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# A Review on Energy Efficient Cooperative Spectrum Sensing Techniques and Clustering Schemes in CRN

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***Abstract :*** In mobile communication systems, with the advancement of new industries, online businesses, medical facilities, and scientific technologies has increased the requirements of the spectrum. This could become possible by using a technique called Cognitive Radio (CR) which reduces the probability of false alarm in multi-fading networks. The CR is an intelligent technology which is used for spectrum detection. This technique senses the vacant channels and detects the availability of the Licensed User (LU). In this study, an overview of Energy efficient CSS techniques along with clustering schemes have been discussed. The overview of the CR network along with non-cooperative and cooperative spectrum sensing is also discussed. The paradigm of clustering is grouped to minimize the collisions and computational costs to enhance the detection performance. In fact, clustering orders nodes into groups, and clusters, to supply network better realization improvement. Clustering challenges are also discussed in this paper. In addition, a brief explanation of Cooperative Spectrum Sensing, Cluster-Based CSS, Fusion Schemes, Cooperative Spectrum Sensing, and Energy Efficiency are included. In the future, research can be related to different hybrid techniques for better communication systems in terms of time, codes, frequency, angle, and space.

***Keywords****:* Cognitive Radio, Energy Efficient, Cooperative Spectrum Sensing, Cluster-Based CSS, Fusion Schemes.

**Introduction:**

The development of mobile technologies has increased the requirement of the spectrum. The advancement of industrial, scientific, and medical (ISM) technologies has enhanced the shortage of bandwidth which can be resolved using spectrum sensing[1]. The wireless networks are managed by governmental organizations, which results in low bandwidth consumption. According to the research by the Federal Communications Commission (FCC), mostly 15% to 85% of the time, the allotted spectral bands are not utilized. These bands are not efficiently used based on their geographical region. The spectral shortage is due to not utilizing the spectral band properly[2].

The advanced spectrum allocation of the licensed user (LU) causes difficulty in finding the idle spectrum bands. Therefore, to utilize the spectrum more precisely unlicensed user (UU) should be allowed to use the idle LU channel without interfering with them. This technique will improve the spectral usage, so to find the idle spaces in the channel Cognitive Radio(CR) method should be used[3]. This method will enhance bandwidth utilization. CR adapts to the environment and accordingly identifies the idle channels.

CR is a smart technology that maximizes the channel utilization. This scheme uses dynamic access of the spectrum and the unutilized LU bands are called as the spectrum hole or white spaces. These white spaces are now accessed by the UU[4]. The main challenge in this scheme is to detect the existence or non-existence of LU. The UU should vacant the path before the LU's arrival and UU should be transferred to the idle channel to avoid interfering with the LU.

The new digital development enhances the requirement for a new system that provides inter-connections of the digital devices/objects which have the ability to transfer information over the wireless network without any human or computer intervention that is called as Internet of Things (IoT)[5]. The rapid growth of the IoT has increased the spectrum requirement so Cognitive Radio Networks (CRNs) are introduced for allocating the packet generated by the IoT devices.

The concept is Cognitive Radio Internet of Things (CRIoT)[6] which avails the idle spectrum as needed by the device without interfering with other devices. The CR uses spectrum sensing techniques for detecting unutilized spectrums. Cyclostationary, Energy, and Matched Filter Detections are the schemes through which idle bandwidths are detected. Energy Detection Scheme is the simplest technique to implement and it is widely used. This technique requires predefined users information of the LU, due to its shortcomings of the technique a new method is introduced known as the Cooperative Spectrum sensing (CSS)[7]. This CSS technique overcomes the shadowing and shrinkage effects that affect the individual CR-sensing user. Hence, it improves the spectrum detection performance[8].

This scheme has a huge overhead of transmission like controlling the data more efficiently, detecting the latency of time, and collecting indurations from fusion centers (FC). Clusters rely on cooperative spectrum sensing(CSS) system which increases the detection performance of all UU as these UU are combined into small groups known as clusters and each cluster has a cluster head (CH) which sends the data to the FC[9]. Using this system time over-heads are reduced, the probability of false alarm are decreased, and collisions of packets are also minimized. The network performance is improved as clusters rearrange the nodes. In this paper, we are briefly discussing Spectrum sensing and its different techniques along with CSS.

The objective of this paper is planned with an overview of Energy efficient (EE) CSS methods with clustering schemes. EE refers to the ability of the network to transmit and receive data while consuming minimal energy. Energy-efficient CSS aims to reduce the energy consumption of cognitive radio nodes while maintaining detection performance. Cluster-based Cognitive Spectrum Sharing (CSS) which is a technique used in CR networks to enable efficient utilization of the available spectrum. In the I section contains the architecture of cognitive radio, its functioning cycle, and the CRN architecture. In the III section includes the description of spectrum detection methods and challenges in CR which is followed by fusion schemes. The IV section is explaining the Cluster-based cooperative spectrum sensing (CSS) with its EE. In the V section system model is evaluated. Additionally, Clustering objectives in CRN are discussed. The VI section is the conclusion of the paper.

