Study & Analysis of Cognitive Radios Based Communication Networks

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Abstract – Cognitive Radio (CR) is the need of an hour due to the rising demands of spectrum with increasing wireless devices and population. It is a fact that the bandwidth has already exceeded, but interestingly the spectrum is not fully utilised. From the report of FCC the license band are still underutilised which bring hope to fulfil the rising demands. CR based communication is taken under study in this paper. The system with 25 nodes is implemented and analysed.

1. Introduction

We are aware about the recent scenario where the numbers of wireless devices are in constant demand which considerably increases the numbers of wireless users. The rising population and demand has made manufacturer to increase more wireless devices. On the other hand the available bandwidth is limited to the users. If we talk about the scenario of the wired devices the solution of bandwidth can be resolved by putting more numbers of cables; whereas the wireless communication has the fixed bandwidth in the specific geographical area and hence is an urgent need to for an algorithm in wireless technology to overcome the scarcity of the bandwidth.

To overcome this scarcity of spectrum, the new technology which is promising has to be developed. In 2002, Federal Communications Commission (FCC) revealed in their report that only 6% of the licensed spectrum is being utilised properly [1]. Hence, the report of FCC clearly showed how the licensed spectrum is being wasted. Now it has become necessary to make a system where the unused spectrum can be taken as an opportunity to fulfil the spectrum scarcity. In few year time a new technique was introduced which can dynamically access the unused spectrum in an opportunistic manner which is called as Dynamic Spectrum Access (DSA) [2]. This technology was promising to resolve the problem of Spectrum scarcity.

The main task of the Cognitive radio is as given below:

1. To make the Communication more Reliable with new algorithm
2. To efficiently utilize the spectrum hole

Sensing being the most important part of the Cognitive Radio, it is equally important to understand which technique will be suitable for the network environment available for communication. Selection of right technique contributes a major role for the detection of the available channel.

From the above explanation and detailed understanding of the sensing technique let us now understand them all in the form of graphs where the characteristics of the technique can be compared with each other.

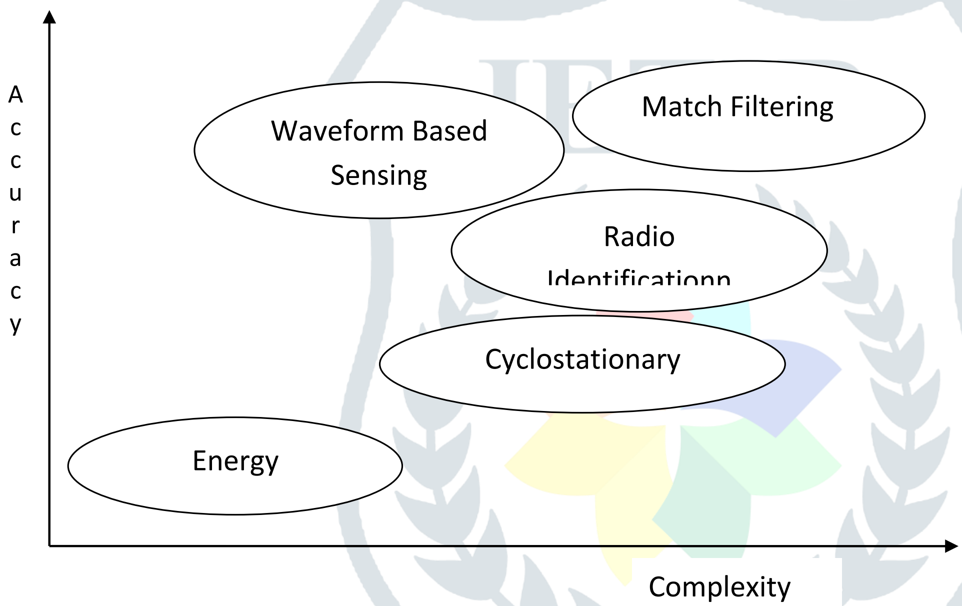

Figure 1 Spectrum Sensing Techniques

The Fig. 1 shows the comparison of different technique with respect to accuracy and complexity. Now, it is clear from the graph why energy detection technique is widely used even after being the lowest in terms of accuracy; the reason is the simplicity.

