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Literature Survey on Cognitive Radio and its Functionalities

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***Abstract* — With recent advancement in wireless technology, it is not hard to imagine that future technologies will face spectral clouding and will be a major concern. Cognitive Radio is an emerging technology that offers optimal use of spectrum. It is regarded as the best technology for reliable communication and data application in wireless networks. In this paper, Cognitive Radio with its architecture, functionalities i.e. Spectrum Sensing, mobility, Decision and Sharing are introduced first followed by its applications.**

Keywords— Cognitive Radio(CR), CR Network Architecture, Primary User (PU), Secondary User (SU), Spectrum Sensing, Mobility, Decision, and Sharing.

I. INTRODUCTION

Bandwidth is limited and there is an exponential rising demand of optimal wireless spectrum utilization. To operate in a specific frequency band licenses are required. In every Country, Radio Spectrum usage are governed by the Government agencies [1]. For instance, the government agencies like FCC (Federal Communications Commission) [2] assigns spectrum to primary users (PUs) or licensed holders. The idea of this concept was introduced by J. Mitola and G. Maguire in 1999[1]. In CR Technology, primary users (PUs) have high priority to exploit spectrum whereas the secondary users (SUs) have low priority. Secondary user can use the spectrum without causing any disturbance to the primary users. In simpler words, "A CR is a radio that can adapt its parameter (transmitting frequency, modulation technique, transmission power, transmission rate etc) based on changing environment using different algorithms". Cognitive Radio mainly has two important functions: i. Reliable Communication whenever and wherever needed ii. Utilization of the radio spectrum in an optimal way [1]. A major part of the licensed radio spectrum is unoccupied and unused (i.e. underutilized) as shown in Fig.1. It means that the entire spectrum is not used by the licensed user all the time [10].So there are always some spectrum opportunities. To utilize the spectrum in an optimal way and to get desired quality of service, a CR technology is used. Thus, Secondary Users, can use the unused Licensed Spectrum temporarily.When PU are absent then by allowing SU to use a licensed band, efficient utilization of spectrum can be achieved. This demands of spectrum hole detection as shown in Fig.2.

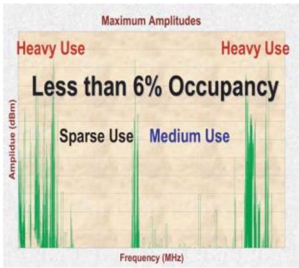

Fig. 1. Spectrum Usage

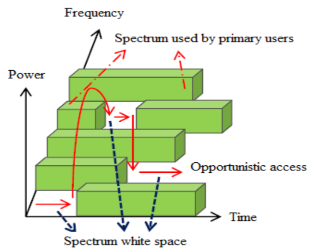

Fig. 2. Spectrum hole

II. COGNITIVE RADIO NETWORKS

The two main characteristics of CR is given below:

A. *Cognitive Capability:*

The radio here senses its environment surrounding so as to find the unoccupied radio spectrum at a specific location in specified time. Then identified portions are selected for effective communication without causing any disturbances to the other respective users [1]. The Cognition cycle is a state cycle where radio senses its current status and reacts to its operating environment. Three important parts of the Cognition Cycle are: Spectrum Sensing, decision and Analysis as shown in Fig. 3.

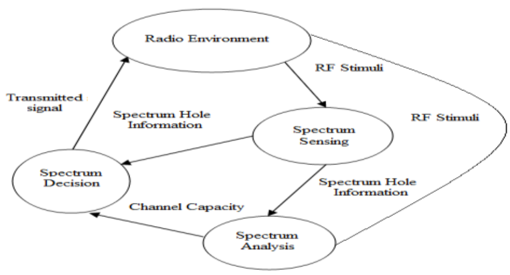

Fig. 3. Cognition Cycle

1) Spectrum Sensing: It determines the portions in the spectrum which are available for communication by detecting the presence of licensed users and spectrum hole. It enables the SUs to use it without causing interference to the PUs.

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2) *Spectrum Analysis*: Through spectrum sensing it determines the spectrum hole.
3) *Spectrum Decision*: It predicts spectrum holes availability for SUs and then the required spectrum band is chosen for the signal transmission.

B. Reconfiguration

Here the Radio Spectrum changes its parameters according to surrounding and can be changed without any modification of the hardware.

