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# Improvement in Utilization of the Spectrum using Cognitive Radio nodes

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***Abstract*-Currently, the research towards spectrum management has been increased inorder to avoid the scarcity of the spectrum and to improve the utilization of the spectrum which shows that researchers concentration towards spectrum utilization also get increased. This paper provides how ways of spectrum utilization and implementation varies from researchers to researchers. The main objective of the paper is to improve the overall spectral efficiency by sharing the spectrum among the service providers and avoiding the spectrum scarcity. The proposed system validates the utilization of spectrum sharing in three different ways like Normal utilization, applying Fuzzy logic system and predicting traffic pattern and finally proves that utilization of the spectrum has been improved with reduced call blockage, reduced interference and reduced high traffic patterns of the calls. This paper also gives the study of Spectrum sharing with different technologies.**

Keywords- Call Blockage, Primary User, Call Holding, Spectrum Sharing, Traffic Pattern

## I. INTRODUCTION

Currently, spectrum allotment operates by providing each new service with its own fixed frequency block. Demand for access to spectrum has been growing dramatically and is likely to continue to grow in the foreseeable future. Dynamic spectrum sharing is a promising approach for reusing the underutilized spectrum in which the spectrum is shared among primary and secondary (unlicensed) users (SUs) to improve spectrum flexibility and therefore efficiency. The CR provides a solution to this dynamic spectrum access (DSA). CR technology is a key enabler for both real time spectrum markets and dynamic sharing of licensed spectrum with unlicensed devices. The CR device is able to perform spectrum acquisition either through purchasing in cleared spectrum or sensing in vacant channels of geographical interleaved spectrum over a range of frequency bands.

The overall spectral efficiency of the work can be also increased with a flexible use of spectrum that adapts to the spatial and temporal variations in the traffic and environment characteristics. The available spectrum will be utilized opportunistically by the unlicensed users of the licensed spectrum without causing interference to the primary users. Hence, it provides opportunistic spectrum access of using the available spectrum. Here, the process of spectrum sharing is carried out in long term spectrum assignment methods which access the spectrum for a long period. If the spectrum is accessed in a long term, then there should be a preagreed amount consideration among the service providers. In this paper, the proposed Cognitive based spectrum access by opportunistic approach of Heterogeneous Wireless networks based on the Normal Utilization of the Spectrum, Fuzzy Logic system (FLS), Traffic prediction.

The paper structure follows: In Sections 2 and 3, the Literature Review and Proposed Spectrum Sharing Techniques are discussed. Simulation Results is discussed in Section 4. Estimation of call holding Time and Comparison of Channel Utilization are discussed in sections 5 & 6. Finally, we draw our conclusions in Section 7.

## II. LITERATURE REVIEW

The current utilization of the spectrum is quite inefficient as consequently, if the spectrum is properly used then there will be no shortage of the spectrum that is currently available. Therefore, it is anticipated that more flexible use of spectrum and spectrum sharing between radio systems will be key enablers to facilitate the successful implementation of future systems. CR is known as the most intelligent and promising technique in solving the problem of spectrum sharing. This proposed method considers the technique of spectrum sharing among users of service providers to share the licensed spectrum of the licensed service providers. There are several research efforts on spectrum sharing in CR technologies inorder to avoid spectrum scarcity and improve the spectrum utilization. This is considered as the main goal of the proposed work in a long term spectrum assignment strategy with coordinated and distributed manner. Many research works were proposed under centralized and decentralized manner of spectrum sharing. The spectrum sharing technology varies among the researchers. The researchers aim to avoid the spectrum scarcity. So that, the service providers tries to improve the spectrum utilization among them. Recent works have been proposed in order to provide the same in a distributed manner.

