Dynamic Spectrum Access with Multiple Channel Assigning in Multi-Hop Cognitive Radio Networks

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Abstract - Radio spectrum is a scarce and precious natural resource that is significantly underutilized with current fixed spectrum-licensing policies. The paradigm of cognitive radio network surcease this issue effectively. The primary users are the incumbents of the spectrum; hence the secondary users should not cause interference while sharing their spectrum. This project is explored on the basis of cooperative sensing, which is an most efficacious way for primary user detection. It provides cognitive radios to achieve a better dynamic spectrum access and this can be made possible by propounding greedy opportunistic routing protocol. The multiple channel assignment algorithm in cooperative detection helps in utilizing channel state information in the discovery of spectrum access opportunities and channel reassigning possibilities to improve transmission performance of SUs. The algorithm initiates self interference cancellation process during the channel allocation for secondary user. The simulation result shows that the spectrum utilization by secondary user, channel capacity are outperforming and channel assigning duration is considerably less than the existing model.

Keywords: Cooperative Sensing, Cognitive Radio Network, Channel State Information, Dynamic Spectrum Access, Primary User, Secondary User.

I. INTRODUCTION

The development of wireless communication techniques cannot get together the fast increasing of communication requirements. Cognitive radio provides a guaranteed solution to a today's emerging wireless technology. Cognitive Radio network is an artificial intelligence network and it has a capability of sensing and reacting to their environment changes. Fig 1 depicts the general working block diagram of cognitive radio system; it details the difference between the conventional radio working. The cognitive radios are evolved from the software defined radio(SDR) with the additional work of Intelligence activity. It enables the radio to sense the environment and has the reconfiguring features like coding adaptation, beam formation, modulation, power control methodologies and coding adaptation.

Most spectrum bands are allocated to certain services but majority of the reviews says that only portions of the spectrum band are fully used. In the future wireless systems the spectrum utilization will play a major role due to the shortage of unallocated spectrum. Moreover, the wireless communication systems are going from fully centralized systems into the direction of self-organizing systems.

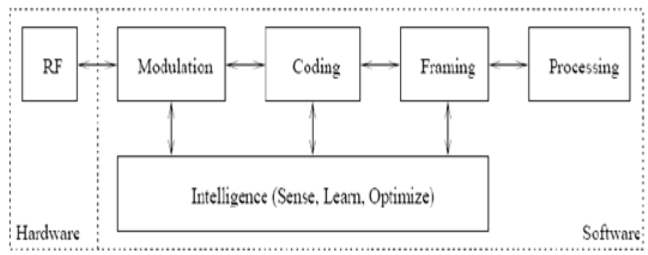

Fig. 1 General representation of cognitive radio

Cognitive process helps in obtaining the best result of sensing and access of the spectrum availabilities. There are four major working methods of the cognitive processing: learning, sensing, interference checking, and spectrum access. These four methods are interconnected to each other. The cognitive processing's employed in a distributed and centralized approach.

Presuming there is manifold frequency bands needed to be scanned, the SUs have to decide if they should develop the identified spectrum opportunities or discover new frequency bands in hope of better opportunities immediately. Sensing policy defines which SUs sense which frequency bands and when. A sensing rule is needed as sensing the entire spectrum of interest concurrently is hard for the hardware and may be energy incompetent. The sensing policy has two odd jobs: user selection and sensing scheduling.

User selection tells which SUs will contribute in the cooperation. It is vital to choose SUs understanding independent fading and shadowing effects so that maximum diversity gain is attained. In addition, insertion of hateful users in the group should be avoided to ensure the dependability of the network. Interference management is the main aspect in cognitive radio networks since secondary user spectrum usage is allowed only if the SU interference does not mortify the PU quality of service below a bearable limit .In addition may be interference between different SU networks due to the lack of harmonization resulting in considerable reduction of SUs' throughputs. Fig 2 describes the spectrum usage in the network. The fixed blocks are the spectrum occupied by the licensed users and white spaces between the blocks are termed as spectrum holes, these are to be effectively sensed and shared by cognitive radios.