III. COGNITIVE RADIO NETWORK ARCHITECTURE

As the CR Technology has emerged, SUs who are un authorized in the spectrum utilization can temporarily use the unoccupieded licensed bands which are owned by the primar y users. Thus in Cognitive Radio Network (CRN) architecture, the components included primary and secondary networks, as shown in Fig. 4. A secondary network consists of SUs with or without a secondary base station. The licensed spectrum can only be accessed by SUs when it is not used by a licensed user. When several spectrum bands are shared by secondary networks, then a central network entity called Spec -trum broker [2] coordinates its spectrum usage. The spectrum broker collects information from every secondary network and helps for efficient spectrum sharing. Whereas in case of primary network consists of primary users with one or more primary base stations.

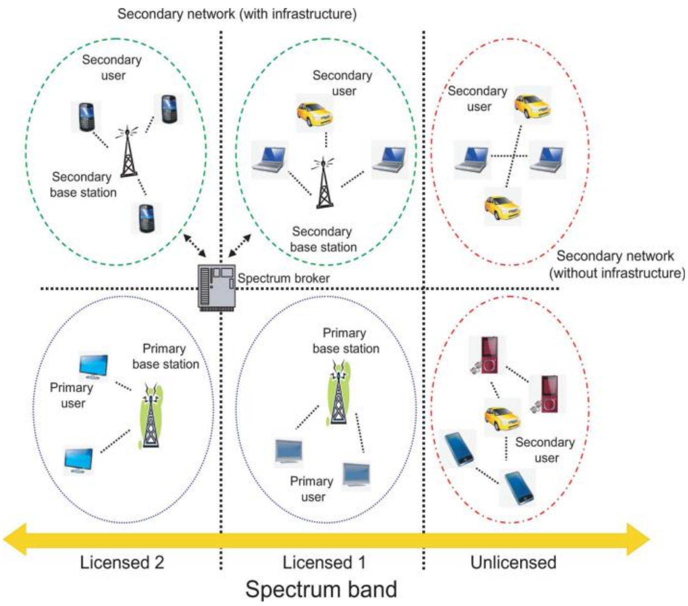

Fig. 4. CRN Architecture

IV. MAIN FUNCTIONS OF COGNITIVE RADIO

There are four main functions of CR. They are as given below:

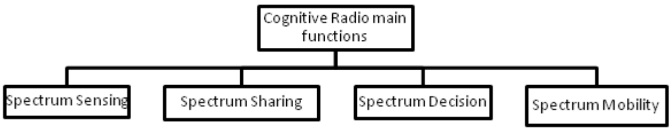

Fig. 5. Functions of CR

A. Spectrum Sensing:

It is the most important part in CR [4], as it recognizes the availability of primary users and unused frequency bands [3]. It comes under physical layer of network topology. The classification of the spectrum sensing is broadly categories as architecture based , detection technique based, band width based and interference based spectrum sensing.

1) *Architecture based spectrum sensing* : It is of two types
(I) *Cooperative spectrum sensing*: Here multiple SUs collaborates and exchange their information for increasing the reliability in PU detection process. Three steps of cooperative sensing are local sensing, reporting and decision.

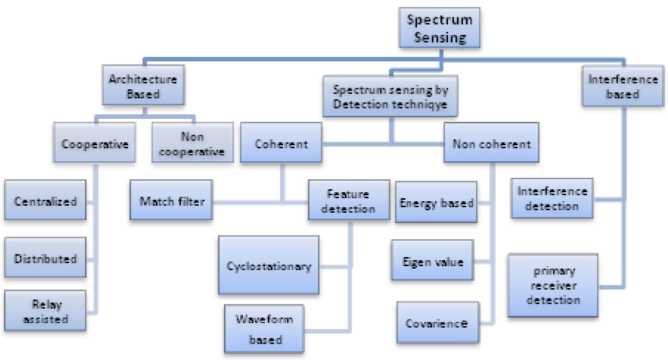

Fig. 6. Spectrum sensing classification.

In cooperative sensing, data exchange approach is classified as Centralized, distributed and relay assisted.

