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# An Overview about Major Research Problems in Cooperative Cognitive Radio and Its Feasible Solutions

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**ABSTRACT**

The rapid development of wireless applications leads the scarcity of spectrum space and the current static allocation of spectrum has to be replaced by Opportunistic Spectrum Access (OSA). Various constraints and challenges are to be faced when implementing OSA model in our ongoing wireless networks. Cooperation between Networks nodes present in the OSA environment achieves efficient way of transmission by sharing the channel availability information with others in cognitive radio networks. In this paper, analyzed the various network models, channel selection solutions and challenges for implementing them into real time have been discussed. A Novel Hybrid method for channel selection in cooperative cognitive radio is also been given for the future direction of research in this field.

***Keywords*****:** Cognitive Radio Networks, Opportunistic Spectrum Access, Co-operative Game Theory, Auction Approach.

## I. INTRODUCTION

This survey work majorly concentrated on key elements in dynamic spectrum sharing between primary and secondary services in mobile wireless networks. Television (TV) broadcasting, satellite communication, FM station and cellular mobile services are example services with primarily-allocated frequency bands (i.e., authorized services) that the research study aims at dynamically sharing among secondary services (e.g., ad-hoc networks, WLANs, WiMAX, etc). Various challenges have to face when we try to develop a dynamic spectrum accessing schemes. The objective of the work was to research and develop autonomous algorithms/mechanism that can facilitate dynamic, efficient, and fair sharing spectrum while providing acceptable levels of QoS; hard QoS for primary users and soft QoS for secondary users.

There are four different ways are there for accessing spectrum:

- **No spectrum sharing***:* In this way, only licensed users can access the spectrum. Strictly sharing of spectrum is restricted. No opportunistic access of spectrum.
- **Primary - Primary Spectrum Access***:* authorized or licensed services with primarily-allocated bands opportunistically accessing bands that are primarily allocated to other licensed services (e.g., cellular operator as a secondary user in TV bands).
- **Secondary– primary Spectrum Access***:* unauthorized or unlicensed services without primarily-allocated bands opportunistically accessing bands that are primarily allocated to a licensed service (e.g., WLAN network in TV or cellular bands).
- **Open Spectrum Access***:* spectrum access is completely unlicensed. Opportunistic spectrum access methods, following defined policies, are utilized (e.g., 802.11, 802.15, 802.16 all sharing unlicensed bands).

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Here, third way of accessing spectrum is dominant way of doing research. Cognitive radio networks and its development is hot research topic in recent years. This cognitive radio network (CRN) comes under third way of spectrum access mechanism. The opportunistic access of licensed spectrum is carried out in unlicensed manner. An example of this is e.g. a mobile ad-hoc network operating indoors, utilizing a spectrum band allocated to a cellular system.

### 1.1. Simplified model of CRN

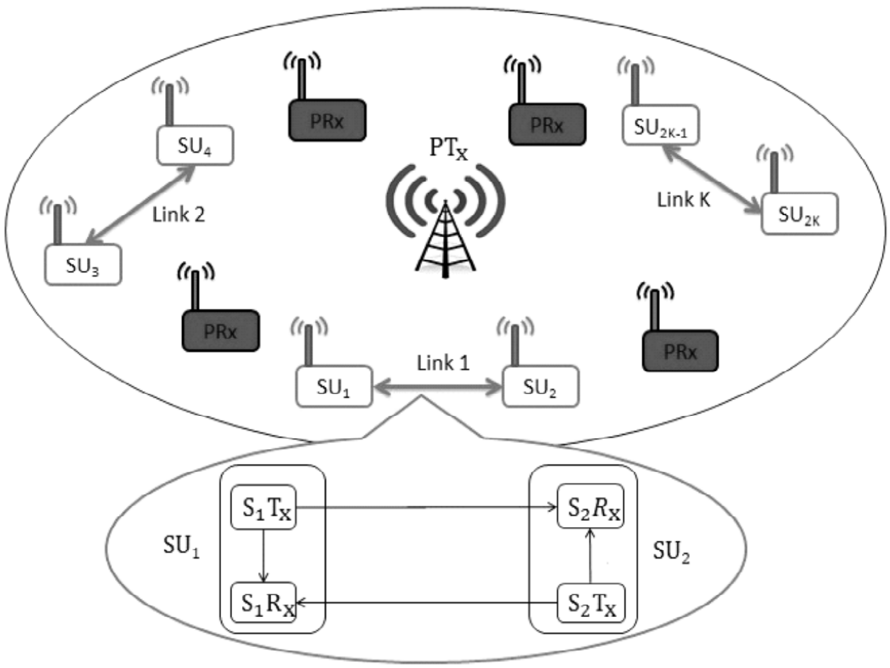


**Figure 1: Simplified CR network model**

In Figure 1, Primary radio Transmitter (PTx) is the licensed network transmitter, it will transmit multiple ranges of frequencies for their users in all direction. In the same coverage area many other wireless services and chances also possible. In some time duration, PTx may not transmit certain frequency bands to the users, same time any one of the secondary user (SU) or cognitive radio (CR) user needs the frequency opportunity for transmission of data with other nodes. Allocation of that available channel to he really needed user is the key problem that we have found to do our future research. Each SU can act as both transmitter and receiver of the wireless system where the SU participates.