2. Related Work

Waveform Based Sensing

In Waveform Based sensing, secondary user (SU) has the pre information about the received signal. Here the known information patterns like preambles, midambles, regularly transmitted pilot patterns and spreading sequences helps to understand what the received signal is going to be like. The preambles are the known sequences which are transmitted before every slot. The study of Waveform Based sensing is superior to energy detecting technique in terms of reliability of the decision made. Also the performance can be improved with increase in the length of the known signal pattern. In case of the WLAN channel, the preamble uses characteristics of IEEE 802.11b [2]. The waveform based sensing represents that it requires short measurement time. The main disadvantage of this sensing is that it is prone to synchronizing error.

Radio ID Based Sensing

The detailed information of the spectrum can be obtained when the transmission technology is known. For example, lets us assume that the technology used by Primary User is Bluetooth signal. This will help the Cognitive Radio to get the information in space domain. The Prime motive is to identify the known communication technology and use them for communication when needed.

There are two main tasks by which the identification of the information is carried out are Initial Mode Identification (IMI) and Alternative Mode Monitoring (AMM). In Radio ID based sensing, Cognitive radio senses the various features of the Primary Users signals information which is used to select the most feasible Primary User technology by using various classification methods. The system with has sampling rate, Processing Unit, efficient Large range Analog to Digital Converters are import part of the hardware that needs to be addressed. The receivers have to be capable to sensing wide band signals with higher complexity to sensing the higher number of Spectrum holes in the channels. CR requires the system with wide band require the antenna which has the capacity to sense wide band and power amplifiers. High speed processors which can compute large data in real time should be configured to avoid signal delay. The radio has the competence to sense the spectrum at a specific time slot which reduces the sensing efficiency. It has the advantages of low power consumption and simplicity but the spectrum efficiency is degraded. On the other hand the dual radio has the capability to sense the spectrum which is dedicated for sensing and receiving and other part for monitoring.

Table 1: Spectrum Technique Comparison

Sr.	Technique	Accuracy	Complexit y	Comments	Reference
1	Energy Detection	Low	Low	This technique is one of the basic techniques in sensing. Here threshold value is fixed to avoid false alarm. No knowledge of primary user required. Easy to Implement. Less expensive	[3]
2	Cyclostatioary	Moderate	Moderate	Knowledge of PU is cyclic frequency required .Can differentiate types of signal and noise. Works on the fact that modulated signals are	[4]

				cyclostationary in nature which have spectral correlation. Noise has wide stationary signal, so no correlation and hence can be strong to ambiguity.	
3	Radio Identification Spectrum Sensing	High	High		[5]
4	Match Filter			Correlation of primary User and an Unknown signal. Compatible for Stationary Gausian noise situation which maximize of SNR of received signal. Prior info of the PU has to been known earlier. More energy consumption	[6]
5	Wave Form Based	High	High	Accuracy and complexity is higher than Match filter. Prior info of the PU is required.	[7]

Hidden Primary User

The rule followed by the CR is to provide no interference to the PU when it is in use but in this situation the PU are also affected of course the SU will leave the channel once it senses PU presence but the accuracy of the system reduces. There are two main problem of hidden PU namely multipath fading and shadowing.

Multi path fading which is also called small path fading is caused when the received signals has travelled multiple paths to reach the receiver. This reduces the sensing difficulty due to the different delays of the signals. In Shadowing the node is hidden behind the large object which is difficult to sense [2].

Detecting Spread Spectrum PU

In communication, the users (primary) which uses spread spectrum technology are not easy to detect which in turn causes difficult to detect for Secondary User. This is because the power of primary users is distributed over a wide range of frequency [3]. This can be resolved if the hoping pattern of the primary user signal is known and the signals are well synchronized. But to achieve this synchronization and coordination in code dimension it is difficult to design an algorithm.

