

# Different Spectrum Sensing Technique in Cognitive Radio Environment

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**Abstract:** A cognitive radio (CR) is one of the wireless sensor networks and the use of CR is increasing day by day. It is the process of learning via perception, planning, reasoning and continuously updating and upgrading the academic history of information. The cognitive radio has spectrum sensing (SS) problem in opportunistic spectrum access process. The SS, where the second user has to fill the unused spectrum of a licensed user when primary user (PU) not in use. It may arise interference problem to the user by the transmission of information in WSNs. Thus; this paper providing the comprehensive survey with the brief explanation of cognitive radio along with SS methods to reduce the issues appear in CR. The open research problems are discussed by considering previously existed research papers.

**Keywords:** Cognitive radio (CR), Primary user (PU), Spectrum sensing (SS), Wireless Sensor Network (WSN)

## I. INTRODUCTION

Cognitive radio (CR) is an adaptive intelligent radio and network technology which can automatically detect channel in a wireless spectrum [1]. It also can change the transmission parameter to allow more communication in the network that enhances the radio operating behavior [1]. The CR technology is using to unauthorized spectrum that plays an essential role in spectrum utilization [2]. CR is more suitable in a wireless communication network. It can detect the frequency which is utilized in an authorized and unauthorized spectrum band [2]. The SS is a process where unauthorized users obtain information about the status of the radio spectrum allocated to an authorized user with the intention of accessing license bands which have not used [3]. This process is formulated without causing interference during transmission [3]. The unauthorized or unlicensed user is also known as secondary user similarly the authorized or licensed user is identified as primary user (PU) [2]. The main thing of SS in CR process secondary user (SU) should not affect the accessing authority of the PU when a spectrum is required. The PU has rights to use the spectrum at any time but SU only can access the spectrum when PU is not using [2]. The SU should be active each and every time because whenever the PU gets active the SU has must be abandoned the channel quickly or it should minimize the transmitting power within a certain period of time [2].

In CR, to communicate data it does not have any fixed channel allocation so sensor has advised with the neighbors which choose the frequency channel to transmit data [4]. This

is difficult since the coordination between PUs and SUs is very less or no; hence different spectrum sensing algorithm is utilizing to predict the arrival of the PU on the channel [4]. Federal communication (FCC) distinct the CR [5]: "A system or radio that operates in an electromagnetic environment and also can automatically and dynamically adjust its radio working parameters to adjust or modify system operation, likewise as maximize throughput, facilitate interoperability and interference." The CR has cognitive capability to communicate in real time mode with an atmosphere that helps to adjust the varying radio environment by adjusting suitable communication parameter. So CR follows cognitive cycle steps such as spectrum- sensing, analysis, and decision. Thus cognitive-technology helps the user to utilize the spectrum in a useful manner by following steps spectrum-sensing, management, sharing, and mobility, etc.

The cognitive user is needed to participate SS to determine the availability of spectrum holes [5]. SS primarily used to obtain the spectrum use in multiple dimensions like frequency, code, angle, space and time [5]. These processes are accurately performed by different SS methods. The current study, multiple SS techniques are discussed for efficient SS such as cooperative or collaborative SS (CSS), matched filter detection (MFD), energy detection (ED) and cyclo stationarity based detection (CSD)[6].

The current study, focusing on spectrum sensing performed on CRs because of wider application in wireless networks. In below section II brief explanations about CR and working process. Section III explains the spectrum sensing concepts. Section IV spectrum sensing techniques. In section V discuss the previous research work related to present scheme which is more useful for discoloring different new idea for future work. Finally, the section VI concludes the topic theoretically and discusses challenges for next work.

## II. COGNITIVE RADIOS

CR has the capability to change the parameter to work in real time mode to adjust the nonstable radio environment.

### A. Dynamic spectrum Access (D-SA)

It is used to allocate the fixed spectrum resources to the primary or a licensed user has resulting to the underutilization of the spectrum band. In this, the static spectrum access method is used by conventional wireless networks which has been replaced by DSA and DSM [55]. The spectrum sharing is allows secondary users to exploit unused spectrum or spectrum holes in the licensed spectrum by the help of DSA. From the cooperation of PUs this all works fluently and also avoid interference that make the SS process reliable and smooth.

