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# Survey of Energy Efficient Spectrum Sensing in Cognitive Radio Network

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**Abstract:** Energy Efficient scheme in Cognitive radio networks (CRNs) has many advantages compared to the traditional networks. But the dynamic allocation of spectrum by enabling unlicensed users to use the licensed spectrum in a proficient manner is difficult for dynamic spectrum access. In this paper , we analyze and compare some of the existing works on energy efficient spectrum sensing in CRNs, We categorize the works as Energy based spectrum sensing scheme, Energy based MAC Scheme, Clustering,Resource allocation,green energy powered CR and Quality of service.We also present the advantages and disadvantages of these techniques and suggest a best energy efficient approach based on the observation.

**Keywords:** Cognitive Radio, MAC protocol, Spectrum Sensing, Quality of Service.

## I . INTRODCUTION

In current recent years the cognitive radio network for spectrum usage is highly increased in commercial and social life. Due to the reason Traffic load for spectrum usage is high for assign the bandwidth to the user. Where RF spectrum is to allocate the service in frequency at 3 kHz to 300GHz for licensed primary user and few can used for unlicensed user. Statistics from Federal Communication Commission uses low ranges 15% to 85% is assigned wireless spectrum.

According to a CR is a radio that can change its transmitter parameters based on interaction with the environment in which it operates. It refers to the ability of the CR to sense and capture spectrum-related information such as the set of frequency bands that are not in use by the PUs. This capability requires sophisticated techniques which capture the temporal and spatial variations of the radio environment and typically involves (a) spectrum sensing, (b) spectrum analysis, (c) spectrum decision, and (d) spectrum sharing.

During spectrum sensing, the CR monitors the available spectrum bands to detect if they are in use by the PU and hence detect free channels. Through spectrum analysis, the characteristics of the free channels that are detected through spectrum sensing are estimated and then a channel that best meets the SU's communication requirements is selected.

In spectrum decision, once the CR determines the transmission mode, data rate, and bandwidth required for transmission, it determines the spectrum it will use for transmission Power control is used for both opportunistic spectrum access and spectrum sharing CR systems for finding the cut-off level in SNR supporting the channel allocation and imposing interference power constraints for the primary user's protection respectively. A classic work in studying power allocation schemes to maximize the capacity of cognitive radio networks is. In a joint power control and spectrum sensing is proposed for capacity maximization.

**Spectrum Management**

Capturing the best available spectrum to meet user communication requirements, while not creating undue interference to other (primary) users. Cognitive radios should decide on the best spectrum band (of all bands available) to meet quality of service requirements; therefore, spectrum-management functions are required for cognitive radios. Spectrum-management functions are classified as

- Spectrum analysis
- Spectrum decision

The practical implementation of spectrum-management functions is a complex and multifaceted issue, since it must address a variety of technical and legal requirements. An example of the former is choosing an appropriate sensing threshold to detect other users, while the latter is exemplified by the need to meet the rules and regulations set out for radio spectrum access in international (ITU radio regulations) and national (telecommunications law) legislation.

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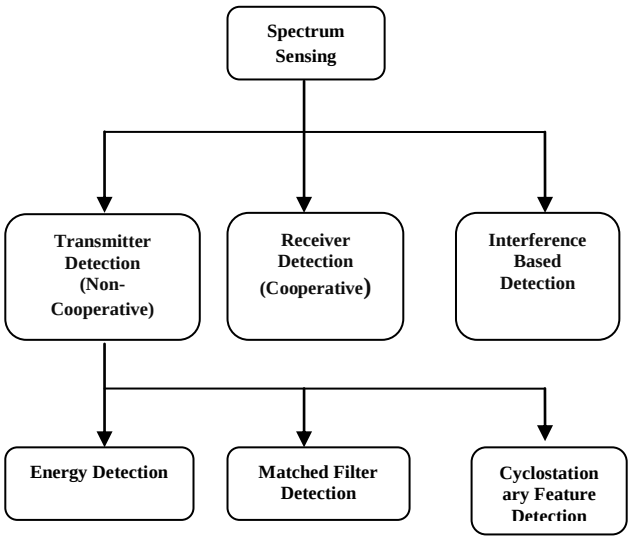


**Spectrum Detection Techniques**

## II. RELATED WORK

The contributions of various scholars are studied for survey and analyzing the merits and demerits in order to enhance the consequences for making the system work better.