This survey work has fully concentrated about the entire feature of cognitive radio environment and different strategies to achieve QOS for both primary and secondary users. The following sections as organized as Opportunistic Spectrum Access (OSA), suitable network model for CRN, Algorithm Influencing in CRN sensing, Energy minimization problems for each node, Multi-hop CR network and future direction for finding optimal sensing methods.

## II. OPPORTUNISTIC SPECTRUM ACCESS (OSA)

It's new for our current wireless networks, because right now we are using transmitter and receiver in each and every radio device will do modulation and demodulation with fixed carried frequency. Because of this static nature of transmission we can't utilize efficiently even though, the need of the spectrum resources increasing day by day. Scientist Mitola developed an efficient and dynamic radio device after observed the inefficiency of static spectrum usage policies [11].

**SDR (Software Defined Radio):** For achieving dynamic property, Each and every radio devices are attached with special function circuitries called SDR (software defined radio). This will change the PHY layer parameter and change the normal working principle of PHY layer. So the Static way of environment sensing and modulation changed by the SDR. Adaptively radio devices tune their current operating frequency, that's the primary difference between existing wireless radio device and SDR enabled radio device.

## 2.1. Importance of sensing in CRN

If our goal is to use unused frequency by the unauthorized secondary users then we have collect the multiple available opportunities or available frequency bands. Without collecting any information about the present environment, optimal decision making by the radio device is too tough. Even though so many algorithms provides solution for collecting optimal sets of frequency holes without the knowledge of availability, we couldn't assure that taken decision is optimal one. On the way decision always give worst case result in this type of spectrum knowledge collection, after collecting spectrum information; radio device has to take decision based on the calculation by the collected knowledge. For collecting the status of the frequencies energy detector, cyclostationary methods are used at the radio device sides. They may maintain one separate database about the availability details of all the channels surrounded by device. Sensing Environments Majorly classified as:

i) Free-use: In this case, the available ranges of frequencies are completely static in nature, there won't any licensed user for any spectrum, SU can access all the possible ranges of spectrum, but multiple SU access leads collision between SU's, still sensing and switching mechanisms is much needed one. (eg.,) middle of the ocean, sky , etc.

ii) Share-use: Here the real need of intelligence in sensing, more competitors and more real need of the spectrum opportunity will be in radio environment. For a single spectrum band more SU's may wait for access. So, efficient and optimal algorithm is much needed here.

The following schemes for shared-use spectrum environment only, Sensing an optimal channel from available spectrum space is recent and most welcome research area in opportunistic spectrum access scheme.

- **Blind sensing:** Without any additional calculation randomly selects one available channel from the database of the database. It is simpler model, if the Number of licensed channels ($P_{ch}$) greater than the requesting secondary user (SU) this may give better performance, that too when $SU<P_{ch}$(unused channels). But in real time this won't happen in all the cases.
- **Aloha Schemes in Sensing:** Our entire sensing approach in Cognitive radio networks (CRN) assumed as Time slotted sensing, so aloha schemes are also be the possible way to find next operating channel for SU radio devices. Because the slotted nature, we can avoid the interference and overhead of continuous frame based transmission. Slotted aloha technique can be used for sensing channel from available database. We can't set constraint or optimal condition for channel selection here. If we identify collision then immediately it will skip that into some other timeslot.
- **Conditional Sensing schemes:** Previous two schemes selects channel without considers the special conditions. But for optimal channel selection we need some intelligence at the channel decision. Based on the SU's Need we can select the channels, there we have to apply our intelligence. For that so many algorithms already have been developed and proved as optimal one. Our research also going to study the excising optimal channel selection and improve them in some higher extend.

Major classification of Existing Optimal selection:

- Statistical Approach
- Evolutionary algorithms
- Game theory

### 2.2. Interference consideration in sensing

Primary Objective of our CRN model is to provide opportunistic service for SU's without interfering the licensed spectrum holders. Interference is related to scheme which we are selecting for the spectrum sensing. So, it is important to consider interference factor at the time of sensing, otherwise entire CRN system also the existing wireless networks will collapse.

In primary sensing techniques like blind or random, aloha has not considered the interference free transmission. After SU recognize the interference, then the radio device guided to some other opportunity. This will create inefficient environment also time consuming process. But in customized optimal algorithms we can set the conditions for interference free transmission. Optimal solution for interference free transmission can be achieved by multiple methods with multiple factors and parameters.

- **Interference threshold:** Since, it is unpredictable radio environment, still negligible amount of interference incurred in spectrum sensing. We can set threshold interference value for our future sensing model. Reducing the interference threshold value is also being a targeted goal for us.
- **Effects due to interference:** If the proposing algorithm for interference minimization is not efficient, sure it will lead co-channel interference in CR network. Co-channel interference in CRN can be defined in terms of probability of the same operating frequency in neighbor CR users. It has to under the minimum threshold value, otherwise serious problems like packet loss, noise and connection drop will degrade the existing ongoing wireless networks. So the proposing solution has to monitor periodically the current radio usage details to the channel decision maker. Outdated channel information database also will create major problem in other wireless networks.

