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Novel Analytical Framework for harnessing Cognitive Radio Resource Optimization in 5G Networks

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Abstract: ***The adoption of cognitive radio technology is characterized by various beneficial characteristics that can facilitate better spectrum sensing performance in a 5G network and thereby acting as a boosting element towards a high data transmission rate. However, it is also characterized by various challenges that limit the significant development in resource utilization in 5G. Therefore, this paper introduces a novel and simplified mechanism that facilitates the 5G network to perform better in data transmission and its associated quality of it. The proposed system also performs modeling using practical constraints associated with the usage of cognitive radio over 5G networks using a convex optimization approach. The model is simulated using practical environmental parameters to prove that the proposed system excels better performance in faster processing and quality signal in contrast to the existing resource allocation scheme exercised in 5G networks.***

Keywords: Cognitive Radio, Internet of Things, 5G networks Resource, Cost.

I. INTRODUCTION

5G network is basically meant for supporting the connectivity among the applications that demand higher data transmission capabilities [1] [2]. It consists of the transmission and communication area that ranges in the geographic area called cells. All the devices of wireless form in 5G cells performs data transmission with each other using radio waves that are facilitated by an array of the local antenna as well as sophisticated transceivers [3]. There is an ongoing study that discusses the usage of millimeter waves to further improve the transmission rate in 5G.[4]. It is believed that the adoption of 5G offers supportability towards millions of communication devices, which offers an appropriate communication bridge in Internet-of-Things (IoT) networks [5][6]. However, apart from the beneficial aspect of a 5G network, it has associated challenges, too [7]. The first challenge is associated with the usage of the frequency band in 5G networks as there is less number of higher spectrum band availability.

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The second challenge is associated with the coverage and the deployment aspect of 5G network as it has a restricted range of operation. For higher range, beamforming is used for supporting higher frequency; however, still, the challenges remain, which are the usage of 5G antenna. The third problem is associated with building cost and purchasing costs associated with initial network construction, which is quite higher. The fourth problem is associated with the supportability of the device, which is extremely less in present times. The fifth challenge is associated with security issues in 5G. In the present time, it has been seen that the adoption of cognitive radio offers a significant advantage to improve the performance of a 5G network [8]. The biggest capability of cognitive radio technology is its potential to address the scarcity problems of the spectrum with the aid of accessing dynamic spectrum as well as sharing spectrum [9]. Interestingly, this process of cognitive radio technique has absolutely no dependency on increasing the expenditure of surplus resources of radio frequencies. It can significantly control the cost, capital, and overall expenditure. The existing research trend is basically to ensure that there is a presence of multiple spectrums with multiple heterogeneous wireless networks considering multiple attributes of it viz. space, frequency, time, polarization, etc. There have been various survey work carried out on the cognitive radio network on 5G, where various environmental scenarios have been considered viz. presence of microcells and small cells, ii) presence of communication system and radar, iii) the presence of different satellite services, etc. [10]. By including intelligence towards different types of wireless networks, cognitive radio technology can offer various beneficial information to the 5G networks. Moreover, harnessing the capability of the smart antenna with better beam forming capacity can actually boost the performance of 5G networks. Apart from this, usage of Licensed Shared Access over cognitive radio technology dynamically can facilitate better sharing of spectrum, time, and frequency. Finally, cognitive radio also assists in integrating various devices of self-organizing capability that can be built with more potential to further assists in forming a network with self-optimized wireless nodes in the 5G network. However, it is not that simple to incorporate cognitive radio in the 5G network as it has its own challenges that are required to be explored and investigated. The biggest challenging factor associated with the usage of the cognitive radio over the 5G network is the resource constraint, which is quite difficult. Hence, the proposed system has introduced a novel analytical solution that is meant for overcoming the performance tradeoff associated with resource allocation in a 5G network when cognitive radio is incorporated.

The organization of the proposed manuscript is as follows: Section **"A"** discusses the existing literature where different techniques are discussed for detection schemes used in 5G network and cognitive radio technology is briefed, followed by a discussion of research problems in Section **"B"** and proposed solution in **"C"**. Section II discusses system implementation along with the backbone strategy used and algorithm implementation, followed by a discussion of result analysis in Section III. Finally, the conclusive remarks are provided in Section IV.

