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Evolution of Open Spectrum Sharing Technology- A Survey

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Abstract— The increasing demand for wireless communication introduces efficient spectrum utilization challenge. To address this challenge, cognitive radio has emerged as the key technology, which enables opportunistic access to the spectrum. The main potential advantages introduced by cognitive radio are improving spectrum utilization and increasing communication quality. These appealing features match the unique requirements and challenges of resource-constrained multi-hop wireless sensor networks (WSN). Furthermore, dynamic spectrum access stands as very promising and spectrum-efficient communication paradigm for WSN due to its event-driven communication nature, which generally yields bursty traffic depending on the event characteristics. In addition, opportunistic spectrum access may also help eliminate collision and excessive contention delay incurred by dense deployment of sensor nodes. Clearly, it is conceivable to adopt cognitive radio capability in sensor networks, which, in turn yields a new sensor networking paradigm, i.e.,cognitive radio sensor networks (CRSN). In this paper, the main design principles, potential advantages and application areas and network architectures of CRSN are introduced. The existing sensing methods adopted in WSN are discussed along with the open research avenues for the realization of CRSN.

Index Terms—Cognitive radio, sensor networks, opportunistic spectrum access, efficient spectrum sensing.

I. INTRODUCTION

The capability of a cognitive radio to best suit its surroundings greatly depends on the amount and accuracy of information it an acquire about its radio environment. The process by which the cognitive radio becomes aware of its surroundings termed as spectrum sensing and is a key challenge in cognitive radio design. Radio mode identification is a comprehensive spectrum sensing algorithm that provides the cognitive radio with elaborate spectral information about the primary users. The approach has not been explored extensively due to its complexity and difficulties in real time implementation.

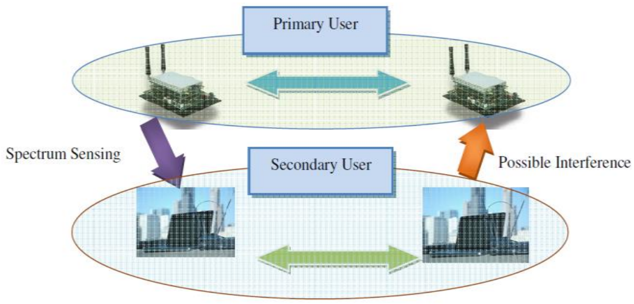

Figure 1: Dynamic Spectrum Access

However the recent advancements in the field of signal processing render the complexity problem rapidly evolving wireless communication industry has caused an apparent spectrum scarcity whereby, the available spectrum has already been allocated to various users by governing agencies under monetary agreements. Analysis has revealed that this apparent scarcity is attributable to the inefficient fixed spectrum allocation techniques. These techniques are simple to implement but result in major portion of spectrum being underutilized. For example, federal communication commission places the spectrum usage in USA between the ranges 15% _ 85% at all times . This has opened a new avenue in research to explore more efficient but complex dynamic spectrum access techniques. Dynamic spectrum access envisions the use of licensed spectral bands by smart unlicensed cognitive users that can exploit any opportunities that may exist in the form of temporal or spatial holes. A spectrum hole is that part of the spectrum where the primary users' transmission strength falls below a certain regulated level termed as interference cap by federal communication commission The smart nodes that constitute the secondary users are called cognitive radios. A cognitive radio is an evolved software defined radio that in addition to reconfiguration capability also possesses the ability to analyze its surrounding radio environment. This allows the cognitive radio to decide how best to reconfigure itself in existing radio conditions. This paper reviews various spectrum sensing approaches highlighting the strength and weaknesses of each. Section 3 lays down the analytical framework for the proposed algorithm and introduces the proposed radio mode identification algorithm.