### 2.3. Dynamic VS static spectrum opportunity

In shared spectrum environment, heterogeneous spectrum bands and different usage models are used by wireless users. Majorly we can classify that into dynamic: spectrum opportunities are unpredictable, static: predictable and repeating pattern used by the users regularly.

In first type of spectrum environment, the need of intelligence is must because in certain unpredictable condition spectrum selection cannot be easy task, if no additional effort in channel selection, then CR network will get waited for long time. Example: cellular wireless networks like GSM, CDMA and other wireless based services. But, in the second category, no need of complex calculation from the available spectrum details. For taking efficient decision from the database which has the details of spectrum availability is simpler one compared to previous one. After learning (complete monitoring process of the environment frequency bands) nature of the different frequencies, decision can be taken by the result of learnt things. Example: Television and FM radio station. These are the frequency bands which are used mostly in a routine order. For example some of the FM stations only broadcast its services only between (5AM to 11PM), so constantly the remaining time another user (CR user) can utilize this spectrum band. Before using that licensed band, CR user has to get permission from authorized person. Then only the reliable secondary radio environment is possible for CR users.

#### *2.3.1. Direction of Solution for Dynamic Spectrum*

This is the area for better future research; optimal decision from multiple available free spectrum space is the ultimate aim here. Due to the unpredictable in nature, instead of getting optimal solution from multiple algorithms, most of the channel selection methodologies are trying to get sub-optimal solutions. A game model considers the multiple CR user environments and focuses the solution for channel selection. Dynamic nature of spectrum change mapped with the player mobility and sets the changeable target to reach the task completion in an optimal way.

### *2.3.2. Direction of Solution for Static Spectrum*

Deterministic spectrum models and its opportunities are easily predictable. So, simple spectrum decision making is enough for this type of spectrum. The future solutions under this category has to focus the decision making along with false alarm, because in certain cases deterministic pattern also will a changeable one, that time the reaction of proposing model has to focus.

## 2.4. Sequential VS parallel sensing model

Model that we considered here is completely time slot based transmission from each SU's. Before each time slot there will be some minimum amount of time spent for sensing the channels. Amount of energy used for channel sensing has to be under some minimum value, because sensing going to be a routine task. So, within that particular minimum time interval CR's cannot cover all the frequencies present in the environment. Channel selection in CR network is

$$CH_{sel}(T) = CH_{sensing}(t) + CH_{optimal\_sel}$$

Where, --

$CH_{sel}(T)$ - Channel selection Time

$CH_{sensing}(t)$ - Channel sensing time

$CH_{optimal-sel}$ - Time to select Optimal channel

In the radio environment, collecting fixed number of channel for applying optimal condition is the primary task called channel sensing. After collecting the knowledge about fixed number channels, we can apply our targeted optimal channel selection algorithms (game mode, markovian approach, genetic algorithm, etc.). In CR network mostly the CR devices are the handheld devices, powered by small amount of battery resources. Due to this type of energy restriction, CR devices capable to sense within their energy level, among the collected channel information that should select its next operating channel [13].

In sequential channel selection method, CR sequentially senses the channels according to a pre-defined order and stops to sense when some criterion is met. Here sensing order of channels is one of the important task, let we consider M number channels are collected for sequential sensing, in worst case sensing, N number sensing has to be done by the CR users (i.e., M=N). But from the multiple analysis and mathematical models researchers are trying to minimize the number of senses. This is key research area in sequential sensing processes, when try to minimize the number of senses in the sensing order (i.e., M>N), we should give importance also for the efficiency, interference factor and correctness of the results. The defined sensing order has to achieve higher probability of successful channel for the sensed CR user [7].

In parallel channel selection, the CR user simultaneously senses a fixed set of channels in a slot. Here, CR device no need consider all the collected channels, based on the information about the channels directly CR device can make decision to access or reject. In a single attempt the optimal condition based channel selection can be done by these categories of sensing algorithms. Optimal condition used to select the channel gets the important factor, rather than the order of sensing. Let we consider, M is the number of channels collected for sense, then parallel sensing technique will take very few countable senses to achieve a successful next operating channel (i.e., M<N, N is too small). If the decided channel selection algorithm is efficient, may be in a single attempt CR can fix its optimal next operating channel.

Two major tasks are needed for parallel sensing, they are collecting the knowledge like previous usage models and channel transmission properties. Based on that attempting to choose a channel will greatly reduces the time and energy resource from sensing CR users. But if the sensed channel is not efficient means utilizing by primary user or low quality transmission, then frequent channel senses needed to find next operating channel.

### *2.4.1. Direction of future solution for sequential sensing*

Some of the researches already been done for finding a best order, which will cover the factors like interference, noise, delay and power usage. All the channels present in the environment as treated as input for generating permutation combination. The order of sensing based on the results of permutations achieved by the channels. All the generated permutations are unique to one another. For example, 'N' numbers of channels are participating at the time of sensing, and then the maximum number of sensing is factorial (N). These solutions are suitable for single CR user senses channels in radio environment.