**Architecture of Cognitive Radio**

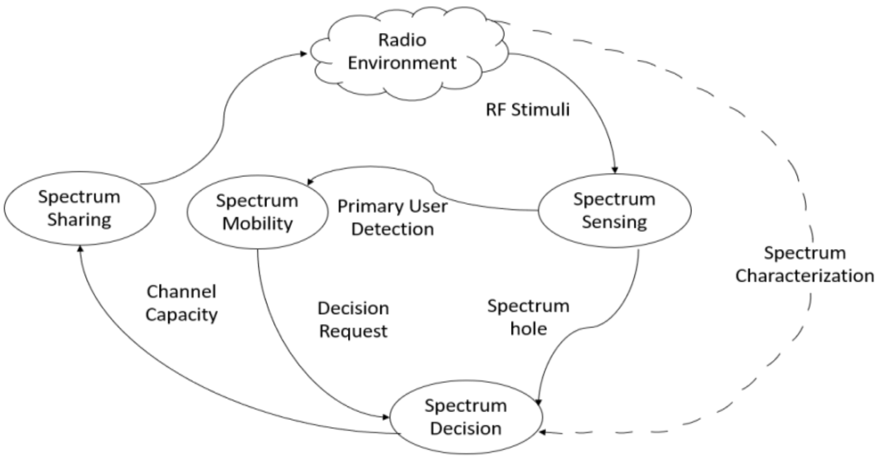


**Figure 1. Architecture of Cognitive Radio[10]**

The architecture of the cognitive cycle involves decision-making capability, spectrum mobility, spectrum detection, and spectrum sharing which increases the performance of the network. The Cognitive radio is an advanced wireless communication system. This system has the ability to sense the environment which makes it more efficient for detecting the communication signals without interfering with licensed users[11]. This system consists of many cognitive radios which sense its neighboring wireless networks and systems. This Cognitive Radio system consists of three main components:

| | |
|---|---|
| Base station (BSt) | A fixed transmission station which contains many receiving and transmitting antennas. Also can be called as the controller of cellular wireless communication traffic. |
| Backbone networks | A mechanism which interconnects n-number of networks which provides exchange of information/data between different networks and subnetworks. |
| Mobile Station | A wireless communication moving device which adapts all the broadband systems |

**Table 1. The components of CR system.**

Cognitive radio networks architecture can be broadly divided into three parts:

1.***Infrastructure of CRN***

In CRN infrastructure, BSts are present through this wireless communication system and can connect with other wireless communication devices which are having CR capabilities. When devices communicate across cells, the BSt can operate as a router.

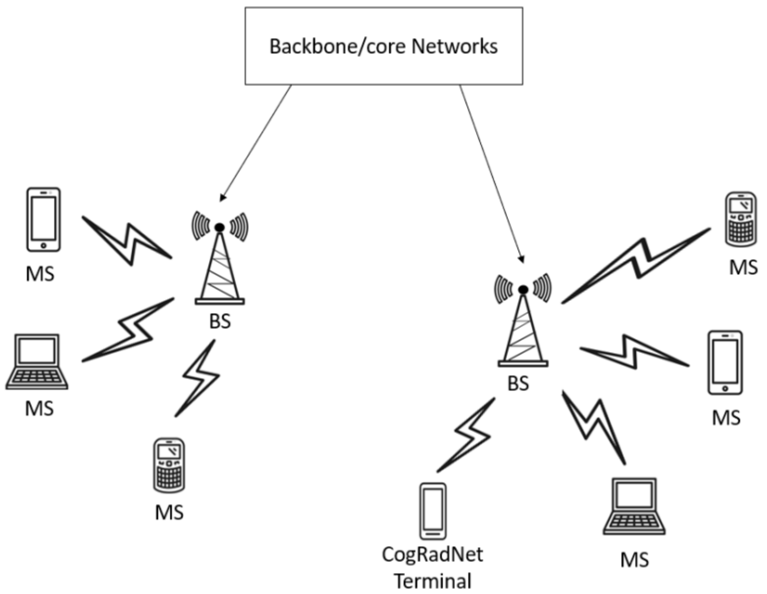


**Figure 2. Infrastructure of CRN [10]**

2. ***The AdHoc Architecture***

In this architecture, Bts are not required. The wireless communication devices can create a connection between them using various protocols.

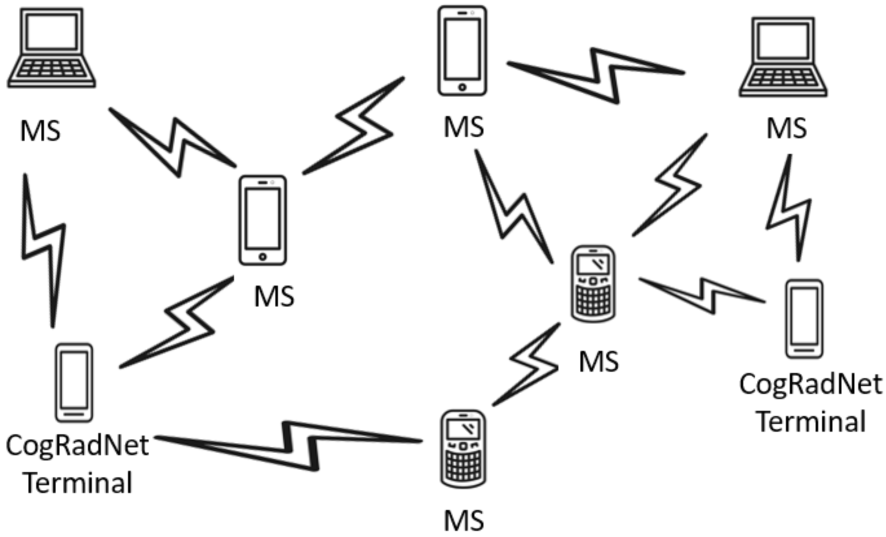


**Figure 3. AdHoc Architecture [10]**

3. ***Mesh Architecture***

In this architecture, the mesh routers are connected with each other and act as the backbone of the infrastructure[11]. The wireless devices are only connected to the Bts through adjacent devices, where the Bts act as the router for forwarding the data packets.