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II. RELATED WORK

Spectrum sensing algorithms generally offer a compromise between accuracy and complexity. The attribute of accuracy is not only critical from a secondary user's perspective enabling it to optimally utilize the available opportunities but also for the primary user, minimizing the interference due to secondary users. Conversely the complexity of spectrum sensing algorithm has to be kept to minimum in order to allow real time operation of cognitive radio. Energy detection is a simple spectrum sensing technique. The received signal strength in a certain channel is compared against a carefully selected sensing threshold to ascertain the presence or absence of primary user in that channel. The sensing threshold is defined on the basis of noise floor and is a critical challenge. This results in poor performance at low SNR and/or very small buffer sizes. Energy detection is desirable because of its simplicity and its non-parametric nature .i.e. it is independent of the type of primary user. The waveform based detection is carried out by identifying the preambles and cyclic prefixes that are generally used with various types of transmissions. This approach outperforms energy detection in convergence time and accuracy, but is dependent on the type of primary user transmission. The major drawback of the algorithm is its parametric nature. Cyclo stationary feature detectors make use of the inherent periodicity in the radio signals. The correlation function is used to measure the periodicity of the received signal. The algorithm is computationally complex but the cyclic frequencies can also be used for signal classification. Improvement in energy detection performance based on Bayesian sequential testing considering previous spectrum states has been discussed. The most elaborate survey of spectrum sensing techniques has been carried out in. The broad categorization of these techniques is done and a comparison for varying condition of SNR, noise models and buffer size has been carried out.various performance metrics that could be used for comparison have also been summarized. Haykin has advocated use of multi-taper method for spectrum sensing considering spatial, temporal and spectral dimensions simultaneously. Radio mode identification enables the cognitive radio to identify various useful parameters of primary user transmission such as modulation scheme, transmission technology, frame size and multiplexing technique etc. This can be utilized by the cognitive radio for optimizing spectrum sensing. The radio mode identification approach has been explored. The papers suggest using the instantaneous frequency and delay spread obtained through time frequency analysis. Variable reduction is carried out and neural networks are used to predict which transmission scheme is present in the received signal. However the approach is limited only to identifying the modulation scheme of the primary user. In this paper we suggest a framework that in addition to identifying the modulation scheme may also be used to detect various features of the primary user transmission.

III. CRSN ARCHITECTURE

Cognitive radio sensor nodes form a wireless communication architecture of CRSN over which the information obtained from the field is conveyed to the sink in multiple hops.