### *A. Spectrum Sharing using Cognitive Radio*

CR technology seeks the unutilized spectrum portion opportunistically and shares them with the neighboring devices. In [1], an approach has been developed for spectrum allocation using a multi-agent system that enables CR devices to work cooperatively with their neighboring licensed devices in order to utilize the available spectrum dynamically. A spectrum band can be either licensed or unlicensed, where a license gives a network the exclusive right of spectrum usage. Depending on whether holding a license, a wireless network is referred to as the primary or secondary network. Accessing a licensed band, the secondary transmitters must not cause significant interference to the primary receivers. One simple method of sharing a licensed band is to spread the signal energy radiated by each secondary transmitter over the whole band using spread spectrum techniques, suppressing the power spectrum density of the resultant interference to the primary receivers. This method is called spectrum underlay [2].

Another method for sharing a licensed spectrum is called spectrum overlay, where secondary transmitters access frequency sub channels unused by nearby primary receivers. Recent research on spectrum overlay has been focusing on designing CR algorithms for secondary transmitters to opportunistically access the spectrum [3]. In [4], the authors discussed how to avoid collisions as well as mutual interference using the overlay system which detects the allocation of the licensed system and dynamically adapts its system parameters for dynamic spectrum access. In [5], the authors outlined the challenges associated with the CR and also investigated new technological solutions to facilitate the shared access to the spectrum among operators, inorder to ensure efficient spectrum utilization.

In [6], the authors proposed an efficient utilization of the resources of deployed wireless communication systems, based on a bandwidth sharing approach. In [7], the authors proposed a cognitive based spectrum sharing scheme including autocorrelation based advanced energy spectrum sensing method and spectrum sharing procedure for efficient spectrum utilization. In [8], spectrum utilization was mainly depended upon the percentage of spectrum utilized by one service provider and it also depended on how many users were served and how much spectrum each user application demands with coordinated manner in a centralized network.

In [9, 10], the authors proposed a novel spectrum sharing strategy based on the throughput model in a CR network, where maximum theoretical throughput is taken into account. Most current work e.g. [11, 12, 13] have focused on allowing secondary devices to transmit when and where the strength of primary transmissions were so weak that spectrum was considered as unused. The spectrum sharing opportunities were not affected by the increase in the field size even if the field size grows to infinity [14]. However, in most of the existing works are on spectrum allocation and sharing [15 - 20] allocations are done in unlicensed band in a distributed manner.

### *B. Spectrum Decision using Fuzzy Logic via CR*

CR technology seeks the unutilized spectrum portion opportunistically and shares them with the neighboring devices. Fuzzy Logic System is chosen for the decision making because it is very much suited for nonlinear, imprecision and multi valued problems as it is capable of making real time decisions. This research will focus on the fuzzy decision making to opportunistically utilize spectrum in a heterogeneous cognitive radio network. Different methods of DSA, Dynamic spectrum access and main functions of Cognitive Radio were depicted in [21]. Here, the author discussed a model for fuzzy logic based spectrum access method in which the possibility of decision increases based on the other antecedents.

A novel fuzzy logic based opportunistic spectrum access system was proposed in [22]. The author discussed how the unlicensed user can utilize available licensed spectrum in dynamic manner depending on the possibility of access based on external parameters. At a particular time and place, the available spectrum has been chosen for accessing with the maximum possibility of decision. In [23], the authors presented a scheme for bandwidth allocation to cognitive radio and the proposal helped the channel distributor to decide the quantity of bandwidth that can be allocated to an unlicensed user at any given time. Fuzzy rules were used to optimize the bandwidth allocation based on three antecedents as: arrival rate of both licensed and unlicensed users and the availability of unoccupied number of channels within the system. The scheme was found independent of the service times for user's requests and thus may be applicable to any service distribution type.

In [24], a novel routing procedure based on the inferred behavior of licensed users has been introduced. Each channel at each node was evaluated by two metrics based on the utilization efficiency of the spectrum by studying the sporadic availability of the licensed bands to the unlicensed users. A naive spectrum access for secondary users can make spectrum utilization inefficient and increase interference to adjacent users were discussed in [25].