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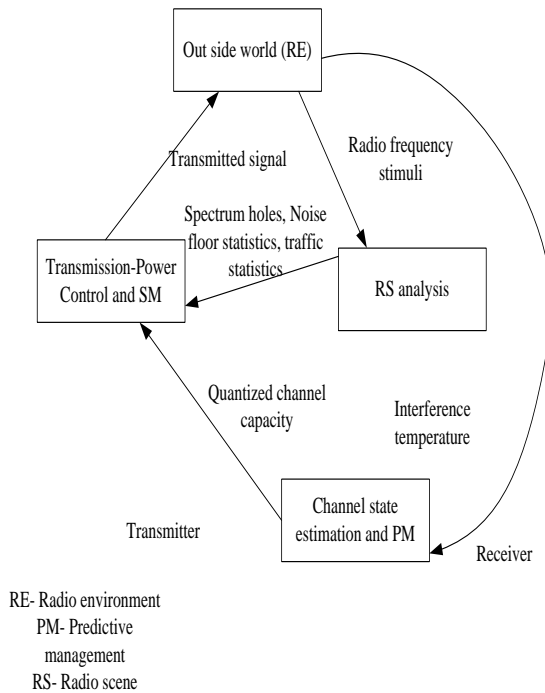
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## B. CR cycle

The overall working process of CRN decides around CR cycle. Cognitive cycle or adaptive operation of CR is following shown in figure 1 [5].



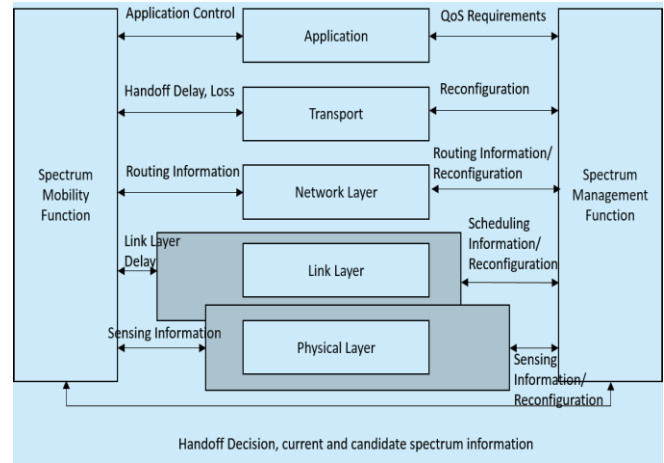
**Fig. 1.Cognitive cycle [5]**

Cognitive cycle's steps such as spectrum-sensing, analysis and decision are as follows-

- **The SS** task involves finding spectrum holes in the electromagnetic spectrum by sensing the neighboring atmosphere.
- After finding the spectrum hole by SS, **spectrum analysis** has to make a role like CR characterize these spectrum holes that predict the channel capacity and estimate the channel state.
- Based on spectrum analysis information **spectrum decision** performs such as CR node determines the transmit power data rate of the CR transmission and involves dynamic spectrum management.

The functionality of CR technology is shown in below figure 2.

CR technology helps to user to determine the availability of the spectrum and find the occurrence of licensed-users when the secondary user activates in a licensed band. This type of process is called SS. Based on SS spectrum management perform in the correct manner that selects the best available channel in the spectrum. Spectrum sharing makes coordinate access to this available channel with other unlicensed users. Finally, the spectrum mobility performing as if any licensed user is detected then abandoned the channel and gives the higher priority to the PU.