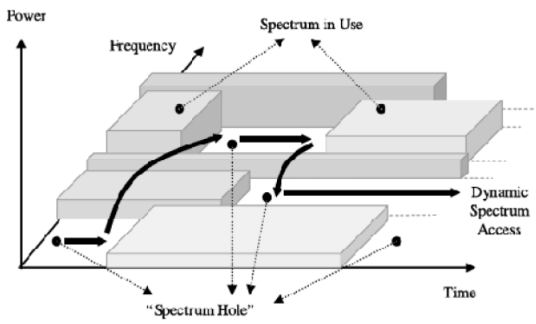

Figure 2: Spectrum hole

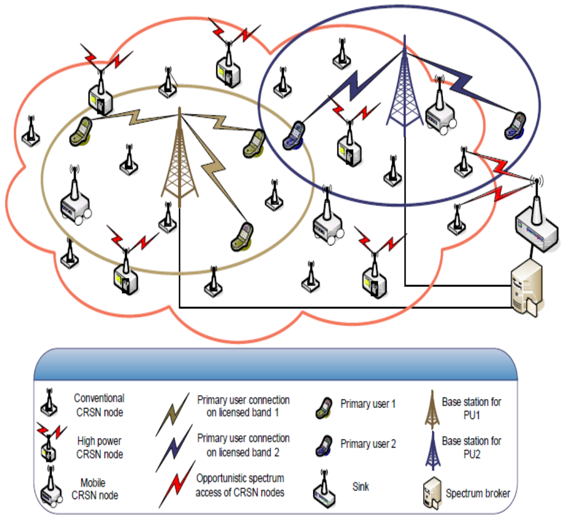

Figure 3. CRSN Architecture

The main duty of the sensor nodes is to perform sensing on the environment. In addition to this conventional sensing duty, CRSN nodes also perform sensing on the spectrum. Depending on the spectrum availability ,sensor nodes transmit their readings in an opportunistic manner to their next hop cognitive radio sensor nodes, and ultimately, to the sink. The sink may be also equipped with cognitive radio capability, i.e., cognitive radio sink. In addition to the event readings, sensors may exchange additional information with the sink including control data for group formation, spectrum allocation, spectrum handoff-aware route determination depending on the specific topology. A typical sensor field contains resource-constrained CRSN nodes and CRSN sink. However, in certain application scenarios, special nodes with high power sources, i.e., actors, which act upon the sensed event, may be part of the architecture as well. These nodes perform additional tasks like local spectrum bargaining, or acting as a spectrum broker. Therefore, they may be actively part of the network topology. It is assumed that the sink has unlimited power and a number of cognitive transceivers, enabling it to transmit and receive multiple data flows concurrently.

IV. SENSING MODEL

The scenario we consider is sketched in Figure and comprises two low-power and duty-cycled sensor nodes, *S*1 and *S*2, that communicate over an unlicensed channel: packets generated by *S*2, the transmitting node, need to be delivered to the receiver *S*1. Even though we focus on this single link, the two nodes might be part of a larger mesh network with arbitrary topology.

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The same channel is also used by a set of other devices *I*1, *I*2, . that induce interference to sensor communications: this might cause loss of packets, requiring retransmissions and thus increasing energy consumption.

At a certain time instant the considered channel can be in two different states: *Busy* if some of the interfering devices is transmitting or *Idle* otherwise. We describe channel occupancy using a simple two-state semi-Markov model: busy periods last for the time required to carry out packet transmissions while the length of idle periods follows a certain probability distribution function *FT*I (*t*I).

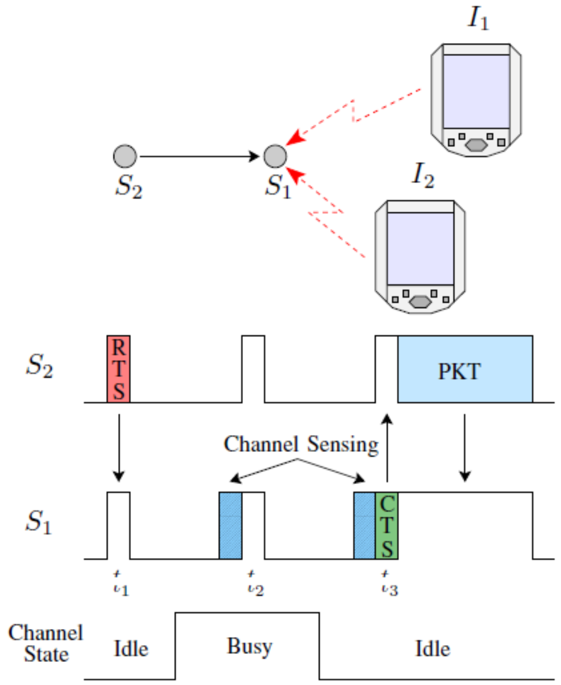

Figure 4. Channel sensing scenario

This model has been proposed in is based on the stochastic analysis of WLAN traffic patterns in the 2.4 GHz ISM band. The average duration of busy and idle periods is respectively equal to E[*TB*] and E[*TI*] and the channel occupancy is defined by the parameter:

$$\rho = \frac{E[TB]}{[E[TB]+E[TI]]}, \rho \in [0,1] \quad (1)$$

denoting the average fraction of time during which the considered frequency band is on the busy state. For the sake of simplicity and without loss of generality we assume that *S*1 and *S*2 are synchronized and periodically wake up at defined time instants *ti*: a short preamble scheme like the one implemented in X-MAC could be alternatively adopted in unsynchronized networks. A packet transmission among the two nodes involves a simple handshake procedure (see Figure 1): *S*2 first sends an RTS (Request To Send) to *S*1; *S*1 senses the channel before the upcoming wake-up period. If the channel is sensed idle, a CTS (Clear To Send) is sent back to *S*2, both nodes keep their radio active and the packet transmission starts. Otherwise nodes enter in low-power mode and the channel is sensed again in the next wake-up period.Note that since interference corrupts packets at the receiver side, there is no need for *S*2 to perform interference detection: *S*2 might eventually perform carrier sensing (using matched filter detection, thus achieving reliable outcomes with very limited energy requirements) in order to prevent that its RTS/packet collides with transmissions of neighboring nodes. We assume that the channel noise as well as the superposition of noise and interfering signals are both perceived by *S*1 as white Gaussian processes with average power respectively equal to σ2 0 and σ2We further suppose that the state of the channel does not change while these are gathered.Sensing is prone to errors: these might originate missed opportunities or cause loss of packets that will have to be retransmitted. Nodes normally operate in low-power mode and activate their radio unit only at wake-up instants. Energy consumption for exchanging a packet is determined by the energy required for channel sensing and the energy needed to transmit and receive packets and control messages (RTS/CTS). We assume that transmitting or receiving one bit and collecting a single channel sample *xi* result in the same elementary energy cost *Eu*. We further suppose that while receiving packets or idle listening nodes consume the same amount of energ.[13].

V. SPECTRUM SENSING FOR SPECTRUM SHARING

Detection of any phenomenon, based on stochastic data, can lead to errors in decision. When a PU is present, the sensing device could declare that it is not present, leading to a miss, which is the complement of detection. Similarly, when a PU is absent (or spectral hole), the sensing device could declare that a PU is present, leading to a false alarm. If a sensing device is designed to control one type of error, say, the probability of miss , which is One minus the probability of detection , below a specified value, the other probability of error, the probability of false alarm , is determined by the quality of the received signal and the noise in the system. From a PU point of view, a larger probability of detection would provide it with better protection, as the chance of a SU transmitting while the PU is present will be less. From a SU point of view a low probability of false alarm is better, as it provides a SU with more access. It is interesting that, depending on the values of these probabilities, one can classify the sensing system in three different categories as *Conservative System* which has an opportunistic spectrum utilization rate less than or equal to 50% and a probability of interference less than 50% that is . *Aggressive System* which expects to achieve more than 50% opportunistic spectrum utilization while maintaining less than 50% probability to interfere with the PU. *Hostile System* that targets more than 50% opportunistic spectrum utilization and is likely to cause interference to the PU with a probability greater than or equal to 50% . Furthermore, according to the nature of sensing techniques we can divide the sensing systems into two major groups: *Blind Sensing* that does not rely on any target signal features, like energy detection and autocorrelation detection or *Signal Specific Sensing* that utilizes specific target signal features, like matched filter detection and cyclo stationary detection. On the other hand, IEEE 802.22 standard proposal mentions that no specific spectrum sensing technique is mandatory in the standard and designers will be free to implement whatever spectrum sensing technique they choose as long as it meets the specified sensing requirements

Energy aware sensing

High energy budgets will result in accurate sensing outcomes but on the other hand, investing too much on this task might not be worth if interfering signals are sporadic or are perceived with very high power and are thus easy to detect.

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Furthermore, in order to achieve the highest energy efficiency, the sensing energy budget should be dimensioned accounting for the size of transmitted packets. The loss of long packets caused by sensing errors results in costly retransmissions and has to be avoided, by achieving sensing outcomes as reliable as possible; when transmitting shorter packets instead, lower energy budgets might originate sensing inaccuracies but result in lower overall energy consumption. It should be noted that this problem is of extreme interest for wireless sensor networks. consumption. It should be noted that this problem is of extreme interest for wireless sensor networks.Packets can be as small as a few tens of bytes1 therefore selecting the right amount of energy devoted to spectrum sensing might improve the energy efficiency [12]