**Zhiping Shi[1]** describes the optimal sensing time and power allocation scheme for energy efficient CRN. The author proposed a MSSS scheme subject to the constraints of average transmit power of SU and the interference power caused to PU. One algorithm that acquires the optimal sensing time and power allocation has also been proposed. The performance of the system using MSSS scheme has been evaluated by changing the number of channels sensed, the average tolerable interference power by PU, the distribution of channel usage state of PU and the accuracy of channel gain estimation. The system consists of a primary link (PU-Tx to PU-Rx) and a secondary link (SU-Tx to SU-Rx), and each of them consists of M channels. If the PU transmits complex-valued phase-shift keying signals and the noise received at the SU is assumed to be independent and identically distributed circularly symmetric complex Gaussian with zero mean and variance considering the fact that the detection result of a frequency band is binary (idle (H0,k) or active (H1,k)),the probability of false alarm . The proposed work was reliable by gathering global snapshots and the protocol required only less energy and storage.

**Faroq Awin[2]** et al focuses on impact of varying the transmission power on the probability of false alarm of single CR has been investigated. The conventional method aims to assure that increasing transmission power is not always effective to meet probability of false alarm target. To meet the target, designing an optimal energy efficient CBSS that satisfies the sensing accuracy metrics has been considered. An iterative algorithm with low computational complexity has been proposed to jointly determine the optimal design parameters of CBSS system that maximize the energy efficiency while satisfying all detection accuracy metrics. The analysis of energy consumption reveals that the suggested technique can considers joint sensing time and data transmission time while the second variable considers the number of CR users. The objective function is the EE metric which is subjected to both the probability of detection and the probability of false alarm constraint.

**Chengyu Wun[3]** addressed that the energy harvesting strategy with the energy half-duplex constraint, which determines when and how long to harvest, and the access strategy to improve the secondary performance in an EHCRN.Initially the author focused on a three-mode-selection SST protocol to adapt the harvesting and access strategy during a frame based on a pre-defined save-ratio threshold and the residual energy of the battery. Furthermore, the noticeably the minimum save-ratio in the normal mode considering the EC-constraint.From the obtain results maximize the energy utilization efficiency (EE) of the secondary user by jointly optimizing the save-ratio and transmission power under both the EC-constraint and the minimum throughput constraint and determining the best save-ratio in closed-form and optimizing the power allocation using Dinkelbach method.

**Cheng Sunl [4]** addressed that the fair energy-efficient resource allocation for a cooperative Orthogonal Frequency Division Multiplexing (OFDM)-based cognitive radio network.. These methhods belongs to a category of indices for attaining better performance. The author noticed that The power efficiency is simultaneously taken into account to prolong the operating lifetime of networks and fairness based on the B-fair cost functions proposed In the resource allocation scheme has three types of wireless resources, power, subcarriers, relay nodes, among the primary and secondary systems while guaranteeing the fairness of resource allocation.The results of simulation reveal that the proposed method minimizing the cost of transmit power while fulfilling the rate constraints of both the primary and secondary system.By employing the Lagrangian dual technique for optimal resource allocation. where the secondary system assists the communication of primary system via acting as DF mode relays. In the proposed scheme, a class of 3-fair cost function was adopted to balance the energy efficiency and the fairness.

**LiFeng [5]** described that the censor-based cooperative spectrum sensing strategies, called adaptive energy efficient sensing in which both sequential sensing and censoring are employed aiming to reduce the sensing energyconsumption of secondary user relays . In AES an anchor secondary user requires cooperative sensing only when itself.The AES scheme to reduce the sensing overhead while satisfying a given sensing accuracy requirement. naturally integrate censoring, sequential detection and time optimization in AES, which can save

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energy. The author proposed a scheme for false alarm and detection probabilities over Rayleigh fading channels for AES, and then analyze the sensing energy overhead. with high reference positions The author proposed a technique by employing a novel sequential sensing policies to reduce the sensing energy consumptions while satisfying a given detection perfonnance requirement. The closed-form expressions of false alarm and detection probabilities of AES are derived over Rayleigh fading channels. The obtained results estimate the performance of the proposed technique by using a the minimization average sensing energy subject to a global probability of miss detection.