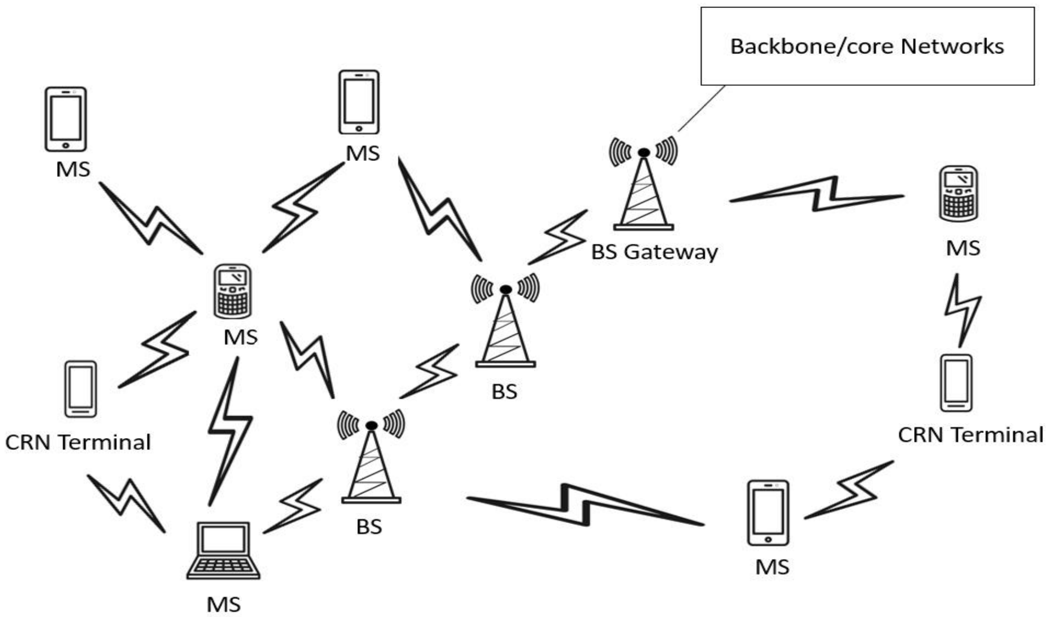


**Figure 4. Mesh Architecture [10]**

**Spectrum Detection Methods and Challenges in CR**

Spectrum detection is the primary challenge of CR. The CR is an intelligent wireless communication scheme that detects the absence and presence of the spectrum[12]. It detects the presence of licensed users and shifts to the vacant channels for avoiding interference between the licensed and unlicensed users. Spectrum detection can be broadly divided in three parts i.e. Non-Cooperative Detection System, Cooperative Detection System and Interference Base.

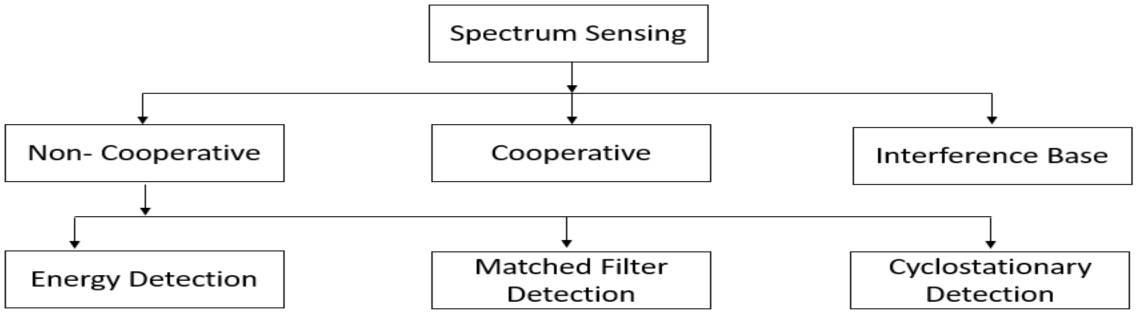


**Figure 5. Classification of Spectrum Sensing [13]**

A. ***Non-cooperative Detection Scheme:*** In this system, each CR independently determines the licensed signal's existence and non-existence in the spectrum.

i. *Energy Detection Scheme:* This system is a non-coherent sensing scheme which measures the energy of a received signal over the spectrum band. If the energy of the received signal exceeds a certain threshold, the presence of a signal in that frequency band is detected. The method is relatively simple and does not require any prior knowledge of the transmitted signal.


**Figure 6. Energy Detection Scheme [13]**

In this scheme, the input signals are passed through a Band Pass Filter (BPF) which selects the only specific range of frequencies. These frequencies are passed through squared devices to measure the energy values. The output is then passed through the integrator which compares the integrated output with the threshold energy values. To determine the presence of a licensed user the energy values should be greater than the threshold, otherwise the licensed user is absent. This method is not complex as compared to other techniques and previous knowledge of licensed user is also not required[14]. The shortcoming of this technique is that it is not able to differentiate between licensed user and noise. It also requires more sensing time for accomplishing the required outcomes.

ii. *Matched Filter (MF) Scheme :*This system is a coherent sensing scheme which requires prior data/information from licensed user to measure the energy of a received signal over the spectrum band. The performance of this scheme is comparatively better than the Energy sensing scheme. The accurate data is measured due to maximized Signal-to-Noise Ratio (SNR).