In [26], the authors proposed a distributed cognitive network access scheme with the aim of providing the best quality of service with respect to both radio link and core network performance and user application requirements using Fuzzy logic system.

*C. Traffic Pattern Prediction using Spectrum Sharing*

Traffic models are at the heart of any performance evaluation of telecommunications networks. An accurate estimation of network performance is critical for the success of heterogeneous wireless networks. Such networks need to guarantee an acceptable quality of service (QoS) level to the users. Therefore, traffic models need to be accurate and able to capture the statistical characteristics of the actual traffic. Prediction of future idle times of different channels based on history information allows a CR to select the best channels for control and data transmission. In [27], the authors shared that the dynamic spectrum sharing has become an important approach to improve spectrum efficiency by exploiting traffic loads variations of multiple wireless networks when a radio band was shared. The authors presented an effective centralized decision approach to deal with the problem regarding how a spectrum manager should periodically reallocate the spectrum between two networks in a single cell.

In [28], the authors studied the blocking probability behavior of connection oriented traffic and investigated dynamic channel assignment algorithms for multi-hop wireless networks. The authors derived both exact and approximate blocking probability formulas for a line network that yielded useful insights into the effect of transmission radius on call blocking. The authors in [29] has discussed about the queuing system with a M/M/N/N queue for two types of users compete for the N resources for traffic prediction. The users may have different call arrivals and service rates and they were denoted as primary or secondary users. The authors [30] aim at inferring the most appropriate conditions for an efficient secondary service provision according to the CR network characteristics. The author presented that how to tackle the issue of multimedia traffic distribution in TDMA based CR networks with the assumption that the primary system evolved with either a Markovian process or a Poissonian distribution.

The authors in [31] illustrated how to predict the call arrival rate of the primary users using a linear ARMA predictor following which the call holding time was estimated. The authors forecasted the traffic pattern of primary users, so that the secondary users can estimate the utilization of frequency bands and select one for radio transmission to reduce the frequency hopping rate. The call holding time distribution in cellular systems was analyzed for several system performance measures. Several statistical distributions were used to model the call holding time distribution in 3 generations cellular systems, such as exponential, Erlang, Gamma, and generalized Gamma in [32] and several factors affecting the call holding time such as the service plan, the class of the service area. In [33], the authors discussed the effect of long calls on the call holding distribution and concluded that call holding time was best modeled by a 4-component phase type distribution. The author in [34] described call holding time for PCS networks and provided analytical study for each of Gamma, (staged) Erlang, hyper exponential and hyper Erlang distributions. Previous research shows that it was possible to achieve good fit using a mixture of log-normals when the long hold times were truncated.

Although this truncation permits a good fit, it might lead to loss of significant fraction of calls. On the other hand, leaving all the calls including the few extremely long duration ones might lead to infinite variance/mean distribution [34]. According to this paper, the exponential and Erlang distributions have simple properties for modeling service time. This simplicity makes analyzing the queuing system easier. The differences between the current work and previous works are summarized as follows: First of all, resource allocation in a cognitive wireless network is quite different from that in traditional wireless network such as 802.11 based wireless networks due to its special features such as dynamic channel availability, channel heterogeneity and so on. Second, fairness is considered as a major one of this work. However, the proposed work achieves different goals such as minimized active users when there is a high traffic, reduced call blockage and maximized system efficiency. Third, this proposed work focuses on the call blocking, channel selection and assignment. In this chapter, a fuzzy based approaches based on the antecedents has been discussed for selecting the available spectrum in an opportunistic manner. This chapter also described and discussed various approaches for time series analysis and traffic pattern prediction.

## III. Proposed Spectrum Sharing Technique

During the peak hours, the communication of the users will be blocked due the number of active users is greater than the maximal number of users i.e., the infrastructure is found to be overloaded because of the channel scarcity. At the same time, infrastructure of the other service providers might be in the under loaded status. Hence, the available channels of the under loaded service providers can be utilized by the overloaded service providers. This may vary according to the services offered by the customers example Wireless internet for laptops, mobile communications and so on. So this may lead to the difference in the traffic of the active users across service providers. Here, both of these two service providers operate cell based wireless networks.