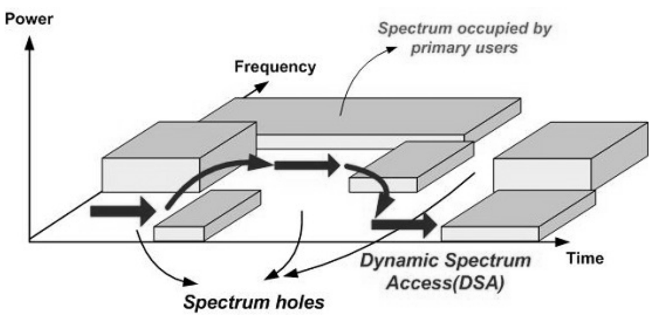

Fig. 2 Spectrum occupied by PU and unoccupied spectrum holes

Spectrum access can be divided based on the cooperation model used by the SUs cooperative and non-cooperative. Cooperative access schemes require organization among the cooperating SUs. Since SUs may need to broadcast over noncontiguous frequency bands, OFDMA is an attractive aspirant for medium access in cognitive networks .In the absence of data from other users; SU can use non-cooperative access schemes.

The existing non-cooperative approach is described in section II. Section III of this paper consists of details about the proposed cooperative detection method and multiple channel assignment algorithm which helps in achieving dynamic spectrum access. Section IV consists of simulation results which provide the efficacy of proposed method. The conclusion of the paper is presented in section V.

II. EXISTING NON-COOPERATIVE APPROACH OF SPECTRUM SENSING

The opportunistic spectrum detection is done through non-cooperative sensing with mere consideration of energy efficient method. The Distributed energy efficient routing algorithm provokes the nodes to achieve high sensing capacity. In transmitter detection, the cognitive radio act on its own, the received signal at cognitive radios determines the unused spectrum of primary user which has less effect on dynamic spectrum access. There is no cooperation among the cognitive radios, hence it individually perform its task. This section undergoes with the brief explanations of existing non-cooperative approach of spectrum detection.

In [1] Cognitive radio technology improves spectrum exploitation efficiently by permitting secondary users to access licensed spectrum without creating interference to the licensed primary users. Majority of existing mechanism on cognitive radio networks were paying attention on improving spectrum efficiency by considering spectrum sensing and sharing schemes. The important factor such as energy efficiency of nodes and network was highly disregarded. This paper deals with the overview of non-cooperative cognitive radio networks with energy efficient techniques from classified perspectives such as macro, micro and meso view. Here the macro view describes the deployment of cognitive radio networks in an energy-efficient way. The micro view helps in designing energy-efficient spectrum sensing algorithms for identical cognitive radios in the network. The meso view does the work of sharing the spectrum effectively by coordinating non-cooperative secondary users.

In [2] the secondary users in the cognitive radio network are at different locations, hence they may tend to incident different spectrum opportunities. This paper provides the conventional detection of primary user along with the detection of spectrum availability in temporal and spatial domains mutually. The stochastic geometry form of cognitive radio network helps to control spatial temporal false alarm, detection and spectrum access likelihoods for energy based non-cooperative method.

In [3] the Spectrum Sensing Optimizations for Energy-Harvesting Cognitive Radio System was proposed to identify the best sensing result to the secondary user. And it maximizes the average throughput of the secondary network by the energy detector's sensing threshold. The sensing duration must be shorter and satisfied the collision constraint in the paper.

General issues occur while designing a wireless networks are Spectrum scarcity and energy expenses which are mitigated using the concept in [4]. By achieving dynamic spectrum access under transmitter detection method, the cognitive radios excel the spectrum efficiency and user capacity of the networks. At the same time, radio frequency (RF) energy harvesting method is becoming a potential resource to supply energy to the networks and by this means increase the overall energy efficiency. Hence RF energy harvesting capabilities merged with cognitive radio network helps in achieving effective spectrum usage.

In [5] In Gaussian relay channel, the additive noises at the relay and destination are linked, it is obvious that noises at the destination nodes and relay channel are Gaussian and self-governing of each other. The energy harvesting model exhibits the energy arrival time and harvested energy amount are known beforehand to that of transmission. the throughput maximization problem was investigated. The Decode and Forward method helps in decoding and re-encoding the data in source node, the relay node rejects the noise part present in the source-relay channel part.

