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Implementation of Spectrum Sensing for Maximum Throughput & Better Probability of Detection using Energy Detector

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***Abstract**: In Radio Resource Management, channel allocation protocols plays a crucial role in ensuring that Cognitive Radio(CR) technology achieves more efficiency in radio resource utilization. CR is an improved Software Defined Radio (SDR) that consequently distinguishes the encompassing Radio Frequency (RF) at that point quickens and after that intelligently obliges its working parameters to the foundation of a system to fulfill client characterized needs. CR innovation manages the unlicensed (auxiliary) user to utilize the authorized range briefly when authorized (essential) user doesn't utilize the range. Initially, Maximum Throughput allocation protocol is aimed to achieve optimal throughput and to compare with existing protocols and then introducing another protocol and then prove whether it will give best outperformance than maximum throughput or not. Performance comparisons of different parameters for various secondary users (SUs) were carried out to compare the different protocols comprehensively. In the same way to implement spectrum sensing for increasing of probability of detection by using energy detector under different conditions. increasing of the Maximum Throughput and Probability of Detection leads to efficient spectrum utilization by reuse of the channels results in many network applications like telecommunications, television broadcasting, ect.*

***Keywords:** Cognitive Radio, Channel allocation protocol, Maximum throughput, maximum capacity for secondary user, channel capacity*

I. INTRODUCTION

Subjective radio (CR) is an engrowing innovation that resolves clashes between the shortage of range assets, and quick increment in correspondence requests. Subjective Radio (CR) is a remote correspondence innovation that distinguishes the correspondence channels which were involved and which were not involved and afterward promptly possesses the vacant channels leaving the involved ones. Means Cognitive Radio innovation empowers the entrance of the intermitted times of abandoned recurrence groups called range gaps, in this way expanding otherworldly effectiveness. Along these lines, in CR arranges the assignment of Secondary User (SU) which is likewise called as CR user is to recognize the authorized user, known as Primary User (PU), if present and distinguish the accessible range on the off chance that they are missing. This is typically accomplished by detecting the RF condition, a procedure called range detecting.

Maximizing the channel throughput is our main motto. In general every channel has some parameters and here two parameters have been implemented. Those were maximizing throughput and reducing rejection rate. In [1], two channel allocation protocols have been implemented. Those were maximum rate [2] and maximum throughput [1]. However, the existing protocol has some limitations. That is potential throughput is not much efficient for communication channel. Here the main objective is to introduce new protocol and verify whether it gives better results than existing protocols. The numerical results with number of simulations will prove that new protocol will maximize the throughput and reduce rejection rate. In the same way throughput can be increased by implementing spectrum sensing by using energy detector [5]. Spectrum sensing detects unused spectrum and use that vacant spectrum band by the secondary user without harmful interference to the primary user. In general throughput can be increased with the increased probability of detector also with decrease probability of false alarm [4].

II. CR NETWORK

A. CR Architecture:

The below figure is cognitive radio network architecture consists of two networks. Those were primary network and cognitive network.

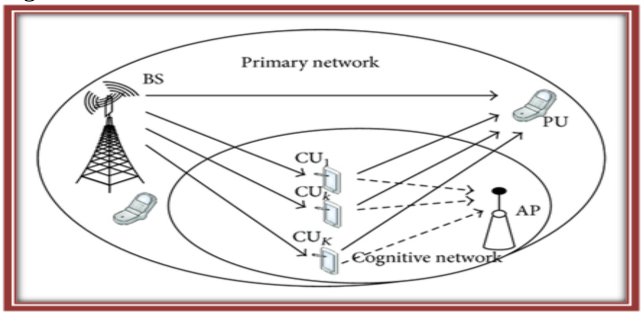

Fig. 1. Cognitive radio network architecture

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The existing network in the given architecture is primary network. The primary network consists of no. of users those were termed as primary users. These primary users has the right, to operate at certain band of frequencies, those bands were called as licensed bands. Examples for this network are cellular mobile communication, television broadcasting.

The second network that present is cognitive network which is also called as secondary network and users that present here were called as secondary users or cognitive users. This user doesn't have any certain band of frequencies to operate. So that these users were allowed to use licensed band of frequencies which is not licensed to that certain user.

B. CR Functions

CR technology made the advantage of using available channel effectively and efficiently around its vicinity with increase of potential throughput, decrease of rejection rate and decrease of delay characteristics. Means CR network selects best available channel and make the channel in use without leaving as an empty channel [8].

The underneath figure indicated was CR Cycle. It comprises of four phases specifically Spectrum detecting, Spectrum Management, Spectrum Sharing and Spectrum Mobility.

Spectrum sensing: Detects unused spectrum and use that vacant spectrum band by the secondary user without harmful interference to the primary user.

Spectrum Management: Select best available channel which is suitable to the secondary user when channel is vacant.

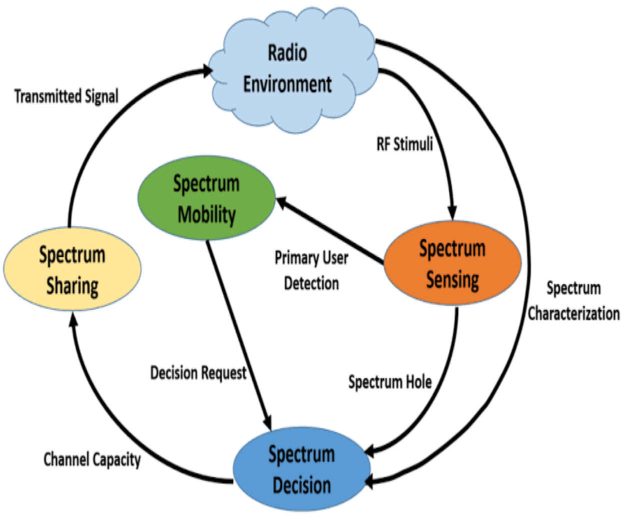

Fig. 2. CR Cycle

Spectrum Sharing: Establish the access to this channel with other users.