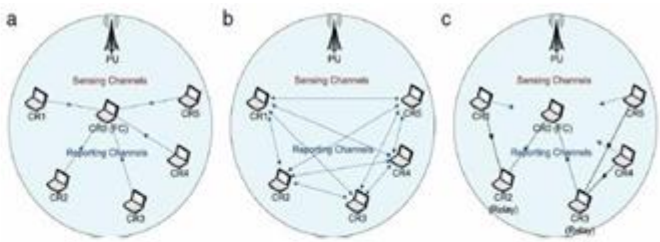

Fig. 7. Cooperative Sensing (a) Centralized (b) Distributed (c)Relay Assisted

a) Centralized approach: In this approach Fusion centre instructs all its cooperating cognitive radio users to perform individual sensing. The sensing results of all cooperating SUs are reported back to FC by control channel. Fusion centre(FC) collects all data, identify the presence of PU and relay back the same information to other users.[12]
b) Distributed approach: All cooperating SUs exchange information among themselves directly and converge to the decision of absence or presence of PU without involving FC.
c) Relay assisted: Cooperating SUs near to PU has strong sensing channel but has weak reporting channel whereas SUs

which are far from PU, has strong reporting but weak sensing channel. Here instead of individual sensing, SUs near to PU detects the presence and transfers the information to others through SUs which are far from PU and acts as relay.

(a.1) Elements of centralized approach are:

(i) Cooperation models: To perform cooperative sensing, Cooperation models are used. The cooperation of SUs for spectrum sensing has two different model approach *Parallel fusion model* and *Game theory model.*

(ii) Sensing techniques: Individual cooperating SUs inspects the frequency band of interest and broadly classified into coherent and non coherent. In coherent detection, PU detects the prior knowledge of the primary signal. Coherent detections are like matched filter, Cyclostationary and waveform based. In non coherent detection no prior information is needed. Types of non coherent detections are energy detection, wavelets detection ,covariance type, Eigen value type and compressed sensing detection[13].Energy detection used both for narrow and wideband. Energy detection use the multiband joint detection in wide band sensing. In compressed technique multiple RF frontends are used for sensing multiple bands to get set of observations sampled by analog to digital converter at Nyquist rate in the interested spectrum band. Challenges in Compressed technique are near far problem and installation issue.

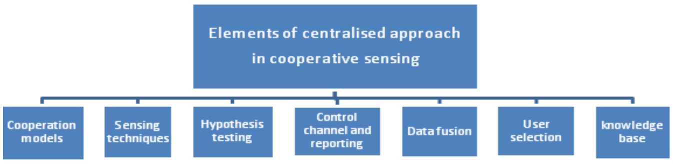

Fig. 8. Elements of centralized approach

(iii) Hypothesis testing: Here the test is performed to decide the presence or absence of a primary user (PU).Types of hypothetical test are binary , composite hypothesis test and Sequential testing. Two schemes are used here and they are the Bayes test and the Neyman–Pearson (NP) test. [5]

(iv) Control channel and reporting: It is used by the unlicensed users to say about the sensing result to FC. Bandwidth, reliability and security are the three major requirements of control channel.

(v) Data fusion: It's a combination of local sensing data to make cooperation decision about absence or presence of PU. Data fusion has been classified as (a) Soft Combining: CR users can transmit complete sample set of local test. (b) Quantized Soft Combining: CR Users send only the quantized data of sensing result. (c) Hard Combining: CR users transmit the one bit decision by making a local decision. Soft combining gives the best result with high accuracy as compared to the three at the cost of more control channel bandwidth. Rest two methods require less bandwidth with possible performance degradation due to information loss from quantization. Equal gain combining (EGC) and maximal ratio combining (MRC) can be used for soft local tests. Commonly used fusion rule for hard combining are AND rule and OR rule.OR rule gives the best rule when number of cooperating SUs are more and AND rule gives the best when less number of cooperating SUs are present.

(vi) User selection: Proper selection of cooperating SUs will improve cooperative gain and address the issues. User selection has been categorized in centralized and cluster based. In centralized based, FC collects information from all cooperating SUs directly, it causes redundancy in channel bandwidth, energy efficiency and also large delay in information exchange due to participation of large number of cooperating SUs. In cluster based these problems can be overcome by grouping cooperating SUs in clusters or coalitions. Four clustering methods are random clustering, reference-based clustering, distance-based and statistical clustering. There are three cluster based schemes given as performance improvement oriented scheme, overhead reduction oriented scheme and combined matrix based scheme.

(vii) Knowledge base: Storage of information like PU location, PU activity, and models. There are six knowledge based approaches given as Received Signal Strength (RSS) profiles, Channel Gain Map, Radio Environment Map (REM), Power Spectral Density, primary user activity and statistics ,primary user localization and tracking.

(II) Non cooperative spectrum sensing: In this sensing method information from the multiple the cognitive radio users are not used to detect licensed user. Rather parameters of SU adapts in changing environment based on the information received.

2) Spectrum sensing by detection technique: It can be of coherent or non coherent type.

