A Comprehensive Review On Energy Harvesting Techniques For Cognitive Radio Network

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Abstract—***Latest focus on green communications has created great interest in research into connectivity and networking for energy harvesting. Energy harvesting from natural sources may theoretically minimize dependency on grid or battery energy supply, adding several enticing environmental benefits and usage. However, unlike traditional reliable electricity, the erratic and random aspect of renewable energy renders transmission networks impossible to introduce. During the past few years, comprehensive investigation has been conducted over to resolve the Implicit complexity in several factors: energy sources and models, protocols for energy conservation and usage, monitoring and utilization of energy,Usage of energy storage in mutual networks, smart radio networks, wireless and multi-user networks, etc. However, as their number is increasing, adequate and regular reviews of advances must now be rendered in the sector. In addition, a growing array of proven energy harvesters are expanding into commercial markets from the laboratory. Energy harvesters must be combined in operation with power storage and/or end users such as wireless sensor networks and sensors. The harvester-storage and harvester-sensor integration systems must also be regularly checked. We study various hybrid spectrum access schemes and energy harvesting methods for cognitive radio signals.***

***Index Terms*—** Cognitive radio, Energy harvesting, Radio, wireless communication**.**

I. INTRODUCTION

Recently, the widespread usage of cellular networks has clashed with the scarcity of infrastructure to connect. The implementation of the idea of cognitive radio was exacerbated by spectral shortages associated with under-use of the licensed spectrum. The secondary use of a licensed spectrum band will increase spectrum use and offer a stable alternative to its loss. Secondary consumers may use the spectrum under the basis that the main users are promised a certain level of service. The range of radio frequency (RF) that allows wireless contact simpler is a tiny resource. Today we face a severe spectrum shortage issue with the abundance of wireless networks and users because virtually all spectrum have been allocated to different applications which, in turn, are inadequate to satisfy the growing number of users. A fruitful way to allow diverse connectivity to the spectrum is cognitive radio (CR). It is a smart wireless communication system that can sense and benefit from its environment and can alter its parameters accordingly[2]. It therefore not only enhances spectrum output, but also allows it to senses the radio atmosphere and adjust it accordingly. It may select optimum allocations of resources , for example transmitting capacity, bandwidth of the channel, modulation scheme, etc., to maximize total use of re-source sources by achieving higher energy consumption output, throughput, latency, likelihood of failure, etc. Unlicensed CR customers are referred to as secondary consumers (SUs) who dynamically use the authorized spectrum without risking unnecessary harm to licenced spectrum users known as primary users (PUs).There are two operating modes for the CR networks based on how they reach the approved band.

Energy is present in many forms in the form of sunlight rays etc so we can can easily get energy in different forms. The energy can get converted that processes are, to there height and in-equal. The amount of some energy get released or get wasted such as motors, electricity bulbs, automobiles etc. Radio station generate some of the energy which get transmitted to every stations or antennas some of megawatts of RF and this signal reach to every station. The device that capture some of the un-useful energy and transfer it into electrical energy is called energy harvesting. With important methods energy harvesting energy can be replaced by batteries together with some devices or applications. Large solar cells and wind mills have been another form of electricity for the power grid called energy harvesting. Therefore, less amount of embedded systems must depend on energy scavenging systems that capture some amount of energy from light, thermal, vibration and biological sources.

Therefore some use of energy harvesting methods with some of the great design above the horizon. The commonly known sources are heat, light energy, and vibration energy etc.

Solar energy can generate more energy, so many of them can be of low power devices in a particular nature

In this review paper the spectrum sharing is discussed and the parts of spectrum sharing is also discussed. The architecture of spectrum is given in details. The classification of cognitive radio is given. The details of energy harvesting and classification of energy harvesting is shared in this review paper. The conclusion, future scope , references Is also given.

II. SPECTRUM SENSING

In an opportunistic CR model, SUs identify and exploit the idle PU spectrum bands. Such an opportunistically available SU can clear the spectrum band as soon as the PU returns to the spectrum. SUs therefore ought to perform spectrum sensing at sufficient intervals to identify the existence or lack of PUs. The received signal y(n) at the SU shall be transmitted by :

$y(n) = x(n) + w(n)$……………………………………..(1)

Where $x(n)$ denotes the received PU signal and $w(n)$ is the additive white Gaussian noise. Spectrum sensing at the SU involves deciding between the following two hypotheses [29]

$H_0 : y(n) = w(n)$………………………………………….(2)

$H_1 : y(n) = x(n) + w(n)$……………………………….(3)

Where H0 and H1 correspond to the cases when PU signal is absent and present, respectively. There is a missed detection when the PU signal is present but is wrongly decided to be absent by the SU. When the SU decides the PU signal to be present while the PU is not transmitting, it is a false alarm. The efficiency of the spectrum sensing system shall be measured in assessing the probability of failure to detect p_{md} and the probability of false alarm p_f, which shall be specified as

$p_{md} = P\{H_0|H_1\}$…………………………………(4)

$p_f = P\{H_1|H_0\}$……………………………………..(5)

Where $P\{Hi|Hj\}$ denotes probability of deciding Hi when we actually have Hj. It is desirable to have low probabilities of miss detection and false alarm.

A. Energy detection

Energy detection is a basic form of sensing which needs no information of the PU signal to be detected [32, 33]. The sensing decision is made by comparing the signal energy measured over a sequence of *L* received samples against a suitable threshold *s*.

$$T_{ed} = \frac{1}{L} \sum_{n=} |y(n)|^2 \underset{H0}{\overset{H_1}{\gtrless}} s$$

In order to determine the appropriate detection threshold, complete knowledge of the noise variation is required. Hence, this algorithm is highly susceptible to noise uncertainty, which introduces a signal-to-noise ratio (SNR) wall [15]. For optimum performance, we need to find an optimal *L* and detection threshold, which presents a tradeoff between SU throughput and sensing reliability [16]. In another work on energy detection, the sensing performance degradation due to uncertainty in the PU signal was analyzed [17].

III. SPECTRUM SHARING

Cognitive radio (CR) provides dynamic spectrum access and provides a promising workaround for the inevitable issue of spectrum depletion. It detects the licensed spectrum and defines spectrum possibilities that secondary users (SUs) may use without disturbing the main consumer (PU) transmission. Therefore, it increases bandwidth performance by opportunistic access to the bandwidth. Power is another main resource. A lot of work has lately been focusing on using technologies for energy storage to achieve self-sustaining wireless networks. The addition of power for energy storage would further expand the power of CR systems. The random and intermittent design of the energy source, however, raises problems in the application of such autonomous CR systems. We find and resolve several important new research problems occurring in various forms of CR systems for energy harvesting. The wireless channel's broadcast character involves synchronization of transmitting attempts by cognitive radio users. Spectrum exchange can also provide all of the features of a MAC protocol. Spectrum sharing can be categorized on the basis of four classification criteria: design, spectrum sharing within a CR network, or between several coexistent CR networks.

A. Spectrum Sharing Architecture

Centralized spectrum sharing: a central body manages the spectrum distribution and access procedures. Measures of the dispersed nodes' spectrum allocation can also be redirected to the central agency and a spectrum allocation chart can be created. The central agency will lease bandwidth for a certain period of time from consumers in a restricted geographical region [1].

Distributed spectrum sharing: the allocation of spectrum is focused on the distribution of local policies by each secondary user [2]. Distributed systems are often used between various networks such that a base station is competing with its BS interferors in compliance with its users' QoS specifications. The distinction between centralized and distributed solutions indicates that distributed solutions strongly adopt centralized output solutions, but exchange messages between nodes cost them. [3].

1) Spectrum exchange between intranetwork and Internetwork—

- The second category is focused on whether spectrum sharing is within a CR (intranetwork spectrum exchange) network or between several co-existing CR (internetwork spectrum sharing) networks[3]
- Intranet spectrum sharing: These approaches concentrate on the distribution of spectrum between cognitive radio network organisations, as seen in Fig. Consequently, cognitive radio network users aim to reach the available bandwidth without allowing the main users to intervene.
- Online spectrum sharing: As seen in Fig., the intelligent radio design allows different devices to be implemented in overlapping locations and spectrum.