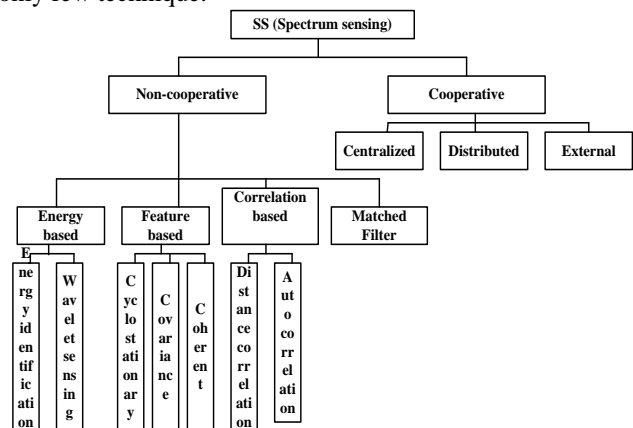
**Fig. 2.Functionality of CR**

## C. PUs and SUs

The CRs users are generally called as SUs (secondary users) and the network used by this called as secondary networks. The licensed user is considered as the PUs and the network corresponding them is termed as PU networks. In CR environment, SUs sense PUs movement on the primary grids that find the spectrum wholes or white spaces and start utilizing the licensed spectrum resources. Hence the utilization of licensed spectrum is decreased in CRNs.

## III. SPECTRUM SENSING TECHNIQUES

The SS is the process of sensing the spectrum in a helpful manner to the user; if licensed users are unpresent the SU which is unlicensed that occupy the licensed spectrum. There is different method are available to identify or detect the existence of transmission of signal and signal types. By the time of signal transmission, some interference or signal effect may occur that all cleared by using a below mentioned different type of SS techniques. In below figure 3 shows the classification of various SS techniques. In the study, discusses only few technique.



**Fig. 3.Classification of SS techniques [10]**

**A. Energy identification (EId):** The energy detector based technique is also known as periodogram or radiometry. This method decidedly less computational and implementation complexity because of that this technique is very common or more famous for SS [5][6]. As compare to other below-mentioned method energy detector is more genetic[7].

It is also deliberate as an optimum sensing scheme when no information of the available primary signal. The PU occurrence and nonappearance are decided by measuring PU signal energy that comparing against detection energy threshold [8]. The main challenge of energy detector base sensing is threshold-selection for check the availability of PUs and also difficult to overcome the interference from PUs and bad performance under low SNR[5] [7][9].

Primarily, let us consider the received signal  $z(n)$  is,

$$z(n) = x(n) + g(n) \text{ ---- (1)}$$

where  $x(n)$  is the detected signal,  $g(n)$  is AWGN sample and number of samples ( $n$ ) to be considered. The energy detector decision metric, when  $g(n) = 0$  which can be considered as

$$M = \sum_{n=0}^N |y(n)|^2 \text{ ----(2)}$$

Where  $N$  is the observation vector size. The decision of the band occupancy can get by comparing the fixed threshold  $\lambda E$  and the decision metric  $M$ . This is equivalent to distinguish between two binary hypothesis which is shown in below equation,

$$H_0 : z(n) = g(n), \text{ ---- (3)}$$

$$H_1 : z(n) = x(n) + g(n) \text{ ---- (4)}$$

Where hypothesis  $H_0$  indicates the absent of PU signal and hypothesis  $H_1$  indicate that the presence of PU signal.

The detection algorithm performance can be summarized with a probability of false ( $P_f$ ) alarm and probability of detection ( $P_d$ ) which detects signal probability on considered frequency when it is really present. Thus, large  $P_d$  is desired. Which can be written as

$$P_d = P_r(M > \lambda E | H_1) \text{ ---- (5)}$$

$P_f$  is the probability that the test wrongly decides that the considered frequency is occupied when actually it is not and it can be formulated as

$$P_f = P_r(M > \lambda E | H_0) \text{ ---- (6)}$$

To prevent underutilization of transmission opportunity,  $P_f$  should be kept as much as small. The decision threshold  $\lambda E$  used to find an optimal balance between  $P_d$  and  $P_f$ . The estimation of noise power can be performed and is very hard to perform the estimation of signal power as it varies with ongoing transmission characteristics and the separation among PU and CR. Thus, the knowledge about noise variance can be helpful in threshold selection.