Spectrum Mobility: Vacate the channel when licensed user is returns to its channel.

C. System Models

The network scenario shown in below figure 1 Uplink channel allocation is considered here.

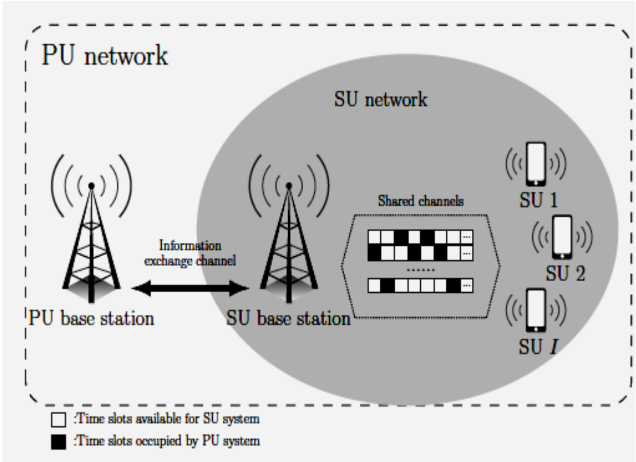

Fig. 3. System Model

The above figure has PU network and SU network. In this PU network consists of PU base station and SU network consists of SU base station. Exchange of information can be taken place in between PU base station and SU base station [3]. In general SU base station consists of no. of secondary users (SU). The system model has M no. of SUs and J no. of PU channels and each SU have size of buffer denoted by K.

D. Channel Allocation Protocol Rule:

SU system has to decide at the beginning of the time slot which SU has to operate with certain band of frequency when PU is absent and which SU should not be transmit over the channel when PU is present.

E. Primary User Activity Model:

The SU framework could not transmit over a channel when PU is transmitting on it. The mediation brought about by the PU exercises over a channel was worked as a time-homogeneous first-order Markov procedure comprises of two Free states. The two states were busy state and Free State which were represented by "0" and "1" respectively. Busy state means PU is transmitting over a channel. Free State means PU is not transmitting over a channel.

F. Secondary System Transmission Model:

The SU system's data transmission is considered as a time slot structure synchronized with PU system.

Time slot is divided into 3 consecutive parts:

(a) Spectrum sensing part
(b) Channel allocation part
(c) Data transmission part

(1)Spectrum sensing part:

SU has to sense whether PU is transmitting over a channel or not during this part [6].

(2)Channel allocation part:

Contingent on the data gathered by SU framework in the range sensing part, SU framework needs to distribute reasonable SU to the empty PU channel during current schedule opening. Here expected as one SU user can be relegated to different PU channels however one PU channel can't be apportioned to various SU users.

Means one PU channel must be utilized by only one SU client at certain specific space of time. A *J*-by-(*M* + 1) distribution probability matrix has been developed which is denoted as [1]:

$$P_{DPM} = \begin{bmatrix} d_0^1 & \cdots & d_M^1 \\ \vdots & \ddots & \vdots \\ d_0^J & \cdots & d_M^J \end{bmatrix} \qquad (1)$$

Where d^j_0 represents that the probability of *j*th channel is not assigned to any SU, and d_i^j for $i \neq 0$ represents the probability of SU system assigned the *j*th channel to the *i*th SU. It is to be noted as $\boldsymbol{P}_{\text{DPM}}$: $\sum_{i=0}^{M} d_i^j = 1$ for any $j \in [1, J]$.

(3)Data transmission part:
Data will be transmitted in terms of packets in this part. All the packets will enter into the SU buffer after data transmission. If no. of packets will exceed the buffer size, then exceeded packets will be rejected.

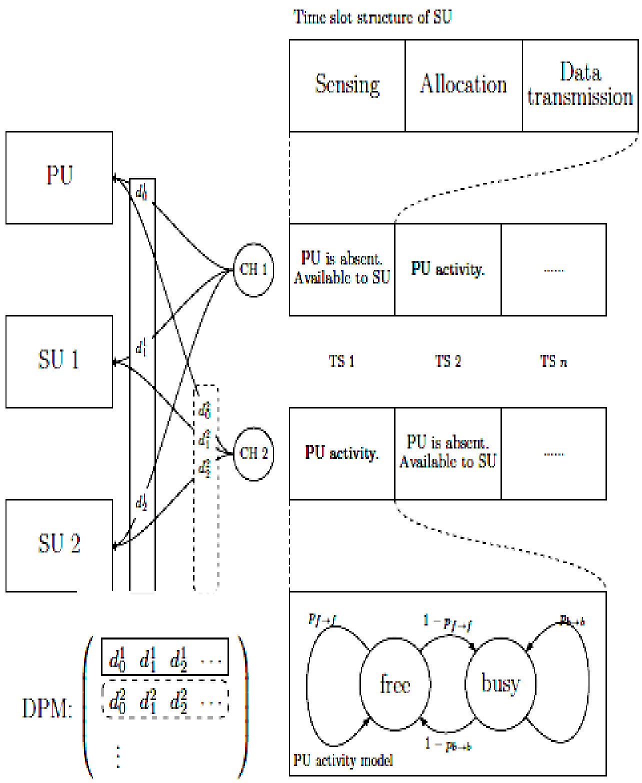

Fig. 4. Time slot structure of CR system and the PU activity model for the illustration of DPM

III. SPECTRUM SENSING

Spectrum sensing is one of the key legalized functions in CR network that is used to lookout vacant spectrum band and to avoid interference with the PUs [7]. There are two important criteria to determine spectrum sensing performance. They were:

(i) Probability of false alarm and
(ii) Probability of detection.

Probability of false detection denotes that the probability of a CR user declaring that a PU is present when the spectrum is actually free. Probability of detection denotes the probability of a CR user declaring that a PU is present when the spectrum is indeed occupied by the PU.