**Figure 7. Matched filter Detection Scheme [13]**

In this scheme, the detection time is less and the performance of SNR is maximum which results in an accurate outcome[15]. The main disadvantage of this method is that it is comparatively complex and it also needs prior information from licensed user.

iii. *Cyclostationary Detection Scheme:* The existence of a licensed user is detected by the periodical auto-correlation of the modulated signals. The periodical signals are embedded with pulse-train, spread codes, hopping sequences, and insinusodial-carriers of the licensed user signals.

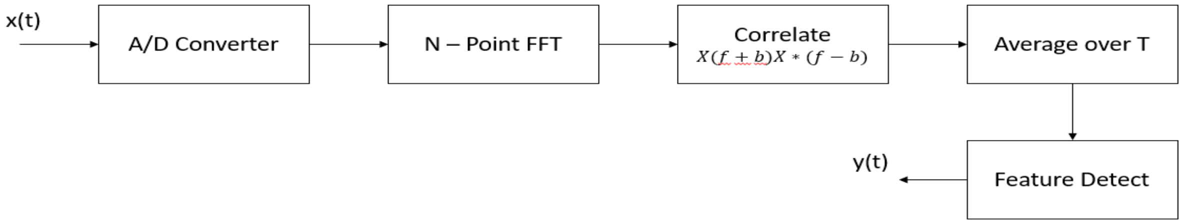


**Figure 8. Cyclostationary Detection Scheme [13]**

The input signal is passed to the Analog to Digital (A/D) Converter. The converted data is sent to Fast Fourier Transform (FFT) which minimizes the total number of computational problems of N size. The signals are then correlated and averaged over the time domain (T). Now, the signals are detected which sense the presence and absence of the licensed user. This method is robust to noise and the performance is increased in low S/N(signal-to-noise ratio) regions. This technique needs prior information of the signals and due to high complexity, it is not commonly used [16].

| **Monitoring/ Detection Methods** | **Category** | **Advantages** | **Disadvantages** |
|---|---|---|---|
| Energy Detection Scheme [17-19] | Detection | • Less complex and simple design<br>• Non-coherent<br>• No prior information required | • Performance is decreased in low SNR<br>• Not able to differentiate between licensed user and unlicensed user. |
| Matched Filter [20-22] | Detection | • Optimal sensing performance<br>• Increases the received SNR | • Prior data/information required of the licensed user<br>• Computational complexity |
| Feature Detection[23-25] | Detection | • Robust to uncertain noise<br>• Highly reliable<br>• More accurate sensing as compared to energy detection method | • More computational cost<br>• Less sensing as compared to energy detection<br>• Prior data/information required of the licensed user |

**Table 2. Comparing different spectrum detection schemes.**

***2. Cooperative Spectrum Detection***

The Cooperative detection method reduces the hidden node issue, the probability of missing the sensing, decreasing detection time, and false alarm detection. It can be classed as follows:

*i) Centralized Cooperative Sensing*

The main central unit of the base station is the fusion center (FC) which manages the detection process of CCS. The FC selects a channel or a frequency band, all the CRs are instructed to individually detect and combine their detection results. Lastly, the received information is calculated by the FC and determines the absence or presence of the licensed user. The diffused decision data is then sent back to the CR.

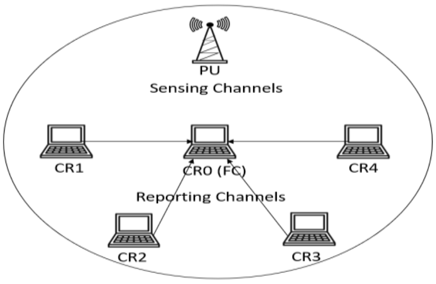


**Figure 9. The Centralized Architecture [10]**

*ii) Distributed Cooperative Sensing*

In this system, individually each CR collects information and collaborates with other CRs. The combined iterations/data are considered to make a decision on the absence or presence of the licensed user.

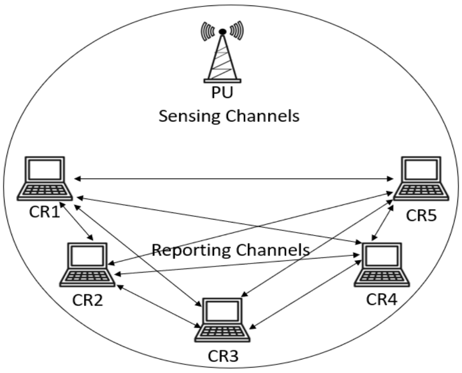


**Figure 10. Distributed Cooperative SensingArchitecture [10]**

*iii) Relay assisted Cooperative Sensing*

This system is used when the reporter network channel (RNC) and sensing network channel(SNC) are not so feasible. The CR user network is observing a strong RNC and peak SNC and CR user with weak RNC and strong SNC.