**Yan Jiao [6]** proposed a novel technique EERA method called TTCS based on a twotier GA to maximize the system downlink capacity in overlapping areas where heterogeneous PNets coexist with multiRATs. The first phase aims that maximize energy efficiency of the whole system. The genetic algorithm (GA), which is a search heuristic that mimics the process of natural evolution is an ideal search method to solve this complex optimization Problem for radio environment map to manage the resource allocation and network synchronization**.** The evaluation results showed that this method had better convergence because it could select good genes for the next population and could operate two-tier crossover after 900 iterations. The results also proved that the two-tier crossover genetic search scheme could find an optimal resource allocation solution.

**Satyam Agarwal [7]** et al discussed on three protocol variants of eDSA for the CR nodes. The proposed approach accounts for the realistic traffic and primary transmission characteristics, and the protocols are aimed at maximizing the SU channel utilization without degrading the PU performance below a predefined threshold. For neutralizing these high failure rates use Markov modeling, protocol performance in terms of goodput, energy efficiency, as well as PU collision ratio have been captured. Optimum data transmission and sensing parameters have been derived via two optimization formulations for maximizing respectively SU goodput and energy efficiency, The author proposed a N level optimization problems have been solved using branch-an dbound algorithm. To avoid time-consuming computation of the optimal operating parameters, a look-up table based approach coupled with augmented Lagrange pattern search algorithm is proposed, which can be easily implemented on simple hardware. A simple PU channel activity parameter estimation technique has also been presented, which is used for dynamically adjusting the SU operating parameters according to the PU traffic. The SU protocol performance have been studied by generating PU activity traces from real-time video call experiment and cellular band measurements. Numerical and simulation results confirm that the protocol performances are significantly better than the competitive DSA protocols. The proposed protocols and implementation techniques would be of interest for low-cost and energy constrained CRNs.

**Muhammad Usman [8]** et al described that the CR Network with disjoint subsets for each cluster of sensor nodes as a solution to the problem effective sensing achieved with high energy efficiency.. The scheme allows each The CRN is composed of ad hoc CRs assigning mobility to CRs to be more general, and infrastructure sensor nodes. An ad hoc CR, which is a cluster head is surrounded by a cluster of infrastructure sensor nodes within one-hop communication range of the CR, and each cluster is further partitioned into subsets. To achieve energy efficiency sleepwake scheduling for the subsets based on the statistical. The technique is based on Multiple subsets are created in a cluster and only one subset is active in sensing to reduce energy consumption. Here each actual sensor nodes for spectrum sensing are selected in the given active subset according to a separately proposed algorithm. In addition all the subsets including the one active subset switch to sleep mode for the duration of PU activity to achieve another reduction in energy consumption. A novel subset scheduling algorithm to achieve this goal is developed on the basis of PU statistics. As a result, the CRN with the proposed architecture consumes significantly less energy and incurs lower end-to-end delay in comparison with the SENDORA network and the CRN with the LEACH-C protocol.

**Jianqing Liu [9]** discussed that the future energy-efficient selection strategy for the SU to cooperate with the appropriate PU in CCRNs. The author noticed SU blindly follows PU's decision in cooperation process actively select the qualified PU to cooperate based on SU's energy concern. In order to achieve success applying backward induction and derived the optimal stopping rule for SU's selection strategy. Where CCRN architecture consisting of entities that can reliably and continuously sense the PUs' traffic demands. The SUs then query the sensing results from these entities and calculate the instantaneous cooperation-induced energy cost. Afterwards the SUs compare the current energy cost with the expected energy consumption and make the decision whether to stop and cooperate right away or not. Extensive simulations were conducted to study the impacts of different PUs' channel parameters on SU's decision strategy. SUs stop at the first time slot where the instantaneous cost is no more than the expected cost and then pick the PU with minimum traffic demand to cooperate compare the system performance of the optimal stopping rule with the greedy strategy to validate the benefit of our proposed strategy for the SU. The author deals with this issue and suggested an relay selection by jointly considering the energy efficiency for SU networks and PU networks.