Therefore implementing spectrum sharing among service providers would highly improve the spectrum efficiency and it also reduces the call blocking rate and Co-Channel Interference. In order to reduce the Co-

Channel Interference and to remove the need of equipping CRs in each infrastructure of service providers, the proposed method that implements a spectrum sharing among service providers via CR nodes in a long term spectrum assignment scheme. These CR nodes are distributed regularly within an area of interest.

Each CR node senses the surrounding environment and monitors the channel usage within its sensing range of different service providers. To avoid co-channel Interference, CR nodes provides the list of the channel availability of each cell for the overloaded infrastructure of service provider. CR nodes are connected to each other via wire or they communicate wirelessly to form a network. This network is called as spectrum management network and it coexists with the wireless networks operated by different service providers.

The proposed work considers the distributed spectrum sharing architecture, cooperative spectrum sharing as the spectrum allocation behavior and Spectrum Overlay as the access technology. Similarly, both Intra-network and Inter-network spectrum sharing techniques are considered in this work. Hence, provides the opportunistic access to the licensed spectrum for unlicensed users and the users of a CR network try to access the available spectrum without causing interference to the licensed users.

## IV. SIMULATION RESULTS

The shared nature of the wireless channel necessitates coordination of transmission attempts among CR users. In this respect, spectrum sharing provides the capability to maintain the QoS of CR users without causing interference to the primary users by coordinating multiple accesses of CR users as well as allocating communication resources adaptively to the changes of radio environment. However, the unique characteristics of cognitive radios such as the coexistence of CR users with primary users and the wide range of available spectrum incurs substantially different challenges for spectrum sharing in CR. In this section, Using NS2 simulation the performance of the overall system efficiency has been evaluated.

### *A. Simulation results for Normal Utilization of the Spectrum via CR nodes*

If the infrastructure of one service provider is found to be overloaded, it sends the requests to the adjacent CR nodes regarding the availability of the Channel [35]. Channel availability can be determined by sending the service request to BS. BS receives the service request from the mobile node and it will send the channel request to the CR node. Fig. 1 shows the BS before sending request to CR nodes.

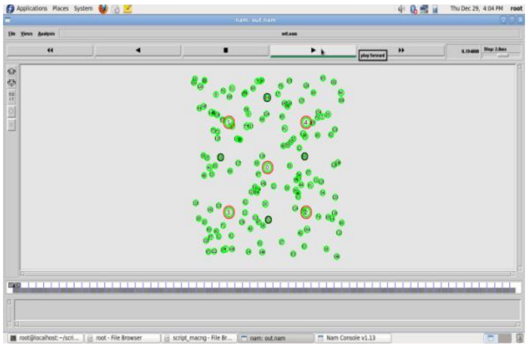

Figure 1. Before sending request to CR nodes

CR node receives the channel request and sends the broadcast message to the adjacent CR nodes. The neighbor CR nodes receive the broadcast message and send the available channel list to BS. CR node and its neighbors, updates the channel availability list and sends the response to BS. Fig. 2 shows the sending and receiving the request and response from CR nodes.

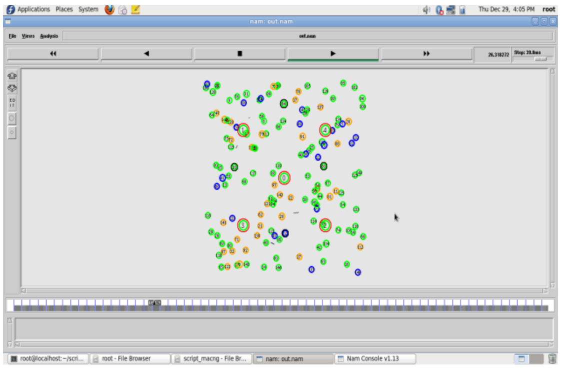

Figure 2. Sending request to CR nodes and response from CR nodes

If BS receives the response from CR node, it selects the available channel and sends the service reply to the mobile nodes with the allocated channel. This shows the maximum utilization of the channel and it offers several services such as internet service, call service, multimedia service and so on to the mobile nodes. Fig. 3 shows the maximum utilization of the channel by sending the response to BS regarding the channel availability.