Majority of the routing algorithms eyes on finding energy efficient paths between the nodes to increase the lifetime of the networks. Hence it leads to power wastage in the cognitive radios, when the power drains, the nodes become incapable of observing the available spectrum from some parts of their destination areas which ultimately ends up with delayed spectrum sensing and sharing. The event that must be followed occurs at random destination and it should have non-deterministic patterns. Hence, supremely, distributed energy efficient routing algorithms (DEERA) are not only expands the pathway for energy efficiency, but also consider the remaining amount of energy in nodes and network, thus circumventing non-functioning nodes due to its power depletion issue.

III. COOPERATIVE SENSING METHOD WITH MULTIPLE CHANNEL ASSINGNMENT ALOGORITHM

A. COOPERATIVE SENSING ARCHITECTURE FOR CRN

The performance of a local detector degrades in the presence of propagation effects such as shadowing and fading caused by many paths. These channel conditions may also result in the problem of hidden node, where a secondary transceiver is outside the listening range of a primary transmitter but close enough to the primary receiver to create interference. These issues can be overcome using cooperative sensing (CS), where neighboring yet geographically distributed SUs cooperate in sensing a common PU transmission by exchanging sensing information among them before making a final decision.

Most of the CS schemes stem from the field of distributed energy detection [6]. Fig. 3 shows an example of CS, where N SUs sense listening channels for the PU signal activity and send the sensing information on reporting channels to the fusion center (FC), which makes the final decision.

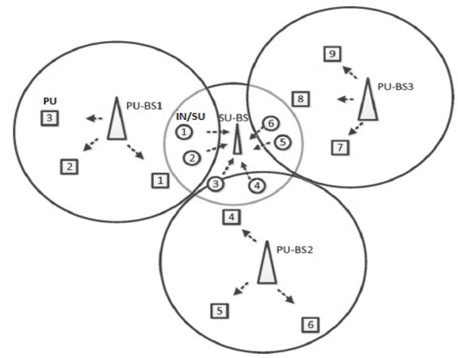

Fig. 3 Cooperative sensing architecture

It is very unlikely that all the channels between the PU and the SUs will be in a deep fade simultaneously. Thus cooperative detection helps in mitigating the channel effects through multipath diversity [7]. Other benefits of cooperative detection include improved detector performance, increased coverage, simplified local detector design, and increased robustness to non-idealities. Therefore, CS has generated lot of interest in the cognitive radio literature.

There are several components of CS: knowledge of PU waveform and activity, selection of SUs for cooperation, listening channels, local detectors, cooperation models, reporting channels, detection criterion, and fusion rule at the FC. The effects of non-idealities on CS are important while dealing about its components. It has contributions in the fields of sequential detection, CS with censoring, CS with quantized decision statistics and effects of reporting channel errors on CS.

B. PRIMARY USER DETECTION

The cooperative approach initiate with the activity called local sensing, where each cognitive secondary user sense the primary user and availability of unused spectrum individually. The local sensing for primary user spectrum detection can be devised in equation (1):

$$m(t) = \begin{cases} a(t) & U0 \\ c(t).n(t) + a(t) & U1 \end{cases} \quad (1)$$

m(t) - received signal at the CR user,
n(t) - transmitted PU signal,
c(t) - channel gain,
a(t) - additive white Gaussian noise at zero mean value,

U0, U1 - supposition of absence and the presence of PU signal in the frequency band.

For the assessment of the performance of signal detection, the probabilities of detection denoted as Pd in equation (2) and probabilities of false alarm denoted as Pf in equation (3) which are given as:

$$Pd = P\{decision = U1|U1\} = P\{X > \lambda \mid U1\} \quad (2)$$
$$Pf = P\{decision = U1|U0\} = P\{X > \lambda \mid U0\} \quad (3)$$

Where X and λ denotes the decision statistics and decision threshold.

The value of λ is set as per the necessities of primary user detection performance. From the above conviction, the probability of miss detection, Pm is given in equation (4) by,

$$Pm = 1 - Pd \quad (4)$$
$$= P\{decision = U0|U1\}$$

The probability of miss detection concludes the false detection of primary user and those spectrums can't be utilized.

The spatial diversity is generously exploited by the cooperative sensing method by observing the spatially distributed secondary users or CR users. The cooperative sensing method is also called as receiver detection because primary signals for spectrum opportunities are detected reliably by interacting or cooperating with other CR users.