(I) Non coherent detection: Blind spectrum or non coherent detection is highly in demand because of insufficient primary user information with the secondary.

(a) Energy based detection: Here, detection method is non-coherent technique [1]. It's easy to implement , and doesn't require any prior knowledge and also the cost is low. The disadvantage is it requires high sensing time. It cannot function well at low SNR [6].Detection performance changes with the uncertainty in noise power measurement.

(b) Covariance Based Detection: It exploits the correlation in between the received signals at the CR terminal. It shows high accuracy as compared to other methods

(c) *Eigen value based detection*: Eigen values of received signal samples are used for PU detection. Along with this other detection techniques are also present like *Moment - based detection*: Here the received signal samples are being used for PU detection and *Signal space dimension estimation* : It is a sensing technique based on signal space analysis. Advantage is that at low SNR, it performs best than the energy detection method.

(II) Coherent techniques :This technique is also used widely like non coherent because of its advantages.

*(a) Matched Filter Detection :*It's a linear filter which maximizes the received signal-to-noise ratio (SNR)[1]. Advantage of this method is the detection time requirement is less and also having low cost [4].Disadvantages are prior knowledge of pulse shape, modulation ,bandwidth and

operating frequency etc is required for PU's signal detection [1, 4].

(b)Feature detection: Spectrum sensing can also be done based on signal feature. Feature detection has been classified as Cyclostationary feature detection and waveform based feature detection .Generally modulation signals are associated with sinusoidal carrier, pulse train , hop sequences, cyclic prefixes, spreading codes, which results in build in periodicity. It exploits the periodicity of modulated signals in statistical manner like mean and autocorrelation to identify the received primary signal .Its Robustness at low SNR and interference are the main advantages of this method. [4].Disadvantages are, High computation time required with high cost. In waveform based detection prior information of PU is correlated with the detected signal to know the presence of PU. It is more advantageous in terms of reliability and convergence time than that of energy detection. Demerits are larger computational time and complexity.

3) Interference based detection: Spectrum Sensing for Interference Detection are classified into :

(I) Interference temperature detection: Generally interference occurs at receiver and can be controlled to avoid harmful interference. [1] Its main Advantages are, CR users are not required to sense and wait for spectrum opportunities for their communications [6].The disadvantage is SUs cannot transmit data with higher power because of imposed low power transmission rate to avoid interference.

(II) Primary Receiver Detection:

In this method, a low cost sensor is mounted on the receiver of the primary user to detect the leakage power emitted at the local oscillator of the RF front end of licensed user's receiver [6].Advantages of this method, it detects the Local Oscillator leakage with high accuracy and makes very fast decision. Disadvantage is Power loss.

4) *Spectrum sensing based on bandwidth*:

(I) Wideband Sensing : Wideband frequency spectrum sensing is done on large frequency range where the channel frequency response is not considered as flat i,e it exceeds the coherent bandwidth of the channel and can dynamically change. Here the entire band of interest is scrutinized at once to find a vacant channel for communication. It is broadly classified into Nyquist rate and sub-Nyquist rate.

(a) Nyquist wideband sensing: Here the samples taken at Nyquist rate or higher than Nyquist rate are processed by ADC and digital signal processing technique. Types are Multiband joint, Wavelet, Sweep-tune, and Filter-bank detections.[14]

(i) Multi-band Joint Detection : The wideband signal x(t) is first sampled at higher or same as Nyuist rate by ADC and then passes to serial to parallel convert block(S/P) to up root it into parallel data stream. The wideband spectrum X(f) is converted into a series of narrowband spectra $X_1(t), X_2(t)\ldots X_n(t)$ by FFT block. The PSD of each narrowband decides the presence and absence of PU as shown in Fig 10a.