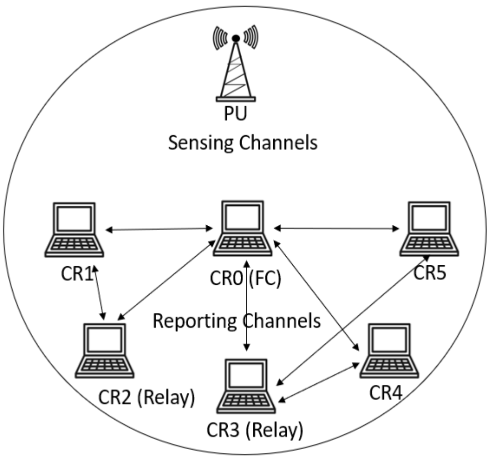


**Figure 11. Relay assisted Cooperative SensingArchitecture [10]**

| **Cooperative Sensing** | **Description** | **Advantages** | **Disadvantages** |
|---|---|---|---|
| Centralized Cooperative | All sensor nodes send their sensing results to a | Accurate decision-making, easy to | High communication overhead, single point of |

| | | | |
|---|---|---|---|
| Sensing<br>[26-27] | central entity for decision-making. | implement. | failure. |
| Distributed Cooperative Sensing<br>[28-30] | Sensor nodes collaborate with each other to make a decision without the need for a central entity. | Low communication overhead, robustness against node failures. | More complex decision-making algorithms, potential for disagreement among nodes. |
| Relay-assisted Cooperative Sensing<br>[31-32] | Some nodes act as relays, forwarding sensing results to a central entity or other nodes. | Reduced communication overhead, can increase coverage range. | Need for relay nodes, potential for relay node failure. |

**Table 3. Comparing different Cooperative schemes.**

3*. Interference Based Spectrum Sensing*

This method is used to detect the existence and non-existence of licensed user. The unlicensed user measures the different interference levels, if this interference level exceeds the threshold level then the licensed user is existing, otherwise it's not. This scheme can be classified as follows:

*i) Primary Receiver Detection*

When the data is received from a licensed transmitter, a leakage of local oscillator power is produced by the licensed receiver from its radio frequency front-end. To sense the licensed user (LU) a minimal cost detector node is positioned near the LUs receiver. The occupancy status of the spectrum is calculated from the sensed data that is cycled through CRs. Using CR users on the spectral surface, this technique locates spectral opportunities.

ii) *Interference Temperature Management*

In this method, a maximum interference threshold limit is set for a certain spectrum band. The users of CR could not produce unwanted interference, if they are utilizing a particular band in the specific region. The transmitting user interference is managed by controlling the transmitted power which is depending on their specific positions with reference to LUs. This technique measures the receiver's side interference and limits the interference temperature levels. Hence, it is not interfering with the LU.

**Fusion Schemes**

In this system, CR are used to combine the results of several spectrum detection techniques or numerous sensor nodes to enhance the accuracy and reliability of the LU detection. There are several types of fusion schemes that are used in CR, as follows:

- Hard Decision Fusion: In this system, the results of each individual sensor node or spectrum detection method are combined using different logic gates like OR or AND operation. If any one of the sensors detects the availability f the LU, the entire network considers to have detected the LU.
- Soft Decision Fusion: In this scheme, each sensor or node in the network provides a probability value for detecting the presence or absence of LU. The probability values are then combined using a weighted average or maximum likelihood estimation to make a final decision.
- Multi-Level Fusion: In this scheme, the results of multiple sensing techniques or several nodes are combined at multiple levels, such as at the sensor level, cluster level, and network level, to make a final decision [33]. This approach can provide more robust and accurate results, but it requires more computational resources.

**Cluster based cooperative spectrum sensing (CSS)**

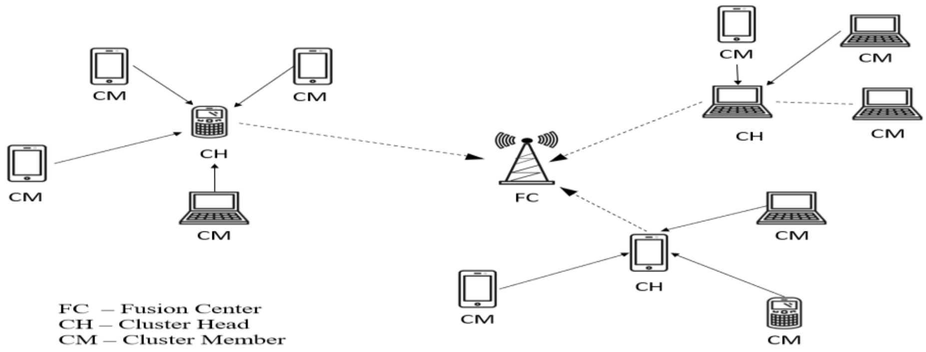


**Figure 12. A Cluster-based CSS Example[34]**

In cognitive radio, clustering refers to the process of grouping cognitive radios (CRs) into clusters based on certain criteria such as proximity, signal quality, or network topology. The clustering technique in cognitive radio networks (CRNs) improves network efficiency, reduces interference, and enhances spectrum utilization. In a clustered CRN, the network is divided into a number of clusters, each of which is managed by a cluster head (CH). The CH is responsible for coordinating with the CRs within its cluster to gather information, such as spectrum sensing, resource allocation, and data forwarding. The CRs within each cluster are referred to as cluster members (CMs).

