Dynamic Spectrum sharing with co-operative sensing for 5G cellular Networks

Adnaan Ahmad[1], Prof. Vijaykumar Joshi[2]
[1, 2] Department of Electronics & Telecommunication
[1, 2] G.H. Raisoni College of Engineering & Management, Savitribai Phule Pune University, Pune, Maharashtra, India

Abstract- *Recent researches show that more than 70% of the available spectrum is not utilized efficiently. This underutilization of the cellular spectrum has led to a shortage of spectral resources making the available bandwidth even more expensive. Therefore, for efficient utilization of spectrum, we need to do away with the traditional methods of spectrum access used in earlier generations of cellular standards. Dynamic spectrum access, is a worthy solution, which sniffs the spectrum to determine whether it is being used by primary user and then allocates it to unlicensed secondary user if it is idle. This paper explores the various aspects of spectrum sharing from a cognitive radio perspective. A multi-dimensional co-operative spectrum sensing concept is introduced, inculcating all the possible challenging scenarios with their remedial counterparts. The paper also presents the application of co-operative sensing and schemes to counter the effect of Selfish attacks so as to further improve the performance of Spectrum sensing and ultimately the utilization of the entire frequency spectrum. Results show that there is a considerable increase in the throughput of the communication system using the same amount of spectral resources.*

Keywords- Cognitive Radio Networks, Spectrum Utilisation, Selfish Attacks, Spectrum Sharing, Spectrum Sensing

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. 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 say 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. Cognitive radio is one concrete solution to this spectrum shortage or precisely, spectrum underutilization.

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.

Spectrum access can be divided based on the cooperation model used by the SUs cooperative and non-cooperative [1]. 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.

There is a huge domain of applications covered by this spectrum efficiency improvement but the main field of application exploited is 5G cellular networks. The main contributions and objectives of this paper are:

- Analyzing the spectrum data and extract information for improvement spectrum utilization
- Improving the efficiency of Spectrum Sharing by employing Co-operative sensing,
- Improving the sensing mechanism by solving the problem of Selfish attacks,
- Quantitatively analyzing the graphical results and comparing them with the traditional techniques used for

spectrum sensing

- Appling the improvement schemes presented in this project for the 5G cellular networks as per the ITU-T standards for 5G

The project presents the application of co-operative sensing and schemes to counter the effect of Selfish attacks so as to improve the performance of Spectrum sensing and ultimately the utilization of the entire frequency spectrum.

II. COOPERATIVE SENSING

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 neighbouring 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 [2]. 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 [3]. 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.

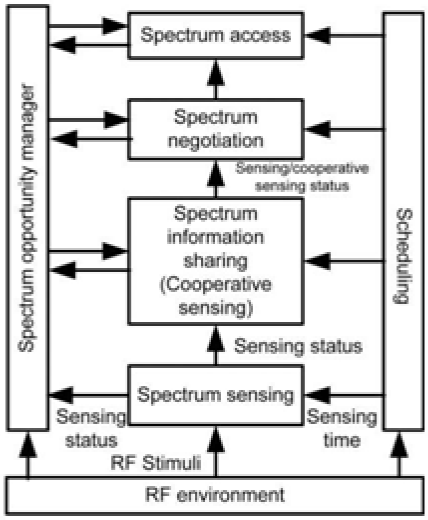


Figure 1 Functional overview of Co-operative sensing

There are several components of CS [4]: 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.