Duration of sensing and Mobility

The Cognitive Radio takes the advantage of vacant channels and used them to build a communication. It is to equally necessary for the Secondary User (SU) to faithfully return the channel when the Primary User return for communication. Hence sensing is constantly required to sensing the returning of Primary Users and the hand-off has to be as quick as possible. To have this capability of sensing in cognitive radio is a challenge.

The standard in Cognitive Radio has to decided where the Cognitive Radio return the channel in a short duration of time for the emergency situation like medical, security, etc [4].

The sensing parameters selection is very important like how frequently the sensing is to be performed is to be decided carefully. If cognitive radio is aware about the status of the primary users like its return period, in such scenario the sensing should not waste their time and power in sensing of the return of the PU and the optional channel for it to switch so that it can continue its communication. The similar scenario can be seen in TV broadcasting where the change of frequency is not very often is a given geographical location [5].

Decision Fusion Cooperative Sensing

The sensing of the available channel is challenge in Cognitive Radio. The work in sensing we have realised how important Cooperating Spectrum sensing is to detect the available channel. The cooperative sensing can either be done as soft or hard spectrum sensing to detect the presence of PU. The probability of miss detection is seen less in case of soft decision and the hard decision technique is seen superior in efficiency when the numbers of secondary users are large numbers. The best technique to analyse the result of the Secondary Users for fusion rule is log-likelihood ratio test.

Security

Another which is a major issue in Cognitive Radio is security. The selfish nodes in the network can manipulate the results which reduces the efficiency of the cognitive radio. The security is equally important while sensing, decision making, allotment and mobility. In case of sensing, the malicious node can mimic the behaviour of the Primary User and can mislead the SU with manipulated and misguiding data. The detailed analysis is done on the attack is done in is known as Primary User emulation (PUE) attack. The harmful effect of such attacks has to be analysed to countermeasures them. The position of the transmitter can also be used to find the attackers and it is really a challenging to countermeasure them once the attackers is been identified in the network. This problem can be resolved when the encryption technique is used where the PU is identified key. In this technique only authorised Primary Users can transmit the signature that is being generated using Private Key along the signal

3. Allocation of Secondary User

The allocation of the spectrum to the secondary user is a challenging task. Once we are available with the channels that are vacant and not used by licensed users, it has to be allotted to the cognitive users in a manner that no discrimination is done. The allocation technique takes an important step in fulfilling the demands of spectrum. Here, in cognitive Radio network we are talking in consideration of interview network where the secondary users are only allowed to access the vacant channel or the spectrum hole by the license users. This means that primary users and the secondary users do not access to the same resources at the same time. In this student will be be studying of selecting the best suitable channels and how it will be allocated. In cognitive

Radio selecting the best spectrum is a challenging task. The available spectrum hole changes dynamically and their size may not be same all the time [4].

Resource Allocation

The allocation of channels to the secondary users plays a very important role in efficiently utilization of the spectrum. If the sensing is done with any of the given technique in section 3 but if the distribution of the channels is not properly done; then it won't be called as the successful communication in cognitive radio. Let us now assume that the available spectrum as described in the picture below.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

Figure 2 Spectrum availability

For the sake of simplicity let us take a spectrum of 30 channels in which there are 5 available spectrum holes [5]. The largest spectrum hole in frequency domain is channel number 15, 16, 17, 18, 19 which will be allocated to the secondary users. If there are n numbers of secondary users then we can provide the channel in FIFO (first in first out) fashion. The channel which requested the channel will be allotted the channel first. In this way we try to provide channels to the users without discriminating them. The question which arises is how do we allocate the channel, are secondary users themselves sense the channels and use it for allocation on availability. If yes then what about the allocation in case of cooperative sensing?

Spectrum Sensing can be done in two different way i.e. centralised or distributed one. In the centralise one central element takes the responsibility of the allocation based on the data sends by the secondary users. Along with it the SUs sends the information about the need of channel for communication. In distributed spectrum sharing the Secondary Users (SU) takes the decision individually and allocates the channel. Whatever the spectrum technique is use uncless and unless some if certain parameters or provisions are not made the allocation is going to happen in random fashion and non-deterministic manner.