The fusion center (FC) in a clustered CRN is used to collect and process information from the CHs and make decisions about spectrum allocation, spectrum usage, availability in their clusters, resource management, and uses this information to allocate resources to the different clusters. The CH is responsible for managing the CMs in its cluster. It performs functions such as spectrum sensing, data fusion, and routing. The CH communicates with the CMs to gather spectrum sensing data and combine it with data from other CMs in the cluster to improve the accuracy of the sensing results. The CH also allocates resources to the CMs in its cluster based on their needs and the availability of spectrum. The CMs are responsible for spectrum sensing, data transmission, etc. The CMs communicate with the CH to report their sensing results, request resources, and receive instructions on data transmission. Table 4, provides a summary[35] of the most significant methods utilized for clustering formation and updating the CRNs. It also lists the characteristics, benefits, and drawbacks of each technique.

| **References** | **Technique** | **Benefits** | **Limitations** |
|---|---|---|---|
| [36-38] | Affinity propagation (AP) | • More accurate<br>• Highly Efficient while comparing to another clustering methods | • It is wasting the spectral bandwidth and time by using excessive message transfer convergent algorithms. |
| [39-41] | Graph theory | • Assumptions are Simple<br>• Utilise the developed graph theory solutions including the bipartite graphs, minimal dominating set (MDS), and biclique graphs. | • Finding the largest edge biclique of a bipartite graph and the least dominant sets are the issues that are NP-complete, meaning that no polynomial time technique can ensure an ideal solution. |

| | | | |
|---|---|---|---|
| [42-44] | Greedy Heuristic | • Easy Implementation.<br>• Fast Execution.<br>• Needs less computational resources. | • This technique do not thoroughly analyse all the data, they frequently fall short of accomplishing the globally optimal solution. They dedicate themselves early to specific possibilities(while searching for the correct solution, they choose the most suitable a part without considering the other parts of the solution), which blocks them from obtaining the bestcomprehensive solution later. |
| [45-47] | Gametheory | • An highly effective analytical tool for researching and analysing rational behavior of the entities. | • Highly complex.<br>• It's hard to design the game in which the equilibrium will always be maintained. Even with the best players' responsive moves, the convergence time to the Nash Equilibrium could be really long. |
| [48-50] | Heuristics | • Simple Design<br>• Easy Execution<br>• Compatible to accept the complexity of space and time. | • The majorities of developed strategies are designed to solve a specific issue and can't be applied to further issues. Acquire local ideal solution and not the worldwide ideal solution. The analytical system is not available for analyzing their convergence. |

**Table 4. Different Techniques used in Cluster-based CSS.**

Cluster-based Cognitive Spectrum Sharing (CSS) is a technique used in CR networks to enable efficient utilization of the available spectrum. In cluster-based CSS, the cognitive radio network is divided into several clusters, with each cluster containing a number of CR nodes. The purpose of clustering is to create a subset of the CR nodes that can effectively coordinate with each other to utilize the available spectrum efficiently. The cluster head (CH) is responsible for managing the spectrum access of the nodes within the cluster. This method has several advantages, including efficient utilization of the available spectrum, improved spectrum access for cognitive radio nodes, reduced interference, and enhanced network performance [51]. However, it also has some challenges, such as the need for efficient clustering algorithms, the complexity of cluster head selection, and the need for effective communication between nodes within a cluster. This scheme involves:

- Cluster Formation: In cluster-based CSS, the CR network is first divided into several clusters, with each cluster consisting of a number of cognitive radio nodes. The goal is to create a subset of nodes that can coordinate with each other effectively to utilize the available spectrum.
- Cluster Head (CH) Selection: Each cluster has a CH, which is responsible for managing the spectrum access of the nodes within the cluster. The selection of the CH can be based on various factors such as the node's connectivity, location, or node's previous information of successfully accessing the spectrum. The CH should have higher processing capabilities, as it has to manage the spectrum access of all nodes within its cluster.

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- Spectrum Division: After forming the clusters, the available spectrum is divided into several sub-bands. Each sub-band is assigned to a particular cluster head, which is responsible for managing and allocating the sub-band to the nodes within its cluster.
- Spectrum Allocation: The CH allocates the sub-band to the nodes within its cluster based on the nodes' requirements and availability of spectrum. The cluster head considers various factors such as the current spectrum usage of the node, its priority, and the type of application it is running.
- Spectrum Usage Information Sharing: The CR nodes within a cluster communicate with each other to share their spectrum usage information. The information includes the node's current spectrum usage, available spectrum, and required spectrum. The cluster head then uses this information to allocate spectrum to the nodes within the cluster.
- Interference Management: Cluster-based CSS also helps in reducing interference between nodes [52]. The nodes within a cluster communicate with each other to avoid interference and ensure efficient spectrum utilization.
- Performance Improvement: Cluster-based CSS improves the network performance by efficiently utilizing the available spectrum, reducing interference, and providing better spectrum access to cognitive radio nodes

In Table 5, different detection methods are compared with their advantages, limitations, throughputs, and EE. CSS is a method that has the benefit of reducing requirements, sensitivities, and thresholds but has the drawback of adding data overhead. The proposed papers shows that EE is better when compared to different strategies.

| **Related Work** | **Detection methods** | **Advantages** | **Limitations** | **Energy Efficiency** | **Throughput** |
|---|---|---|---|---|---|
| [53-57] | Periodicity of the signal received | • Throughput of SPU is improved<br>• Robust t the noise | • Highly complex<br>• sensing Time is more | Normalized | Less |
| [58-63] | Detection of Energy | • Easy implementation<br>• Prior information not needed. | • Noise power is uncertain<br>• More sensing time | Normalized | Normalized |
| [64-68] | Prior Information of FPU | • Optimal Noise Sensing<br>• Less sensing time | • Requires a dedicated receiver<br>• Needs FPU's prior information | Less | Normalized |
| [69-73] | Collaboration between Several SPUs | • Easy implementation<br>• Less threshold | • More data overhead<br>• High sensing time | Normalized | Normalized |