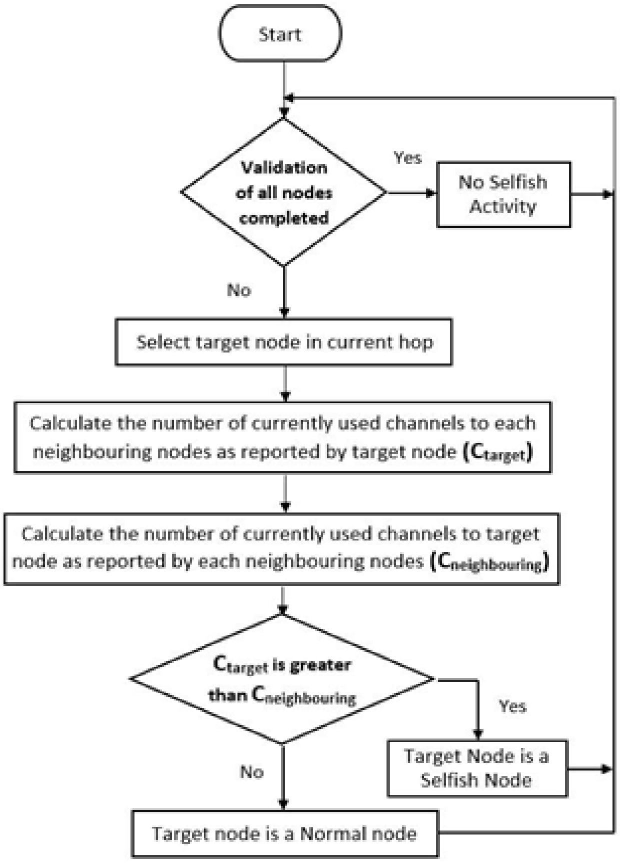
The spatial diversity is generously exploited by the cooperative sensing method by observing the spatially distributed secondary users or CR users. The cooperative sensing method is also called as receiver detection because primary signals for spectrum opportunities are detected reliably by interacting or cooperating with other CR users. They can share their sensing information for making a combined decision using a fusion centre. The user detection and spectrum holes' accessibility is enriched due to spatial diversity, which results in a gain called cooperative gain.

III. SELFISH ATTACKS & THEIR DETECTION

CR nodes compete to sense available channels [5–7]. But some SUs are selfish, and try to occupy all or part of available channels. Usually selfish CR attacks are carried out by sending fake signals or fake channel information. If a SU recognizes the presence of a PU by sensing the signals of the PU, the SU won't use the licensed channels. In this case, by sending faked PU signals, a selfish SU prohibits other competing SUs from accessing the channels. Another type of selfish attack is carried out when SUs share the sensed available channels. Usually each SU periodically informs its neighboring SUs of current available channels by broadcasting channel allocation information such as the number of available channels and channels in use. In this case, a selfish SU broadcasts faked channel allocation information to other neighboring SUs in order to occupy all or a part of the available channels. For example, even though a selfish SU uses only two out of five channels, it will broadcast that all five channels are in use and then pre-occupy the three extra channels. Thus, these selfish attacks degrade the performance of a CR network significantly.

The proposed scheme aims at eradicating the effect of these attacks by introducing a selfish attack detection technique, COOPON (called Cooperative neighboring cognitive radio Nodes). We focus on selfish attacks of SUs toward multiple channel access in cognitive radio ad-hoc networks. We assume that an individual SU accommodates multiple channels. Each SU will regularly broadcast the current multiple channel allocation information to all of its neighboring SUs, including the number of channels in current use and the number of available channels, respectively. The selfish SU will broadcast fake information on available channels in order to pre-occupy them. The selfish SU will send a larger number of channels in current use than real in order to reserve available channels for later use.

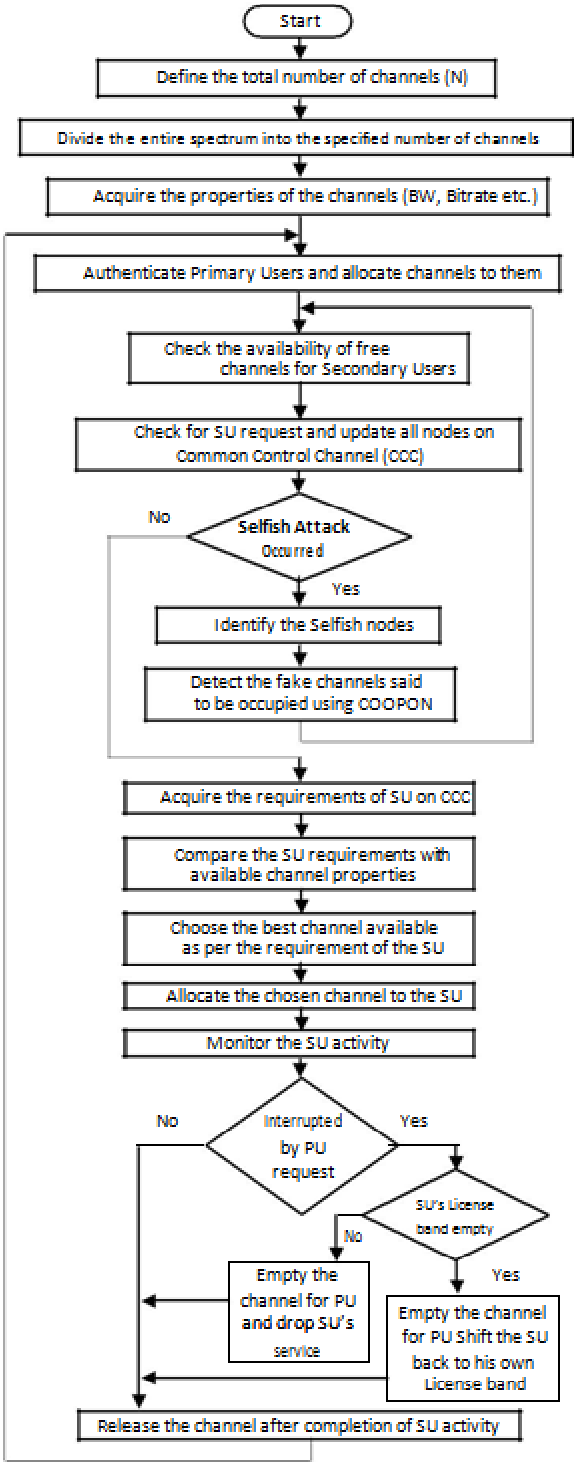
The COOPON [8] will detect the attacks of selfish SUs by the cooperation of other legitimate neighboring SUs. All neighboring SUs exchange the channel allocation information both received from and sent to the target SU, which will be investigated by all of its neighboring SUs. The target SU and its neighboring SUs are 1-hop neighbors. Then, each individual SU will compare the total number of channels reported to be currently used by the target node to the total number of channels reported to be currently used by all of the neighboring SUs. If there is any discrepancy between the two figures, all of the legitimate SUs will recognize a selfish attacker. Our proposed technique is an intuitive approach and simple to compute, but reliable due to using deterministic channel allocation information as well as the support of cooperative neighboring nodes.