Further, the white noise is given with zero- mean Gaussian random variable consisting of variance of  $\sigma_g^2$ ,  $g(n) = N(0, \sigma_g^2)$  and the signal term modeled,  $x(n) = N(0, \sigma_x^2)$ . The model for  $x(n)$  is complicated as fading must be considered, hence decision metric -2 proceeds a chi-square distribution with  $2N$  freedom degrees  $Y_{2N}^2$  and is expressed as

$$M = \begin{cases} \sigma_g^2 / 2 Y_{2N}^2 & H_0 \\ \sigma_g^2 + \sigma_x^2 / 2 Y_{2N}^2 & H_1 \end{cases} \text{ ---- (7)}$$

The probabilities of  $P_f$  and  $P_d$  calculated for energy detector as

$$P_f = 1 - \gamma(L_f L_t, \lambda E / \sigma_g^2), \text{ ---- (8)}$$

$$P_d = 1 - \gamma(L_f L_t, \lambda E / \sigma_g^2 + \sigma_x^2) \text{ ---- (9)}$$

Where  $\lambda_E$  is the decision threshold and  $\gamma(a, y)$  is the incomplete gamma function which is given in reference [7]. To compare the performance for different threshold value, ROC (receiver operating curve) can use [7]. Signal to noise

ratio (SNR) can also calculate, i.e. the PU power signal to noise power.

$$SNR = \sigma_x^2 / \sigma_g^2, \text{ ---- (10)}$$

The threshold of sensing algorithm based energy detector is depends on noise variance.

a. Matched Filter Identification (MFId) [7][8]:

This is an optimal signal identification mechanism because it enhances the SNR. The MFId needs complete knowledge of PUs signal properties such as data rate, modulation format etc. The significant feature of MFId is that it performs the comparison of known signal with the input signal for detection of template within unknown signal. The output of matched filter is compared with the set threshold to take decision on PUs availability.

**B. Wavelet identification (WId):** The WId mechanism considers the wavelet transform, mathematical tool to perform investigation of signal regularity and analysis of power spectrum singularity and irregularity generated by spectrum usage. The wavelets are utilized to perform the detection of the edges wide band channel.

**C. Cyclostationary based detection:** The PUs transmitted signals are cyclostationary one (means statistics exhibits periodicity). This kind of periodicity is mainly subjected to the primary signals so that the receiver can utilize it for channel and timing estimation. This also can be used to identify the PUs. This periodicity can be detected by SUs in modulated signals by spectral correlation function analysis. This kind of SS mechanism is appealing due to its ability of filtering the primary signals from interference and noises even at low SNR environments.

**D. Collaborative sensing (Cs):** This mechanism is more significant if the collaborating CRs observe shadowing or independent fading. Many analysts have suggested that performance of collaborating spectrum may decreases due to correlated shadowing. Also, to have equal amount of users collaboration over a big area than small area. For combat shadowing, the antennas like directional as well as beam-forming antennas can be used. Further, by cooperating all the users in a network doesn't provide optimal performance and cognitive users having higher SNR of PUs are selected for collaboration.

#### IV. RESULTS OF RELATED WORK

Rajkumari and Marchang [11] introduced non-consensus based distributed SS (NCSS) in CR system, which was purely based on message passing. In the process some abnormal behaviour of a node may make problem for CR so that secure NCSS was used to recognize such abnormal, which isolate the extreme energy generating node. NCSS was mainly used for detecting high energy injection attack and low energy injection attack. The performance of present algorithm was checked by comparing with existing consensus scheme. From the analysis and simulation of present method, results shows out performance under noise variance compare to existing method.



The work of Yucek et al. [12] discusses the SS algorithm for CR which helps for spectrum access. The CR technology involves recognition of PU signal at the secondary users to assign the spectrum hole to the unauthorized user. The main task for CR is to find the existence of PU to decrease the interference to the PU; hence SS was main role in CR. Thus the present study SS CR was briefly discussed with blind semi-blind and non- bling spectrum scheme.

The SS in CR was used adaptive technology in work of Salam et al. [13]. The robust multiple model with Kalman filter was introduced to interrogate the channel state information and to adjust the adaptive threshold and optimum frame duration; which reduce or control the spectrum leakage. The analysis of present method gives results with high SS performance by calculating SNR.