IV. THE CHANNEL ALLOCATION PROTOCOL

In general, Maximum throughput focus on capacity of available PU channels and takes the SU transmission demands over the channel into consideration. Potential throughput of one SU is denoted by the minimum between the channel capacity according to the channel condition state & AMC and the transmission demands. So as to limit the likelihood of dismissing entry bundle, when at least two SU have a similar transmission potential, we will dispense the channel to the SU whose support is bound to be full thereafter. Finally, the allocation results are represented in the form of DPM.

thr(i)=min(B(i),cap(i)) **(2)**
Th=∑thr(i) **(3)**
cap(i)=cap(i)+cap(j,i) **(4)**

where thr(i) : throughput of ith SU ,
B(i) : no.of packets in ith buffer ,
Cap(i) : capacity of ith SU ,
Cap(j,i) :capacity of ith SU to the jth channel ,
Th : total throughput .

For achieving of some more throughput than maximum throughput algorithm, introduced another algorithm as "maximum capacity of secondary user". It is similar to maximum throughput algorithm. But the modification that done is potential throughput is sum of the secondary channel capacity with respective to primary user.

V. ENERGY DETECTOR

In general, Spectrum sensing is one of the key stage in the cycle of cognitive radio. So as to appoint CR users to the empty groups in the range, CR user should detect the range ceaselessly. Three distinctive recognition strategies have been Acquainted in Range detecting with realize the opportunity groups: Energy detection, Matched filter detection and Cyclostationary detection. Out of these three, Energy Detection is used most widely due to the complexity that present in remaining two strategies [5]. Assume that the received signal is as follows:

$$y(n) = x(n) + w(n) \qquad (5)$$

then the metric to threshold will be:

$$M = \sum_{n=0}^{N} |y(n)|^2 \qquad (6)$$

CR network has to decide to select in between two states: those were primary user signal is absent also called as free state, denoted by H_0, and primary user signal is present also called as busy state, denoted by H_1 [6].

Busy state means PU is transmitting over a channel. Free State means PU is not transmitting over a channel. These two states can be modelled as follows:

$$\mathbf{H_0}: y(n) = w(n) \quad (7)$$
$$\mathbf{H_1}: y(n) = x(n) + w(n) \quad (8)$$

Where $y(n)$ denotes the received signal of secondary user, $x(n)$ denotes the transmitted signal of primary user, and $w(n)$ denotes the noise affecting the transmitted signal.

The performance of the method can be quantified by P_f, probability of false alarm and P_d , probability of detection. When w and x are modelled as zero-mean Gaussian random variables normally distributed with variances $\sigma_w{}^2 = N_0 W$ and $\sigma_x{}^2$ the metric follows a chi-squared distribution with 2N degrees of freedom. Where N_0 represents single sided noise power spectral density and W represents single sided single bandwidth [5].

VI. RESULTS

The performance of maximum rate and maximum throughput channel allocation protocols are analysed. The results showed that, maximum throughput protocol had maximum potential and is shown in the below fig. 5. Throughput is varied with respect to the SNR (dB).

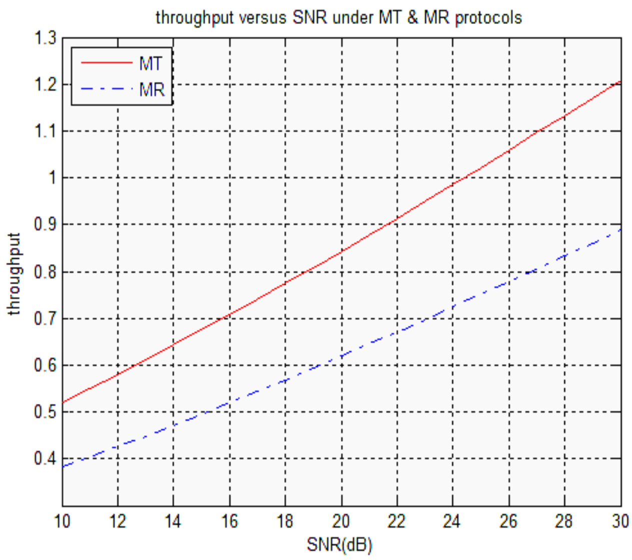

Fig. 5. Throughput versus SNR under MT & MR Protocols

In the case of rejection rate fig. 6, while comparing maximum rate and maximum throughput, maximum rate has the more rejection rate than the maximum throughput. That means it explains that the potential throughput is inversely proportional to the rejection rate and vice-versa.

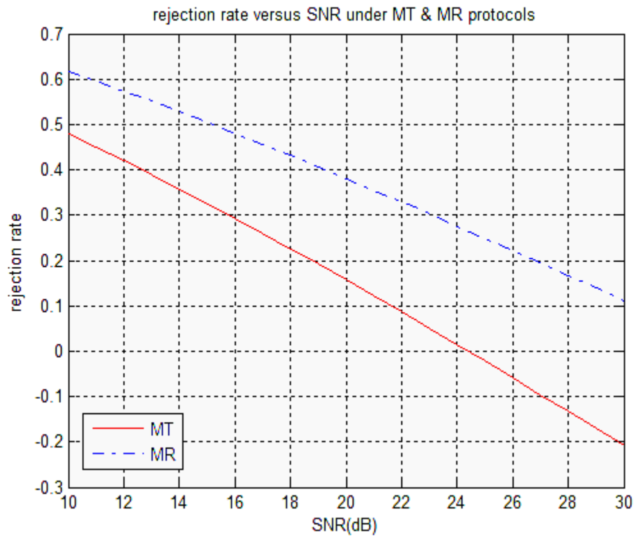

Fig. 6. Rejection ratio versus SNR under MT & MR Protocols

Later on decided to implement another protocol which is named as "maximum capacity for secondary user". In this, compared the maximum rate, maximum throughput and maximum capacity for secondary user. Here desired to improve more potential throughput for the new protocol.