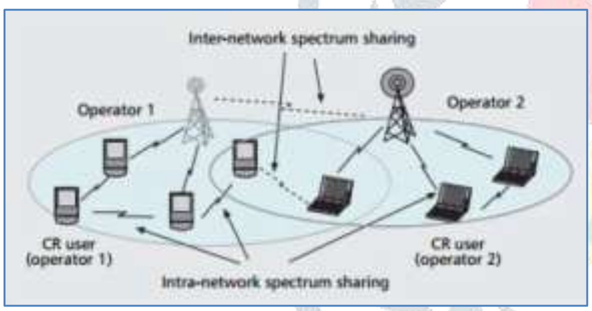


Figure 1: Channel structure of the multi-spectrum decision [3]

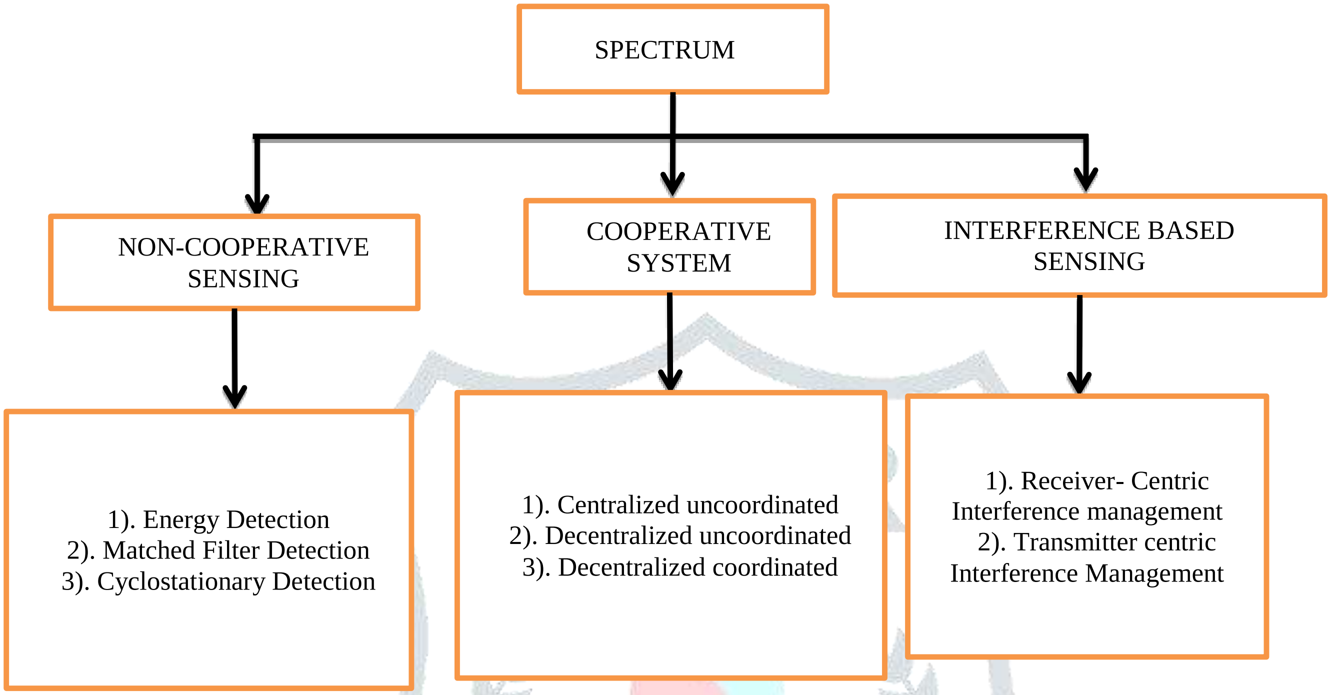
1) Spectrum Sharing Allocation Behaviour

Connection to spectrum can be cooperative or non-cooperative. Cooperative (collaborative) spectrum exchange uses interference calculations of each node such that one node's contact on other nodes is taken into consideration. Just one node is considered in non-cooperative spectrum sharing [8]. As interference is not considered in other CR nodes, non-cooperative solutions can contribute to a decreased spectrum usage. These solutions do not, however, involve regular exchanging of messages between neighbours as in cooperative solutions. Cooperative methods usually outperform non-cooperative methods and near the optimal usage of the spectrum [9].

2) Spectrum Sharing Access Technology

Spectrum share overlay: Secondary users enter the network from a part of the spectrum that the approved users have not occupied. This eliminates interference with the main customers. Underlay spectrum sharing: strategies of Distributed Spectrum (SS) such that primary consumers perceive CR node propagation to be noise. Underlay technology will provide more possibilities for access at the expense of a small rise in difficulty and intervention. In cognitive radio networks the introduction of effective and streamlined technologies for the exchange of spectrum has several research areas available, including the general control channel [10] and the complex radio range.

CLASSIFICATION OF SENSING TECHNIQUES:-



COGNITIVE RADIO NETWORK PARADIGMS:-

Cognitive radio technique depends on the fact that the primary user are not utilizing the spectrum bands so there is a need of the cognitive radio which checks the spectrum holes and makes use of these according to their access. In todays development CR technique is also known as future technology and it has great use in the 5G .

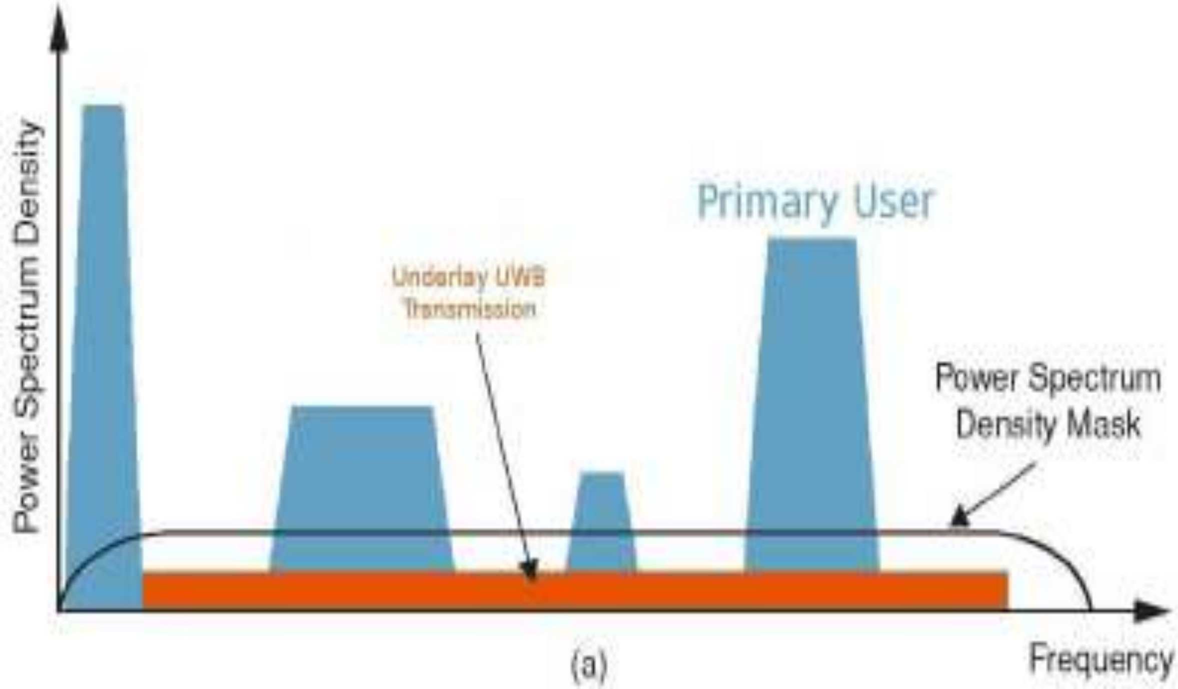
The cognitive radio network paradigm are as follows:-

A) . UNDERLAY PARADIGM:-

The underlay paradigm allows for simultaneous secondary and primary user transmission.

The primary user are the cognitive radio. To ensure the primary user protection, secondary user may not cross the certain level of noise or the level is limited.

