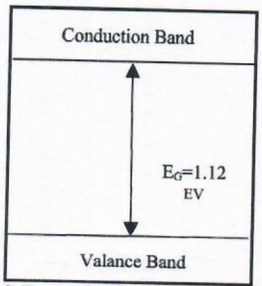

Fig.2. Energy Gap Diagram for Silicon absorption.

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2020 7th International Conference on Signal Processing and Integrated Networks (SPIN)

Empowering Wireless Sensor Networks with RF Energy Harvesting

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***Abstract*—In the past few years Wireless Sensor Networks (WSNs) played a prominent role in the Information, Communication and Technology (ICT). With a vast number of applications in various emerging fields like the Internet of Things (IOT), Cyber Physical Systems, medical, agriculture, structural engineering, military, etc., it is moving towards dominancy in the future. But, the sensors, processors and communicating devices are backed up by the energy sources which are limited to provide energy. The energy efficiency is achieved to some level with energy efficient protocols. For the continuous operation of the system, a continuous source of energy is needed. Energy harvested systems provide a regular source of energy for the continued operation in WSN. A number of energy harvesting techniques are available to harvest energy from the environment namely, solar energy, RF energy, mechanical energy, thermal energy, vibrations, etc. In this paper, a detailed review of RF energy harvesting in WSN is presented explaining its technique, components, energy consumption and harvesting models, its merits and demerits.**

Keywords—Wireless Sensor Networks (WSNs), Energy Harvested WSN (EHWSN), RF Energy Harvesting, Rectenna, Matching Network.

I. Introduction

In the past few years, development in the field of micro sensors for the purpose of tracking and monitoring has opened up the gateway to a number of sensor applications. Sensor networks are being rapidly developed for various applications such as industrial, agricultural, domestic, biomedical, etc. But the application specific design and resource constrained behavior of sensor networks have drawn focus of the researchers to work for better performance of sensor networks. Energy is the major source of the sensor network. Energy consumption plays a vital role in Wireless Sensor Network (WSN) where the sensor nodes are operated with limited power and small sized batteries. The life of the network depends on the rate of drainage of the energy of those batteries. Therefore, designing protocols that conserve energy is an important area of interest to extend the network lifetime of WSN. There are numerous energy conservation algorithms like clustering algorithms, power scheduling algorithms and on-demand routing techniques [1], [2]. The lifetime of sensor nodes can also be enhanced with a little compromise in performance parameters [3]. For example, the depletion of a battery can be slowed down using low power processors/transmitters while compromising with the transmission range and processing speed of operation. This can enhance the lifetime of the network to some extent, but in order to run for long-term operation, it is necessary to use an external source of energy for battery recharging or replacement. Battery replacement may not be a good option for far flanged or inaccessible areas. The battery recharge option is best available for the long-term operation of WSNs for the areas without human intervention.

This paper is organized as follows: Section II describes the Energy Harvesting Wireless Sensor Network, Section III describes RF energy harvesting, Section IV describes RF energy harvesting in WSN, merits and demerits of RF energy harvesting are listed in section V and VI, at the last Section VII concludes the paper.

II. ENERGY HARVESTING WIRELESS SENSOR NETWORK (EHWSN)

Energy Harvesting based Wireless Sensor Network (EHWSN) is emerging as a permanent source to provide energy to sensor nodes by extracting the already available energy from its environment. EHWSN harvests energy from different sources such as solar power, wind, mechanical energy, magnetic fields, temperature gradient, piezoelectricity, radio frequency, etc. which can provide a constant source of energy. The energy extracted from the environment can also be stored for future use in order to run the wireless sensor system forever.