This type of random permutation combination methods always leads collision in multiple CR channel selection. In some cases multiple CR can sense the same channel at same time; collision is the only result for the both CR's. So future sequential sensing has to concentrate more on selection of sensing order without collision between CR's. One of the basic solution already been developed is Latin square matrix form of sensing order generation. In this method each row of the matrix dependent to the other rows. There won't be any same sensing order in the Latin square matrix method.

Example:

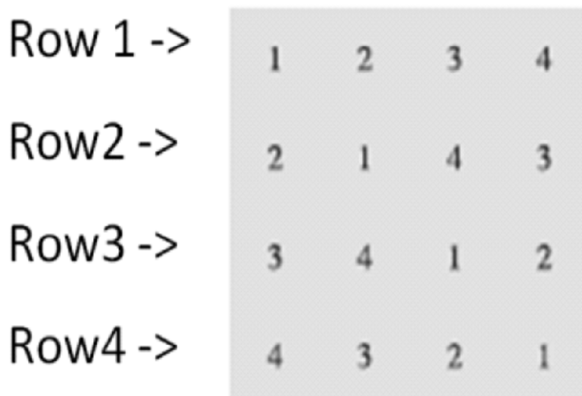


**Figure 2: Latin square matrix**

### *2.4.2. Direction of future solution for parallel sensing*

In a single CR, sensing more than one channel at the same time is complex task compared to the previous model. But the time needed to get the targeted optimal channel is very less. Once we reduced the sensing time of the CR, it will reduce all the other optimization parameters like power usage, delay and collision. Numbers of sensing channels are limited for the parallel sensing, this is one of the limitation here, because channels present out of sensing may give better usage than the sensed channels.

Mostly of the existing solutions for parallel sensing are the probabilistic models like markovian decision process and markovian state chain. This type of solutions always requires prior knowledge about the channel environment. After the learning process about the present channel only the given solutions will select optimal next operating channel. But it takes only one or very few sensing steps. Game theories also contributed well in this kind of simultaneous sensing and selection. Multiple CR environments are the real are which we have to create solution for finding optimal channel. Game theories were supported for sensing in multiple CR's, it conceder's all other CR's sensing and selects the targeted optimal next operating channel.

## 2.5. Local information VS Global Information

The entire OSA environment working based on three major operations, they are,

- Observation
- Spectrum decision
- Channel Switching

In Spectrum Observation operation, CR has to sample and collect environment information such as spectrum occupancy, location, user preference, and traffic and network state. It very important for sensing algorithms, because based on the information available only the proposing algorithm will direct the CR users in network. If the collected information is invalid or not efficient, the entire environment will collapse. Before making the decision prior information about available channels are the most general cases. In sometimes without any prior information CR can decide the next operating channels randomly. In previous research papers, researchers have stated with prior information about the channels, Most of the cases CR achieve better decision. The combinations of these three functional areas are going to be the important part of the future researches. Information needed for channel sensing can be classified as two types, *local* information and *global* information.

### *2.5.1. Local information*

Let we assume multiple CR environment, collecting the prior statistical and availability information about the neighbors operating channel and their collected channel state information. This will greatly reduce the complexity for the CR users. Since we are discussing about the problem and solution for cooperative sensing environment this type of local information sharing will suitable for at the time of channel sensing. Having information about others is not always possible in practical applications, especially in wireless communication systems. Thus, achieving desirable solutions without information about others is an interesting but challenging task because such statistical information may not be available a priori in some scenarios. [1].

### *2.5.2. Global information*

Collection of prior information about the occupancy details of channels from multiple CR users beyond the single-hop. Minimizing the co-channel interference is one of the important requirements to achieve better sensing algorithm. In multiple CRN environments, cooperation between the CR's has to be defined well. Even though it is too complex in wireless networks, sure it will give efficient channel sensing. In future, researchers has to touch the areas like reduced cost Global information collection, simplified model for Global channel sensing in CRN etc.

## III. SUITABLE NETWORK MODEL FOR CRN

OSA schemes can be applied in centralized or distributed manner. In the centralized OSA schemes, there is a central controller which schedules the sensing and access of SUs. On the contrary, the CR's in the distributed OSA schemes behave distributive and autonomously. In comparison, the centralized OSA schemes involve heavy computational complexity and communication overhead, while the distributed schemes can be implemented with low computational complexity and communication overhead. Furthermore, distributed control model is easy to implement and robust to observation error and link failure. Based on this consideration, we discuss distributed and slotted OSA models in this survey.