From the above figure of spectrum hole, let us assume that the available channels is 5 (P) and the secondary users which demands for the channels is n. If the available channel P is greater than n (P>n), then the allocation can happened without any interruption or delay. But if the situation is (P<n), then in such case one secondary users which have no channel will wait for their change to get allocated with channel. Here we are not sure about the urgency of the users which are still waiting for the channel. We can define it with the help of blocking probability of secondary users. We can also divide the channel on the basis of type 1 till Type 10. Here, the Type 1 channel will have least blocking probability and Type 10 with highest blocking probability. The Secondary User can also demand for Type of users based on the budget. In this way we can divide the channel based on priority where the user knows about their priority. The spectrum sensing method where the presence of primary user is done with the help of cooperative Spectrum sensing method; where Fusion Center takes the role of deciding the vacant spectrum hole. We can use the same idea of fusion center in allocation of channel.

To achieve this method of allocation, the central element must take the task of allocation the channels to the secondary users. To make it more practical, we use the concept of Master and Slave technique to allocate the channel.

In this method any one secondary user will be chosen as Master and the other secondary users will be slaves, were the allocation is done by the Master node or the primary node. Now here we need to decide which technique. In the figure SU one is the master and the rest of the nodes are treated as slaves. Now master takes the control of allocation. In this thesis, we uses the k means clustering to decide the centre midpoint. Here k means clustering calculates the distance between each and every nodes and creates a mid pointi.e the cluster head. The cluster head now takes the responsibility of resource allocation to each and every users.

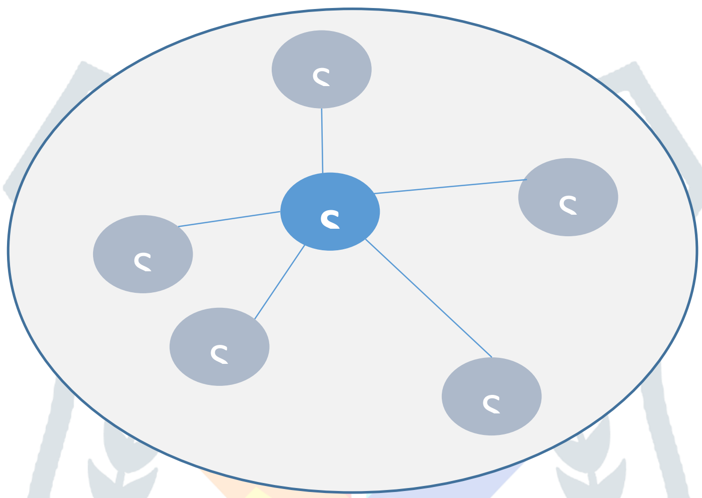

Figure 3 Selection of Center Head

Real-time allocation Algorithm

The algorithm for real time allocation shows the practical scenario of the Cognitive Radio.

1). All the Secondary users will carry out ‘Spectrum Sensing’ and the information will be passed to all the secondary users operating in the same region.

2). Out of these Secondary Users, one of them will take the role of the Master based and analyse the available channels for communication.

3). The Secondary Users (slave) will share their spectrum need to the master in terms of SU1 to SU4 and Type 1 to Type 4 for the first time,also they share their real time needs.

4).The master takes the next task of spectrum management. The available spectrum will b shared to all the other Secondary Users (slaves) as per their requirements.

5). The Secondary Users will transmit their data for communication. as long as the master demands him to evacuate the channel or the Primary User users does not demands for their channel.

6). In the situation of above case 5, the master will allocate a new channel to the Secondary User who loses the channel while evacuating.

In the above formulated algorithm, when we implement this is real environment, a control channel can be made which sends messages from the master to all the slaves. The blocking probability of the Secondary Users with respect the increase in channels (with increasing primary User) is shown in the figure 4.