**Table 5. Comparing different Methodsin EE.**

**Energy Efficiency (EE) of Cooperative Spectrum Sensing (CSS)**

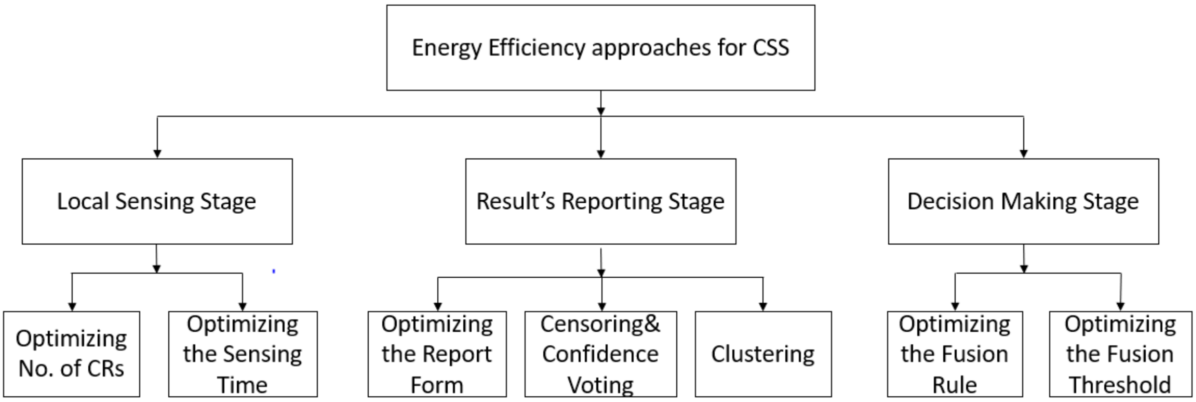


**Figure 13. Energy Efficiency of CSS [34]**

Cluster-based Cognitive Spectrum Sharing (CCSS) is a method that allows wireless devices to share vacant frequency bands in a cognitive radio network. To improve EE in CCSS, energy-efficient approaches can be applied at different stages of the process, including the local sensing stage, results reporting stage, and decision making stage.

1. **Local Sensing Stage:** In this stage, wireless devices sense their local environment to detect available frequency bands. To improve EE, devices can use low-power sensing techniques, such as energy detection or cyclostationary detection, and limit the duration and frequency of sensing to conserve energy.

a) ***Optimizing the number of CRs:*** To improve EE, the number of cognitive radios (CRs) in a cluster can be optimized based on the network requirements and available resources. However, too many CRs can result in excessive energy consumption, while having too few CRs can result in suboptimal sensing performance.

b) ***Optimizing the sensing time:*** The sensing time can be optimized to reduce energy consumption while still achieving the desired sensing performance. This can be achieved by using adaptive sensing methods that adjust the sensing time based on the available energy or by using optimized sensing schedules.

2. **Result's Reporting Stage:** In this stage, wireless devices report their sensing results to the cluster head (CH), which aggregates the data and makes a decision about which frequency band to use. To improve EE, devices can use low-power communication protocols, compress data before transmitting it, and limit the frequency of reporting to reduce energy consumption.

a) ***Optimizing the report form:*** By optimizing the format of the sensing results report, energy consumption can be reduced. For example, compressing the report or sending only the necessary information can reduce the amount of data transmitted and therefore reduce energy consumption.

b) ***Censoring and confidence voting:*** By using censoring and confidence voting techniques, sensing results that are uncertain or unreliable can be eliminated before transmission, reducing the amount of data transmitted and the energy consumed.

c) ***Clustering:*** Clustering can be used to group CRs into clusters based on their geographical proximity and communication requirements[34]. By clustering, the amount of data transmitted can be reduced, thereby reducing energy consumption.

3. **Decision Making Stage:** In this stage, the CH makes a decision about which frequency band to use based on the sensing results reported by the wireless devices. To improve EE, the CH can use optimization techniques to find the most EE frequency allocation and transmission power levels and minimize the use of energy-intensive decision making algorithms.

a) ***Optimizing the fusion rule:*** The fusion rule determines the sensing results are combined to make a decision. By optimizing the fusion rule, energy consumption can be reduced while still achieving the desired performance.

b) ***Optimizing the fusion threshold:*** The fusion threshold determines the minimum number of CRs required to make a decision [71]. By optimizing the threshold, energy consumption can be reduced while still achieving the desired performance.

CSS can improve EE by reducing the sensing time and reducing the number of false alarms. Here, are some points:

- **Reduced energy consumption:** CSS can reduce the energy consumption of CR devices as they can operate in low-power mode when not sensing the spectrum. This saves energy and extends the battery life of the devices.
- **Minimized transmission overhead:** In CSS, only a few devices are selected to transmit their sensing results to the base station or fusion center. This minimizes the transmission overhead and reduces the energy consumption of the devices.
- **Efficient use of spectrum:** CSS allows CR devices to use spectrum more efficiently by detecting available frequency bands that can be used for communication. This reduces the need for spectrum wastage, which in turn reduces the energy consumption of the devices.
- **Improved detection accuracy:** CSS can improve the detection accuracy of spectrum holes by combining the sensing results of multiple devices [71]. This reduces the probability of false alarms and missed detections, which can result in reduced energy consumption of the devices.
- **Adaptive sensing:** CSS allows CR devices to adapt their sensing strategies based on the network conditions. This means that devices can adjust their sensing interval, sensing frequency, and transmission power based on the availability of spectrum, which in turn improves EE.
- **Reduced interference:** CSS can reduce interference in the network by detecting and avoiding occupied frequency bands. This improves the reliability of communication and reduces the need for retransmission, which in turn reduces energy consumption.