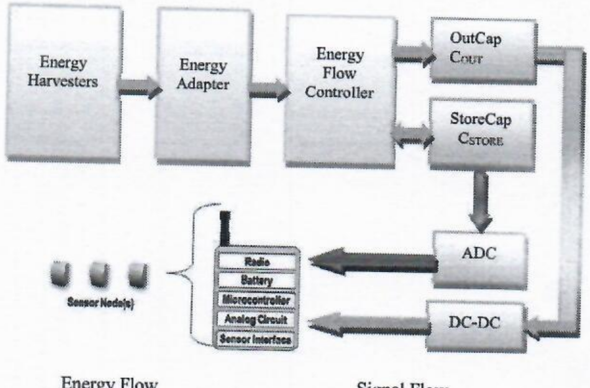

Fig.1. Energy Harvesting based Wireless Sensor Network

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AN AMALGAMATION OF FIREFLY ALGORITHM AND WiMAX REFINING BER AND SNR

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***Abstract*— The newest favorable technology which supplies to the customer end data amenities at a high speed is the Worldwide Interoperability for Microwaves Access (WiMAX). By witnessing the foundation of the WiMAX physical layer a thought has been excellently attained concerning the system of WiMAX. The foundation improving the BER vs. SNR variation using the Firefly algorithm has been discussed in this paper using MATLAB (R2013b) simulator. The studies and research of the students and scholars are based on the meadow of WiMAX can use this model as a helpful reserve. The reimbursements of using Firefly algorithm in a WiMAX system have been depicted in this paper.**

***Keywords*— Orthogonal Frequency Division Multiplexing (OFDM), FA(Firefly Algorithm), Wide Area Ntwork(WAN).**

I. Introduction

The showground of telecommunication has a blowup demand of a superior set of amenities, for instance, immediate messaging, video conferencing, or any other kind of communication provision. New technologies are settled for the attainment of high data rates with the hundreds of persons demanding to get entree at an analogous tower. WiMAX (Worldwide Interoperability for Microwave Access) is an encouraging elucidation or a technology conveying digital Broadband Wireless Access (BWA) with augmented rapidity and distance that marks it underneath the Fourth Generation (4G) of expertise [1].

Expansion of the WiMAX was completed by IEEE (Institute of Electrical and Electronics Engineers), a society that mechanisms for the educational and technical origination in innumerable castigations. IEEE 802.16 was the profitable standardization of the WiMAX family for which a group in June 2001 was molded baptized as WiMAX Forum. A wireless auxiliary to cables, DSL, and fiber providing much-advanced bandwidth over the corresponding reportage areas. Another headway in the clan of wireless communication is the forefront version of WiMAX, commonly known as WiMAX 2+ that can exert in amalgamation with LTE (Long Term Evolution) [2]. It is also from time to time termed as MAN (Metropolitan Area Network) interrelating the operators in a geographical section proposing resourceful interconnection to a Wide Area Network (WAN) [3].

Two groups of WiMAX have been volunteered to discourse the supplication of dissimilar types of access. IEEE802.16-2004 is the first version of WiMAX also designated as Fixed WiMAX intended for fixed applications from its base stations. It is centered upon the two standards specifically ETSI HiperMAN (High-Performance Radio Metropolitan Area Network) in addition to IEEE 802.16 agreeing global deployment. It encompasses the usage of 256 carriers Orthogonal Frequency Division Multiplexing (OFDM) and the profiles aimed at compliance testing. This version has its provision expanding to both line-of-sight and non-line-of-sight provinces providing a bit rate ranging from 32 Mbps to 134 Mbps. The second version or the modification i.e. IEEE 802.16e provisions mobile applications [4, 5]. This standard reinforced a lower bit rate of 15 Mbps while providing access in the non-line-of-sight domain. It enabled full nomadic besides mobile users organized with roaming and handoff [6].

In the existence of noise, WiMAX writhes from stark enactment deprivation. In the literature, plentiful approaches have been offered to correct channel noise either in the time domain otherwise in the frequency domain. In previous papers, numerous computational intelligence techniques have been used that does not deliver a better result, here the proposed technique is utilized to deliver an improved result in comparisons to already implemented intelligence technique. For such circumstances, the proposed method in this paper i.e. the firefly algorithm is appropriate wherever performance is very authoritative although the computational cost is less indispensable [7-10].