The research work of Elnahas et al. [14] presents a SS on CR with secondary users using game theoretic methods. The gamming model first involves cooperating sense the spectrum or denying being a free driver. The sensed data is forwarded to fusion center to find the existence of PU. The Stackelberg game was applied in second part to model if fusion center acts as a leader in the game. The simulation results of present method shows that game model have better performance and high throughputs.

The study of Xiong [15] introduced multiband SS such as adaptive SS strategy (ASSS) and random SS strategy (RSSS) in CR systems with hardware limitation at the secondary user terminal. The present strategy the secondary user only can sense a multiband spectrum portion under given interval of time. RSSS involves select the sub channel to react in random manner and ASSS was designs novel decision rule that takes two decision to determine the sub channel to sense for SU. The analysis of present method gives accurate result with significant performance gain of ASSS as compare to RSSS.

The enhanced SS algorithm was used in CR system to protect the PU from bad interference was presented in work of Saifan at al. [16] The proposed study three optimization problem was minimized by using three different algorithm for each by specifying FC, cooperative sensing node, sensing time and detection threshold time. From the simulation results present method shows better performance compare to previous existing method in terms of sensing time, throughput and total sensing energy.

Chu et al. [17] approached hybrid interweave underlay cognitive cooperative CR network (CCRN) with two enhanced power allocation strategy which maximize the channel capacity and decrease outage probability. The present scheme strategy was derived in case of Rayleigh fading. The analysis of the present method gives results with advantage of the hybrid spectrum access by comparing channel capacity, overlay, hybrid interweave underlay CCRN.

The work of Kim [18] presents a low pass wavelet based energy detection SS which gives high order band pass filter function in CR. The Ultra-wide band SS with some harmonic mixing problems were reduced by Low power high frequency harmonic rejection process. From the analysis of proposed WEDSS gives better performance compare to other related normalized sensing time metrics.

The wide band spectral sensing method by used a 1-bit quantization in CR scheme in work of Ali [19]. The window based AC (Autocorrelation) was exhibited to give the PSD (Power Spectral Density) of the quantized signal. The evaluation of spectrum parameter, the identification algorithm

with probability of identification and PFA (Probability of False Alarm) were simulated. By the simulation results, the accuracy and sensing performance were calculated and the current method was compared with other existed technique that gives low system complexity, little sensing time and good performance.

The research work of Nguyen [20] introduced a new spectrum sharing scheme for identify or detect SS in CR field. The main initial aim of the present method is to improve or increase the sum-rate of all available unauthorized secondary users (SUs), reduce the interference and signal effect of PU and power restraints at SU. The outcomes of the method provide better performance over previously existed approaches.

The work of Ali and Nam [21], discuss the spectral sensing in CR networks and the spectrum-hole utilization (SHU) time in transmission. By using probability of SHU (PSHU), the best SS time period and size of the time frame were existed. From the simulation analysis of proposed method gives qualified results and it shows that the use of optimal size of time frame and the best sensing time period gives the high PSHU.

The CCD SS (Centralized Cooperative Directional SS) methods proposed in CR in work of Na et al [22]. The occurrence of nonlinear optimization issues were cleared by utilizing an improved gradient method. With the evidence of the report the fusion center (FC) enhances the sensing power, period and sensing beams/ subordinate node. The outcomes of the present approach concludes that the CCD-SS scheme was more appropriated for CR atmosphere and proposed optimal scheme gives good performance in all parameters compare to other non-optimized technique. The work of Ostovar and Chang [23] presents an investigation of channel gain effect and SNR (Signal to noise ratio) to unlicensed SU collaboration in WCEI (Weighted combined Energy Investigation). The process, improve the identification probability as well as optimal LCW (linear combining weight) and transmission power of every unauthorized user for sense the data from SUs to the FC(fusion center). From the simulation results of present method, the probability identification can enhance and it was performing excellent in recent work based on detection. The multiple inputs and multiple outputs (MIMO) CR were introduced by the use of robust cooperative SS and it has considered under uncertain channel state information (CSI) in work of Patel and Adarsh [24]. Different kind of techniques were used which service cooperative decision rule based on native sensor conclusion transmitted to the FS (fusion center). The robust likelihood ratio detector was derived in the scheme and Pf, Pd was calculated at the fusion center. From the analysis and simulation, the present method provides high performance rate compare to other conventional detector scheme. The research study of Ye et al. [25] presented a new scheme unilateral right-tail Anderson-Darling URAD test based SS for CR. URAD technique functioned based on the features of non-symmetrical differences between the theoretical CDF( cumulative function) and the empirical CDF. The theoretical performance of URAD was analyzed and the theoretical results were verified by numerical results. The performance of present scheme was checked by comparing with existing Anderson- Darling scheme.