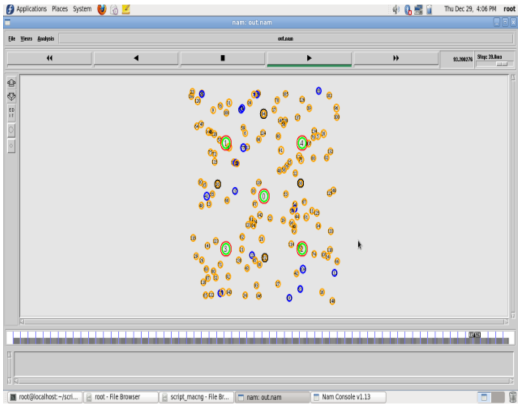

Figure 3. Response from CR nodes

The proposed scheme identifies the available channel list for each CR node. Such a list shows which channel is available to use depending on the distance among the CR nodes and high frequency band. Within a given neighborhood, multiple CR nodes may contend for access to one or more of the available channels.

### *B. Simulation result for Spectrum Selection using Fuzzy logic system via CR nodes*

The SU has been selected based on the highest possibility of accessing the available spectrum. The simulation results from Fig. 4, 5 shows that the network has been created to make transmission [36].

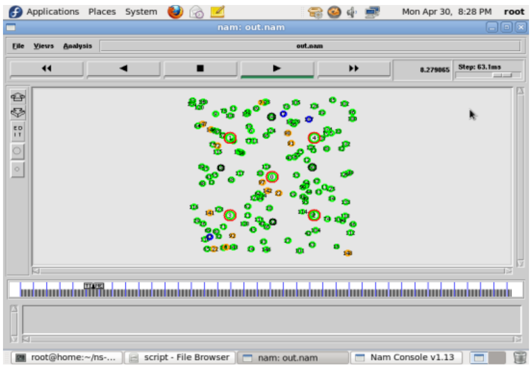


Figure 4. Initial stage of transmission

In Fig. 4, red color shows that the network has been created with BS. Here, the brown color indicates the CR nodes and green color indicates the mobile nodes. The blue color indicates that the transmission has been carried out with the selected spectrum. The Fig. 5 indicates the overall transmission made through the created network with the selected spectrum. Here, the orange color indicates that the transmission has been completed.

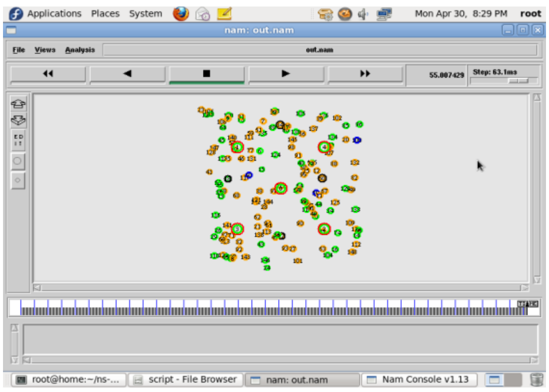


Figure 5. Completion of Transmission over the network

### C. *Simulation result of Traffic Prediction for Spectrum Sharing via CR nodes*

Here, the call arrivals are modeled using the Poisson distribution while the call holding times are exponentially distributed. Fig. 6 predicts that in the simulation, two BSs are defined (Node 0 and 1). Blue color node indicates the currently accessing the service provider of the spectrum by BS. Orange color nodes indicate that the nodes are already accessed the service in the previous time periods. Fig. 7 represents the service access between BS and mobile devices are carried out dynamically. Due to mobility, nodes are moving in the network by choosing random position in topography and the service are accessed dynamically.