**Daewon Jung[10]** described the improving the energy efficiency of IEEE 802.11 DCF-based cognitive networks while retaining high throughput performance. To accomplish allow a sender to determine the transmission order and transmit burst packets until the current frame ends. In this cognitive network, available transmission time for SUs is very limited and energy resources easily

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become overused owing to frequent contention among SUs and the power consumption of destination nodes. Author deals on energy efficiency is improved by allowing only the node that has grasped the medium to transmit a sequence of packets until the next spectrum sensing period. a sender decides the order of packet transmission by taking energy efficiency into consideration At the same time, all other nodes except intended receivers switch to sleep mode in order to significantly increase energy efficiency. It can be numerically derived using analytical model for power consumption and throughput performance under the proposed energy-efficient MAC protocol. Through various simulations, results showed that the proposed MAC protocol minimizes power consumption of IEEE 802.11-based cognitive nodes and also improves throughput performance. The proposed attempts to decrease the process overheads in coordinated messages and also minimizes the failures in processes during its synchronization with others.

**Subhankar Chatterjee [11]** addressed the challenges faced by the CR systems for spectrum management, dynamic spectrum access, secondary transmission. The author proposed a new spectrum sensing (SS) and sharing is considered in this work. System model is assumed to be a cognitive ad hoc network that consists of multiple secondary transmitter (ST) and receiver (SR) pairs sharing transmission over a spectrum with a primary network of single transmitter-receiver pair. Based on SS outcome, secondary users (SUs) either cooperate in primary user's (PU) transmission or proceed with its own transmission. The overall goal is to maximize energy efficiency for SU networks in terms of self and cooperative transmission. A set of optimal values for sensing duration, self and cooperative transmission power gains are calculated under the constraints of PU detection probability, SU power budget, PU and SU throughput. A large set of simulation results highlight the optimal performance gain of the proposed system.

**Satish Anamalamudi [12]** discussed that the traditional Node synchronization is crucial to provide cooperative cognitive communication in decentralized networks. The author proposed a new domino with time division multiple access based cognitive coordination function for cognitive control message exchange and distributed coordination function -based carrier sense multiple access with collision avoidance for directional data transmission. Our protocol provides strict node synchronizationthrough slot and frame synchronization-based TDMA control channel to exchange PU-free channel list and select rendezvous channel. The initial phase uses a CCC-based CR-MAC protocols design cognitive control channel in in-band or out-of-band for load balancing to avoid the high load collisions and enhance the performance of CSMA/CA protocol even with high traffic. The last phase need TDMA-based synchronized control channel and CSMA/CAbased directional data transmission. The obtained results in higher energy consumption and reduced network throughput that severely degrades the performance of the CR-MAC protocol. results shows the energy-efficient hybrid CCC-based CR-MAC protocol to avoid existing problems during control transmission. Subsequently, directional antenna-based data transmission is implemented which conserves node power consumption and enhance network throughput through spatial reuse.

**Anirudha[13]** et al conversed the necessity of checkpointing for delay, to stabilize wireless connectivity proposed a QoS based route management algorithm in cognitive radio networks which considers multiple QoS metrics such as transmission power, channel availability, PU presence, and link failure. where current model selects a routing path with low end-to-end transmission power, high probability of channel availability, low probability of PU presence and low ETX, to increase life span of network users, to decrease delay, to stabilize wireless connectivity and to increase throughput of the communication respectively based on the QoS level requested by a SU. There are many prevailing approaches on author idea first to Enable sureness in the sensing information by profile exchange mechanism combined with location services.second Lower down the excess overhead on the network by reducing number of control and profile exchange messages to a greater extent. And third Reduce the redundancy in profile exchange messages.