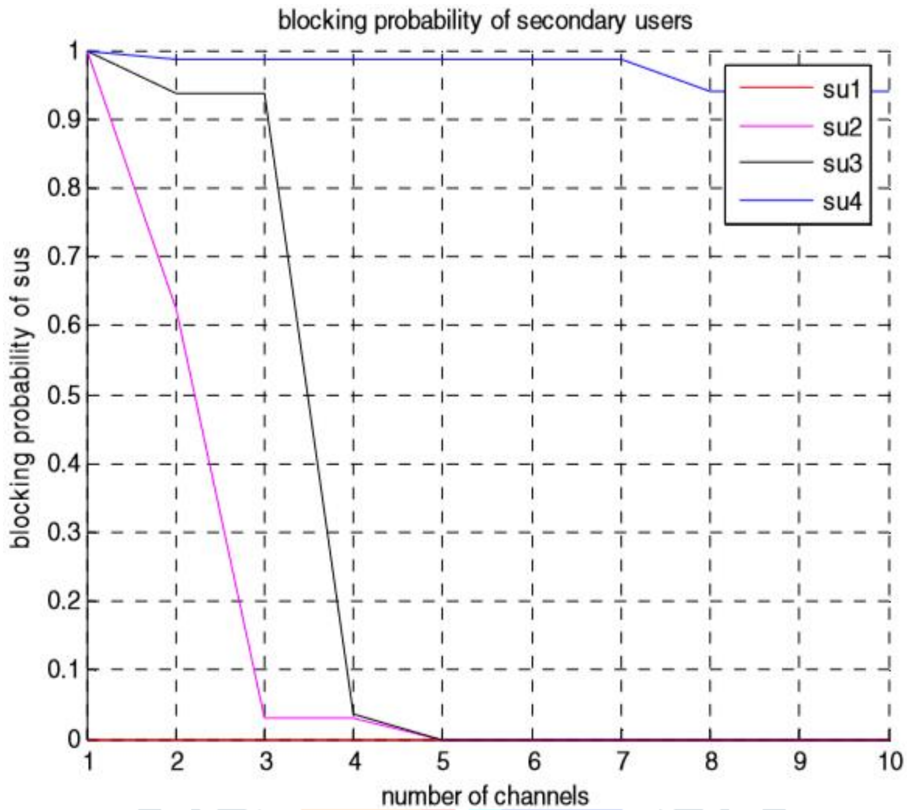

Figure 4 Blocking Probability of SUs with increasing channels

Limitation in the related work

The above discussed algorithm gives satisfactory results for smaller network with 10 secondary users. It does not discuss the scenario of bigger network. It also does not discuss about the scenario when the Secondary Users are in mobile state and their applications. The Master node/ Head in bigger network is not been taken into consideration.

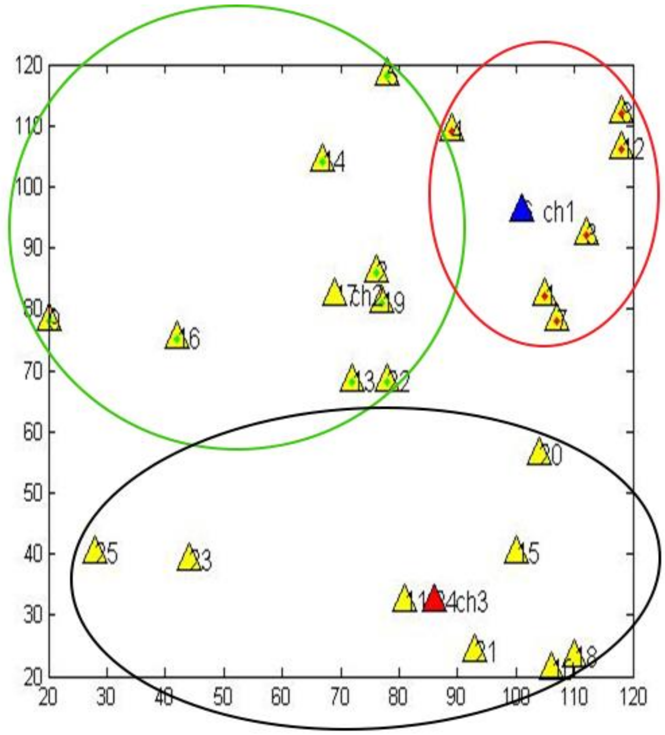

Figure 5 Cluster network creations

Table 2: Users Priority based on Applications

User types	Applications	Priority
SU1	Medical Emergency, Scientific Explorations	High
SU2	Education, Video Calling	SU2<SU1
SU3	News, entertainment, Audio	SU3<SU2
SU4	Chat	lowest

4. Proposed Algorithm

The allocation of Secondary Users in bigger cluster network of 25 will follow the following steps

1). Cluster head will be made based on the distance and separation of the nodes/ secondary users.