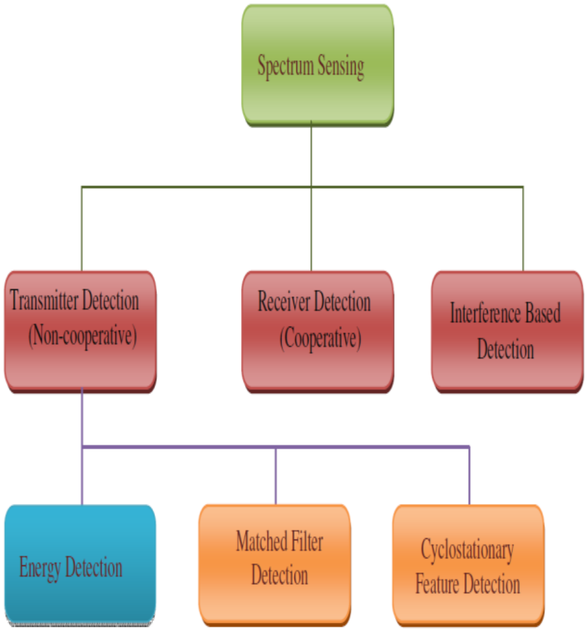

Figure 5 .Detection Techniques

Transmitter detection (Non co-operative)

In transmitter detection each CR must independently have the ability to determine the presence or absence of the PU in a specified spectrum.

Cyclo stationary

If a signal exhibits cyclostationary properties, its presence could be detected even in low SNR because CD is capable of differentiating the primary signal from the interference and noise. A signal is cyclo stationary, if its autocorrelation is a periodic function. By searching for the peak in the spectral correlation function, the presence of the signal can be identified. It is more robust as noise does not possess any cyclic property whereas different modulated signals have different unique cyclic frequencies.

Matched Filter Detection

The MFD method provides coherent detection and gives the best performance in terms of signal power to noise power ratio (SNR) as the secondary user receiver assumes the exact knowledge of the signal arriving from the transmission of a primary user. This means necessity of having exact knowledge of the modulation scheme employed by the primary transmitter, time synchronization of arriving symbols, and the channel parameters and if this information is not correct, the MFD performs poorly. In many practical scenarios, such exact knowledge is unavailable and hence it may not be realizable. Of course, the main advantage of MFD is that it needs less time to determine the presence of a PU signal with acceptable probabilities of errors tolerance, when compared to other methods. However, a significant drawback of a matched filter is that a cognitive radio would need a dedicated receiver for every primary user class. The

drawback is that CD is more complex to implement and requires the knowledge of modulation format .We can say CD method, as well as MFD technique, are good to be used in high processing power systems. For more efficient and reliable performance, the enhanced feature detection scheme, combining cyclic spectral analysis with pattern recognition based on neural networks. An Eigen Value Detection is not computationally complex and primary user waveform information is not required. EVD is based on random matrix theory and autocorrelations are applied on received signal samples thereby estimating the covariance matrix. Then, the maximum eigen value of the covariance matrix is compared with predetermined threshold value to determine primary user presence; it has been shown that at lower value of SNR, EVD has even better results compare to MFD, ED and CD.

Energy Detection

Energy detection (also denoted as non-coherent detection), is the signal detection mechanism using an energy detector (also known as radiometer) to specify the presence or absence of signal in the band. The most often used approaches in the energy detection are based on the Neyman-Pearson (NP) lemma. The NP lemma criterion increases the probability of detection_(p_d) for a given probability of false alarm(p_{fa}).It is an essential and a common approach to spectrum sensing since it has moderate computational complexities, and can be implemented in both time domain and frequency domain. To adjust the threshold of detection, energy detector requires knowledge of the power of noise in the band to be sensed. Compared with energy detection, matched filter detection and cyclo stationary detection require a priori information of the PUs to operate efficiently, which is hard to realize practically since PUs differ in different situation. Energy detection is not optimal but simple to implement, so It is widely adopted. The signal is detected by comparing the output of energy detector with threshold which depends on the noise floor

Receiver Detection (Cooperative Detection)

A collaborative spectrum sensing method has been first proposed by Ghasemi and Sousain CR cooperative spectrum sensing occurs when a group or network of CRs share the sense information they gain for PU detection. This provides a more accurate spectrum sensing over the area where the CRs are located. Cooperative spectrum sensing plays a very important role in the research of CR due to its ability in improving sensing performance especially in the fading, shadowing and noise uncertainty Figure 5 illustrated multipath fading, shadowing and receiver's uncertainty. As shown in the figure, CR1 and CR2 are placed inside the transmission range of the PU transmitter (PU TX) while CR3 is outside the range. Due to multiple attenuated copies of the PU signal and the locking of a house, CR2 experiences multipath and shadow fading such that the PU's signal may not be correctly detected.