The secondary user knows that how much the interference is imposed on the primary user



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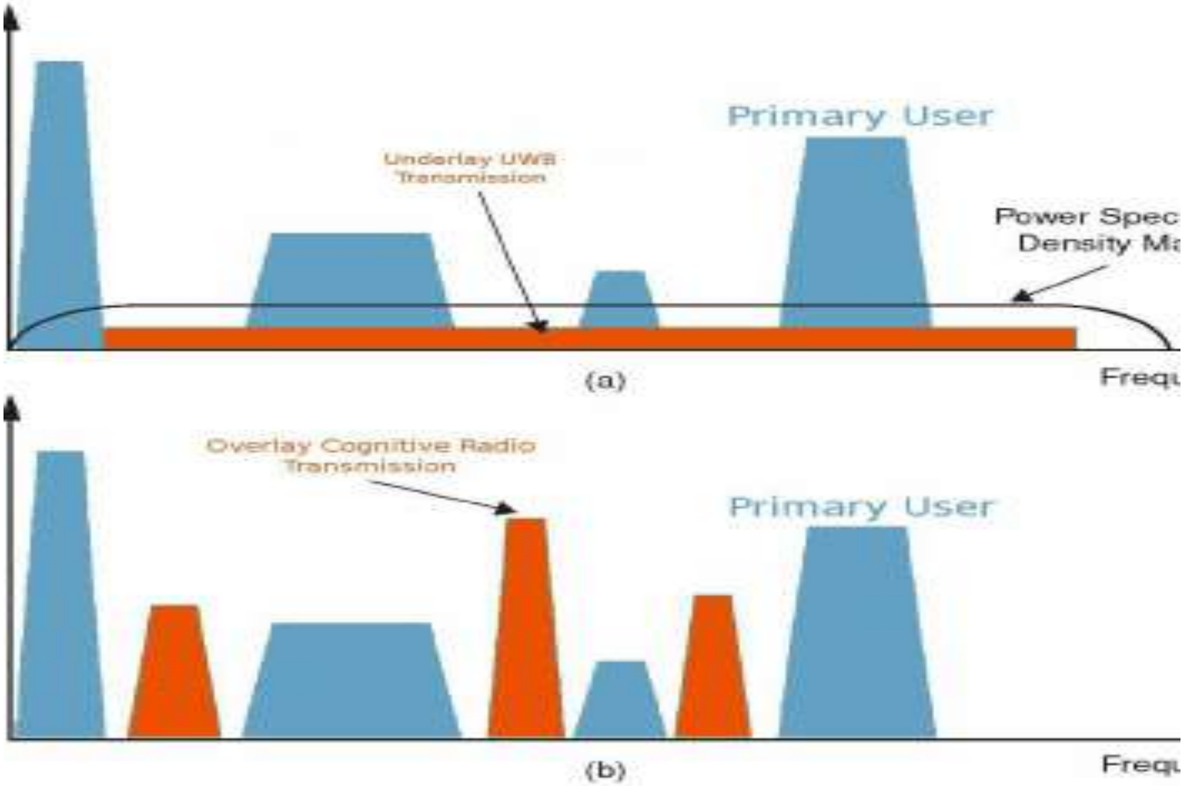
B) . OVERLAY PARADIGM:-

The overlay paradigm, similarly to underlay allows for co-existence between secondary and primary user in the same band.
Secondary user can transmit with maximum power.
Both can simultaneously transmit.
Secondary user uses some kind of information i.e, codebook in terms of certain code.



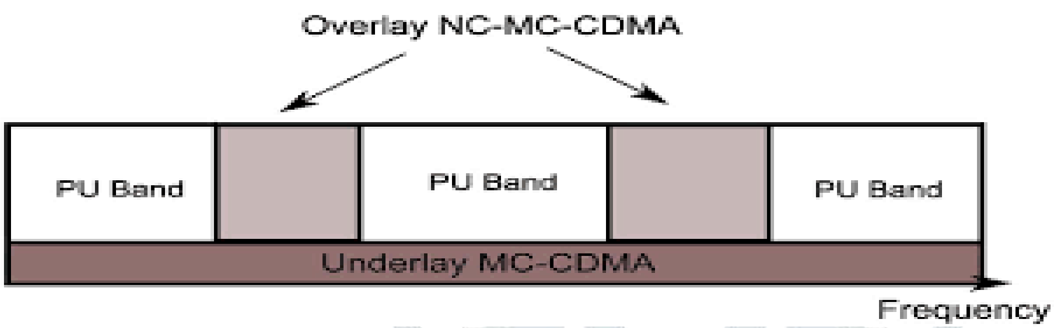
C) . INTERWEAVE PARADIGM:-

The interweave approach was originally sharing technique proposed for cognitive radio.
It does not allow simultaneous to transmit primary user and secondary user can transmit by utilizing the idle party of the user When the primary user is free to transmit.

Secondary user may access licensed frequency only if the primary user is not transmitting. No certain pattern of transmission is followed.

Secondary user can use sensing technique.

D). HYBRID PARADIGM:-



The hybrid paradigm is the combination of both underlay paradigm and overlay paradigm.

DIFFERENCE BETWEEN UNDERLAY, OVERLAY, HYBRID AND INTERWEAVE COGNITIVE RADIO TECHNIQUES:-

S.NO	UNDERLAY	OVERLAY	INTERWEAVE	HYBERID
1.	The primary user knows the channel strength of the secondary user.	Code-book side information. Cognitive radio user knows the channel gain . the user knows their information of the information of the code-books	Activity side information. The primary user knows the information of the spectral holes when the secondary user is not using these holes.	Has features of both interweave and underlay approaches.
2.	Secondary user can simultaneously transmit with the primary user without the interference or disturbing.	Cognitive user can transmit simultaneously with the primary and secondary user.	Primary user can transmit simultaneously with the primary user only in the false spectral hole	Can use the spectrum opportunity or simultaneously.
3.	Primary user transmit power is limited by the interference constraints.	Cognitive user can transmit at any power.	Both the users has limited transmit power in the range .	Overcome the limitations of both the approaches i.e,.interweave and underlay..

IV. Energy Efficient Cognitive RadioSystems

SUs are also battery operated in CR wireless networks. This contributes to an energy limitation in the cell. The access sensing techniques concentrate on low electricity usage to achieve optimum output with the available energy capital. For e.g, if the current channel accessible is of poor quality, the SU may decide not to use a high power to reach the channel at a low transmission rate. It will now stay idle to conserve resources for a better channel, which would contribute to delays and decreases in SU output in the next slot. Such a scenario was analyzed in [17], where an incentive was established in relation to the time and energy costs associated with the SU's remaining idle, sensing and transmitting, and the successfully generated transmitting throughput. A POMDP system has been used to achieve the optimum spectrum sensing length as well as to choose optimal policies to optimize the predicted compensation between idle and sensing modes. Sensing and access strategies with SU rate adaptation are required in different channel conditions for better performance [18]. Slowing down the SU transmission rate and saving transmission power on a deep fading channel could be preferable. The rate reduction thus contributes to disruptions and increased energy usage in potential slots for sensing and idling. A discrete MDP was formulated to reduce SU's overall total costs, including energy usage and the costs of delay, to complete the target traffic payload through a suitable rate allocation. It was solved with the value iteration algorithm as a stochastic shortest path problem. Excellent distributed spectrum sensing and access policies to optimize the SU's movement over a short time span prior to its battery depletions have been achieved [10]. For the energy-controlled SU, a sequential decision-making dilemma was devised which would specify whether to feel, what channel to feel and whether to enter. The problem was conceived as a stochastic series of decision-making problem for a defined sensing order, which was plugged in another parametric formula and DP was used to define the optimum approach. In [19], the authors mentioned two big energy minimization trade-offs: the sensor-transmission agreement and the wait-switch trade-off. The sensor slot length and the channel-switching likelihood were solved by a convex optimization problem which reduced the average consumed energy in spectrum sensing, mobility of the spectrum, and data transfer, while satisfying sensing reliability constraints, minimum throughput requirements and delays in SU transmission. In [20], a collaborative concept for energy-efficient CR systems was examined to concurrently achieve maximum sensing and transmitting durations. The PU was covered by restrictions on the likelihood of identification and the likelihood of reoccupation by the PU, which called disturbance between PU and SU during the SU transmission. A hybrid spectrum access system was suggested to eliminate overall energy usage thus fulfilling the need for efficiency and the latency maximum in cognitive ad hoc networks [9]. Stackleberg was formulated in an underlay CR framework to gain transmitting capacity and channels for the SU and the PU to optimize their energy efficiency. [21].