A. The Background

This section discusses the existing research work towards the proper utilization of the resource factor associated with 5G networks. Most recently, the adoption of cognitive radio has significantly improved the performance of the 5G network with respect to its resources. The work of Wang et al. [11] has considered the usage of artificial intelligence, where the resource spectrum is targeted to be improved. Another recent work of Balieiro et al. [12] has a virtual networking system has been improved for better access using a unique mapping model. The work of Bega et al. [13] [14] has used a deep learning approach over a cognitive radio targeted for predicting the capacity to hold an upcoming traffic system. Dudin et al. [15] have developed a model for evaluating the quality of experience by constructing architecture for the allocation of resources using involuntary services. The work carried out by Halabian [16] has presented an optimization concept for resource allocation that is carried out in a distributed manner. Kakalou et al. [17] have used the concept of an environmental map of radio considering the heterogeneous environment for the cognitive radio network. Khan et al. [18] have used the evidence theory for formulating effective feature extraction schemes over cognitive radio for obtaining better spectral efficiency. Liu et al. [19] have used a wavelet filter to perform optimization for improving the data transmission rate for the unlicensed user using an intelligent search algorithm. Thummaluru et al. [20] have used the concept of MIMO for improving the performance of the reconfigurable antenna. Yan et al.[21] have used deep learning as well as a reinforcement learning mechanism in order to perform the allocation of the resource over the 5G network. Ali-Tolppa et al. [22] have used a self-organizing concept in order to perform anomaly detection over 5G cognitive networks. Bahaei et al. [23] have discussed the full-duplex concept using cognitive radio over 5G networks. Kryszkiewicz et al. [24] have also used the environment map concept for the sharing of spectrum using a contextual approach. Masek et al. [25] have enhanced the standard process of licensed Shared access in order to control the spectrum management system over the 5G network. A similar form of discussion has also been carried out by Sadreddini et al. [26], where the mobile network operator concept has been used for performing the utilization of resources. Xu et al. [27] have presented a mechanism of spectrum sensing where a time-varying channel has been used for the cognitive radio system. The work of Yau et al. [28] has discussed various schemes assisting in perform of 5G mobile networks and studied their effectiveness. Zhang et al. [29] have discussed the spectrum of lean management towards catering up management of dynamic spectrum using the water-filling algorithm. Kliks et al. [30] have presented a discussion about the environmental mapping scheme to present a sophisticated architecture considering the software-defined network as well as the virtualization environment. Therefore, it can be seen that there is various work being carried out towards improving the 5G networking system where the inclusion of cognitive radio is proven to be highly helpful. The next section discusses the open end research challenges associated with the use of cognitive radio in 5G networks.

B. The Research Problem

Significant research problems are as follows:

- The adoption of multiple numbers of cellular structure and its associated components inclusion was not significantly studied in 5G networks
- Inclusion of cognitive radio in 5G was found not to consider a beamforming strategy, which is one of the significant concepts to be considered.
- The inclusion of a cognitive radio network should be characterized by various practical constraints associated with the resources which are not considered in the existing system.
- The environment of 5G considered in the existing scheme was found to be implemented using a controlled environment where flexibility and scope of the study are significantly required.

Therefore, the problem statement of the proposed study can be stated as "*To develop a cost-effective framework that can perform simplified resource management considering the practicality of constraint associated with cognitive radio usage over-improving spectrum sensing in 5G network*".

C. The Proposed Solution

The prime purpose of the proposed system is to address the open research problems briefed in the prior section. The concept used in the proposed solution is basically an analytical method that has an explicit design module to improve the performance of cognitive radio operation when integrated with a 5G network. The schematic diagram of the proposed system is as follows:

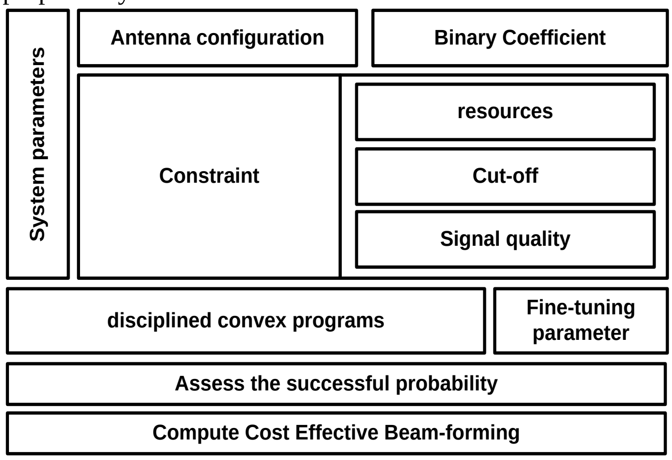

Fig.1 Proposed Schematic Diagram

The implementation of the proposed study is carried out considering a different number of the cells in the 5G network.

The implemented strategy of the allocation of resources is developed considering the essential characteristics of the cognitive radio network, which is classified into primary and secondary users. Fig.1 highlights the scheme of the proposed system that consists of essential system parameters viz. i) antenna configuration, ii) binary coefficient, and iii) constraints. The study considers the constraint of the resource factor that is required to be allocated to the subcarriers in 5G networks. These resources factors consider signal quality in the presence of artifacts and threshold mainly. The proposed study represents the problem of resource allocation as non-convex problems that are transformed to convex programmed for discipline form as a part of the solution. The study also uses a fine-tuning parameter in order to perform normalization of traffic. The proposed study finally performs the evaluation of the success probability for allocating the resources towards the subcarriers in 5G networks, which is later followed up by evaluating cost-effective beamforming. Therefore, the proposed system uses a simplified, cost-effective mechanism in order to perform resource allocation while using cognitive radio-based 5G networks. The next section outlines system implementation.