### 3.1. Centralized Models

In Wireless networks, centralized models are successful one, but in case of large number of CR's are participated in the CR network, it is difficult to manage the CR's by a single centralized controller. Central controller has to manage all the connected CR's with equal priority. In Most of the scenarios, this kind of

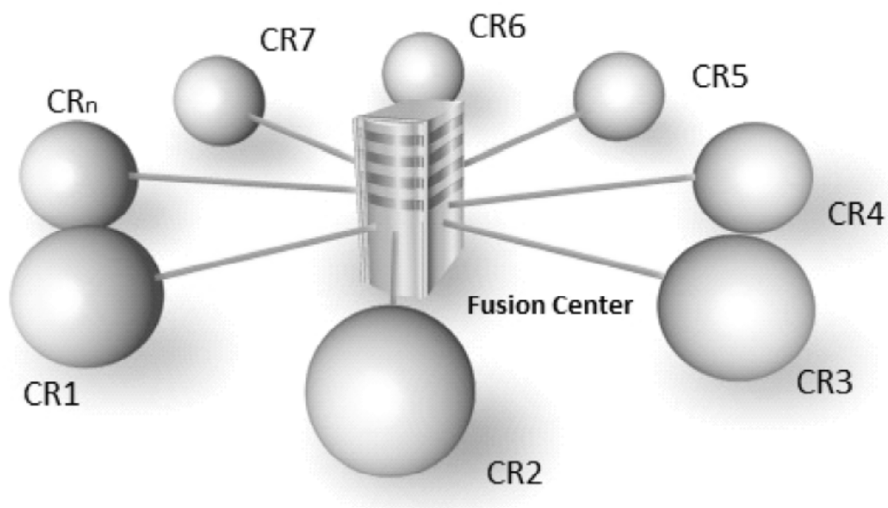


**Figure 3: Centralized CRN model**

temporary OSA environments has created within a short period of duration. So, within that time establishing one central controller is not possible and unnecessary one.

Previous Work in centralized approach is pretty interesting, Each CR equipped with GPS. Wherever it moves, their geographical location has monitored by its GPS device, and it is forwarded to nearby centralized controller. In this scenario, CR network has considered as implemented well in all locations. Example, if CR moves Position1 to position2, the movement has tracked by GPS attached with the CR and simultaneously CR will sense the channel availability of that particular location using centralized controller. Each and every location has to be equipped with the central controller attached with Geo-location Database (GLDB), which will collect the present radio environment details up-to-date. Periodically Central controller monitors and updates the GLDB for efficient information provision to the CR users. Power consumption for the central controller will be high, because it has to monitor the environment regularly and managing the incoming CR users.

### 3.2. Distributed Model

Instead of Believing a single Central controller for selecting the next operating channel, CR's are independently and autonomously choose its next channels has been derived in this kind of models. The Overall complexity in on CR network is distributed over all the CR's which are participated in the Network. Because of the autonomous in nature, Each CR can fix its own constrained for selecting channels. Further Distributed Model can be classified as: Co-operative and Non-cooperative.

#### *3.2.1. Cooperative sensing*

Existing researches have proven that, multiple CR sensors based sensing is outperforms than the single CR participated at the time of spectrum sensing. Cooperation between Multiple CR's is needed to achieve quality output from the sensing schemes. In cooperative spectrum sensing, different users share their results and decide on the status of the channel. [3] Show that the sensing performance can be improved significantly if cooperative spectrum sensing is used.

In previous works, they have considered that increasing the number of cooperating users can decrease the required detector sensitivity and the sensing time significantly. We need to redefine the cooperative sensing environments based on our need and our radio environment. However, it should be noted that as the number of user's increases in the cooperative sensing environment, the communication overhead will also increase in terms of exchanged control messages and processing overhead. Even though large numbers of cooperative users are complex to handle, increasing the number of sensing nodes does not change the detection performance significantly [3][15][16].

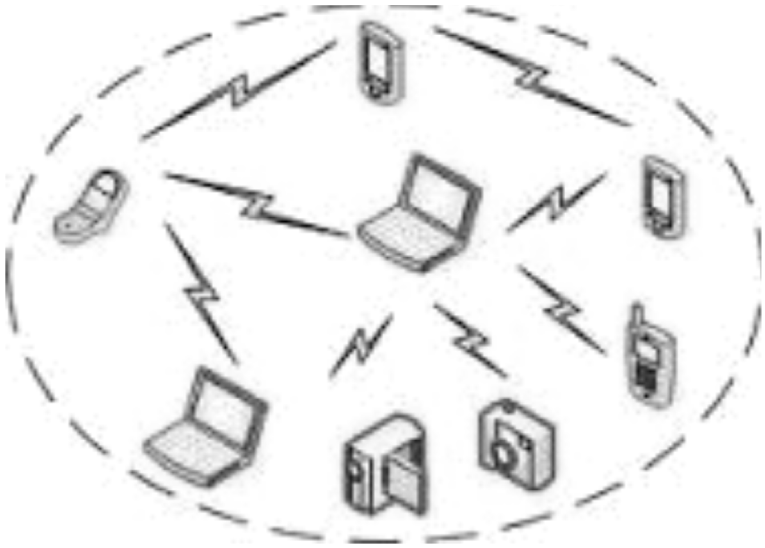

**Figure 4: Cooperative CRN model**

### *3.2.2. Non-cooperative sensing*

In this type of radio user's environment, we can't see the helping nodes. Everyone in the sensing environment can try to achieve the target without the help of neighborhood devices. Here, one of the primary advantages is reduced complexity for exchanging control messages between participating neighborhood devices. Non-cooperative models are suitable for sensing environment which is not having the deterministic pattern of channel usage. Randomly channel behavior changes within a short period of time; this will lead inefficient sensing and decision. Selfish nature of sensing nodes may help them for some of the radio sensing environment. [17]