COGNITIVE RADIO NETWORK:-

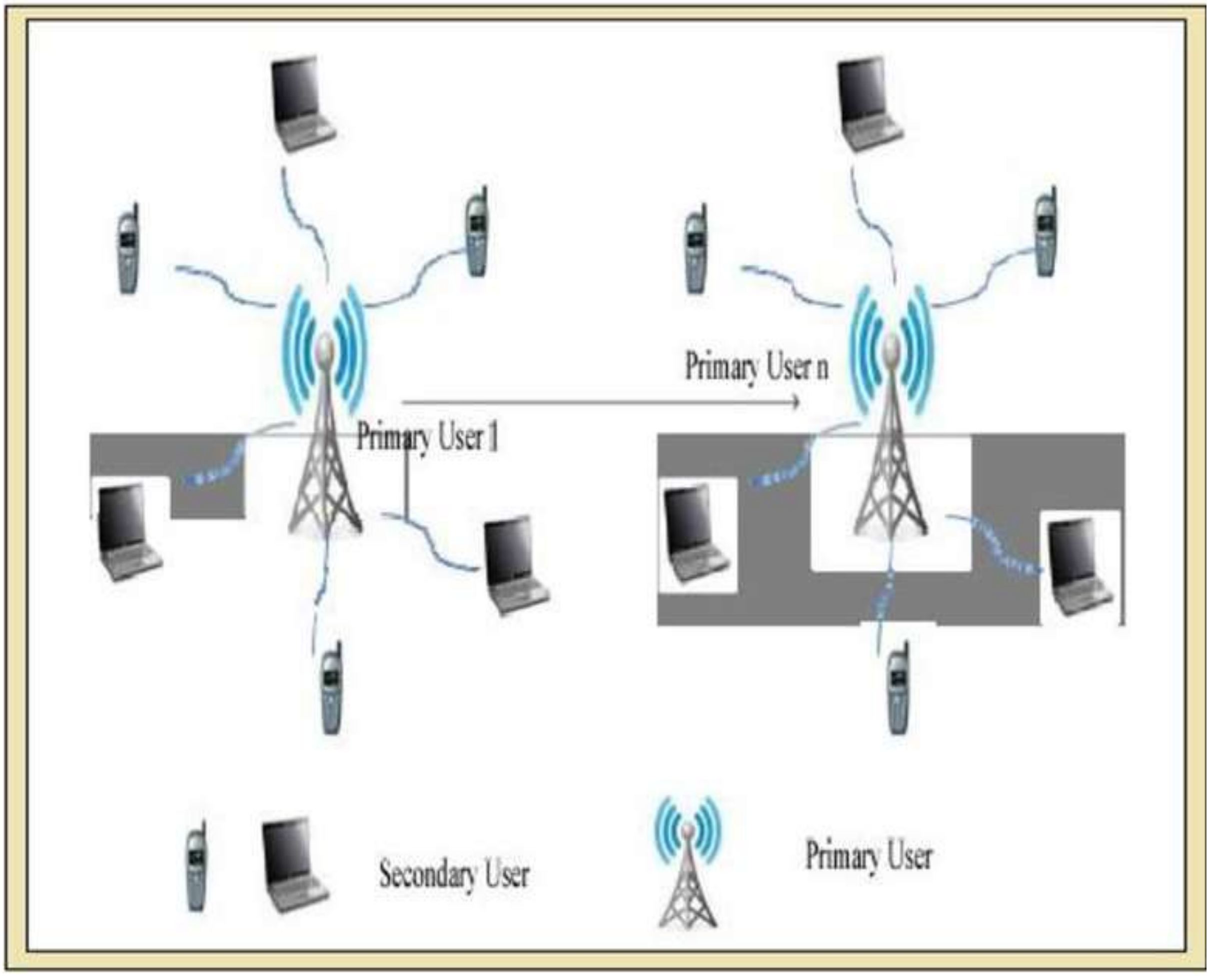


Fig: Concept of primary and secondary user

There are two types of users in the cognitive radio:-

* primary user
* secondary user

The primary user are having the specific bands and they use that allocated bands. If they are not using that bands it means that bands are getting wasted so in that place there comes a secondary user who use that bands in that time without interfering the primary user.

The secondary user are free to use that bands without disturbing the primary users. It does not cause any disturbance to the specified users

WHY COGNITIVE RADIO:-

Underutilization of licensed spectrum

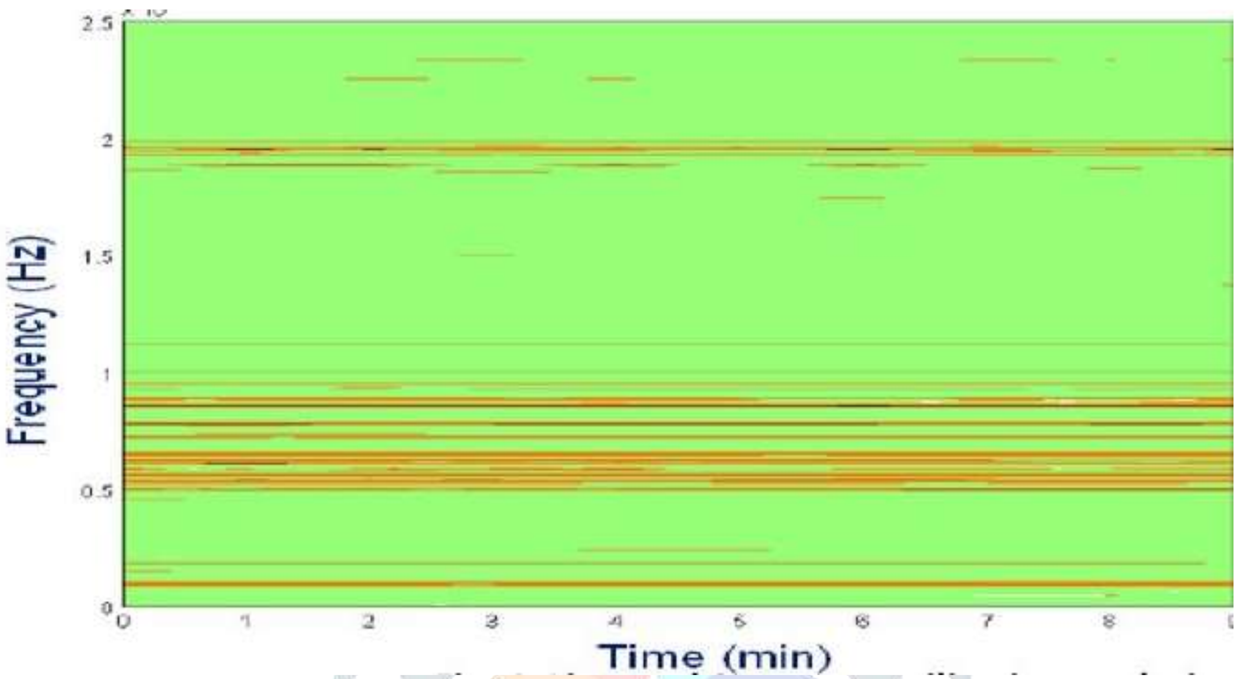


Figure 2: licensed spectrum utilization analysis

Cognitive radio is a form of wireless technology in which the sender can see where the allocated spectrum bands are free from the primary user and in that place the secondary user can easily use without interfering the primary user.

In this place the use of cognitive radio is used.

HOW COGNITIVE RADIO WORKS:-

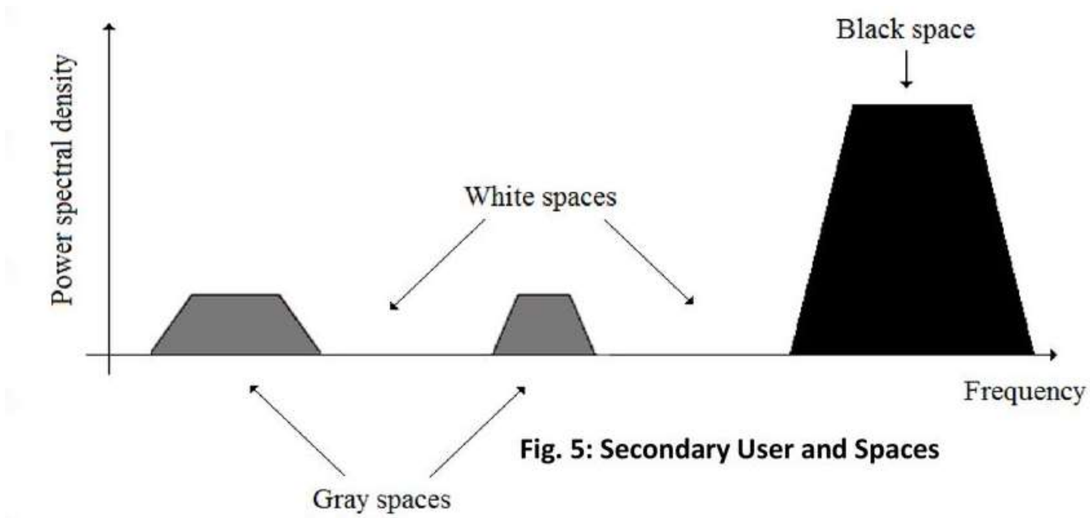


Figure 3: secondary User & spaces

- the main functions of the cognitive radio are as follows:-

POWER CONTROL:- power control is used mainly for spectrum sharing cognitive radio systems to maximize the capacity of secondary users with interference power constraints to protect the primary user.

SPECTRUM SENSING:- the spectrum sensing is the technique which senses the available spectrum and make them available for the secondary user. Detecting unsed spectrum and sharing it, without disturbing the primary users.