IV. SIMULATION

The implementation starts with dividing the entire spectrum into heterogeneous channels with varying properties for a variety of applications. These channels are allocated to the licensed Primary Users (PU) with proper authentication of their license.

We consider a case where the channels are pre-occupied by some Secondary Users (SU). So the sensing mechanism will first ensure the legibility of SU channel usage by checking for Selfish Attack and then it will announce the number of free channels available for new SU request.



The COOPON algorithm will detect the attacks of selfish SUs by the cooperation of other legitimate neighboring SUs. All neighboring SUs exchange the channel allocation information both received from and sent to the target SU, which will be investigated by all of its neighboring SUs. The target SU and its neighboring SUs are 1-hop neighbors. Then, each individual SU will compare the total number of channels reported to be currently used by the target node to the total number of channels reported to be currently used by all of the neighboring SUs. If there is any discrepancy between the two figures, all of the legitimate SUs will recognize a selfish attacker [38].

Once it is made sure that no selfish activity is prevalent among the SU, the co-operative sensing mechanism takes over by incorporating the requirements of various SU requests. It then matches their requirement with the most appropriate free channel available. SU is allocated to a channel that may provide the best service to his requirement. The co-operative sensing monitors the SU activity in the allocated channel and updates its own table with the amount of time SU was serviced in its unlicensed band.

This mechanism also checks for an interruption from PU during SU activity. This interruption will result in evacuation of SU from this unlicensed band. The SU will be shifted to his own primary licensed band if it is free. On the contrary, if his license band is already equipped, the service will be dropped and the SU will have to wait till his new request is catered.

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

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

where, 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 probability of detection (denoted as Pd) and probability of false alarm (denoted as Pf) in equation:

$$\mathrm{Pd} = \mathrm{P}\{\mathrm{decision} = \mathrm{U1}|\mathrm{U1}\} = \mathrm{P}\{\mathrm{X} > \lambda \mid \mathrm{U1}\}$$
$$\mathrm{Pf} = \mathrm{P}\{\mathrm{decision} = \mathrm{U1}|\mathrm{U0}\} = \mathrm{P}\{\mathrm{X} > \lambda \mid \mathrm{U0}\}$$

where, X and λ denotes the decision statistics and decision threshold.