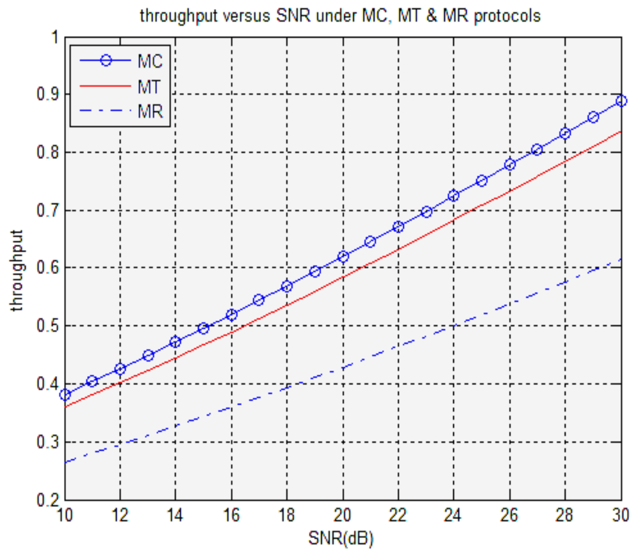

Fig. 7. Throughput versus SNR under MT & MR Protocols

As expected new protocol i.e., "Maximum Capacity for Secondary User" achieved maximum potential in the case of throughput and least rejection rate in the case of rejection ratio in comparison with Maximum Rate and Maximum Throughput.

The below fig.9. Shows Throughput versus SNR for Secondary User 1 with Maximum capacity for secondary user Protocol. Here throughput of Secondary user 1 is going on increasing with respect to the SNR (dB).

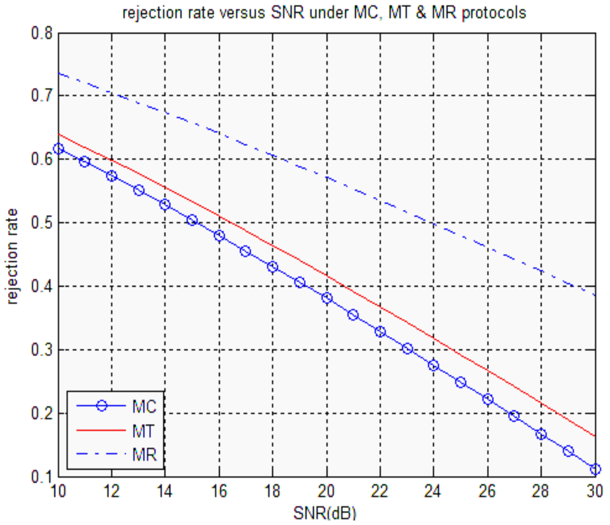

Fig. 8. Rejection ratio versus SNR under MC, MT & MR Protocols

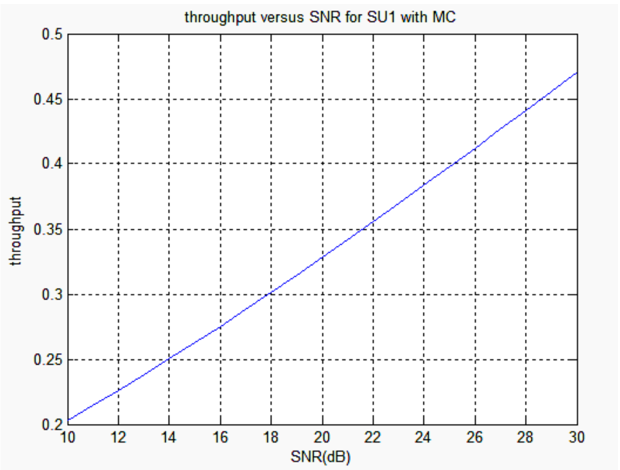

Fig. 9. Throughput versus SNR for SU1 with MC

The below fig. 10. Shows Rejection rate versus SNR for Secondary User1 with Maximum capacity for secondary user Protocol. Here rate of rejection for Secondary user1 is going on decreasing with respect to the SNR (dB).

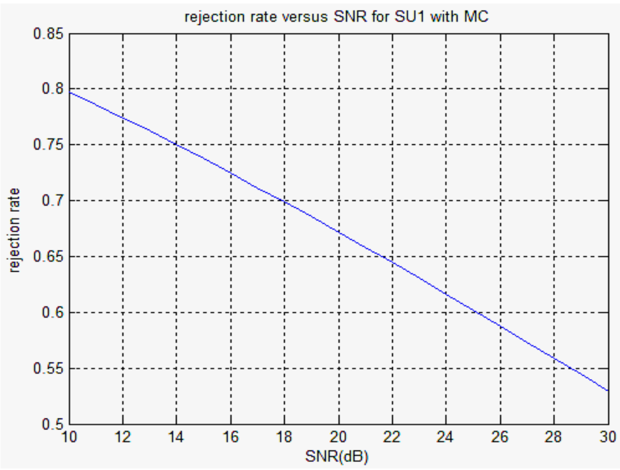

Fig. 10. Rejection rate versus SNR for SU1 with MC

The below fig. 11. Shows Throughput versus SNR for Secondary User 1 with Maximum capacity for secondary user Protocol. Here throughput of Secondary user 2 is going on increasing with respect to the SNR (dB).