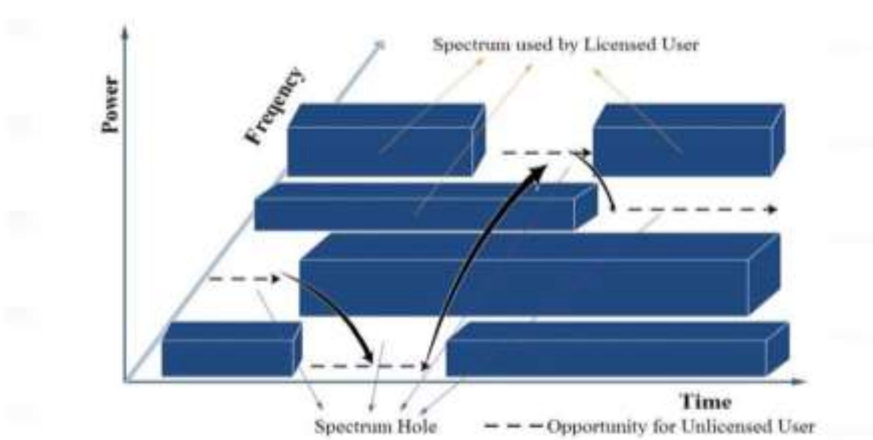
HOLE OR WHITE SPACE CONCEPT:-

Cognitive radio technique depends on the fact that the primary user are not utilizing the spectrum bands so there is a need of cognitive radio which checks the spectrum holes and make of these according to their access. In today's generation cognitive radio technique is also known as future technology because it has great use in the 5G technology.

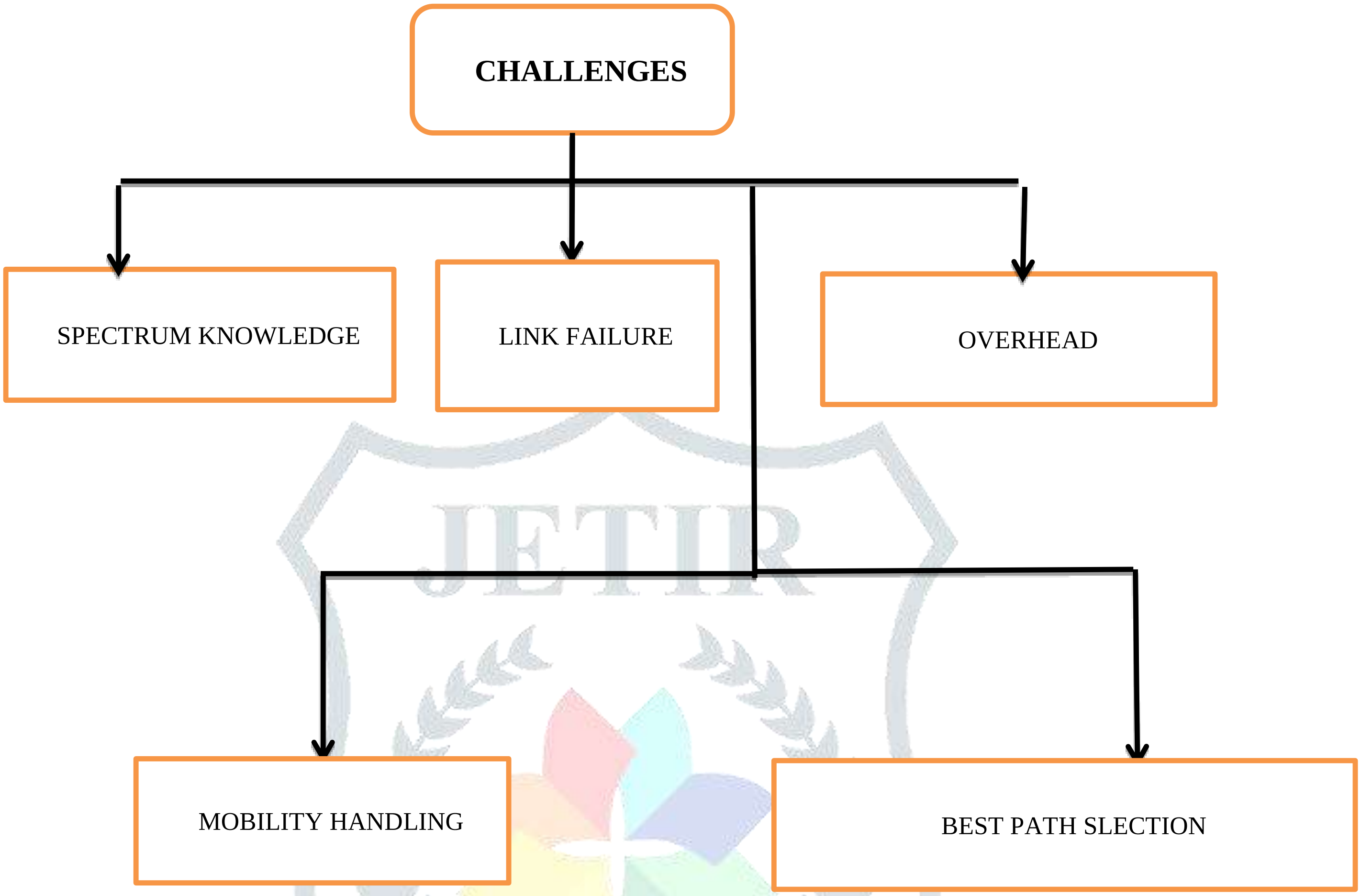
The graph of the spectrum or hole concept is based on the time and power. At the specific time the bands are fixed and on the other hand the bands are free from the primary user and are get wasted so this bands are used by secondary users without the interference or disturbing the secondary user. The bands which are free are denoted by spectrum holes or white space concept.

The hole concept is used when the bands are free. It shows that the respected time the allocated bands are free and the secondary user are free to use. Without the interference of the secondary user.

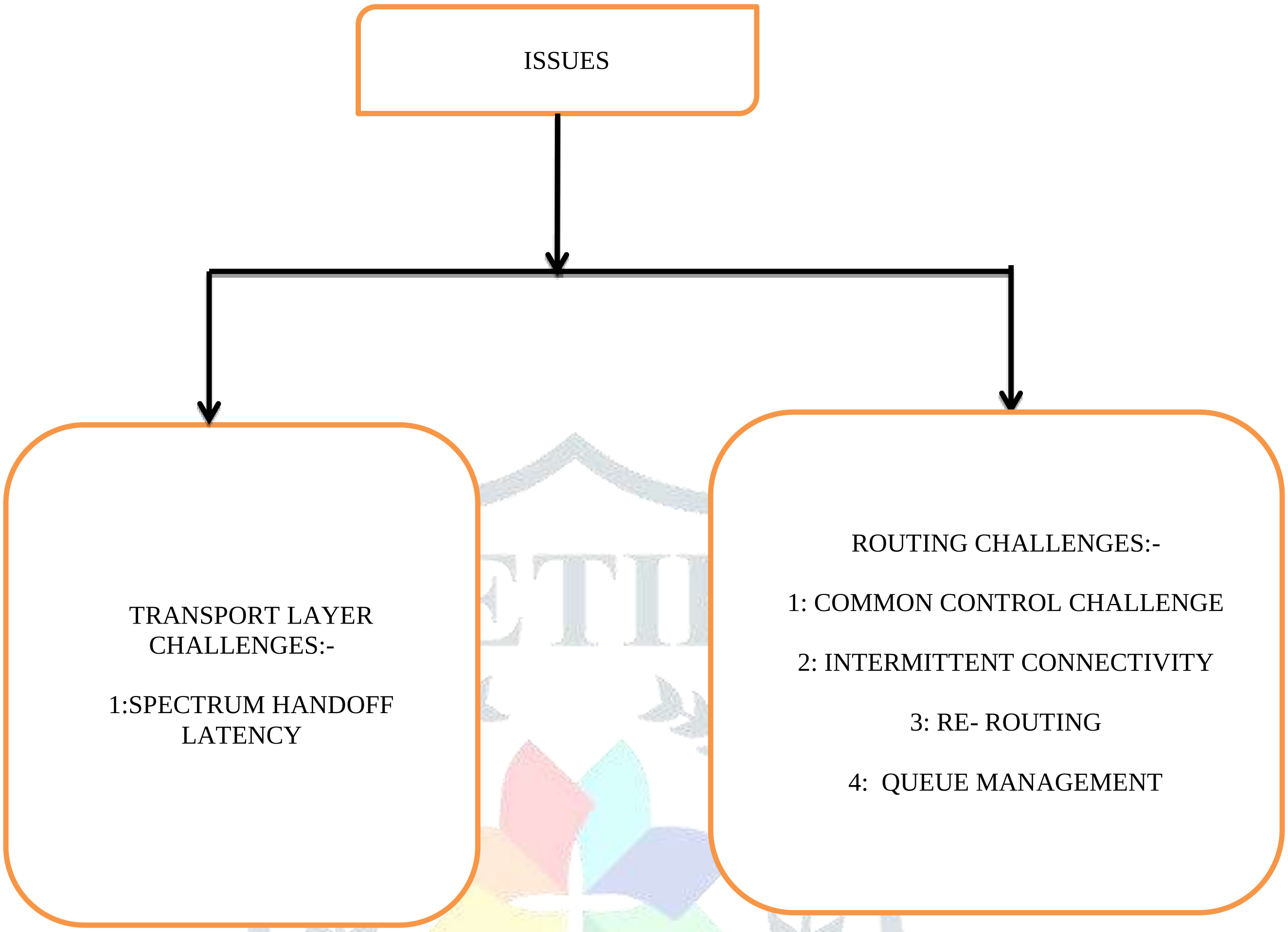
The holes represent the vacant spectrum and the secondary user can use them without disturbing the primary user.