**Jian Chen[14]** explored the energy efficient cooperation mechanism in a spectrum sharing network for the primary system leases portion of a frame to the secondary system for its own traffic in exchange for the SUs assisting the transmission of the PU as relays. the authors formulate a joint optimisation ofrelay selection and power allocation under QoS requirements to improve energy efficiency. By employing a greedy spectrum sharing algorithm, the optimal relay selection, power and sharing time allocation are readily obtained.where the primary system are centralised cooperation decision process is performed at the PBS. the PBS has to inform all SUs of the cooperation decision by broadcasting the flag messages Success or Failure. If the flag message is 'Success', the corresponding SU participates in the cooperative relaying; otherwise, it remains silent and waits for the next transmission process. Considering the individual QoS requirement of each user a joint optimisation of joint relay selection and power allocation towards energy efficient communications is formulated. After employing the GSS algorithm, the optimal relay selection and power and sharing time allocation are determined. The scheme results are provided to demonstrate that significant EE improvement is achieved by the proposed GSS algorithm and that the network performance is enhanced.

**Tengyi Zhang [15]** study the problem of Cooperative Sensing Scheduling in the CRN with the objective of maximizing the energy efficiency of the CRN. The author propose the expected throughput and energy consumption

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of the CRN on basic tradeoff of CSS between achieving higher sensing accuracy and exploiting more spectrum opportunities. where analytical framework in different network scenarios for small-scale homogeneous networks to general heterogeneous networks.therefore M-convex concept to design an algorithm to solve the heterogeneous scenario optimally, and also present two heuristic algorithms which can greatly reduce the computational complexity. The proposed work able to detect the point on the curve ROC curve implies that achieving a higher individual probability of detection will also lead to a higher individual probability of false alarm, and such fact is well interpreted in the literature. When it comes to cooperative sensing, the relationship between the overall probability of detection and the overall probability of false alarm for a certain channel is not only determined by the detection threshold .where the numerical examples are provided to demonstrate that the performance loss of the proposed heuristic algorithms compared to the optimal one is small.

**Majed Haddad [16]** presented a mechanism which is helpful for a hierarchical concept in a power control game for energy efficient multi-carrier cognitive radio systems. In the proposed solution spectrum underlay concept used in which the PU experiences interference from the SU. Most of the current work has been focusing on the spectrum sharing between cognitive radio pairs, where cognitive radionodes dynamically detect spectrum holes of primary spectrum users and opportunistically utilize them in frequency and time.where system goes toward the vision of a fully coordinated cognitive radio multi-carrier network, whereby transmit powers are coordinated across the users. Results shown that each user is prone to interference from the other transmitter on the same carrier for the vast majority of cases there exists a natural coordination pattern where the PU and the SU have incentive choose their transmitting carriers orthogonally.

**Mohamed Kashef [17]** presented the novel effect of estimating the sensing-channel by the secondary source in a cognitive radio system. The proposed system uses one primary and one secondary source-destination communications pairs. The secondary source senses the primary activity imperfectly with certain missed detection and false alarm probabilities and it has also knowledge about the steady state statistics of the channel being busy by the primary source transmissions. The secondary source estimates the channel from the primary source to assess the reliability of the sensing decision. The channel is estimated opportunistically when the channel is sensed to be busy. Experimental results shows that obtaining the optimal transmission probabilities can be done through linear programing in the cases of no channel estimation and accurate channel estimation. In the case of opportunistic channel estimation, the system is modeled by a Markov chain and then the problem of finding the optimal transmission probabilities is formulated as an infinite linear program.

**S.M.Kamruzzaman[18]** addressed few related works concerned on frame aggregation and backup channel is being under taken in this research which reduces the overhead between the nodes during communication and save energy. When the sender and receiver for the multiple frames are same then at MAC layer frame aggregation is being carried out by combining ten data frame, this will reduce the overhead and save energy because without .adopting this technique every frame carries its own header and footer, but here the addition of one bit information in the first header carries the number of frame that are aggregated to the receiver The other factor that makes this approach more reliable is the availability of backup channel, if PU claims to acquire the channel at any instance during communication between SUs then without communication interruption the SUs shifts over the backup channel this will in turn save energy and make the protocol design more efficient.where three-state channel detection model in CRAHN enhances the throughput of the SU from any network can cooperate in performing ad hoc communication while maintaining fairness.

**Xueqing Huang et.al [19]** presented a green powered cognitive radio network. The concept of energy harvester has been proposed to capture and store ambient energy to generate electricity or other energy form, which is renewable and more environmentally friendly than that derived from fossil fuels. The author proposed a green energy source is ample and stable in the sense of availability, the cognitive radio network can be powered to opportunistically exploit the nderutilized spectrum by harnessing free energy without requiring energy supplement from external power grid or battery on achieving power aware functionality in the CR systems, and designing energy efficient wireless access systems via cognitive radio and and optimizing green CR networks.