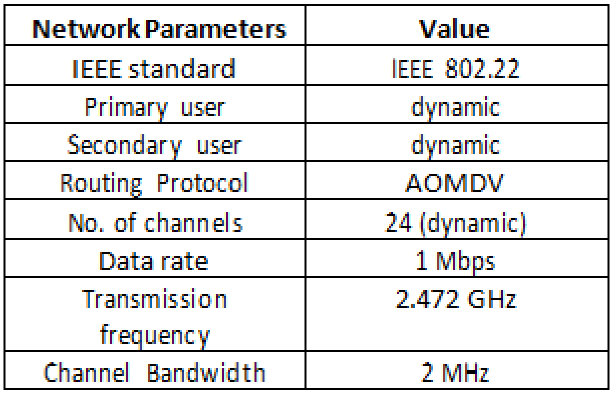
The value of λ is set as per the necessities of primary user detection performance. From the above conviction, the probability of miss detection, Pm is given in equation:

$$\begin{aligned} \mathrm{Pm} &= 1 - \mathrm{Pd} \\ &= \mathrm{P}\{\mathrm{decision} = \mathrm{U0}|\mathrm{U1}\} \end{aligned}$$

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

V. RESULTS

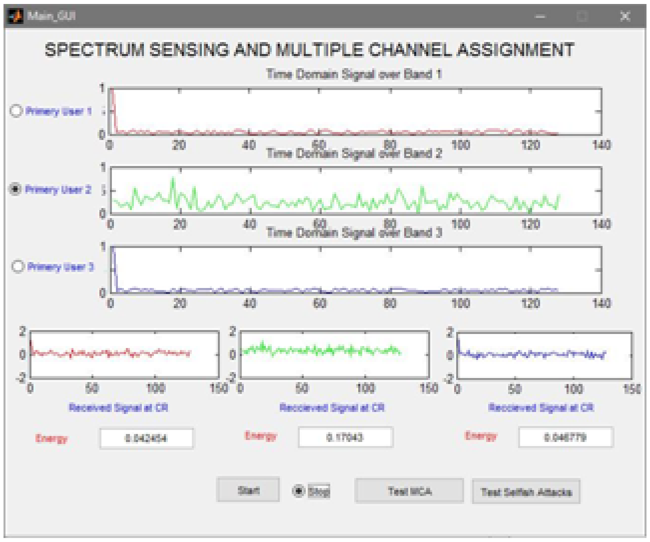
The details of the simulated network parameters and values are presented in the table below.



Network Parameters	Value
IEEE standard	IEEE 802.22
Primary user	dynamic
Secondary user	dynamic
Routing Protocol	AOMDV
No. of channels	24 (dynamic)
Data rate	1 Mbps
Transmission frequency	2.472 GHz
Channel Bandwidth	2 MHz

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 propounding the weightage of proposed method.

The energy detection mechanism is depicted in the GUI shown in Fig. 2. The energy sensed from the spectrum is considerable higher when there is a PU present in the channel as compared to a vacant channel.



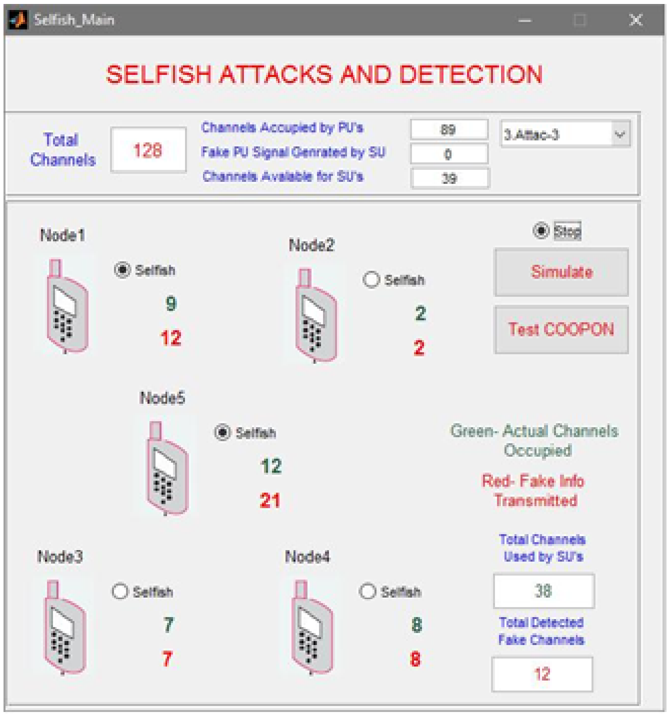
Energy 0.042454

Energy 0.17043

Energy 0.046779

Figure 2 Main GUI for Energy detection algorithm

Clicking on the ‘Test Selfish Attacks’ on the bottom right corner in the main GUI takes us into a new window that simulates a selfish attack detection mechanism. The detection mechanism shows that there are two selfish nodes. Their selfish activity results in the transmission of a fake channel information. As a result 12 channels are wasted as shown by the COOPON mechanism. It affects the performance of spectrum sensing and ultimately spectrum utilisation.