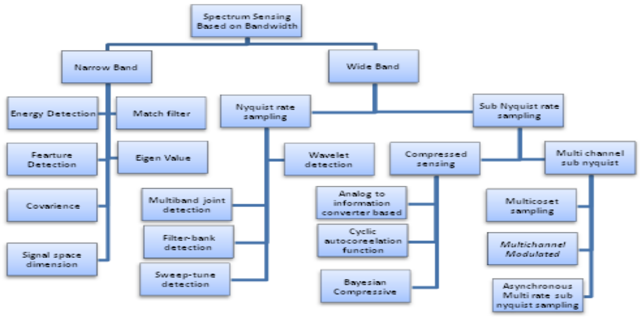

Fig. 9.spectrum sensing based of bandwidth

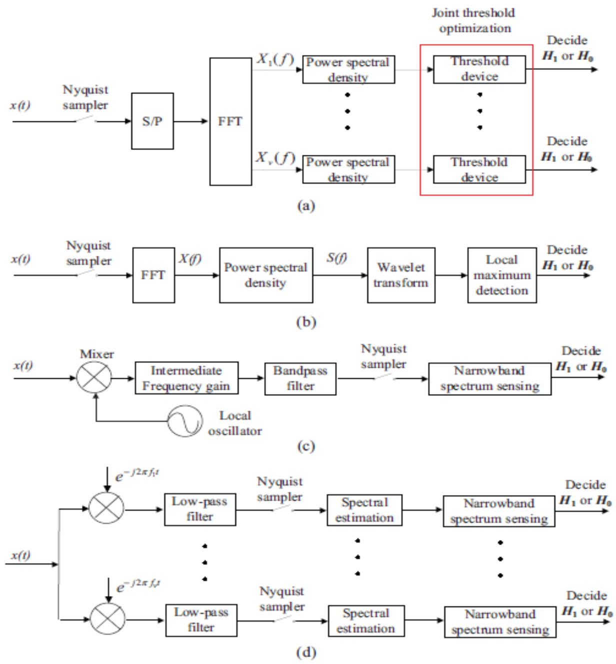

fig. 10. (a) multi-band joint detection (b)wavelet transform based (c) sweep time detection (d) filter bank method

(ii) Wavelet Transform-Based: A wideband spectrum is composed by several narrowband spectrum with different magnitude, spectrum ranges and PSD. Here SU transceiver examine wideband of interest without use of multiple BPF. Wavelet transform is used to identify the average power level in each identified sub-band which will lead to the identification of the spectrum holes shown in fig 10b.

(iii) Sweep-Tune Detection: The wideband signal is multiplied with a sinusoidal signal generated by local oscillator to convert it into lower frequency. The BPF filters out down converted signal and output of the sampler can be used for narrowband spectrum sensing.

*(iv) Filter Bank Algorithm :*Array of prototype filters with different centre frequency are used in the wideband signal as in fig.10.(d). Corresponding spectrum of wideband is down converted to baseband followed by LPF for narrowband extraction.

(b) Sub Nyquist wideband sensing: Samples are taken lower than the Nyquist rate. Sub Nyquist wideband sensing is more popular because of its less computational complexity as

compare to Nyquist wide band sensing. Its two important types are: Wideband compressive sensing and wideband multichannel Sub Nyquist sensing.

(i) Compressive Sensing(CS): Signals are sampled at information rate rather than Nyquist rate. CS requires statistics of the sparse level. Detection with CS for the foremost spectrum estimation is performed by high complexity recursive algorithm. This technique also has challenges like proper design of CS matrix and using right reconstruction algorithm. Types are (i) Analog-to-information converter-based wideband sensing, (ii) Bayesian compressive and (iii) Cyclic Autocorrelation Function (CAF) Symmetry-Based Detector

(i) *Analog-to-information(AIC) converter-based wideband sensing* .The pseudorandom number generator is discrete-in- time sequence which demodulates the respective signal x(t) by a mixer carrier inserted along with x(t).The output of the signal is then sampled at lower sampling rate for reconstructing the sparse signal by compressive sensing algorithms as in fig. 11(a).

(ii) *Bayesian compressive sensing:* BCS method estimates the parameter of PU from compressed signal and neglect the reconstruction stage unlike others .No need of reconstructing the entire signal thereby reduces computational time and complexity.

(iii) *Cyclic Autocorrelation Function (CAF) Symmetry-Based Detector:* Sensing of spectrum is based on the symmetry property of the cyclic autocorrelation function (CAF). Compressed sensing tool is adopted to get maximum benefit [14].

(ii) Multi channel sub Nyquist sensing:

(i) *Multichannel Modulated Sub-Nyquist Wideband Sensing*: It is modification of AIC model by taking multiple sampling channels[15] with accumulator replaced by LPF in each channel. It is robust against noise and model mismatch. Matrix dimension also reduces resulting in reducing system complexity and computational time.