**F. F.Qureshi [20]** explored the aggregates higher layer packets to minimize the amount of overhead. In ECRQ-MAC the advantages of TDMA and multichannel are being used to its dominance over single channel like increased throughput. The protocol has some functions perform the same task as in ECR-MAC but integrated QOS in it in order to achieve better result. The process time is divided into sensing window and the communication window. Sensing window is the ATIM packet time. A concept of prior or on demand route discovery and spectrum integration applied, this feature improves the communication establishment process where there is limitation of varying channel availability. Another important aspect that deals in this protocol is the division of traffic among the CR users in way that it acquires the knowledge of remaining battery life of the CR users put less traffic over less battery power available nodes.

## III. CONCLUSION

Based on the comparison of various Energy efficient spectrum techniques for CRN and the discussion of

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Energy based approach in the previous section, We can conclude that the spectrum sensing approach is the mostly used technique for frequency band selection and the common parameters for Energy efficient estimation include, Speed, accuracy of estimation, and Quality of service . In some cases, stability and connectivity are also taken into account. So we need an innovative technique like SoftwareDefinedRadio or Observe-orient-Decide Act to select the appropriate design parameters for energy efficient scheme thereby minimizing the overhead and Handoff delay and maximizing the throughput.

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## III. COMPARSION OF ENERGY EFFCIENT CRN TECHNIQUES

| S.No | Tittle | Type | Method | Results |
|---|---|---|---|---|
| 1 | Energy efficient cognitive radio network based on multiband sensing and spectrum sharing | Energy based scheme | The energy consumption on the spectrum sensing and data transmission to obtain optimal sensing time and power allocation for SU system with a fixed circuit power | Energy consumption and optimal sensing time |
| 2 | Designing an Optimal Energy Efficient Cluster-Based Spectrum Sensing for Cognitive Radio Networks | Energy based Clustering | To determine joint optimal sensing time, data transmission time, and the number of cognitive radio (CR) users that maximize energy efficiency of the system. | Maximize the energy efficiency while satisfying all detection accuracy metrics |
| 3 | Energy Utilization Efficient Frame Structure | Energy based scheme | Proposes a novel saving sensing transmitting (SST) frame structure | Optimizing the power allocation |

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| | for Energy Harvesting Cognitive Radio Networks | | for energy harvesting cognitive radio networks (EHCRNs). As in the conventional SST, the proposed SST takes the energy causality constraintinto consideration | using Dinkelbach method |
| 4 | Fair Energy-Efficient Resource Allocation for Spectrum Leasing in Cognitive Radio Networks | Energy based Resource allocation | An adaptive subcarrier assignment and fair power allocation scheme that minimize the fair cost function of average relay powers for wireless cooperative cognitive radio networks | To balance the energy efficiency and the fairness |
| 5 | Energy-Efficient Cooperative Sensing Scheme based on Censoring for Cognitive Radio Networks | Energy based scheme | Aiming to reduce the sensing energy consumption of secondary user relays for novel censor-based cooperative spectrum sensing strategies, called adaptive energy efficient sensing | Reduce the sensing energy consumption |
| 6 | Energy-Efficient Resource Allocation for Heterogeneous Cognitive Radio Network based on Two-Tier Crossover Genetic Algorithm | Energy based scheme | Focus on EERA of SNets in the overlapping region of heterogeneous PNets coverage. | Multi-radioaccess technology can improve network capacity, optimal solution in terms of the power and bandwidth. |
| 7 | eDSA: Energy-Efficient Dynamic Spectrum Access Protocols for Cognitive Radio Networks | Energy based scheme | Energy-efficient dynamic spectrum access (DSA) protocols for secondary user (SU) communication over a single primary user (PU) channel with respect to different back-off strategies and SU packet lengths | low-cost and energy constrained CRNs. changing PU traffic load for optimized spectrum access performance |
| 8 | Energy-Efficient Infrastructure Sensor Network for Ad Hoc Cognitive Radio Network | Energy based scheme | The CRN is composed of ad hoc CRs, assigning mobility to CRs to be more general, and infrastructure sensor nodes. An ad hoc CR, which is a cluster head, is surrounded by a cluster of infrastructure sensor nodes within one-hop communication range of the CR, and each cluster is further partitioned into subset | Reduce the energy consumption and the end-to-end delay |
| 9 | An Energy-Efficient Cooperative Strategy for Secondary Users in Cognitive Radio Networks | Energy based scheme | Optimal stopping theory where SUs observe PUs in time sequence and then make decisions whether to stop observation and cooperate right away or wait till next time slot to repeat the same process | Reduces the spectrum sharing problem |
| 10 | Energy-efficient MAC Protocol for IEEE 802.11-based Cognitive Radio Networks | Energy based MAC | An energy-efficient medium access control protocol that allows a single SU sender to transmit a sequence of packets to its intended receivers until the next spectrum sensing interval begins. | Reduces power consumption while retaining high throughput performance. |
| 11 | On Optimal Sensing Time and Power Allocation for Energy Efficient Cooperative Cognitive Radio Networks | Energy based scheme | To maximize energy efficiency for SU networks in terms of self and cooperative transmission. | Cooperative transmission Power allocation for energy efficient system design |
| 12 | Energy-Efficient Hybrid CCC-Based MAC | Energy based MAC | To reduce power consumption due to link access overhead, | To avoid interference due to multichannel |