COGNITIVE NETWORK CHALLENGES:-



SOME OTHER ISSUES:-



IMPLEMENTATION ISSUES:-

The issues faced in the cognitive radio are as follows:-

1. Read lines of the cognitive radio network backbone:-
   The cognitive radio is a revolutionary technology that helps to improve the efficiency of spectrum usage. This issues is related with the environment.

2. Defining point of interconnect and interface:-
   It is possible to describe the cognitive radio as a radio which is conscious of the atmosphere and the internal state. The cognitive radio search the spectrum bands which are not in usage and this bands is shown by the spectrum holes and this bands is used by the secondary user.

3. Definition of uniform service based priorities:-
   The primary user is served first, because the primary user has payed the services of the spectrum band and the bands are allocated to them. So the services are provided to them. The left over bands which are not used by the primary user are used by the secondary user

4. Default service and routing equipment:-
   The default route is based on the internet protocol that establishes a rule for the packet to travel. When no specific address of a next host is available.

5. Service authentication and authorization:-

Service authentication is the identity verification process so that every service provider get the services and gets verified. There are various types of authentication and in one of them is the user authentication which checks the identity of the user.

Authorization is giving the permission of the authorized user so that he can easily use or access the service.

SECURITY ISSUES:-

The security issues in details are as follows:-

1. Protection from various protocol attacks:-

Very little research has done in new threats to cognitive radio due to their intelligent behaviour . some work has been conducted in the dynamic spectrum access. Internet security is a branch of security which is not connected with internet, involves browser security and the world wide web.

2. Application attacks:-

The application attacks in cognitive radio are:-

Cognitive radio and policy attacks

Policy attacks are as:- policy of the radio is changed and is not allowed to get updated and provide the attacker to get access of the spectrum.

3. Unauthorized user introduction:-

Unauthorized access is when someone gain access to the spectrum or the services by using other id.

This means the user of a computer system that does not have authorization to use that service.

4. Unauthorized access to system data:-

Unauthorized access refers to the individual gaming access to the data or application without asking permission.

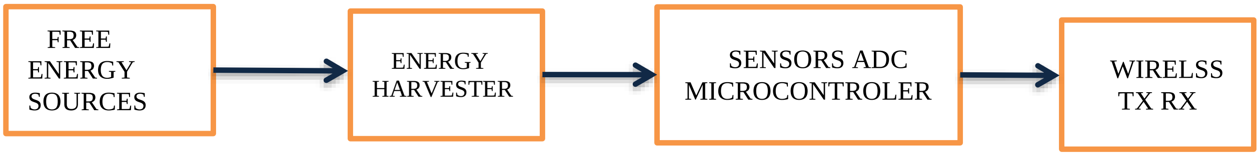
5. Service Denial(DOS) and Distributed Attack Denial of Service (DDOS):-]

Service denial is a cyber attack in which the attacker makes the computer or network resource inaccessible to its users by momentarily interfering with the user-connected host services.

Distributed denial of service(DDOS):- is target of the website and online services.

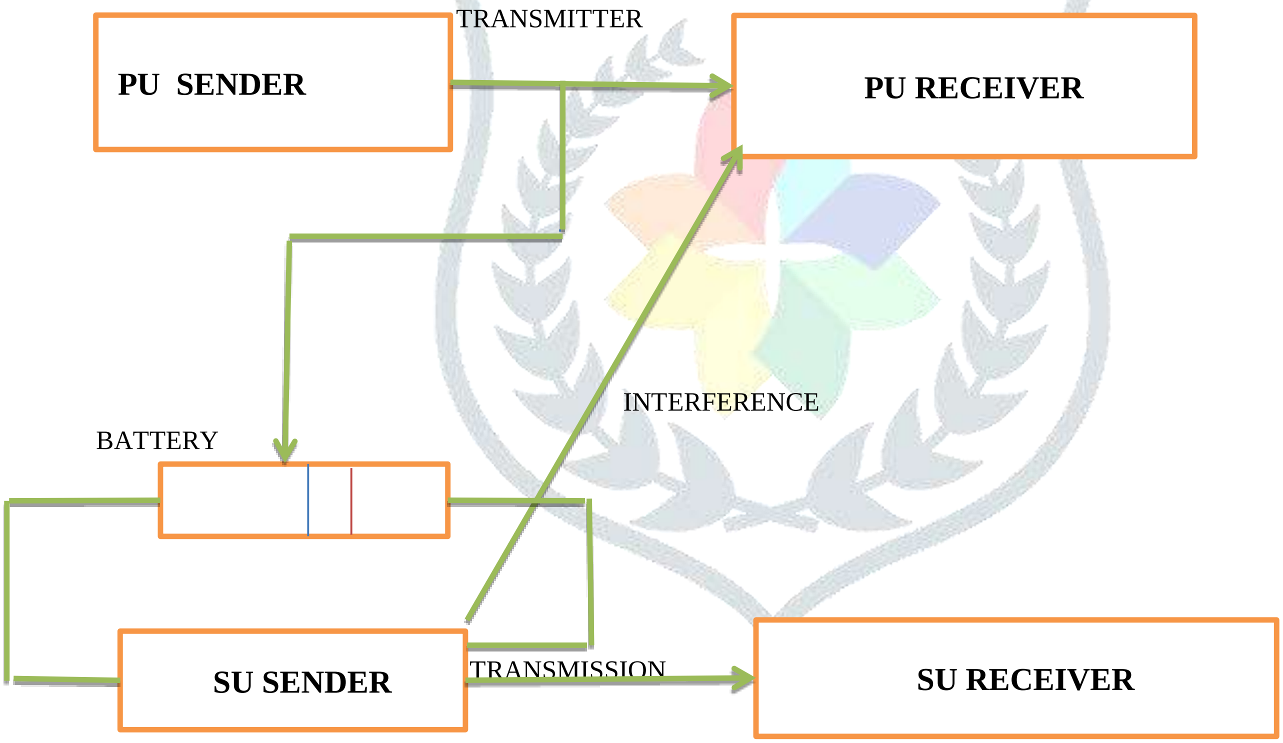
V. ENERGY HARVESTING

The additional carbon emissions related to the increased need for electricity have created significant environmental concern. Renewable electricity is increasingly deemed a renewable energy option in order to counter rising energy prices and reduce carbon footprint. Wireless networking networks fitted with energy collection (EH) have drawn increasing interest in particular lately. Energy harvesting is a method that gathers energy for potential delivery from the atmosphere, transforms it and retains it. Contrary to traditional fixed power supplies (from the grid or from the battery), EH technology scavenges environmental electricity and generates constant power supplies. For energy harvesting, there are several different environmental energy sources, including natural and other environmental energy sources. Natural factors such as solar, wind and water provide an infinite quantity of environmental resources. In addition to natural sources, the process for scavenging environmental energy sources, such as vibrational, electromagnetic, thermal and biological systems[4-6] Energy harvesting provides us with several compelling advantages and innovative features for potential wireless communication that traditional driven battery or grid communications cannot deliver, including auto-sustainable ability Therefore, we should anticipate energy collection in wireless network applications , ranging from remote control of the climate, consumer products, to biomedical implants, to achieve ever greater prominence. IDTechEx estimated the energy harvesting market to $0.7 billion in 2012, and projected to quadruple market growth by 2024. [7]



Energy harvesting block diagram

Energy limits and transmitting capacity restrictions have recently acquired significant attention. More precisely, energy selection was an alternative to the stable energy source in the cognitive radio method. Several papers addressed energy collection as a hard-wired or battery replacement option for rechargeable wireless devices [11-13]. In [14], the cognitive radio network with the multi-packet reception channel paradigm was applied to non-cooperative energy processing. The optimum stable device throughput field is analyzed in this work using a stochastic prevailing methodology to maximize the usage of a shared cognitive channel. A cognitive protocol on the general multi-packet channel reception model is implemented, where even secondary transmission is efficient. As a consequence, secondary users will maximize their performance not only by using the primary user's idle times but also by accessing the channel randomly with a certain likelihood. In addition, two separate models were studied by the scientists. The second transmitter absorbs electricity for transmitting first and the second is fitted with batteries that can be recharged for main and secondary consumers. The overall secure throughput area is then analyzed for the two versions. The [14] device model is shown in Fig.