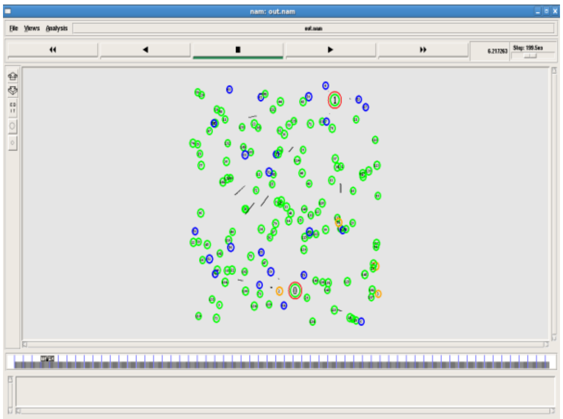

Figure 6. Current accessing of the spectrum

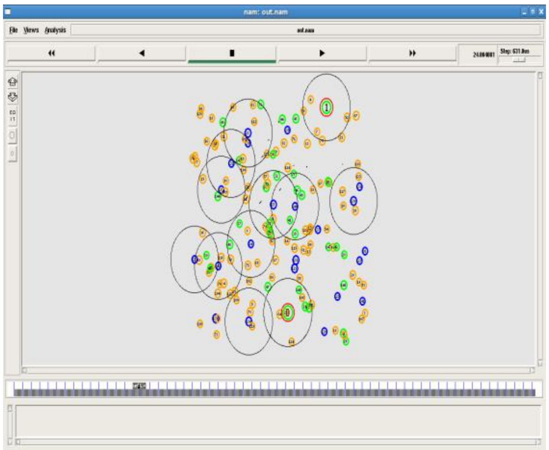

Figure 7. Service performed in a dynamic manner

## V. ESTIMATION OF CALL HOLDING TIME

The duration of call holding time is a fraction of the total call duration. The duration of the requested call connection is referred to as the call holding time. Factors such as mobility, cell shape and size because the dwell time to have a different Probability Distribution Function (PDF) to that of call duration. This difference being greater for higher mobility and smaller cell sizes.

The selection of the call holding times was typically assumed to be Gamma distribution and exponentially distributed [37]. Such an assumption may be reasonable when the calls are charged based on the lengths of the call holding times. To determine the call completion, we should evaluate the call arrival distribution, call holding time and cell residence time i.e., a mobile stays in a cell. However, the time needed for a call to complete should be estimated. It is desirable to know how much time is needed for a complete call to finish and how much time an incomplete call spends using the resource bandwidth.

Fig. 8 shows the relationship between PU and CR within a communication channel. In this figure, TPU, TCR and T are, respectively, the time when PU uses the channel, time when CR uses the channel after PU has already left and the time between PU's arrivals. C Since there is no knowledge of the distribution of T, we assume that it is uniformly distributed in the interval (0, TC). So, TCR is also uniformly distributed in the interval (0, TC).

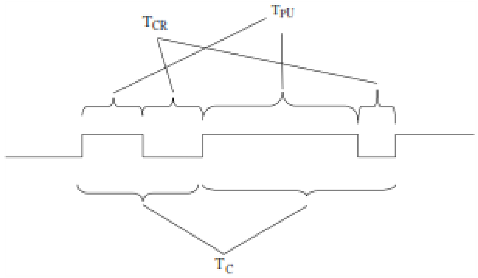


Figure 8. Relationship between the Primary user and Cognitive radio for Poission arrivals

Distribution Models such as Erlang distribution, Exponential distribution, lognormal distribution, Normal distribution and the Gamma distribution are used to approximate the channel or call holding times in the past. Exponential distribution can be used for one parameter approximation of the measured data whereas the Gamma distribution can be used for two parameter approximation. Although the exponential and Erlang distribution models have simple good properties for queuing analysis, however, they are not general enough to fit the field data. The generalized Gamma and log normal distributions are more general. Gamma distribution has been used to approximate the call holding time of Personal Communication Service systems.