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| | Protocol for Cognitive Radio Ad Hoc Networks | | multichannel hidden terminal, deafness, and spectrum mobility. Antenna index numbers through Global Positioning System and angle-of-arrival estimation are used for directional data transmission | hidden terminals |
| 13 | Energy-Efficient QoS based Route Management in Cognitive Radio Networks | Energy based QOS | Proposed model makes use of functionalities of profile exchange mechanism and location services. The QoS routing algorithm contains each licensed user (PU) exchanges properties of the channels it owns with a Central Entity. | Increase the throughput of the communication |
| 14 | Energy efficient relay selection and power allocation for cooperative cognitive radio networks | Energy based scheme | A joint optimisation of relay selection and power allocation under QoS requirements to improve energy efficiency | The optimal relay selection power and sharing time allocation |
| 15 | Cooperative Sensing Scheduling for Energy-Efficient Cognitive Radio Networks | Energy based scheme | Cooperative Sensing Scheduling in the CRN with the objective of maximizing the energy efficiency of the CRN. guaranteeing the optimal solutions to be found small-scale homogeneous networks to general heterogeneous networks | Maximizing the expected throughput of the CRN |
| 16 | Spectrum Coordinationm in Energy Efficient Cognitive Radio Networks | Energy based Spectrum | Address a Stackelberg game model in which individual users attempt to hierarchically access to the wireless spectrum while maximizing their energy efficiency | Optimizes the energy efficiency while still maximizing the throughput at the equilibrium. |
| 17 | Energy-Efficient Transmission Control in Cognitive Radio Networks with Channel State Information | Energy based scheme | Estimating the sensing-channel from the primary source to the secondary source which helps in determining the reliability of the sensing decision | Allowable average failure probability energy efficiency, spectrum efficiency, bandwidth |
| 18 | MC-MAC:An Efficient Multichannel MAC Protocol for Cognitive Radio Ad Hoc Networks | MAC Energy based | An efficient multichannel MAC protocol to address the dynamic availability of the spectrum and which orientates to the fairness in resource sharing | Providing a higher fairness than MAC while maintaining a high throughput |
| 19 | On Green Energy Powered Cognitive Radio Networks | Green Energy based | The green powered cognitive radio network. The concept of energy harvester has been proposed to capture and store ambient energy to generate electricity or other energy form, which is renewable and more environmentally friendly than that derived from fossil fuels | Green energy powered CR increases the network availability |
| 20 | Energy Efficient Cognitive Radio MAC Protocol for Adhoc Networks | Energy based | The protocol uses an adaptive aggregation technique, which aggregates higher layer packets to minimize the amount of overhead a multichannel MAC protocol, which uses frame aggregation and backup channel schemes | Reduce communication overhead |