In [15], network-level collaboration is modelled in a wireless three-node network of nodes for energy harvesting. Energy harvest is shown as a buffer that stores extracted energy to serve explosive data traffic lines. Because energy selection is modelled as a queue in each node, authors have examined the relationship between data and energy queues when queue arrivals are known. The maximum permissible source production and the necessary transmission power for a non-cooperative and cooperative (DF) device are obtained. Cooperation has shown to be more robust than specifically related to situations with low energy prices in.

VI. SPECTRUM-ENERGY COOPERATION

A new research line has been implemented into CR systems by incorporating RF energy-harvesting capacity to evaluate and maximize future benefits in collaboration between SU's and PU's. An RF power harvest SU, worked on a save-then-transmission protocol, which either functions as a relay to support the PU complete its transmission sooner or wait for the PU to complete its transmission, was considered [22]. The SU suggested a cooperative approach to determine whether or not to work with the PU; the best period for energy collection and power for cooperative transmission was identified. A multi antenna SU transmitter has been designed for optimum beam shaping in a cooperative device, in which the PU allows its bandwidth to be utilized opportunistically and has transmitted energy through the SU utilizing power or time splitting techniques. In a similar cooperative device with a single antenna SU, the simultaneous transmitting of PU and SU data is accomplished with the use of Alamouti transmitter coding and recipient mutual encoding and interference encoding [24]. An RF multi-antennas SU may either transmit the PU data when the receiver has a PU interruption or transmit them using the power separating technique while the PU stays quiet and has financial benefits [25]. [25]. In order to select between non-cooperative and cooperation modes and acceptable optimum parameters, i.e. time ratio, price, time and power ratio respectively, a Stackelberg game is devised. Stochastic geometry has been used as the basis for a co-operative device where SUs with a special power supply exchanged energy and transmitted the data of a PU running on the AP transmitted RF energy in exchange for part of the PU spectrum[26]. To optimize SU efficiency while meeting PU efficiency restrictions, optimum bandwidth allocated to the SU and time allocation for PU energy transmission were calculated. The PU receiver used time splitting strategies in another work on PU's energy deficiency method in order to obtain energy from the SU transmitter which was allowed access to spectrum for a fraction of the time [27]. During optimum precoding to optimize the SU transmission and increase energy collection in PU, numerous antennas were used both on the SU transmitter and the PU receiver

.

TYPES OF ENERGY SOURCES:-

S.NO	ENERGYSOURCES	TYPES	CHARACTERISTICS	APPLICATIONS
1	Dedicated RF	Electromagnetic radiation	Partially controllable, Partially predictable.	Wireless sensors, portable devices, power station.
2	Ambient RF	Electromagnetic radiation	Uncontrollable, unpredictable	wireless sensors, RFID
3	EM induction	Electromagnetic radiation	Controllable predictable	Portable devices
4	Knee bending	motion/vibration	Controllable, prediction	Portable wearable devices
5	Blood vessel	motion/vibration	Controllable, prediction	Human body, wearable devices
6	Car engine	Motion/vibration	Controllable, prediction	Vehicle, wireless sensors
7	Wind	Motion/vibration	Uncontrollable, unpredictable	Outdoors, wireless sensors, cellular base stations
8	Thermal	Thermoelectric	Uncontrollable, unpredictable	Human body, wearable, consumer devices
9	Illumination	Solar/light	Partially controllable, predication	Indoor, wireless sensors

10	Solar	solar/light	Uncontrollable, partially predictable.	Outdoor, wireless sensors, cellular base stations.

VII. TYPES OF ENERGY HARVESTING SOURCES

Solar/Light Energy Sources:-

One of the most common sources of environmental energy is clear sunlight / light, which is well researched and used in a broad range of applications [29]–[33]. The light energy is turned by photovoltaic cells into electricity. Solar power is an obvious source of electricity for self-sustaining systems throughout the day, for outdoor conditions. While the sun is theoretically limitless in energy, the energy available to an appliance can differ significantly even in a short period of time and several advanced influences, including daytime, seasonal weather trends, environmental conditions, characteristics of photovoltaic cells u, affect the energy extracted amounts. The sum of solar energy is usually in the range of 100 mW / cm2 during the day, but the drawback is that it falls at night. In addition, in certain stationary situations solar radiation is complex, uncontrollable and only partly predictable but usually unpredictable.

Thermoelectric Energy Sources:-

The thermoelectric effect can be used for energy selection [32], [33]. Specifically, as the junctions are kept at varying temperatures, a circuit voltage can be stimulated by two conductors of different materials. This temperature differential may potentially come from human bodies or machines. The power density of thermoelectric sources is calculated mostly by the thermoelectric properties and the substrate temperature differential, and is comparatively low between 10 µW / cm2 and 1 mW / cm2. Popularity is increasing in wearable technology, including wellness tracking, smart phones, exercise bands and sneakers. Thermoelectric sensors, such as clothes connected to the human body, are capable of producing electricity by detecting the change in temperature between body and climate. Thermo-electric power generation systems have the benefits of long life and low maintenance durability, but the energy conversion performance is limited. The collected power level is around 60 µW / cm2 at a temperature gradient of 5 µC. [28].

Mechanical Motion/Vibration Energy Sources:-

The production of energy from mechanical motion and vibration through transduction methods, including electrostatics, piezoelectric and electromagnetic, may also generate electric power [29]–[33]. Mechanical motion or vibration may affect the gap and tensile difference between 2 condenser electrodes in the electrostatic system and produce the current in a circuit. Piezoelectric strength is achieved using piezoelectric materials; in the electro-magnetic system, the relative movement between a magnet and a metal spindle will stimulate an AC current in the spindle called Faraday's Rule of Induction. Motion and movements may usually come from spontaneous, uncontrollable natural effects such as wind and liquid flow [29], [33] or human acts which are partly controllable, such as blood pressure, heart pounding and heel striking [14]. Different energy sources of movement and vibration contribute to different power densities which may encompass a large spectrum of values. It should be remembered that when the sun's strength is too poor to generate adequate electricity, wind power is a reasonable option for solar power, since it always complements one another in good time. During the day, a region of less daylight appears to be windier if the weather is cloudier. Moreover, solar energy in many places is strong in summer, while wind energy in winter is high. A wind turbine will produce about 100 mW of power at wind speeds between 2 m / s and 9 m / s. [36], [37].

Electromagnetic Radiation Energy Sources: -

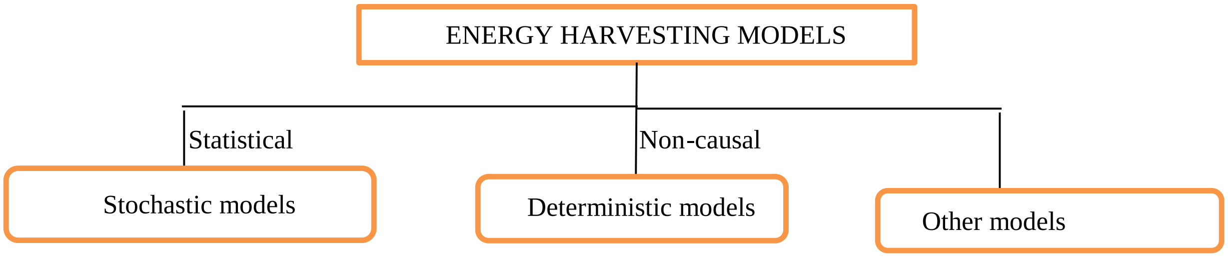
EM radiation is gradually being harvested owing to the transmitted nature of wireless communications [29]–[33], [38],[39]. Electromagnetic energy sources may be classified into two groups, based on short- or long-term applications: close-field and far-field. EM induction and magnetic resonance approaches are commonly used in near-field systems in order to produce electrical power and to recharge equipment wireless within wave lengths. Such approaches therefore concern predictable and controllable dedicated energy sources and the performance of the energy transmission in near-field applications exceeds 80 percent [40].