In Table 6 , different related works have been discussed and the facts are addressed in tabular form. Although, the fact that noise channels and fading detection channels have a significant impact on performance but it has rarely been taken into. Therefore, in order to provide a practical evaluation, we advise assuming actual channel situations for reporting and detecting [71]. Instead of using other metrics, the EE may comprehensively explain the CRN's entire performance. Additionally, limitations should be applied to other measures in order to prevent adverse effects on other performance factors. For example, reducing the consumption of energy is related to other effects like PFA, PDA, and throughputs. By employing the EE the performance will form a balance in the metric.

**[Tick(✔) means 'Yes', Cross(X) means 'No' and NC means ' Not Considered'].**

| **Related Work** | **Consideration of Channel Fading** | **Limitations** | **Consideration of Transmitting Energy** | **Consideration of Noise** | **Active Energy Efficiency** | **Energy Efficiency Measured in?** |
|---|---|---|---|---|---|---|
| **[72]** | NC | Sensing Problem | ✔ | X | ✔ | bit/J |
| **[73]** | X | None | ✔ | X | ✔ | Bit/Hz/J |
| **[74]** | X | None | ✔ | X | ✔ | Bit/Hz/J |
| **[75]** | X | Sensing Problem | X | X | ✔ | Joule |
| **[76]** | X | PFA and Sensing Problem | X | X | ✔ | Joule |

| | | | | | | |
|---|---|---|---|---|---|---|
| **[77]** | X | PFA and Sensing Problem | X | X | ✔ | bit/J |
| **[78]** | X | PFA and Sensing Problem | X | X | ✔ | Total no. of users |
| **[79]** | ✔ | None | X | X | ✔ | ratio |
| **[80]** | X | Sensing Problem | ✔ | X | ✔ | Utility - function |
| **[81]** | ✔ | Sensing Problem | ✔ | ✔ | ✔ | no. of sensors and it's lifespan |
| **[82]** | X | None | X | X | ✔ | Energy saving mode ratio |
| **[83]** | ✔ | None | ✔ | ✔ | ✔ | bit/J |
| **[84]** | NC | None | X | X | ✔ | Energy saving mode ratio |
| **[85]** | X | Sensing Problem | ✔ | X | ✔ | Standardized utility function |
| **[86]** | X | PFA | X | X | ✔ | Joule |

**Table 6. Comparing different techniques and their related works.**

**Clustering objectives in CRN.**

The major objectives in Clustering are as follows:

Number of Clusters reduced: Clustering provides an efficient range of limits and scope by covering using fewer clusters. The reduced cluster density lowers inter-cluster communication costs.

1. **Number of Clusters reduced:** Clustering provides an efficient range of limits and scope by covering using fewer clusters. The reduced cluster density lowers inter-cluster communication costs.
2. **Improvement in stabilizing the cluster:** The stability and security of the cluster improve the performance of the intra-groups and dynamic channel access. Increasing dependency on the cluster security limits the reliability of the system as reclustering may result in adding overhead grouping which will make the system imperfect. For intra-cluster wireless communication when the number of regular channels are increased in a cluster, it gives access to transferring data capacity.
3. **Increasing the efficacy of Energy:** The aim of clustering is to decrease the consumption of energy for enhancing the lifespan of the system and also improve the efficiency of inter-cluster and intra-cluster. This can only be possible by separating the Euclidean within hubs, controlling transmission, and limiting individual heads of cluster for ease of communication.
4. **Establishment of Controlling the Common Channel:** The standard channel control is used by the SU to control the basic traffic of messages like sensing the channel availability. The Scientific, Medical, and industrial cognitive channels may use easy accessible channels which may be selected as a basic channel

control. The worldwide standard channel control might be not available due to the robust procedure of accessibility of the channel.

5. **Enhancing the Cooperative Tasks:** While detecting the channel, each hub detects the blank available spaces and also transfers the collected sensing information with its cluster head, which decides the availability of the LU. The clustering enhances the channel detection (including, the probability of false alarm and accessibility of channel capacity) [87]. By using clustering the performance of detecting the available paths for SU is increased.

**Conclusion:**

In wireless communication systems, the requirement for spectrum has increased. The shortage of bandwidth is a problem which is identified during the study. To resolve this issue CR has been developed. This technique uses the spectrum at the optimum level. In this work, we have discussed the different spectrum sensing schemes. The schemes have different workings to detect the white spaces and challenges for spectrum detection. The Cooperative spectrum sensing system can be a good solution for all common issues in detecting vacant bandwidth. The integration of energy-efficient CSS methods and clustering techniques has also been discussed in this paper. The EE refers to the capacity of the network to receive and transmit the information with a minimal energy consumption. Energy-efficient CSS aims to improves the detection performance by minimising the consumption of energy of the CR nodes. To maximize the utilization of the available spectrum, cluster-based Cognitive Spectrum Sharing (CSS) technique is employed. The future research can be related to different hybrid techniques for better communication systems in terms of time, codes, frequency, angle, and space.

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