Total Channels: 128

Channels Accupied by PU's: 89

Fake PU Signal Genrated by SU: 0

Channels Avalable for SU's: 39

3.Attac-3

Total Channels Used by SU's: 38

Total Detected Fake Channels: 12

Figure 3 GUI for COOPON mechanism

The throughput is the rate of successful data or packet delivered on a channel or medium in a network. The simulation result in fig 4 depicts that the throughput of proposed technique using multiple channel assignment algorithm is high when compare to the previous method. At any point in the graph, throughput of the dynamically co-operated sensed channel is higher than the conventional static energy assigned channel.

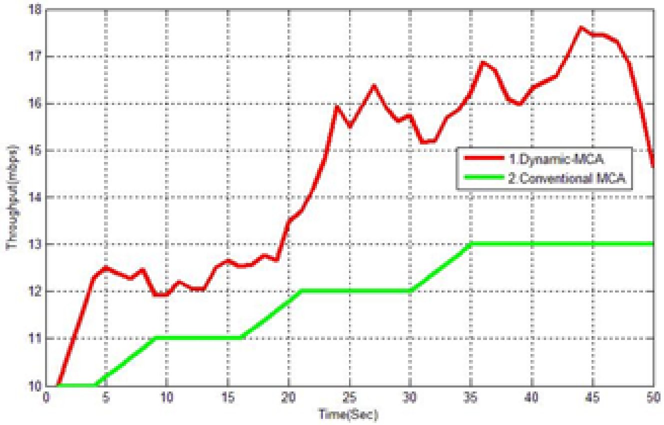


Figure 4 Comparison of throughput

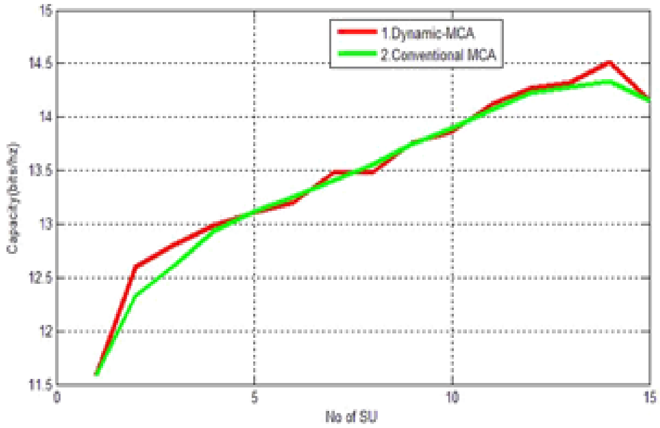


Figure 5 Comparison of Spectral resources utilized

The simulation result in fig 5 depicts that almost same amount of spectral resources are utilized during both of the algorithms. In spite of using same quantity of resources, co-operative sensing produces much better throughput as compared to its traditional counterpart.

The co-operative sensing mechanism allows COOPON algorithm to be implemented thereby improving the efficiency of the spectrum utilisation. The simulation result in fig 6 depicts the performance of COOPON algorithm when the number of neighbouring noted around the target node is varied keeping the total number of nodes constant at 50. More number of neighbors implies a better chance of selfish activity detection which is clearly evident from the graph.

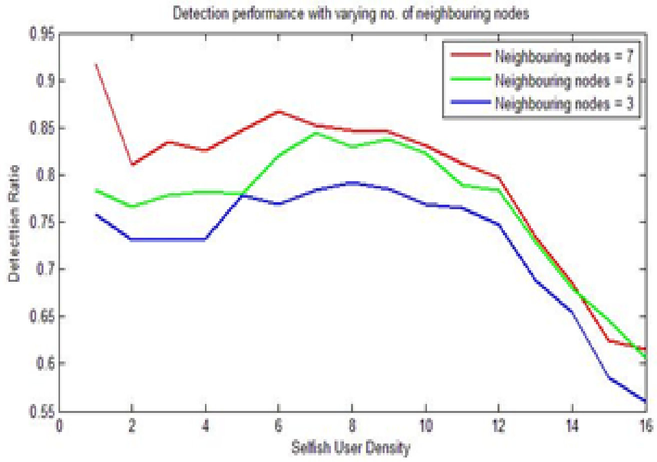


Figure 6 COOPON Detection performance with varying number of neighbouring nodes

The simulation result in fig 7 pulls out the impotent behavior of the detection mechanism when the total number of nodes in the network is varied clearly stating that the performance is inversely proportional to the selfish user density. As the number of nodes in the network increases the detection performance reduces considerably. The number of neighbouring nodes was kept constant at 7 for the entire variation.