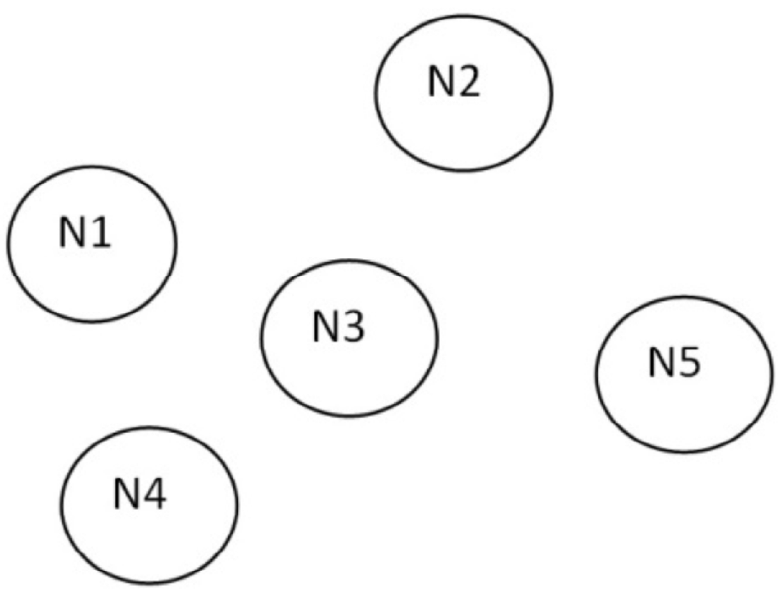


**Figure 5: Non-cooperative CRN model**

For cognitive radio sensing, researches has directed their solutions only towards the cooperative schemes, because it is better one compared to non-cooperative mode of sensing. Cooperative sensing methods considers the noise level of sensing channel and other quality parameters rather than the non-cooperative methods. In cooperative method, the ranges of sensed opportunities are high, once the opportunities are more obviously resultant value of sensing will be efficient.

## IV. ALGORITHM INFLUENCES IN CRN SENSING

### 4.1. Game theory

Since we are discussing about the research problems about the cooperative spectrum sensing models, consideration of multiple CR users in sensing environment is much important one. Large number of CR user going to share limited number of spectrum resources, there we going to apply our optimal sensing algorithms. So, we must consider the interaction among multiple CR users. Such interactions are not easy to analyze by traditional optimization methods, but can be well analyzed by game theory. Depending on the system models and the degree of information availability, different game models can be formulated to address the interactions. Challenges and problems in game theory based sensing are analyzed below, game based solutions become complicated and challenging [8].

Game theory is an applied mathematical tool that models and analyzes the mutual interactions in multiuser systems. Objective of each CR user in game model is to maximize its individual utility operation. There are two Major classifications of game theory: (i) cooperative game, (ii) Non-cooperative game.

Example cooperative game model is coalition game, which was proposed by W. sad et al. this cooperative model focuses three major research areas and improved them together. They are,

- Cooperation among CR's for collecting large number of channel availability.
- Coordinate for electing the channel access order with the mutual interference consideration.
- Immediate sharing of channel availability, it helps to achieve optimal utilization of channels.

### 4.2. Markovian approach

Channel usage by the radio user is not always be a deterministic, it will dynamic. Randomly PR users can access any of its allocated channels at any time. The entire channel usage model has assumed as ON-OFF pattern. Most of the cases, channel usage pattern are independent to the time of accessing that particular channel. In some radio environment channel usage pattern correlated to one another. Based on the previous channel usage pattern, we can predict the next operating channel. Markovian models are most wanted methods for selecting the next operating channel with some probabilistic approaches [14].

State transition based on the probabilistic approach is the key idea behind the markovian models. Dynamic nature of channel utilization and solution for dynamic movement of CR users are the major research problems. Markovian models are the best suitable model where the dynamic channel utilization by the authorized primary users [9].

### 4.3. Multi-armed bandit problem

In wireless networks, keeping other radio users channel usage information is too complex task by each CR users. Buffer used in each CR is very small size also power utilization for each CR will degrade the entire CR network performance. Without collecting any prior information about the channels, CR user can choose one or more optimal channel from several alternatives is called multi-armed bandit problem.

Unknown information about the radio environment needs this king of channel selection schemes. MAB problem gives the optimal solution through better *learning* process of given unknown environment. Research problems are concentrating to find better learning policies. Already some of the researches have given solution for learning policies. Through that defined learning policy how far they are achieving the reward in the sensing process is the main objective.

### 4.4. Evolutionary Algorithm

Generally Evolutionary approaches are widely used in wireless networks for identifying intruders, collecting sampling for malfunctions, optimal routing and relay selection. Single evolutionary solution may satisfy multiple problems in multiple domains. In OSA environments, the domination of evolutionary algorithms is considerably low. Security for the CR users in the OSA networks is more important, because it is entirely open environment for CR users. It should be controlled and monitored efficiently by the central controllers [4].