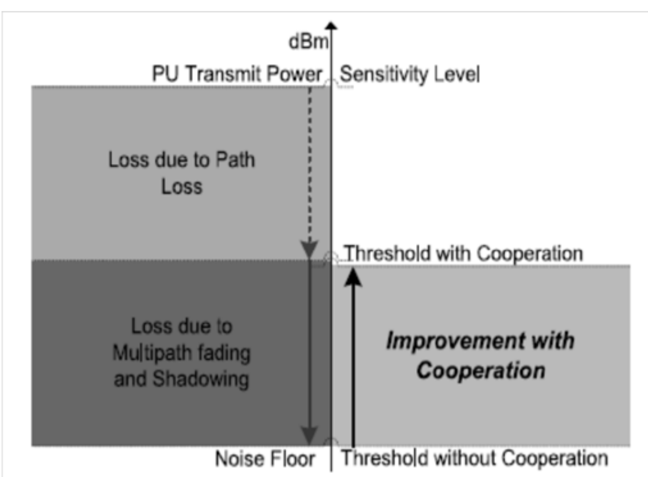

Fig. 4 Sensitivity improvement through cooperative sensing

They can share their sensing information for making a combined decision using a fusion centre, in our approach it can act as an intermediate node. The user detection and spectrum holes accessibility is enriched due to spatial diversity, which results in a gain called cooperative gain. Due to the effect of multipath fading and shadowing, the signal-to-noise ratio of the primary signal is small and detection of spectrum is a difficult thing. Since receiver sensitivity specifies the potential of perceiving weak signals, the receiver will be obligated on a strict sensitivity requirement. Fig 4 shows the performance deprivation due to effects such as multipath fading and shadowing can be surmounted by cooperative sensing with the receiver sensitivity is approximated to supposed path loss.

C. DYNAMIC SPECTRUM ACCESS USING MULTIPLE CHANNEL ASSIGNMENT ALGORITHM

The multi-channel multi-hop cognitive radio network architecture should consist of basic aspects such as traffic outlining, channel assignment methods, routing methods and topology invention. The focus is mainly on the uncharted issues of channel assignment and routing the user. The cooperative sensing method invokes dynamic spectrum access by implementing this algorithm which helps in finding the best topology and traffic outlining techniques. Each node is set with IEEE 802.22 interfaces; presently the issues involved in this architecture, and demonstrate with an extensive simulation study the potential gain in collective bandwidth is achievable. The spectrum-aware channel Assignment harvests the full potential of cooperative sensing architecture by further using the channel state information in multi-hop CRN in [8].

The Fig 5, represents the flowchart of multiple channel assignment algorithm, which gives the step by step working of the algorithm. The process starts by eyeing on the Primary User condition. In Cognitive radio network, the PU's are licensed users with their respective spectrum band and the network also consists of unlicensed SU's in high numbers. Basically PU are large spectrum holders and SU are less capable and indeed a less bandwidth requirement parties. SU also known as cognitive radios requires a free spectrum for communication. As the flowchart depicts that PU during its idle state tends to provide its spectrum as and when the request raised from secondary user. The request is based on the channel state information (CSI). When the request is being sent commonly on the network, here the CSI of every PU is processed for the request of SU. The accurate CSI let the SU to sense the PU spectrum holes, then channels is assigned for spectrum sharing.

The PU service is started by the initial process of channel assigning. The MCA algorithm helps in multiple channel assignment, it provides the possibilities for many cognitive radios to access the single PU spectrum simultaneously by laying concurrent or multiple channels. These channels will accurately shares only the required spectrum for the SU, hence solving the issue of spectrum wastage by malicious users. If there is any bandwidth remaining in PU, though it is not requested by any user at that instant will be further used by spreading the CSI. This helps in achieving dynamic spectrum access(DSA) [9].