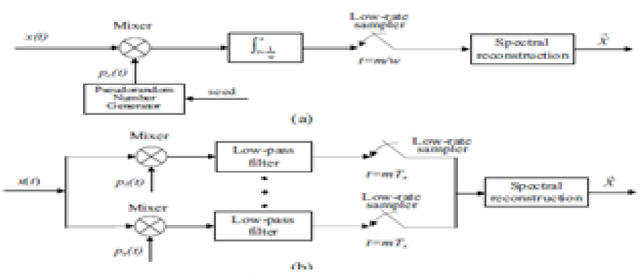

Fig. 11 (a) Analog to information converter based (b)multichannel modulated.

(ii) *Multicoset sampling Sub-Nyquist wideband sensing* :The multicoset sample choose some samples from a uniform grid, which can be obtained by using a sampling rate, f_s , higher than the Nyquist rate.

(iii) *Asynchronous multi-rate wideband sensing*: This approach gives relaxation in synchronization problem. spectrum sensing is improved by different rates in multiple sampling channels [14] .

(II) Narrow Band Sensing : In narrow band sensing technique sensing is done on the bandwidth which is less than coherence bandwidth of the channel. Classification are Energy detection, Matchfilter, Cyclostationary, Eigen value, Covariance, waveform and signal space detection where Match filter ,Cyclostationary, waveform based detection are coherent detection technique and Energy detection, Eigen value, Covariance, Signal space are Non coherent detection.

Challenges in Spectrum Sensing **:**Interference temperature measurement, Spectrum sensing in multi users network, False alarm, misdetection capability, Channel uncertainty, Noise uncertainty, Aggregate Interference Uncertainty, Sensing Interference Limit, Latency and Complexity, Reliable Detection, design of Wideband RF Front-End, Sparse Basis and level Selection, Adaptive Wideband Sensing and adaptive Cooperative Wideband Sensing[15].

B. Spectrum Decision:

It is the selection of the foremost spectrum band among the available bands on the basis of application requirement. It plays a role in allotment of spectrum to the unlicensed users. [10][16].Elements of radio frequency environment to decide the best band are : channel identification, channel capacity, spectrum switching delay, channel interference, channel holding time (CHT),channel error rate and subscriber location. Based on application it has been classified as

1) Real Time Applications: For real time applications, minimum variance based spectrum decision (MVSD) scheme is used that selects spectrum bands to minimize capacity variance for real time application.

2) Best effort application: Here, *Ma*ximum capacity based spectrum decision (MCSD) scheme is used which maximizes the total network capacity.

Challenges of Spectrum decision are: channel selection and Multiple spectrum band decision.

C. Spectrum Mobility:

Reoccurrence of primary user in its license band will cause interference to the unlicensed secondary user using the same spectrum opportunistically, may leads to stop the transmission of secondary data or delay until the spectrum is vacant again. For flawless SU data communication,SU will search alternative vacant spectrum and change its parameters again to use the spectrum.

1) Spectrum Handoff

Switching of CR users from one channel to other channel is termed as Spectrum Handoff. According to target channel selection methods, spectrum handoff is classified into two types: Sensing and cellular based. [10]

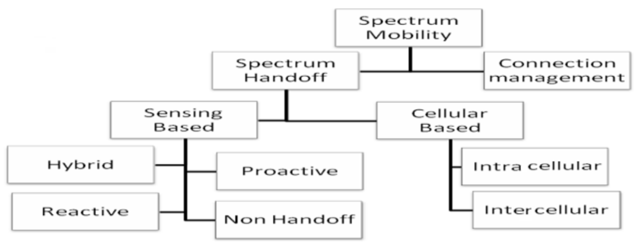

Fig. 12. Spectrum Mobility

(I) Sensing based spectrum handoff :The new target channel is selected based on the sensing result. It is also of four types: *Non Handoff , Proactive-Sensing spectrum handoff, Reactive-Sensing spectrum handoff and Hybrid Handoff.*

(a) Non Handoff : SU stays and postponds its data communication through real channel by being idle when again the channel becomes free.

(b) Reactive-Sensing spectrum handoff: When the channels for spectrum handoff are searched by request from the SU then it is known as *Reactive-Sensing spectrum handoff.*

(c) Proactive-Sensing spectrum handoff : Here the channels for handoff are prepared by the cognitive users before their transmission.

(d) Hybrid Handoff: Channel selection is prepared in advance or while SU data transmission.

*(II) Cellular based spectrum handoff***:** The spectrum mobility of SUs should not only be considered in single cells but also across multiple cells. It is of two types:

(a) Intracellular handoff :When handoff occurs in one WRAN (Wireless Regional Area Network) cell then it is called as Intracellular handoff.

(b) Intercellular handoff: When SU moves from one WRAN cell to another WRAN cell then it is termed as Intercellular handoff.