The work of Zhao [26] introduced a sequential compressed SS (SC SS) and sequential periodic identification scheme for CR network. The present method mainly used to get precise and timely wide band sensing (WBS) in CR. The advantage of this method, it decreases the compressed sensing recovery overhead and also it enhances the sensing quality. Including a reconstruction algorithm like block sparse CS and in depth sensing technique for sensing decision making was utilized to improve the sensing accuracy. By the analysis of the proposed scheme result gives outperformance under low SNR setting.

The work of Yang et al. [27], introduced a blind SS algorithm based on the mathematical Eigen value ratio that used for CR with multiband network. The present method was based on blind identification scheme which can use primary data, the noise, and the channel. The simulation result of present technique gives outperformance and it shows the advantages of the proposed approach.

The work of Xiong et al. [28] presented a random and persistent based adaptive SS scheme for MSS (multiband SS) in CR networks. The authors first consider hardware problems at the unauthorized SUs to make multiband SS popular or which makes MSS more challenging. The RSSS (Random SS scheme) used to choose the sub channels to sense in random manner and PSSS (Persistent SS Scheme) was introduced to the present method to take benefit of the PU traffic patterns for identifying the channel to sense. The ASSS (Adaptive SS Scheme) presented for identifying which method have to use either RSSS or PSSS for SS at certain time based on PU traffic factors. The present technique RSSS, PSSS and ASSS was estimated under various system parameters. The result shows that the present three schemes provides more available unused channel for unauthorized SUs.

The distribution SS for CR to make use of available channel to SU without making disturbance to PU in work of Hajihoseini [29]. The distributive diffusion based scheme that utilized to improve the SS and SU helps to enhance the SS. The simulation results of present scheme gives high performance and it meets two times faster than previous existed algorithm.

The work of Huang et al [30] introduced a space time correlation based fast regional or local spectrum-sensing (RSS) was introduced to decrease the energy feeding and reduce the time of traditional SS. The MCM clustering algorithm was used and meshes were clustered into highly

related groups and some other meshes are detected based on auto-correlation and spatial correlation. The simulation result shows that the consumption of RSS was highly decreased and small loss in accuracy.

The study of Rashid et al. [31] presents the Particle swarm optimization (PSO) based technique for in-band regional SS to discourse the compromise between throughput and sensing time. A fast convergence PSO technique was derived to get identification performance, optimization time and SU gain. The simulation result shows that the present algorithm gives considerable improvement in terms of ROC curve, interference modification to the PU while increasing the unauthorized user throughput.

The work of Chen [32] presents a cooperative SS issues with M- array quantized data under SSDF (SS data falsification) attacks. The malicious SU detection scheme and adaptive linear combination rule was used in the present method to remove the malicious SUs. The outcomes suggest that the presented malicious SU detection scheme can effectively removes the malicious SUs and cooperative SS robust against SSDF attacks.

In CR energy identification method was used to for WBSS high rate ADC (Analog to Digital Converter) needed for large speed signal dispensation. Thus, a compressed sampling for PU signal acquisition was addressed to decrease the sampling rate and crack the operation complication of ADC in work of Hosseini [33]. From the simulation results of the present scheme concludes that the method was very helpful to estimate the PSD of primary signals.