The result is amended by the application of the firefly algorithm in the MATLAB (R2013b) simulator. The numerous iterations will be evaluated and the finest possible result retains the objective of entire operation i.e. improvement of SNR and BER in CODED-OFDM based WiMAX System by the application of FA [10, 11].

Section II of the paper describes the literature survey and while section III describes problem statement and Section IV provides specifics about the system model. Section V describes the simulation results and Section VI describes the Conclusion.

3.4.6 Number of books and chapters in edited volumes published per teacher during the last five years (15)

3.4.6.1: Total number of books and chapters in edited volumes / books published, and papers in national/international conference-proceedings year wise during the last five year

Sr. No.	Name of the teacher	Title of the book/chapters published	Title of the paper	Title of the proceedings of the conference	Name of the conference	National / International	Year of publication	ISBN/ISSN number of the proceeding	Affiliating Institute at the time of publication	Name of the publisher
1	Priya Goyal, A.S Buttar		An efficient spectrum hole utilization for transmission in Cognitive Radio Networks	3rd International Conference on Signal Processing and Integrated Networks (SPIN)	3rd International Conference on Signal Processing and Integrated Networks (SPIN)	International	2016		IKGPTU Kapurthala	
2	Meenakshi,A. S. Buttar		Cyclostationary feature based detection using window method in SIMO cognitive radio system	International Conference on Computing, Communication and Automation (ICCCA)	International Conference on Computing, Communication and Automation (ICCCA)	International	2016		IKGPTU Kapurthala	
3	Mann, Palvinder Singh And Singh, Satvir And Rose, Anil Kumar		Computational intelligence based metaheuristic for energy-efficient routing in wireless sensor networks		IEEE World Conference on Computational Intelligence-2016	International	2016	978-1-5090-0623	S B S State Technical Campus, Ferozepur, Punjab, India	
4	Dalvir Kaur		Design of Higher Order Digital IIR Band Pass Filter using Hydrid Differential Evolution	International Conference on Engineering and Natural Sciences	International Conference on Engineering and Natural Sciences	International	2016		IKGPTU Kapurthala	
5	Ziayur Rahman, Avtar Singh Buttar		A survey on spectrum management techniques in cognitive radio networks	International Conference on Advancements in Engineering and Technology	International Conference on Advancements in Engineering and Technology	International	2017		IKGPTU Kapurthala	
6	Anjali Thakur, Avtar Singh Buttar		A survey on various clustering techniques in Wireless Sensor Networks	International Conference on Advancements in Engineering and Technology	International Conference on Advancements in Engineering and Technology	International	2017		IKGPTU Kapurthala	
7	Sumbul, Avtar Singh Buttar		A Survey on Routing Protocols in Wireless Sensor Networks	International Conference on Advancements in Engineering and Technology	International Conference on Advancements in Engineering and Technology	International	2017		IKGPTU Kapurthala	
8	Dalvir Kaur		Investigation of Microwave absorption in Co-W doped Ba-Sr Hexaferrite	International Conference on Intelligent Circuits and Systems	International Conference on Intelligent Circuits and Systems	International	2017		IKGPTU Kapurthala	
9	Rakesh Goyal,Rupinder Kaur,Gagandeep Aul	**Optical Code Division Multiple Access**		LAMBERT academic publishing		International	2017	978-3-330-03546-1	IKGPTU Kapurthala	
10	Rakesh Goyal,Shivika Rajpal,Monika Rani	**Radio Over Fiber Technology Based Integrated Optical Wireless Network**		LAMBERT academic publishing		International	2017	978-620-2-19721-2	IKGPTU Kapurthala	
11	Rajbir Kaur, A.S Buttar		Methods of Hybrid Cognitive Radio Network: A Survey	Second International Conference on Electronics, Communication and Aerospace Technology (ICECA),	Second International Conference on Electronics, Communication and Aerospace Technology (ICECA),	International	2018		IKGPTU Kapurthala	
12	Rajbir Kaur, A.S Buttar		Spectrum Sharing Schemes in Cognitive Radio Network: A Survey	Second International Conference on Electronics, Communication and Aerospace Technology (ICECA)	Second International Conference on Electronics, Communication and Aerospace Technology (ICECA)	International	2018		IKGPTU Kapurthala	
13	Jayant Anand, A.S Buttar		Fuzzy Logic Based Spectrum Handover Approach in Cognitive Radio Network: A Survey	2nd International Conference on Electronics, Communication and Aerospace Technology (ICECA),	2nd International Conference on Electronics, Communication and Aerospace Technology (ICECA),	International	2018		IKGPTU Kapurthala	
14	Jayant Anand, A.S Buttar		Handover Triggering Based Spectrum Handover Approach in Cognitive Radio Network: A Survey	2nd International Conference on Electronics, Communication and Aerospace Technology (ICECA), Coimbatore	2nd International Conference on Electronics, Communication and Aerospace Technology (ICECA), Coimbatore	International	2018		IKGPTU Kapurthala	
15	Ziyaur Rahman (Author), Avtar Singh Buttar (Author),Rakesh Goyal	**Spectrum Management in Cognitive Radio**		LAMBERT academic publishing		International	2018	978-613-9-86462-1	IKGPTU Kapurthala	
16	Mutneja, Vikram and Singh, Satvir		Size based perfomance analysis of haar-features for detection of facial images from low resolution surveillance videos		2017 International pubConference on Intelligent Computing, Instrumentation and Control Technologies	International	2018	978-1-5090-6106-8	IKGPTU Kapurthala	
17	Rakesh Kumar,Ankur Sharma	**Implementation of OLSR protocol using NS-2 Tool**		LAMBERT academic publishing		International	2018	978-613-9-87080-6	IKGPTU Kapurthala	