### *A. Average number of packets*

In digital communications, data are defined and sent in terms of frames and packets. So, when one packet is transmitted safely, it does not need to be retransmitted even if the rest of the data are not communicated safely. In this section, the effect of PU's parameters on the average number of packets, the average symbol rate that a CR can transmit and the time that CR must wait is analyzed. When PU leaves the channel, TCR starts and so CR starts to transmit. If TCR > T then CR can transmit at least one packet without causing any interference for PUs. Fig. 9 shows possible shapes of the probability density function of TCR for selected values of λ and n. Fig. 11 shows the comparison of the PDF of call holding time T at a particular period with the gamma and exponential distribution of equal mean. The mean values of different time intervals are used to estimate the call holding time during a particular time interval.

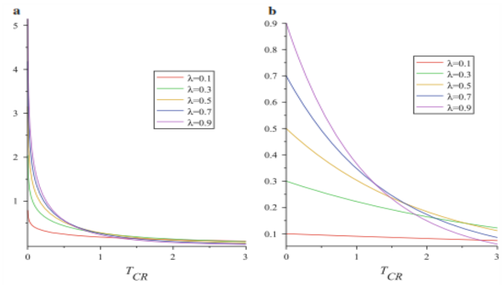


Figure 9. a. PDF of TCR for n=1 and b. PDF of TCR for n=2

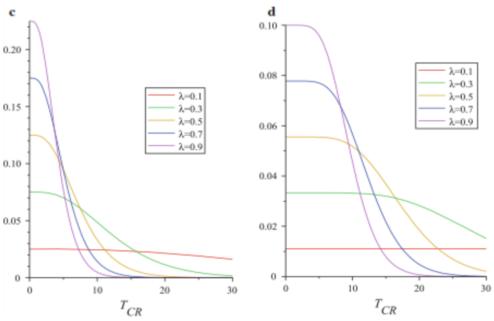


Figure 10. c. PDF of TCR for n=5 and d. PDF of TCR for n=10

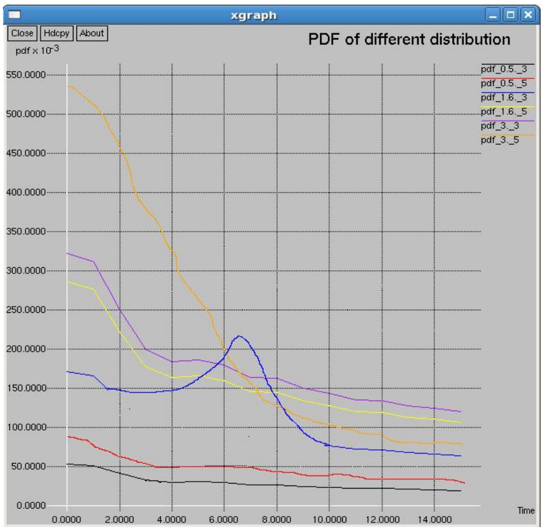


Figure 11. PDF Comparison of T with Gamma and Exponential Distribution

The call holding time is estimated for the PUs because the SUs can predict the probability P of the channel availability within a particular time interval T. Then, this probability can be compared with its waiting time.

### *B. Average waiting Time*

When CR wants to send its data, it must be sure that its packets do not interfere with PU transmissions. If PU starts to transmit, CR must stop and wait until PU leaves the channel. In this case, it is important for CR to know how much time it must wait until it finds an opportunity for transmitting its data.

## VI. COMPARISON OF CHANNEL UTILIZATION

The main objective of the thesis is to improve the spectrum utilization to avoid the scarcity of the spectrum of a particular service provider. Spectrum is a finite resource and its management is contingent on effective policies and efficient practices to optimize its utilization and facilitate equitable sharing among users. Today's spectrum usage is largely licensed access, while only a small part of the spectrum uses license-exempt equipment. The amount of licensed spectrum that could be made available for communications in the future is limited by the unavailability of unallocated spectrum, especially below 2GHz. Today, the users need to fulfil a set of criteria to facilitate coexistence of different systems on the same band which in practice means limited transmission power levels and hence the coverage has been reduced.