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Moreover, CR3 suffers from the receiver uncertainty problem because it is unaware of the PU's transmission and the existence of the primary receiver (PU RX). As a result, the transmission from CR3 may interfere with the reception at PU RX. If CR users, most of which observe a strong PU signal like CR1 in the figure, can cooperate and share the sensing results with other users, the combined cooperative decision derived from the spatially collected observations can overcome the deficiency of individual observations at each CR user

Interference Based Detection

Under the assumptions that if a signal *A* can interfere with signal *B*, then signal *B* is within the communication range of signal *A*. A signal can be detected by checking the interference with the detector's signal.

VI. EVOLVE TO BUILD COGNITIVE RADIO

The term **radio** refers to the wireless transceiver device, used the Radio Frequency (RF) as a part of the electromagnetic spectrum to transfer of information. Traditional Hardware Defined Radio (HDR) can perform only a single or a very limited set of radio functionality, and can only be modified through physical intervention, all of modulation and demodulation is performed in the analog domain. This results in higher production budgets and smallest flexibility in supporting multiple signal standards. Over the past two decades, analog radio systems are being substituted by digital radio systems for several radio applications in military, civilian and commercial spaces. As a result, Mitolain vented the idea of Software Defined Radios (SDR).SDR Forum defines SDR technology as "radios that provide software control of a variety of modulation techniques, wideband or narrowband operation, communications security functions (such as hopping), and waveform requirements of current & evolving standards over a broad frequency range."

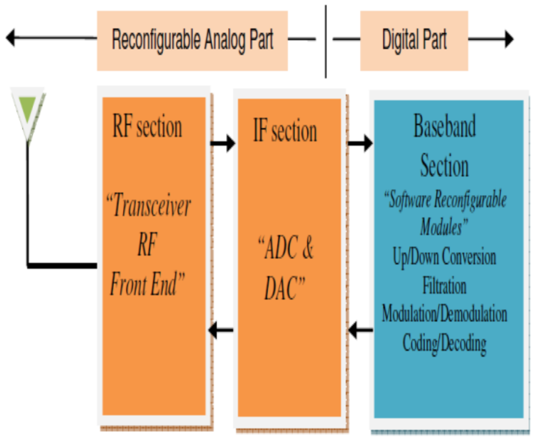

Figure 6.SDR Transceiver

SDR technology facilitates implementation of some of the radio functionality such as modulation/demodulation, signal generation, coding etc. in software modules running on a common hardware platform. SDR contains the same basic functional blocks as any other digital radio, but most, if not all, are implemented in software instead of hardware (e.g. mixer, filters, modulators, demodulators). SDR architecture (a.k.a. physical layer) consists of three main units, which are software tunable RF front end, wideband Analog to Digital Converter (ADC) and Digital to Analog Converter (DAC) conversion the implementation of the Intermediate Frequency (IF)section and software reconfigurable digital baseband.[11]