Evolutionary game models have been applied already for the channel selection problem and power management in CR network. It was first introduced by biologists studying population dynamics.

### 4.5. Aloha schemes

Aloha schemes are widely used to allocate channels in wireless networks for collision avoidance. In OSA schemes, contribution of aloha schemes are very less. Dynamic nature of spectrum change, possibilities of interferences is more and more constraints on the channel switching are the main reason that we are not using basic aloha schemes in the Spectrum sensing environments.

Even though aloha schemes easy way to implement at the time of channel switching, we can’t expect the interference free channel switching. Since most of the existing channel sensing systems have followed the frame or slotted sensing system, frame slotted aloha system can be applied in the sensing environment for simpler and device friendly.

### 4.6. Blind sensing algorithm

Without considering any constraints at the time of channel sensing, CR can blindly choose its next operating channel is called blind sensing scheme. It may slot based or continuous channel sensing model. At any time instance sensing can happen from the CR side, this may interfere the transmission of PR users in sometimes. In blind sensing schemes CR no need to collect the prior information about channels, no need to learn the environment before taking the channel switching decision. A single step channel switching can achieve by the blind sensing, random walk of one drunken man can be a suitable example for the blind sensing schemes. From current operating channel CR can decide the next channel wherever it wants CR can move [10].

## V. ENERGY MINIMIZATION PROBLEM

Generally, there are two kinds of costs for decision-theoretic solutions with respect to practical implementation. The first kind is due to information exchange in the network.

This consumes resources and causes extra overhead, e.g., time, power or bandwidth. The second kind is due to action switching, which involves hardware reconfiguration and signaling transmission to re-synchronize the transmitter and the receiver to a new chosen action. Reconfiguration includes the modulation with newly available frequency as carrier frequency.

### 5.1. A sample Time Slot

Figure 6. Shows ‘n’ number of sensing needed to find the optimal available channel, after reaching the targeted channel, data transmission will start. So, in time slotted model, each slot has sensing time and data sending time. If the sensing slots not detect any of the available channels, CR has to wait until the next time


**Figure 6: A single time slot**

slot. It will increase the overall energy utilization of CR user. Energy or power usage to be minimal one for participating CR's in channel sensing, because most of the CR's are activated by small batteries. It may be periodically rechargeable or use and throw by the CR users. Sensing plays a vital role and energy minimization, though the other factor like modulation, data transmission consumes the power from CR.

## 5.2. Direction of future solution for Energy minimization:

### *5.2.1. Auction approach*

Auction theory has been considered as an efficient model to allocate wireless resource in different scenarios, e.g., spectrum allocation, rate control, spectrum access, and spectrum sharing. In spectrum sensing, taking decision based on channel sensing results or channel availability is directly promotional to the power utilization of that particular CR user. Power needed for that particular CR user is distributed over to other neighborhood CR users. Most of the auction schemes are based on a centralized auctioneer (or a seller) since there is a single divisible resource to be allocated among bidders (buyers). Therefore, these auction-based resource allocation schemes cannot be directly applied to our considered multi-user cooperation scenario [5].

### *5.2.2. Distributed power allocation schemes*

In [3], they have stated that EESS algorithm, sensed channel information has forwarded to the central node which makes the final decision about the channel allocation. But in some cases the distance between sensed CR user and centralized decision maker may be too far, there we need the decision node (DN) concept. Instead of loosing unnecessary power for transmitting long distance for communicating the channel availability to the central decision maker, simply one the relay between the sensing CR user and central decision maker can act as a decision node (DN).

Here, the problem is to find the best sensing node and best decision node. Optimal selection algorithms for decision node also are the important consideration at the time taking final channel decision. Once if the proposing solution for both decision node selection and channel deciding scheme in DN is satisfies the optimal conditions, obviously power consumption of participating CR will be the reduced one.

### *5.2.3. Load balancing schemes*

In computing researches, the resources are utilized well by using load balancing techniques. Based on the need of the operation, resources are allocated to that particular computing environment. Load balancing techniques are exactly matching the need and availability in the computing environments; it can be applied directly to our power management scheme for the CR networks. Variety of sensing schemes are used by all the CR's, based on the need and based the environment they can decide their selection scheme, may more complex and optimal or less complex and considerable results under some fault threshold. It is new for the channel allocation methods in the cooperative environments; we can consider spectrum resources and CR users need as the inputs for the proposing new load balancing technique for the channel selection.

#### *5.2.4. Effective routing methods*

Since the OSA environments are completely dynamic in nature, multiple CR's and its routing schemes are somewhat complex to define and implement. Inefficient routing methods are also one of the factors for loosing unnecessary energy by the CR user. Consider a CR network with N number of CR users, 'User A' sends a packet to 'User B', in between 'R' number of relays can be involved.

If the number of relays is less, then the average power usage of CR users present in the network is low. Otherwise increase in the number of relays obviously will increase the overall average power usage of CR network.