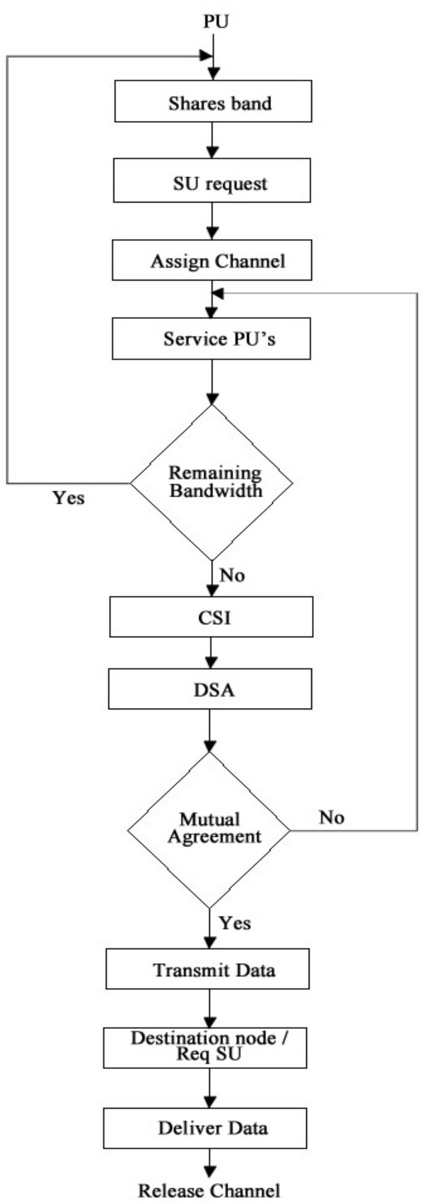

Fig. 5 Multiple channel assignment algorithm

The mutual agreement is one which confirms the occurrence of DSA [10]. Then SU will make use of the shared spectrum for its own communication of data. As the data transmission is succeeded by SU, the channel will be released. Hence that particular spectrum will be used for another SU by reallocating the channel.

The below explained attributes such as channel state information and self interference cancellation results in dynamic spectrum access for cognitive radio networks and highly reduces the occurrence of interference in the network.

(i) Channel state information

The channel state information (CSI) defines the channel properties of a communication link which helps in transferring the data. This CSI explains how the signal propagates from transmitter to the receiver end. Actually the transmitter and receiver consist of different CSI [11], because it is first estimated in receiver side, which will be quantized and given to transmitter. The CSI at the transmitter end is referred as CSIT and the CSI at the receiver end is referred as CSIR. The CSI is basically classified into two types: instantaneous CSI and statistical CSI.

Instantaneous CSI: It is also known as short-term CSI. It provides the information about the current channel conditions, it can be seen as digital filter impulse response. It helps in optimizing the received signal for spatial multiplexing and also accomplishes low bit error rates.

Statistical CSI: It is also known as long-term CSI. It provides the information about the statistical characterization of the channel. The statistical data includes the channel gain, fading distribution types in the channel, spatial correlation and the line-of-sight details about transmitter and receiver.

(ii) Self interference cancellation

Interference occurring in the cognitive radio networks can be differentiated into two types: intra-network and internetwork interference.

Intra-network interference is also known as self-interference, which refers to the interference occurs within one network, it may be in primary user or secondary user side. Examples of such self-interference in the network are inter-symbol interference and multi-access interference which occurs in multi-user networks [12]. This kind of interference commonly exists in every wireless communication system. Internetwork interference basically refers to the mutual interference occurs between the primary and secondary cognitive radio users.

IV. SIMULATION RESULTS AND ANALYSIS

The section IV povides the simulation results of cooperative sensing for dynamic spectrum access by multiple channel assigning algorithm, which excels the performance of network and spectrum usage. The performance metrics are compared with the existing work and the results exposes the proposed work overcomes the drawbacks present in the existing method. The Dynamic spectrum accessibility is enhanced in the network with MCA algorithm. The details of the simulated network parameters and values are presented in Table 1.

Table 1: Simulated environment

Network Parameters	Value
IEEE standard	IEEE 802.22
No. of Nodes	50
Primary user	dynamic
Secondary user	dynamic
Routing Protocol	AOMDV
IFQ (buffer size)	50 packets
Time	50s
Preamble data rate	1mbps
Data rate	1 mb
Channel frequency	2.472e9
Network size	1102*602

The performance metrics such as throughput, user capacity, channel assigning duration and spectrum utilization are evaluated with the proposed cooperative approach of multiple channel assignment algorithm and it is compared with the previous existing method. The analysis helps in profounding the weightage of proposed method.