2). The Spectrum Sensing will be done by all the Secondary users and information will be passed to the Cluster Head.

3). The Cluster Head will take the responsibility of the Spectrum analyses and the needs of the spectrum will be shared to the head by all the secondary users.

4). The Cluster Head will allocate the channel to the secondary users based on the priority, starting from SU1 to SU4.

5). The Secondary user will transmit the data via given channel as long as the Primary User does not demand the channel or Cluster Head ask them to vacate the channel.

6). The Cluster head will allocate the channel to those users who have been asked to vacate the channel to complete their communication.

There are two cases in this network:

Case 1

When the user enter the same key as which is in our Database then Main server allow all the cluster Heads to Respond all the quarries Raised by Nodes According to their Priority.

Case 2

When the user enter wrong key and key is not Matched with the database of Main server then Main server send Alert Message to all the Cluster Heads that Some intrusion are there to access our network and then Nodes which is not being Matched with our Database is being blocked by Respective cluster Heads. Then Rest of the Nodes will get Service/channels. If the Highest priority Nodes have wrong key than our Network will automatically blocked that node and channels are being provided to less priority nodes , channels is not being wasted.

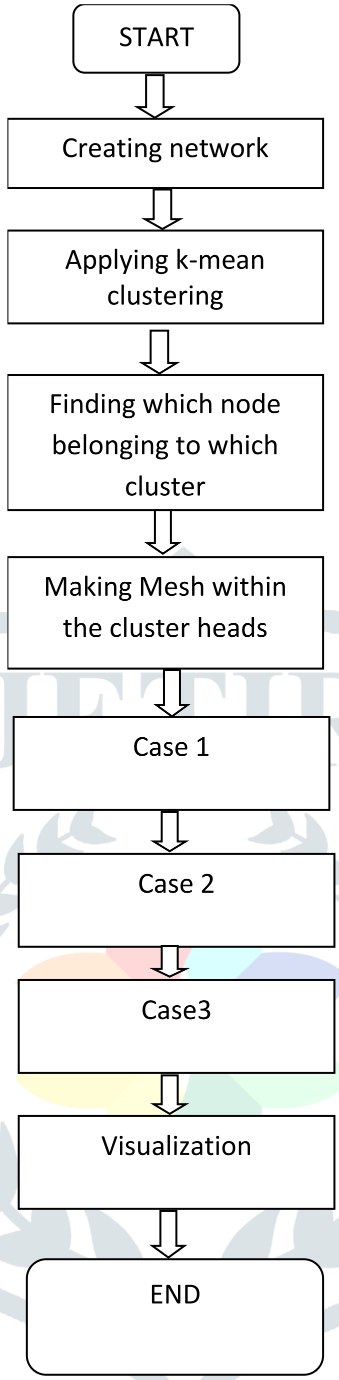

Figure 6 Flow chart of Allocation Algorithm

5. Conclusions

In this study, we use Secure Network to provide channels to the users. Till yet we are using Blind sensing techniques to use Cognitive Radio Networks which means that if some intrusion are there to access or hack our network then we have nothing to stop and our network is not properly Secured. Now we enable a Security Features into this if the Nodes have Match key with our Database then only they will get channels otherwise they will be blocked for future Communication and Rest of all Nodes will get Channels Depending upon their Priority. In future we are going to test our Network with higher mobility to work with Current Techniques and use Spectrum with proper way. Still we are using ad hoc network with lest mobility but in Future we will use Network with High Mobility.

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