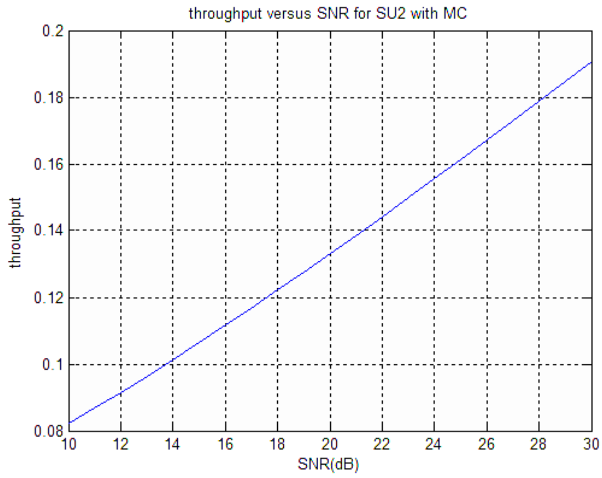

Fig. 11. Throughput versus SNR for SU2 with MC

The below fig. 12. Shows Rejection rate versus SNR for Secondary User 2 with Maximum capacity for secondary user Protocol. Here rate of rejection for Secondary user 2 is going on decreasing with respect to the SNR (dB).

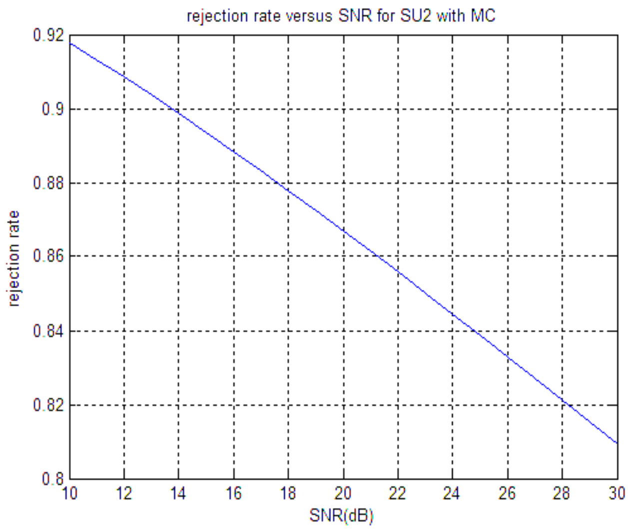

Fig. 12. Rejection rate versus SNR for SU2 with MC

Coming to spectrum sensing, by using energy detector method, determined the probability of detection with respect to the probability of false alarm. From fig. 13. It is probability of detection versus probability of false alarm for SNR=-20dB with no. of montecarlo simulations=1000. While probability of false alarm varying probability of detection is also varying. Means by increasing value of probability of false alarm, probability of detection also increasing.

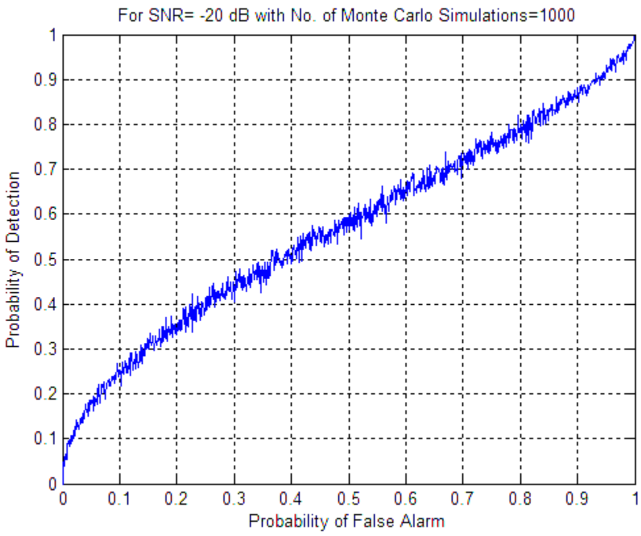

Fig. 13. P_d vs. P_f for SNR=-20dB with no. of Monte Carlo simulations=1000

From fig. 14. The simulation result is shown for theoretical expression of probability of detection with respect to the probability of false alarm. Here value of the probability of detection is somewhat clear than by comparing with fig. 13.

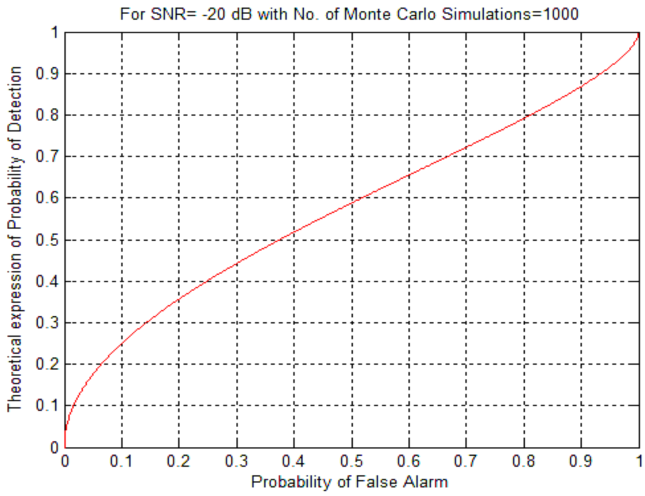

Fig. 14. P_d vs. P_f for SNR=-20dB with no. of Monte Carlo simulations=1000

From fig. 15, it is probability of detection versus probability of false alarm for SNR=-15dB with no. of Monte Carlo simulations=1000. From fig. 16. The simulation result is shown for theoretical expression of probability of detection with respect to the probability of false alarm. Here value of the probability of detection is somewhat clear than by comparing with fig. 15.

From fig. 17, it is probability of detection versus probability of false alarm for SNR=-10dB with no. of Monte Carlo simulations=1000. From fig. 18. The simulation result is shown for theoretical expression of probability of detection with respect to the probability of false alarm. Here value of the probability of detection from fig. 18. is somewhat clear than by comparing with fig. 17.