A. THROUGHPUT

The throughput is the rate of successful data or packet delivered on a channel or medium in a network. The simulation result in fig 6 depicts that the throughput of proposed technique using multiple channel assignment algorithm is high when compare to the previous method. As the throughput increases, the overall efficiency of the network is expected to increase. It eventually describes that data transmission in the sensed spectrum is flawless and highly reliable. Basically the throughput of the network is mathematically given by the equation (5) as,

$$Throughput\ (Th) = \frac{Data\ transferred\ from\ Tx\ to\ Rx}{unit\ time} \quad (5)$$

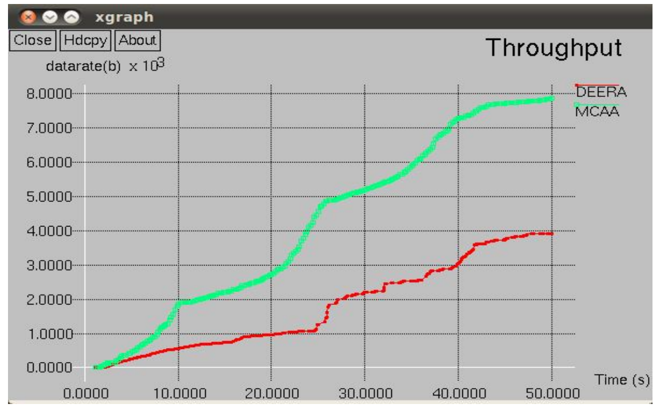

Fig. 6 Comparison of throughput

B. USER CAPACITY

The fig 7 shows the performance of the secondary user capacity which is nothing but the cognitive radio capacity to sense the primary user and spectrum holes. As the number of secondary user increases, the capacity of SU ultimately increases. This is achieved greater by the proposed method which delivers high cooperative gain using spatial diversity concept of receiver detection than the non-cooperative method.

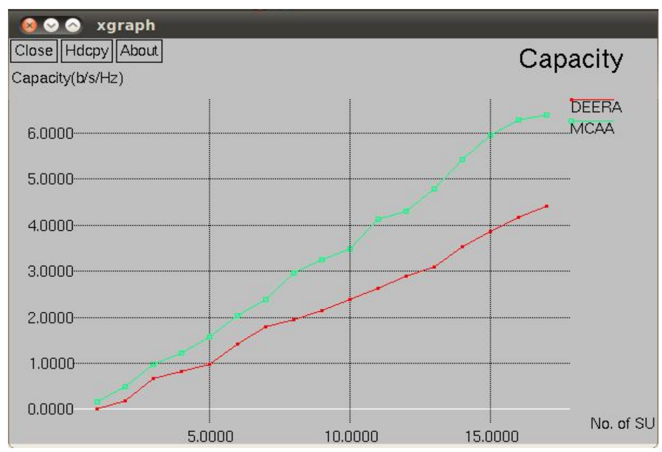

Fig. 7 No of SU vs capacity

C. SPECTRUM UTILIZATION

The spectrum utilization factor (U) is defined as the product of the frequency bandwidth (B), the geometric space (S), and the denial time for other users (T), it is given by the equation (6) as:

$$U = B * S * T \quad (6)$$

In fig 8, the spectrum utilization of SU is compared among proposed method with the previous existing method. As the simulation result depicts that MCAA achieves 6 b/s for the considerable number of SU, whereas the DEERA approach capable to reaching just 3.2 b/s. Hence the cooperative proposed method tends to sense the maximum spectrum holes and reliable to access those spectrum effectively.