2) Connection Management : Connection management process manages and adjusts protocol stack parameters depending on current situation.
Advantages: When primary users arrives in CRNs, the spectrum handoff occurs ,in which secondary users do not need to pause its ongoing transmission by quickly switching to a other available channel for it's transmission. *Disadvantages*: Frequently spectrum handoff degrades the performance of the SUs and results in service interruption. *Challenges In Spectrum Mobility:* Spectrum Handoff (less switching time),Spectrum Mobility in multiple users, Cross-Layer Link Maintenance Protocols, Adaptive Spectrum Handoff Strategy, Energy Efficiency, Target Channel Selection and Routing

D. Spectrum Sharing:

Spectrum as a resource is facing scarcity due to increase in the number of users. Spectrum sharing is the solution to mitigate spectrum resource problem. Sharing of spectrum has been classified by five aspects like architecture, spectrum allocation behavior, spectrum access technique, network basis and scheduling. There are five major steps of spectrum sharing process comprise of spectrum sensing ,allocation, access,
handshake and mobility .Spectrum sharing comes under data link layer of network topology [11].

1) Spectrum Sharing Technique based on the *Architecture* is of two types:

(I) Centralized Spectrum Sharing:
Here all the process and spectrum allocation is controlled by a centralized entity.

(II)Distributed Spectrum Sharing: It is used where an infrastructure is not needed.

2) Spectrum Sharing Technique based on Access Behavior:

(I) Cooperative(Collaborative*) Spectrum Sharing*: PU selects cooperating SUs as relay for data transmission. In return, the PU leases portion of channel access time to the cooperating SUs for their own transmission .

(II). Non-Cooperative Spectrum Sharing: where SU works independently by local observations and spectrum rules, resulting in reduced spectrum utilization. However, frequent message exchanges between neighbors are not needed as in cooperative spectrum sharing.

3) Spectrum Sharing based on the *Access Technique* is of thre e types:

(I) Overlay Spectrum Sharing: SU can use the licensed spectrum only in the absence of PU .

(II) Underlay Spectrum Sharing: Both PU and SU can access the license spectrum simultaneously under a constraint of SU power transmission. In the absence of PU,SU has to transmit below the power interference constraint.

(III) Mixed Spectrum Sharing: The secondary service transmits without considering the interference threshold constraint during the idle periods. [9]

4) Spectrum sharing based of network.

(I) Intra Network Spectrum Sharing: Here, the Spectrum Sharing occurs inside the CRN. It is divided into centralized and distributed. In *Centralized-intra-network* spectrum sharing, a server exists that coordinates all the cognitive radio users. Whereas in case of *Distributed-intra-network* spectrum sharing technique each SU plays its role individually .

(II) Inter Network Spectrum Sharing: This Sharing is among multiple co-existing CRNs. It is also divided in centralized and distributed. In *Centralized-inter-network* spectrum sharing, a spectrum broker shares the spectrum to the SUs. While in case of *Distributed-inter-network* spectrum sharing technique, each and every entity is involved in the spectrum sharing decision and the SUs play its role.

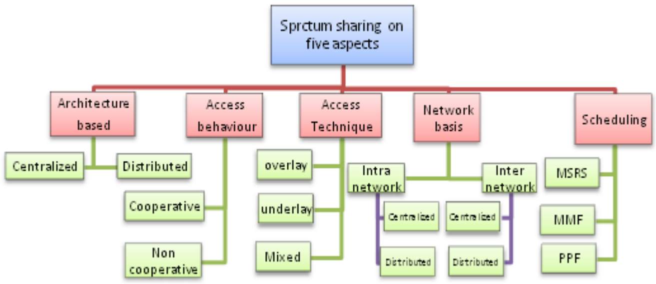

Fig. 13. Spectrum Sharing

5) Spectrum Sharing Schemes Based On Scheduling:
It comprises of three types: MSRS, MMF and PPF.

(I) Maximum Sum Rate Scheduling (MSRS): The work is to maximize the sum of the average data rates on all available link. For transmission, MSRS selects the best quality links i.e. least interference.

(II) Max-Min Fair (MMF): It is a global fairness scheduling scheme which provide equal data rates to all links by adjusting scheduling time. It provides equality to all links.

(III) Proportional Fair (PPF): The performance depends on the quality of individual link [8].

Challenges In Spectrum Sharing: i. Spectrum sensing Capability ii. Sharing delay and iii. Congestion.