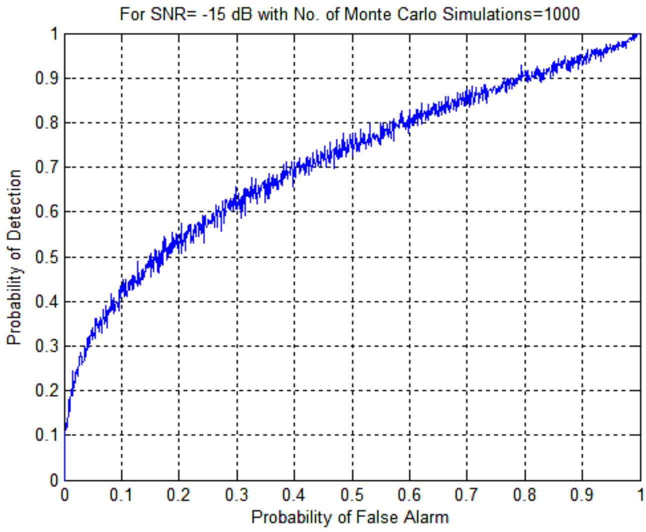

Fig. 15. P_d vs. P_f for SNR=-15dB with no. of Monte Carlo simulations=1000

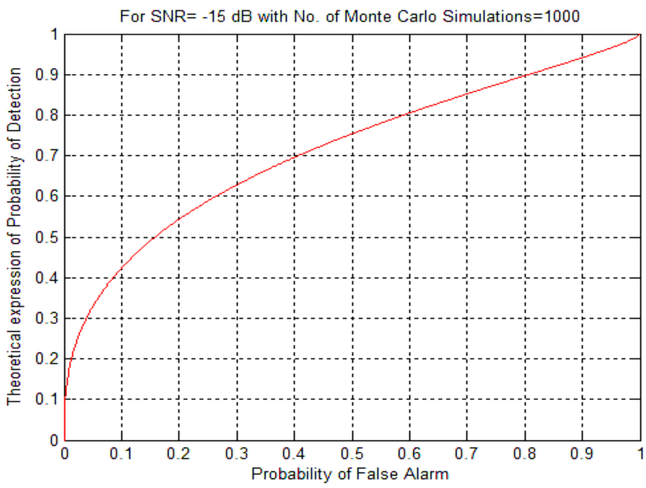

Fig. 16. P_d vs. P_f for SNR=-15dB with no. of Monte Carlo simulations=1000

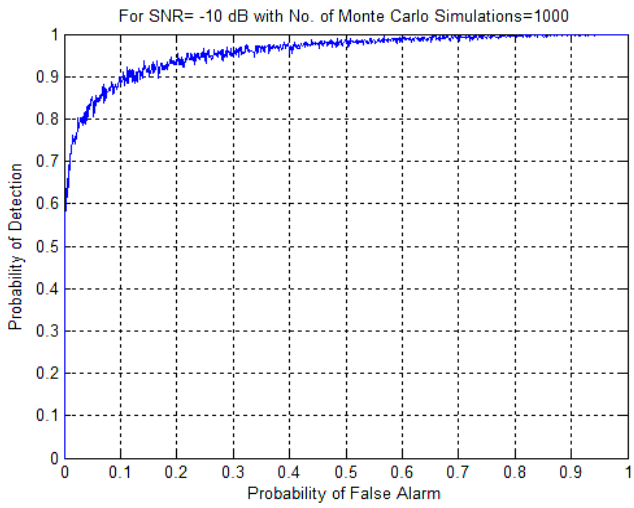

Fig. 17. P_d vs. P_f for SNR=-10dB with no. of Monte Carlo simulations=1000

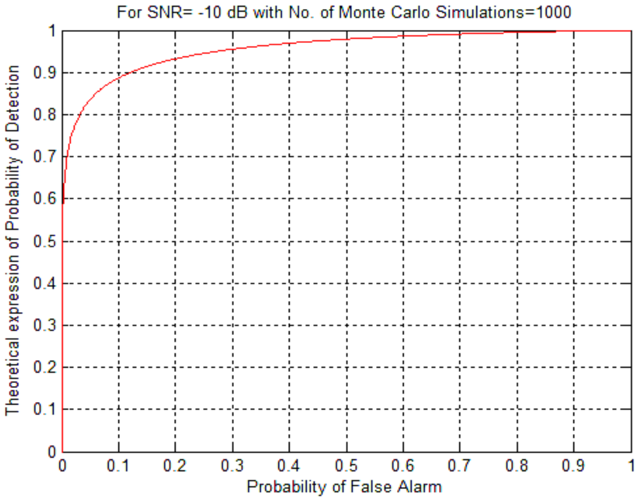

Fig. 18. P_d vs. P_f for SNR=-10dB with no. of Monte Carlo simulations=1000

From fig. 19, it is probability of detection versus probability of false alarm for SNR=-20dB with no. of Monte Carlo simulations=10000. From fig. 20. The simulation result is shown for theoretical expression of probability of detection with respect to the probability of false alarm. Here value of the probability of detection from fig. 20. is somewhat clear than by comparing with fig. 19.

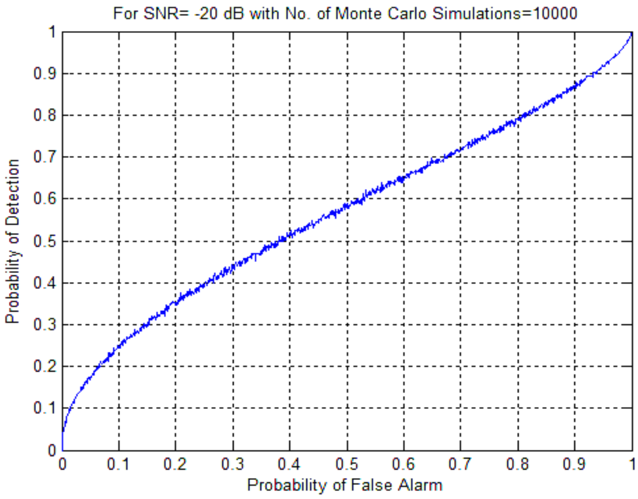

Fig. 19. P_d vs. P_f for SNR=-20dB with no. of Monte Carlo simulations=10000

From fig. 21, it is probability of detection versus probability of false alarm for SNR=-15dB with no. of Monte Carlo simulations=10000. From fig. 22. The simulation result is shown for theoretical expression of probability of detection with respect to the probability of false alarm. Here value of the probability of detection from fig. 22. is somewhat clear than by comparing with fig. 21.