At time T1, operating channels and are not necessary be same until the completion of the entire transmission. Middle of the transmission, CR may change its operating frequency. The new proposing routing mechanism has to consider this constraint also with the usual shortest path routing mechanism.

## VI. MULTI-HOP CRN

When cooperative communication is chosen, there can be more than one user involved and created their network. All the nodes need not be in the single-hop distance, future prosing cooperative sensing model has to support multi-hop scenario. All the participating nodes can act as both transmitter/receiver and relay. Thus, researches needed to decide how to select the transmission mode (direct or relay transmission) and the associated relay node(s) for each source node. Since it is the cooperative network, users can decide to help others as relaying the messages for them, it needs to balance the resource (such as power, bandwidth, and time slots) reserved for itself and the resource provided for others.

### 6.1. Relay Selection

In [5], by employing distributed multiple-input multiple-output (MIMO) techniques for relay transmission, the future proposal has to support for power allocation scheme implicitly incorporates both relay selection and transmission mode selection. Between direct transmission and relay transmission, each user has to decide whether to Cooperate, whom to cooperate with, and how to cooperate in a distributed fashion through a unified framework. Through the relay based transmission only, each CR's can wider their possibilities of data transmission. In future, cognitive radio methodology going be a major part of our existing wireless networks. So, for long distance provision of wireless service is much important, for achieving that we need this kind of relay based wireless radio communication [6].

## VII. TENTATIVE SOLUTIONS (OR) FEASIBLE SOLUTION FOR IMPROVING QOS

### 7.1. A novel Hybrid Approach for CRN sensing

Currently, the cooperative game theory (CGT) and Auction approach have been studied separately for channel selection and relaying communication networks [12]. Combining these two techniques surely can potentially bring more benefits to improve the network performance. The main objective of CGT is minimizing the overall average channel sensing and allocation time for the CR network. The objective of auction approach is decision of relay node selection, whether selected node has to be act as transmitter or relay is the final outcome from Relay selection schemes.

Cooperative game theory is completely different from the other types of games we have studied so far, which we can be refer to as non-cooperative games. In non-cooperative games, actions are taken by individual players (i.e., CR users), and the result produced by the game is described by the action taken by each player, along with the payload that each player achieves. In contrast, cooperative games consider the set of joint actions that any group of players can take. The outcome of a cooperative game will be specified by which group of player's forms, and the joint action that the group takes. We refer to these groups of players as *coalitions*.

At the time forming coalitions, a CR user who wants to join in the coalition can join in coalition. Consider the following game theory example "housing swap" consider a game with n players living in the same neighbor-hood. Each player owns one house initially and each will have a different preference ordering on houses in the neighborhood, depending on the characteristics of the various houses. If a given coalition, S, forms, the set of joint actions that S can take consists of all the possible ways to redistribute among the members of S the set of houses that the members of S owned initially. This game model suits for our cooperative spectrum sensing operation, houses are can be matched with the spectrum. Players can be matched with the primary and secondary users, initially primary users are considered as the owner of each house then based on the need and utilization conditions secondary user can occupy the houses.

In CGT, there is no constraint has been defined for coalition formation. In real cases, some of the participants in the coalition may not have sufficient energy for sensing its environment and forwarding it to others. Here, Auction approach can be applied for group formation for a cooperative game model. Whether participants in the CGT having sufficient energy or not, if yes it has satisfies the minimum eligibility defined by the auction approach. Since we cannot apply auction approach directly to the cooperative models, we need to do some modification as follows.

In the coalition itself we have to find some of the CR's for collecting the information about the other participant CR's, information such as energy capability, sensing capability and accuracy of sensing and named that CR's as Decision nodes (DN). It may looks like centralized model, but inside a coalition only we are assuming one of the CR as DN. So, the Auction conducted by the DN, with some constrained like minimum energy requirement for channel sensing. Surely this hybrid approach brings positive results in real time, because, in existing coalition formation in game theory by willingness from CR users, if CR loses energy, it has to update that manually to the auctioneer. But this proposal has dictates, automated sensing of energy status of the participants and periodically updates the coalition participants.

### 7.2. Challenges for our novel Hybrid Approach

Normally, in cooperative models complexity has considered in the form of message exchange between nodes. This Novel Hybrid model has reduced the work load for low powered CR users. For achieving that, number of messages has to exchange between Decision node (DN) and all other participants in the coalition. It should be under control, the time duration between the two successive auctions has to be maximized one.

## VIII. CONCLUSION

In this paper, we surveyed majorly about the Opportunistic Spectrum Access (OSA) environments and its sensing schemes. Classifications of sensing environments, network model and sensing scheme have been separately analyzed in this paper. In that, we concentrated mostly on cooperative cognitive radio network and its future direction of solutions. For cooperative way of channel sensing, we have discussed about the energy minimization constraints, multiple CR's interaction consideration and challenges to achieve cooperation and all. Finally, we have given one complete suggestion or feasible solution for channel sensing with energy management by combining cooperative game model (CGT) and Auction approach. We have addressed the challenges also for the new hybrid model for cooperative channel sensing.

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