IV. APPLICATIONS OF COGNITIVE RADIO

It has wide application [2] in the field of robotics, smart grid, commercial markets, environmental monitoring, public safety, military applications, and homeland security etc.

V. CONCLUSION

Cognitive Radio is a spectrum awareness concept and can solve the problem of spectrum underutilization and scarcity at the same time quality of service can also be improved. In this paper, the primary concept of cognitive radi o, it's network architecture, main functions with their advantages, disadvantages and applications are discussed.

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REFERENCES

[1] Anita Garhwal and Partha Pratim Bhattacharya, "A Survey on Dynamic Spectrum Access Techniques for Cognitive Radio", International Journal of Next-Generation Networks (IJNGN), Vol.3, No.4, pp.15-32, December 2011.

[2] B. Wang and K.J. Ray Liu, "Advances in Cognitive Radio Networks a Survey", IEEE format of selected topics in signal processing, Vol.5, No.1, pp.5-19, Feb, 2011.

[3] M. K. Raina and G. Singh Ajula, "An Overview of Spectrum Sensing and its Techniques", IOSR Journal of Computer Engineering (IOSR – JCE), Vol.16, Issue3, Ver-I, pp.64-73, May- June, 2014.

[4] R. Kumar, "Analysis of Spectrum Sensing Technologies in Cognitive Radio", International Journal of Information & Computation Technology, Vol.4, No.4. pp.437-444, 2014.

[5] Xiaoyuan Liu Yangling Zhang, Yang Li, Zhong Shan Zhang and Keping Long, "A Survey of Cognitive Radio Technologies & their Optimization Approaches", International Conference on Communications & Networking in China (CHINACOM), pp.974-978, 2013.

[6] M. Subhedar and G. Birajdar, "Spectrum Sensing Technologies in Cognitive Radio Networks: A Survey", International Journal of Next-Generation Networks (IJNGN) Vol.3, No.2, pp.37-51, July 2104.

[7] D.B. Rawat and G. Yan, "Spectrum Sensing Methods & Dynamic Spectrum Sharing in Cognitive Radio Networks: A Survey", International Journal of Research & Reviews in Wireless Sensor Networks (IJRRWSN), Vol.1, No.1, pp.1-12, March 2011.

[8] Varaka Uday Kanth, K R Chandra, R Ravi Kumar, "Spectrum Sharing in CRNs", International Journal of Engineering Trends & Technology (IJETT), Vol.4, Issue 4, pp.1172-1175, April 2013.

[9] M. G. Khoshkholgh, "Access Strategies for Spectrum Sharing in Fading Emit: Overlay,Underlay, & Mixed", IEEE Transactions on Mobile Computing, Vol.9, No.12, pp. 1780-1793, Dec 2010K. Elissa, "Title of paper if known," unpublished.

[10] P.Maheshwari and A.K.Singh,"A Survey on Spectrum Handoff Techniques in Cognitive Radio Network", InternationalConference on Contemporary Computing and Informatics (IC3I), pp. 996-1001, 2014.

[11] Akhila Asokan and Ayyappa Das."Survey on Cognitive Radio and Cognitive Radio Sensor Networks" , International Conference on Electronics and Communication Systems (ICECS), Feb 2014.

[12] Mohd. Sajid Imam , Sheetal Ingle and Shabnam Ara "A Review Paper based on spectrum sensing techniques in Cognitive Radio Networks " International journal on Network and Complex Systems,Vol.3, No.9, 2013.

[13] Ian F. Akyildiz, Brandon F. Lo, Ravikumar Balakrishnan "Cooperative spectrum sensing in cognitive radio networks: A survey" Physical Communication 4,pp. 40–62, 2011.

[14] M. Mourad Mabrook, Aziza I. Hussein "Major Spectrum Sensing Techniques for Cognitive Radio Networks: A Survey" International Journal of Engineering and Innovative Technology (IJEIT)Volume 5, Issue 3, September 2015.

[15] Charushila Axay Patel and Dr.C.H.Vithalani" Compressive Spectrum Sensing: An Overview" International Journal of Innovative Research in Electronics and Communications (IJIREC) Volume 1, Issue 6, pp 1-10, September 2014.

[16] Mitul D. Patel, S. B. Mule and Dr. S. R. Ganorkar "A Spectrum Decision Framework For Cognitive Radio Networks: Overview" IOSR Journal of Electronics and Communication Engineering (IOSR-JECE) Volume 9, Issue 1, Ver. IV, pp 19-22, Jan. 2014.