In parallel, the spectral efficiency of wireless systems in terms of achievable throughput per system bandwidth in bits/s/Hz has been improved significantly. There will be less improvement in the spectral efficiency due to the natural limits of wireless communications. Another dimension in the spectrum use is the spectrum occupancy which characterizes the utilization rate of a frequency band. The spectrum occupancy dimension can offer more improvements by facilitating coexistence of different systems on bands where the current spectrum occupancy is low. The Spectrum sharing among service providers provides a way for efficient and effective spectrum utilization. This can allow for spectral reorganization and sharing of spectrum from the under-loaded network to an over- loaded network, or the offloading of users between the networks. Both have the effect of increasing achievable capacity at given time.

This section presents some comparison results of channel utilization with the existing and the proposed work. From the existing work of [35], the author presented an approach to improve the spectrum efficiency by exploiting traffic loads variations of multiple wireless networks when a radio band is shared. The author periodically re-allocate the spectrum between two networks in a single cell, while maintaining both the call blocking and dropping probabilities in their acceptable levels and improving the spectrum efficiency simultaneously. From the existing work, the author presented to balance coordination amongst the SPs with minimal control messaging. The percentage of spectrum utilized by one SP depends on how many users it is serving and how much spectrum each user application demands. The authors adopted a user utility maximization framework to analyze this system.

The Fig. 12 shows the comparison results of the existing work and proposed work. Based on the results presented, the overall Channel utilization has been improved by purely the proposed Fuzzy logic system and traffic pattern prediction is about 20% [37].

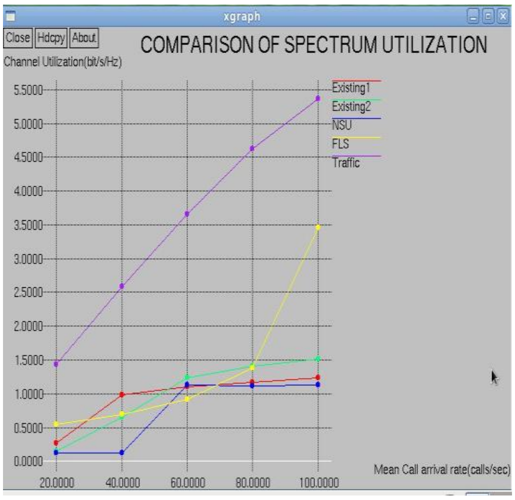


Figure 12. Comparison of Channel Utilization

Future mobile networks will achieve higher spectral efficiency if the operators decide to share parts of the spectrum that has hitherto been exclusively licensed to them. It is expected when the operators share the spectrum in the same geographical location and Time. From the Proposed work, the major impairment that has so far prevented is the interference caused by co-channel transmissions.

## VII. CONCLUSION

If the Spectrum assigned to different service providers is not properly utilized with the allotted frequency. So some service providers may try to use the allocated spectrum fully and even they need more spectrums and which may not be used by service providers fully. The proposed algorithm of traffic pattern prediction predicts the call arrival rate of PUs and it gives an approach to predict the call holding time of the PUs. Predicting the probability of call arrival rate provides the SU regarding the channel availability to determine whether to use the channel or not. This proposed algorithm leads to the optimal transmission and observation time to maximize sensing efficiency satisfying the strict interference constraint of primary networks.

On the other hand, many published studies proved that these distributions were not general enough to fit empirical data. The proposed work is applied with Gamma distribution because it is found to be more flexible and provide better fit for estimation of call durations. This prediction enhances the channel utilization of PUs and enhances the communication of PUs. The simulated results depict that there is a decrease in the call blocking and reduced interference. This helps to improve the channel utilization and avoids the scarce resource of the spectrum.

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