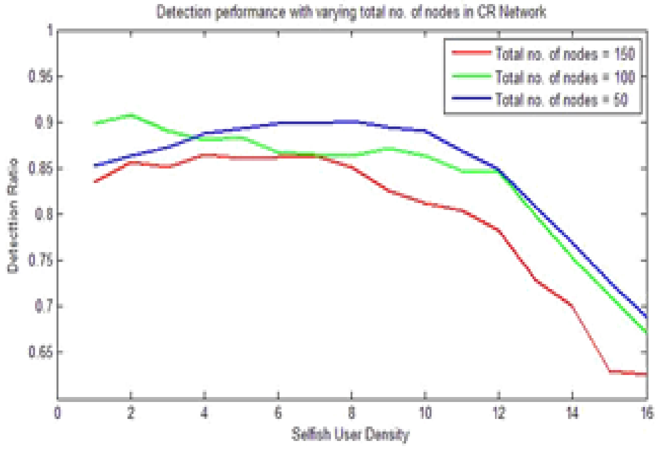


Figure 7 COOPON Detection performance with varying total number of nodes

The table below summarizes the graphical data. This quantitative analysis is for a particular case where the simulated environment was equipped with 24 channels in the 2 MHz bandwidth.

Parameter (Simulated for 24 channels)	Non-cooperative Channel assignment	Cooperative Channel assignment
BW utilised	2 MHz	2 MHz
Average data rate to users	1 Mbps (static)	1.68 Mbps (dynamic)
Data transmitted in 50 seconds	50 Mb	84 Mb
No. of preoccupant PUs	11	11
BW utilisation	70.833 %	95.83 %
No. of SUs serviced	5	12
No of Selfish Users detected	0	2
Detection Ratio	0	0.153

VI. CONCLUSION

It is clearly evident that there is a considerable increase in the Bandwidth utilisation when switching to a co-operative channel allocation scheme. Also there is a larger amount of data transmitted by the co-operative approach in the same stipulated amount of time using exactly the same amount of spectral resources as taken by the non-cooperative approach.

Co-operative sensing applied in multiple channel assignment algorithm when combined with opportunistic routing and multi-hop technique in cognitive radio network, provides higher throughput, better channel capacity and an improved spectrum utilization.

REFERENCES

[1] Manigandan, G. J., and S. Anandalatchoumy. "Dynamic Spectrum Access with Multiple Channel Assigning in Multi-Hop Cognitive Radio Networks.", June 2015, IEEE Xplore, 46-57

[2] S. Park, H. Kim, and D. Hong, "Optimization of Cooperative Spectrum Sensing with Energy Detection in Cognitive Radio Networks," IEEE Trans. Wireless Commun., vol. 8, no. 12, pp. 5761– 5766, Dec 2014.

[3] J. Unnikrishnan and V. Veeravalli, "Cooperative Sensing for Primary Detection in Cognitive Radio," IEEE J. Sel. Signal Processing., vol. 2, no. 1, Feb. 2015.

[4] W. Chung, S. Park, S. Lim and D. Hong “Spectrum Sensing Optimization for Energy-Harvesting Cognitive Radio Systems,” in IEEE Transactions On Wireless Communications, vol. 13, no. 5, pp. 260 – 2613, May 2014.

[5] Z. Gao et al., “Security and Privacy of Collaborative Spectrum Sensing in Cognitive Radio Networks,” IEEE Wireless Commun., vol. 19, no. 6, 2012, pp. 106–12.

[6] Z. Dai, J. Liu, and K. Long, “Cooperative Relaying with Interference Cancellation for Secondary Spectrum Access,” KSII Trans. Internet and Information Systems, vol. 6, no. 10, Oct. 2014, pp. 2455–72.

[7] H. Hu et al., “Optimal Strategies for Cooperative Spectrum Sensing in Multiple Cross-over Cognitive Radio Networks,” KSII Trans. Internet and Info. Systems, vol. 6, no. 12, Dec. 2012, pp. 3061–80.

[8] Jo, Minho, et al. "Selfish attacks and detection in cognitive radio ad-hoc networks." Network, IEEE 27.3 (2015): 46-50.