The study of Thaherpour [34] presents SS technique by considering the energy gathering CR. The scheme supports like the transmitter of the secondary user was permit to produce signal energy of the authorized user when primary signal is present. The present method soft decision rule was applied for energy harvesting. By the simulation results conclude that the current discussed method produced high performance based on different parameter.

The spectrum access in opportunistic base in CR network along with their performance was analyzed in work of MacDonald [35]. The PU activity model by a Markov chain model with two states and investigative expression was derived for false alarm and probabilities of identification. The result of present scheme was obtained by simulation.

Table 1 Summary of CR Network & SS

Authors	Problem statement	Methodology/tool/algorithm	Outcomes
Li [36]	To determine SS interval and energy in CR	EH (Energy harvesting) technique, MDP (Markov decision process)	Throughput, Energy efficiency
Pei et al. [37]	SS data falsification attack detection	Neighbor Detection (ND) based SS algorithm	SSDF can detect effectively
Awe et al. [38]	SS issues in multi-antenna CR network	Beamformer Aided (BFA) SVM algorithm	robust
Amjad et al. [39]	Review of FDC (Full duplex communication) in CR	Different SS schemes	-----
Ali [40]	Review of application to the SS in CR	Discussed various SS methods	-----
Hassan et al. [41]	SS in CR	Trading models of SS discussed	-----
Tanab [42]	Investigation of spectrum-management resource distribution in CR (SM),	RA algorithm	-----

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Kalluri et al. [43]	To perform spectrum sharing	Time splitting and power sharing cooperative SS relying protocol utilized	The performance was calculated
Shafiee et al. [44]	To evaluate the SS algorithm for cognitive WSN	Different comparative technique was discussed	Energy identification, multiteraper technique, united multiteraper was investigated
Alfa et al. [45]	Review of resource allocation (RA) in CR	Existed tools were discussed	-----
Li et al. [46]	Spectrum sharing	Learning based power switch(control)method	The SU can communicate with PU resourcefully and both user can transmit data effectively
Gu et al. [47]	To meet best sensing period in SS of CR	NGSF(Nakagami-Gamma shadowed fading) via-to-sense channels was approached	Optimum sensing time period, Low data rate loss
Trong Nghia Le [48]	The comprehensive review of smart grid (SG) communication in CR	Various techniques based on CR was discussed	-----
Ali et al. [49]	To identify the QoS level and channel gathering for MC-CRN(Multi channel)	Gaussian-mixture- model and collapsed Gibbs-sampler	The performance was calculated
Yan shi et al. [49]	SS communication issue in CR Ad Hoc network with Multi-channel	Robust topology with K-channel connectivity algorithm	The simulated results was helps to future research
Jacob et al. [50]	To collect the information of spectrum management in aeronautical and the use of CR in aeronautical system to solve spectrum insufficiency problem	-----	It helps to future opportunity of research
Yang et al. [51]	To develop a novel routing protocol in smart grid	Green RPL model	The system efficiently simulated that gives better performance than existing method
Gottappu et al. [52]	To overwhelmed the throughput limitation problem in CR	OGTM (Online Greedy Throughput maximization) algorithm	Increase the throughput up to 95% and miss recognition probability reduced by 50%
Wang et al. [53]	SU SS in CR	P-SUAC (Prioritized SU access control) method, energy identification method, OFDM (Orthogonal frequency division multiplexing )method	The present method was efficiently simulated with high performance
Salam et al. [54]	Multiteraper-SS in CR	Adaption model of Kalman filter, OFD(optimum frame duration) algorithm	The simulation outcome shows the benefits for efficient SS use.

## V. CONCLUSION

In this study, first discussed about PU and secondary user how it will occupy the spectrum when licensed spectrum is available. The interference problems appear in the channel occupation process that can be overcome by using various kind of SS method in CR network. By comparing the above discussed SS technique, the energy identification method is well suitable for SS in CR scheme because of less implementation and computational complexity. The various researches held on this theme with different SS problem is reviewed that needed for future research and attention. This whole investigational study will help to the future work.

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