Fig. 23. Shows the simulation results for probability of detection versus probability of false alarm for SNR=-10dB with no. of Monte Carlo simulations=10000. Fig. 24. Shows the simulation results for theoretical expression of probability of detection versus probability of false alarm for SNR=-10dB with no. of Monte Carlo simulations=10000.

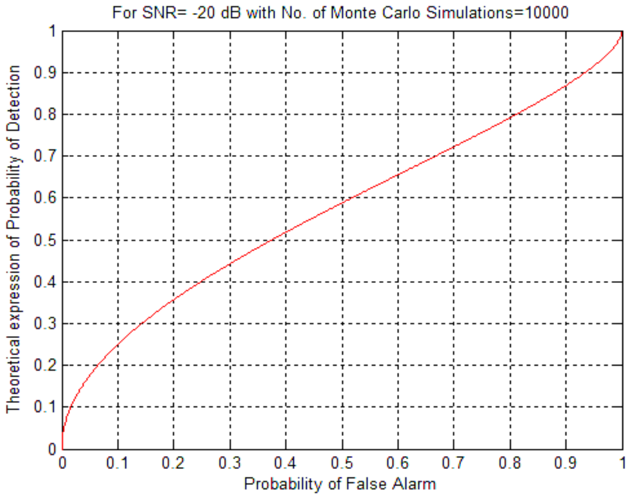

Fig. 20. P_d vs. P_f for SNR=-20dB with no. of Monte Carlo simulations=10000

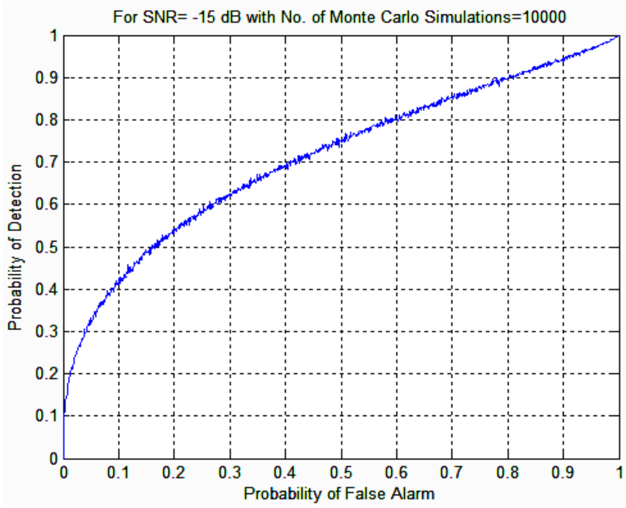

Fig. 21. P_d vs. P_f for SNR=-15dB with no. of Monte Carlo simulations=10000

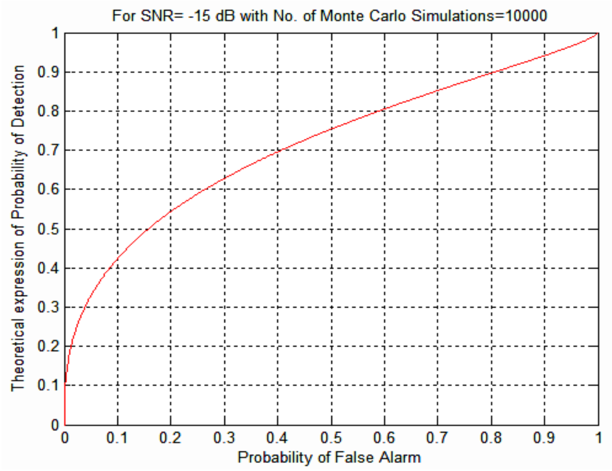

Fig. 22. P_d vs. P_f for SNR=-15dB with no. of Monte Carlo simulations=10000

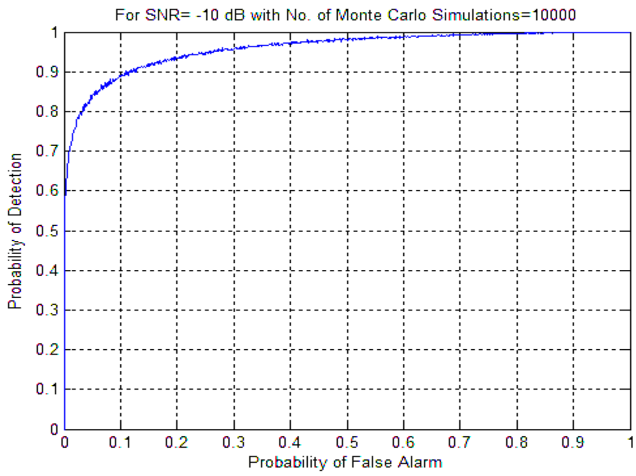

Fig. 23. P_d vs. P_f for SNR=-10dB with no. of Monte Carlo simulations=10000

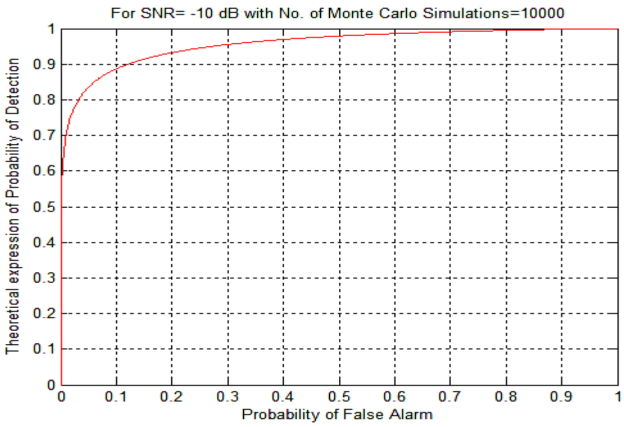

Fig. 24. P_d vs. P_f for SNR=-10dB with no. of Monte Carlo simulations=10000

The below fig. 25 shows the simulation result for probability of detection versus SNR (dB) by using M-PSK with M=16 for 1000 simulations and the fig. 26 is for 10000 simulations. Fig. 26. Shows that if no. of simulations were more than probability of detection will be high for smaller SNR (dB) values as compared with fig. 25.