EM radiation, which occurs in the form of radiofrequency (RF)/microwave signals, can be obtained by antennas and then converted to power utilizing rectifier circuits in distance applications up to a couple of kilometers[41],[42]. Ambient EM emission from the atmosphere or beamforming signals from a known transmitter may be RF / microwave sources [44], [43]. The origins of atmospheric radiation accessible can include WiFi connection points, TV transmitting stations, AM / FM radio transmitters or cellular base stations. While the ambient RF energy in urban areas is readily accessible and satisfactory, it becomes few in suburbs. The sum of energy collected is uncontrollable and may be as poor as 40 dBm [40]. On the other side, dedicated RF energy sources such as cell power towers will provide QoS on-demand energy. While power density at the receiving antennas depends on the power of the available sources and the signal propagation distance, such energy may also be regulated and projected if the energy collection receiver intended is static. In comparison, the extracted energy will be spontaneous if the recipient is in motion. In view of the power usage and size of common mobile devices (there are different antenna openings, a power generator with tens of watts will transmit power sensors, smartphones and laptops to a distance of less than 15 m. [45].

Advantages and Disadvantages of various energy harvesting methods:-

S.NO	MECHANISM	ADVANTAGES	DISADVANTAGES	APPLICATIONS
1	Piezoelectric	No voltage source required, Higher output voltage, Exploitation of waste mechanical energy	Used in dynamic measurements, Temperature senstivity	To run electrical applications(i.e., micro-devices), AC from piezoelectric energy harvesting
2	Wind Energy	Wind energy is the use of wind to provide mechanical energy through wind turbines. The wind energy is used where the wind blows if there is no wind then the wind turbines will not move and it is of no use.	Wind energy harvesting can be done only in small scale area.	Wind energy has many applications such as it can be used in wind pumps, wind battery charges etc.
3	Mechanical vibrations	The significant advantages of harvesting vibration energy from any direction by means of a sandwiched piezoelectric path structure. High efficiency output power.	Many bridges fall because of the vibration, Unwanted vibrations due to noise, The vibration causes rapid wear of machine parts.	Ultrasound is used to detect cracks in the aircrafts etc, Mechanical clocks are used to measure time
4	Thermal	It is also called as heat energy and this form of energy is present everywhere and is produced when the temperature rise.	Low efficiency, Maintenance is high, Large source of water is required	For powering WSN
5	Ambient RF energy	This energy contains many different energy such as thermal, piezoelectric etc, It is provided by RF broadcasting stations.	Not safe for humans when RF energy is high	Long range of areas

CLASSIFICATION OF ENERGY HARVESTING:-

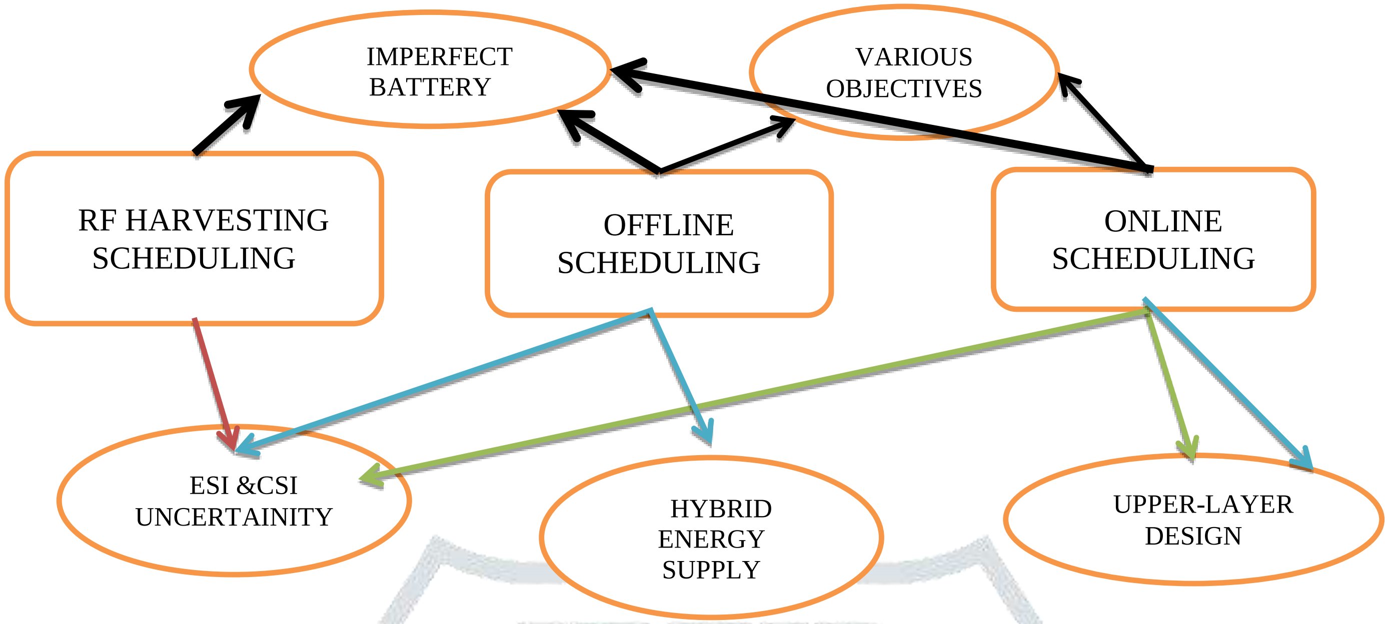


SNO	HARVESTING MODELS	ADVANTAGES	DISADVANTAGES	APPLICATIONS
1	Deterministic models	serve as performance lower bounds	need for non-causal ESI, prediction	Slowly variant sources, e.g, solar
2	Hybrid models	Modelling for multiple sources & storage, better performance	Need for training, very complicated	Hybrid sources, E.g,solar/wind
3	Stochastic models	Modelling for ambient RF energy	Inapplicable to dedicated RF energy sources	Wireless power recharging
4	Friis free space propagation models	Modelling for dedicated RF energy	Inapplicable to ambient RF energy sources	Wireless power recharging
5	Multi state Markov chain stochastic models	No need for non-causal ESI, modelling for dynamics with multiple states	Need for training, more complicated	Time correlated sources, e.g, human motion
6	Simple time-correlated stochastic models	No need for non-causal ESI, better modelling for dynamics	Need for training, complicated	Time correlates sources,e.g solar
7	Time-uncorrelated stochastic models	No need for non-causal ESI, simple modelling	Need for training, only for simple random sources	Time uncorrelatedsources, e.g, wind

VIII. ENERGY SCHEDULING AND OPTIMIZATION

Harvested energy that rests on the characteristic of energy sources and the procedure used for the processing of energy and the utilization of energy is defined by the quality of use of the usable harvested energy. Unlike battery-driven systems, energy storage in energy harvest systems must harmonize energy use and the battery charging speeds, since environmental energy will arrive dynamically and drastically. Therefore excessively ambitious or restrictive usage of the extracted energy will either run out of electricity into a battery with a limited capacity (called energy outage) or refuse to allow use of surplus energy (known as energy overflow).

An example of the energy programming and related architecture problems is seen in Fig. This segment lays forth the priorities for energy harvest communications in current works for the first time. Secondly, we are focused on developing climate planning policies for point-to - point interactions leveraging natural forms of environmental climate. Present study approaches to this energy scheduling design are twofold: offline and online, based on whether channel state information (CSI) and ESI information is accessible at the beginning of transmission either non-causally or causally. Here the phrases "offline" or "online" mean that the energy is intended for offline or online energy arrival awareness and canal gain.



IX. DIFFERENT ISSUES IN ENERGYHARVESTING TECHNIQUES

An inherent challenge that degrades device efficiency is the imperfection of the battery storage. The instability in ESI and CSI contributes to complexity in the preparation of the energy obtained. In the literature, many top-level concerns were discussed to boost the network efficiency by taking into account the different energy harvest capabilities across nodes. Since the combination of the power harvester and the power grid will theoretically increase the viability of infrastructure for energy production, the key problem is how the energy usage of the grid is reduced and the device operates simultaneously. , the transmission power is the only source of energy consumption; however, in certain situations other energy sources which prevail over power radiation in the transmitter. For starters, the transmission potential of the circuit could be higher than that of short distance communications. These feature concerns involve energy loss and the inefficiency of charge / discharging of imperfect batteries. The super-capacitor storage space is reduced when the battery capacity is limitless. The transmitter ages the internal dynamics of the storage device in comparison to previous works. The obtained energy allocation approach generalizes the water filling algorithm. in [16].

X. CONCLUSION

Nowadays, wireless connectivity demand for electricity tends to grow owing to huge amount of data networks. Techniques of energy harvesting has dedicated as a groundbreaking renewable communications solution. In addition to being environmentally sustainable, energy capacity has been established to promote the realization of genuinely unthered smartphone and omnibus research into communication systems. The detailed survey will serve as a reference for further construction of more practical networks of energy harvesting

FUTURE SCOPE:-

Cognitive radio IOT based application works , physicl layer securing in CRN , deep learning ets are the future rsearch topics of cognitive radio Network.

Energy harvesting technology attracts life and improves social resilience as a "enabling technology" that extends the use and possibilities of IOT use.

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