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18	Ridhima, A.S. Buttar		Fundamental Operations of Cognitive Radio: A Survey	IEEE International Conference on Electrical, Computer and Communication Technologies	IEEE International Conference on Electrical, Computer and Communication Technologies	International	2019		IKGPTU Kapurthala	
19	A.S.Buttar		Proficient Resource Allocation to Secondary User Using Nature Inspired Technique in Cognitive Radio Network	International Conference on Communication and Electronics Systems (ICCES)	International Conference on Communication and Electronics Systems (ICCES)	International	2019		IKGPTU Kapurthala	
20	Dalvir Kaur		A Review and Comparison of AODV, DSR and ZRP Routing Protocols on the basis of Qualitative Metrics	International Conference on Computing for Sustainable Global Development (INDIACom	International Conference on Computing for Sustainable Global Development (INDIACom	International	2019		IKGPTU Kapurthala	
21	Dalvir Kaur		Improving mean opinion score of VoIP in Wimax system using an efficient technique	Proceedings of Communication and Electronics Systems	International Conference on Communication and Electronics Systems	International	2019		SIVNS	SIVNS Trivindrum
22	A.S.Buttar		Design and Implementation of Solar Energy Harvesting with Double Booster Circuit in Wireless Sensor Networks	7th International Conference on Signal Processing and Integrated Networks (SPIN)	7th International Conference on Signal Processing and Integrated Networks (SPIN)	International	2020		IKGPTU Kapurthala	
23	A.S.Buttar		"Empowering Wireless Sensor Networks with RF Energy Harvesting	7th International Conference on Signal Processing and Integrated Networks (SPIN)	7th International Conference on Signal Processing and Integrated Networks (SPIN)	International	2020		IKGPTU Kapurthala	
24	Dalvir Kaur		Amalgama of Firefly Algorithm and WiMAX refining BER and SNR	Proceedings of Commnnication and Electronics Systems	International Conference on Communication and Electronics Systems	International	2020		PPG Institute of Technology	PPGIT Coimbatore

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