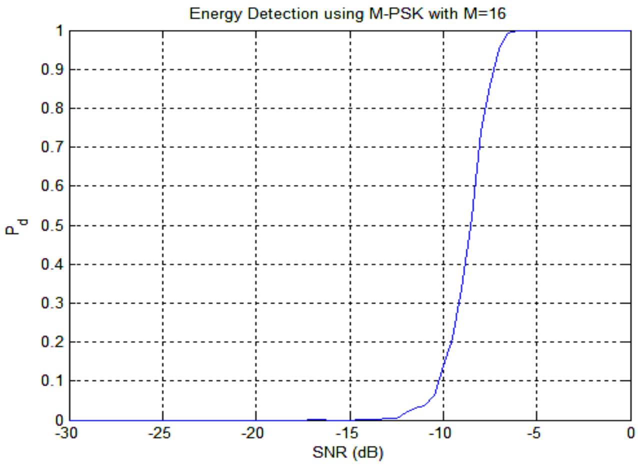

Fig. 25. P_d vs. SNR (dB) using M-PSK with M=16 for 1000 simulations

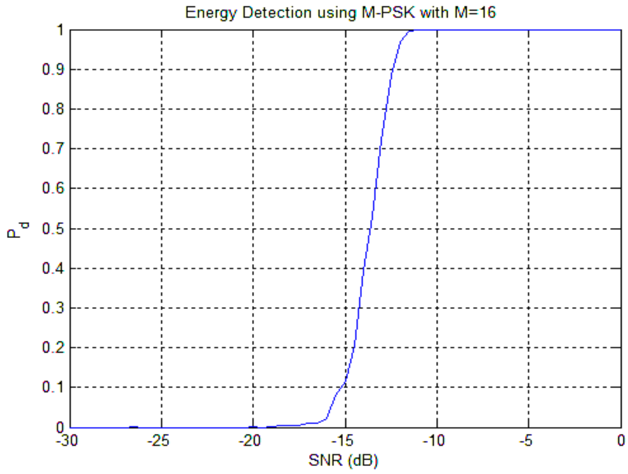

Fig. 26. P_d vs. SNR (dB) using M-PSK with M=16 for 10000 simulations

VII. CONCLUSION

In this paper, an improved channel allocation protocol has been introduced that was named as “Maximum Capacity for Secondary user” protocol has been introduced. Compared with the previous channel allocation protocols, such as Maximum Rate and Maximum Throughput for the two parameters has been implemented. Maximum Capacity for secondary user has been improved the SU system performance of throughput by 4 to 15 % under selected system settings. The parameters such as throughput and rejection rate have been improved.

The following example has been assumed in the above simulation, taken that the no. of primary users were ‘5’ and no. of secondary users were ‘2’ and the channel allocation for secondary users was as : **“ a(j) | $_{j=1\ to\ 5}$ ={2,0,1,1,0} ”.**

Where 0 represents no user is assigned,

1 represents SU1 is assigned,

2 represents SU2 is assigned.

Table-I: Performance analysis of Different Protocols

Name of the Protocol	Throughput	Rejection rate
Maximum Rate	47.36%	52.63%
Maximum Throughput	64.47%	35.52%
Maximum Capacity For Secondary User	68.42%	31.57%

The computation has been done on the basis of the Probability of detection P_d. It is observed that there is a greater chance of false detection at higher Probability of detection P_d. The results from fig. 7, 8 shows Probability of False Alarm versus Probability of Detection for SNR = -20 dB, fig. 9, 10 shows Probability of False Alarm versus Probability of Detection for SNR

= -15 dB and fig. 11, 12 shows Probability of False Alarm vs. Probability of Detection for SNR = -10 dB commonly for 10000 simulations. The results from fig. 13,14 shows Probability of False Alarm versus Probability of Detection for SNR = -20 dB, fig. 15,16 shows Probability of False Alarm versus Probability of Detection for SNR = -15 dB and fig. 17,18 shows Probability of False Alarm vs. Probability of Detection for SNR = -10 dB commonly for 1000 simulations. Finally we can say that by increasing of probability of false alarm, then there is a chance of increasing probability of detection.

Fig. 19 shows the performance of energy detection using M-PSK with M=16 with 1000 simulations and fig. 20. is for 10000 simulations. From fig. 19, observed that energy is varied in between -15 dB to -5 dB for 1000 simulations and from fig. 20, energy is varied in between -20 dB to -10 dB for 10000 simulations.

Table-II: Probability of False Alarm versus Probability of Detection for 10000 Runs

SNR(dB)	-20		-15		-10	
P_f	0.4	0.8	0.4	0.8	0.4	0.8
P_d	0.52	0.8	0.7	0.9	0.98	1

Table-III: SNR (dB) Versus Probability of Detection

No. of simulations=1000	**SNR (dB)**	-20	-15	-10	-5
	P_d	0	0	0.1	1
No. of simulations=10000	**SNR (dB)**	-20	-15	-10	-5
	P_d	0	0.1	1	1

Table-II shows that probability of detection is more for -10 dB compared with – 15 dB with respect to the probability of false alarm. That means probability of detection is more for high SNR (dB). Table-III shows that probability of detection is greater for 10000 simulations than 1000 simulations using M-PSK with M=16. That means probability of detection is greater for more no. of simulations. Therefore it is concluded that the probability of detection increases with increasing SNR (dB) as the no. of simulations increases also for increasing probability of false alarm.

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