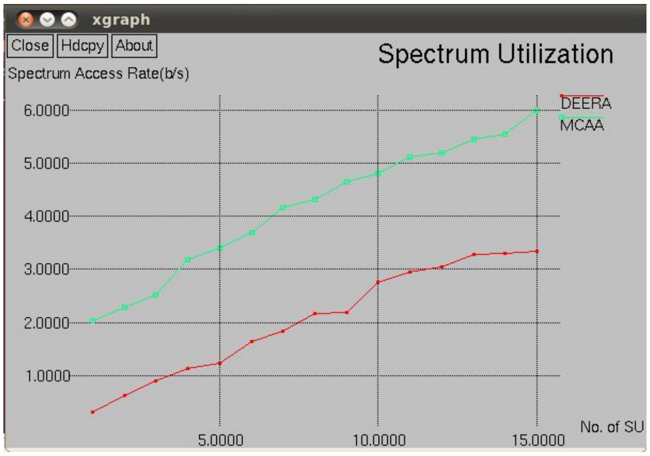

Fig. 8 No of SU vs spectrum access rate

D. CHANNEL ASSIGNING DURATION

The channel assignment duration is the time taken to sense the spectrum, SU sending request to access the spectrum and then PU accepting the request. Basically this duration should be less so that more spectrum will be utilised in particular time in a network. This determines the efficiency of the network. In fig 9 the simulation result obtained between number of request vs channel assign time.

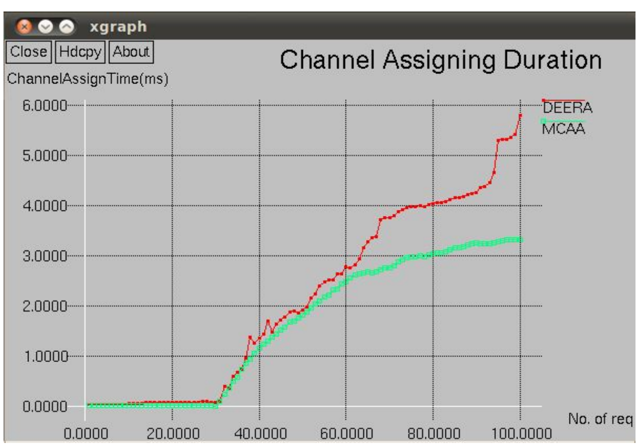

Fig. 9 No of request vs channel assign time

The SU request is ultimately going to increase as the network provides space for the communication. It is evident that the proposed MCA algorithm takes lesser channel assign time i.e lesser delay for more number of SU request when compare to the previous existing algorithm.

E. RETRANSMISSION ERROR

In fig 10, RTX_Error is the retransmission error which basically occurs when the unwanted SU tends to flood the PU by sending more number of request. This causes interference to PU and led to transfer unreliable CSI. These issues are overcome in the proposed method which highly engages the PU to select efficient multiple channel by opportunistic routing technique to reach the SU by multiple-hopping. The proposed work considerably decreases the retransmission error when compare to the existing model.

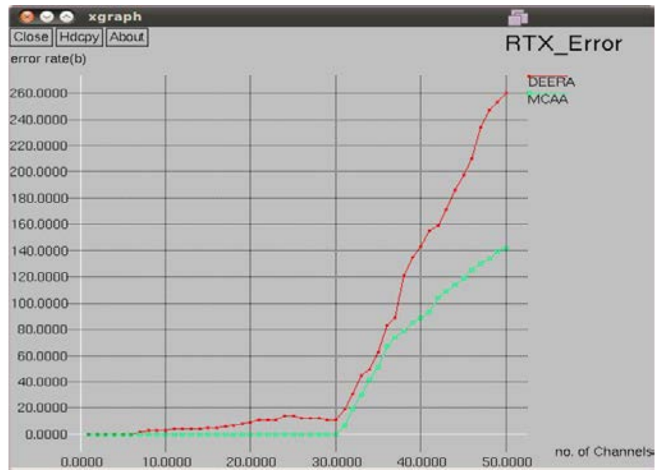

Fig. 10 Retransmission error rate

V. CONCLUSION

The spectrum scarcity issue in the current communication field is overcome by employing cognitive radio technology in the communication system. The general task of cognitive radio system is to properly exploit the underutilized spectrum of the primary user. In this paper, the proposed system makes use of the cooperative sensing method which ensures better detection of primary user than the rival. Multiple channel assignment algorithm combines with opportunistic routing and multi-hop technique excels the dynamic spectrum access in cognitive radio network, hence the throughput, channel capacity, spectrum utilization factors are considerably increased. Channel assigning time and delay will be reduced with the accurate channel state information from primary user. The proposed method makes use of most of the opportunistic spectrum and extremely mitigates the interference in the network and licensed user, hence overcoming the issues in cognitive radio network.

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