VII. CONCLUSION

In this paper a review of the CRs technology was presented. Energy Signal Detection is introduced as a figure of merit on which to base quantitative assessment of a radiometer's design including its calibration architecture and algorithm. The problem of the spectrum detection schemes was formulated which include Energy detection in time and frequency domain. Energy detection has been adopted as an alternative spectrum sensing method for CRs due to its simple circuit in the practical implementation and no information requires about the signal needed to detect. In this review, we have argued that cooperative spectrum sensing, when implemented appropriately, would yield better sensing performance and better throughput in CR networks. We have also indicated the distributed detection algorithms in wireless sensor networks form the basis for cooperative sensing in CR networks. Once we have an appropriate model for observations that sense the presence or absence of a PU in a CR, the results surveyed in this paper are directly applicable to cooperative spectrum sensing. Networks. We focused on an energy constrained system comprising two sensor nodes that avoid interference generated by co-located devices by opportunistically exploiting white spaces in the time domain. packets used by sensors at the transport layer we computed the optimal parameters of the algorithm used for spectrum sensing: these minimize the average energy required for the successful delivery of a packet. We have shown that our cross layer approach outperforms traditional sensing algorithms that do not account for the short length of packets commonly used in sensor networks. Our results further outlined that avoiding interference in the time domain might be an effective and energy efficient solution only if interfering transmissions are sporadic in time: for heavily interfered channels, different interference avoidance schemes for instance implementing channel surfing will have to be adopted. We are currently working on the implementation of our scheme on TMote Sky sensor nodes.

REFERENCES

[1] Linda Doyle, "Essentials of cognitive radios",Cambridge wireless essentials series, Cambridge university press, pp. 96-105, 2009.

[2] Yucek and Arsalan, "A survey of spectrum sensing algorithms for cognitive radio applications", IEEE Communication Surveys & Tutorials, vol. 11, no. 1, pp. 117-122, first quarter, 2009.

[3] Simon Haykin, "Cognitive radio: Brain-empowered wireless communications", IEEE J. Selected Areas Communications, vol. 23, no. 2, pp. 201-220, Feb. 2005.

[4] Beibei Wang and K. J. Ray Liu, "Advances in Cognitive Radio Networks: A Survey", IEEE J. of Selected Topics In Signal Processing, Vol. 5, NO. 1, February 2011.

[5] L. Stabellini, J. Zander, "Interference Aware Self-Organization for Wireless Sensor Networks: a Reinforcement Learning Approach", in Proceedings of the 4*th* annual IEEE Conference on Automation Science and Engineering (CASE 2008), 2008.

[6] S. Geirhofer, L. Tong, B. M. Sadler, "Dynamic Spectrum Access in the Time Domain: Modeling and Exploiting White Space", in IEEE Communication Magazine, Vol. 45, No. 5, May 2007.

[7] A. Ghasemi, E. S. Sousa, "Spectrum Sensing in Cognitive Radio Networks: Requirements, Challenges and Design Trade-offs", in IEEE Communications Magazine, Vol. 46, No. 4, April 2008.

[8] G. Ganesan, Y. G. Li, "Cooperative Spectrum Sensing in Cognitive Radio Networks", in Proceedings of IEEE International Symposium on New Frontiers in Dynamic Spectrum Access Networks (DySPAN), 2005.

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Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

[9] R. Chen, J.-M. Park, K. Bian, “Robust Distributed Spectrum Sensing in Cognitive Radio Networks“, in Proceedings of 27*th* IEEE Conference on Computer Communications (INFOCOM), 2008.
[10] S. Byun, I. Balasingham, X. Liang, “Dynamic Spectrum Allocation in Wireless Cognitive Sensor Networks: Improving Fairness and Energy Efficiency”, in *Proc. IEEE VTC 2008*, pp. 1-5, Sep. 2008.
[11] Mahmood A. Abdulsattar and Zahir A. Hussein “Energy detect technique for spectrum sensing in cognitive radio: a survey” . International Journal of Computer Networks & Communications (IJCNC) Vol.4, No.5, September 2012.
[12] Luca Stabellini and Jens Zander “Energy-Aware Spectrum Sensing in Cognitive Wireless Sensor Networks: a Cross Layer Approach”. IEEE Communications Society subject matter experts for publication in the WCNC 2010 proceedings.
[13]. Farrukh Javel,Imran Shafi and Asad Mahmood “ Novel Radio Mode Identification Approach for Spectrum Sensing in Cognitive Radios”. International Journal of Communication Networks and Information Security (IJCNIS) Vol. 4, No. 2, August 2012.

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