II. SYSTEM IMPLEMENTATION

In order to develop a comprehensive framework for offering seamless and quality-oriented data transmission over 5G networks, the adoption of a cognitive radio system is essentially beneficial aspect. The proposed system design emphasizes an effective resource allocation scheme over 5G networks where devices are considered to be equipped with cognitive radio. This section discusses the assumptions that are considered while implementing the following by briefing of backbone strategy, design implementation, and algorithm implementation.

A. Assumption Considered

The primary assumption of the proposed system is to consider the presence of both the multiple numbers of cells of secondary type as well as primary systems. The center point of the system is considered as a position for the primary system, whereas it also consists of primary users as well as the primary base station. The study considers that secondary cognitive radio possesses a different number of secondary cells that are distributed in uniform fashion within the primary system. There are various numbers of the secondary cells present in the secondary cognitive radio while it performs the distribution of the primary system into uniform fashion. The primary systems are assumed to be asynchronous, and so are the secondary cells, which is highly practical. Therefore, this results in interference owing to the leakage of the spectrum in both the system (secondary and primary). The public sensing nodes are assumed to assists in the sensing spectrum, while the synchronization is carried out for secondary cells. The proposed study assumes the predefined information about the better possibility of distribution of power, which is followed by an assignment of subcarrier on the basis of the maximum interference factor.

B. Backbone Strategy

The proposed system implements the concept of 5G network-enabled with cognitive radio, which is targeted for encapsulating multiple forms of services for upcoming times in mobile networks. The base concept of the proposed study is based on the consideration that it is not feasible for the 5G network to offer high data transmission rate with minimized delay all the time as well as it is also not feasible to cater up the dynamically growing demands of the user. Hence, the proposed system adopts the inclusion of a cognitive radio network, which is considered to be an appropriate technology in order to sort out the challenges associated with the scarcity of quality spectrum in 5G. It is to be known that there are low efficiencies of utilization associated with the resources of the spectrum over normal networks. The primary reason for the adoption of cognitive radio in the proposed system is the fact that it can successfully prevent wastage of resources connected to the spectrum considering the temporal domain. It also targets to increase the cumulative efficiency of the spectrum associated with the network. Another interesting fact about the adoption of cognitive radio in the proposed system is that it can be highly capable of performing an effective resource allocation to the subcarriers. It is because there are dual user forms in cognitive enabled 5G communication viz. primary user and secondary user (also called cognitive user). When the users are facilitated with licensed resources of the spectrum and can perform random data transmission than it is called a primary user. However, there are no exclusive resources of the spectrum to the cognitive users in the 5G network. By doing this operation, it is now possible to perform complete utilization of the resources of the spectrum that are sensed, and such spectrum resources normally are facilitated to the primary users. However, this operation of sensing is only carried out for the users that are considered to be free, and hence a better degree of utilization of the resources could be significantly increased over the 5G networks. The complete study implementation strategy is towards improving the process of spectrum sensing as an effective performance of the sensing spectrum is directly proportional to the complete performance of the cognitive radio. This directly contributes to the cumulative rate of data transmission over the 5G network. Therefore, the proposed study considers the concept associated with spectral leakage, and therefore, a problem is represented in the form of a non-linear approach where the idea is to perform the transformation of the non-convex to convex form. The proposed system performs an optimization of the allocation of the resource in the form of power and also performs an optimal assignment of the subcarrier. The proposed strategy rejects the possibility of fractional structures while adopting convex optimization in progressive order in order to ensure the characteristics of convergence. Therefore, the proposed study offers analytical modeling, which is meant for identifying the most sustainable condition for performing the allocation of resources. The study offers proof that the adoption of cognitive radio over the 5G network can significantly enhance the performance of data transmission. The next section discusses design implementation

C. Design Implementation

The proposed system considers the 5G system that is enabled with cognitive radio with a single primary system and a different number of the secondary cell system. The primary system consists of a base station and users, which is considered to be positioned at the center of the region. For the secondary system, a consistent distribution is carried out nearby to the primary system, and it consists of various numbers of secondary cells too.

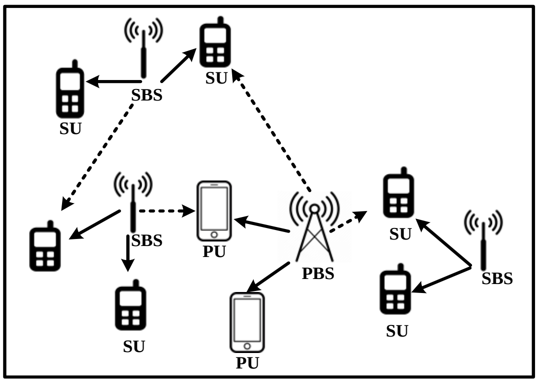

Fig.2 Proposed System Model

The complete analysis was carried out considering downlink transmission where the respective base station forwards the signal to all users, and any signals that are received from different base stations are considered as interference. The model considers one cell allocated for all users. The available base stations act as an access point for all users while the receiver/transmitter is connected with one antenna. The secondary users are allocated with the frequency by the base station of the secondary system where sub-carriers (free and occupied) are designed from the complete band of frequency. The system then evaluates the signal-to-interference noise ratio considering power on subcarriers within specific cells, channel gain from the base station (of the secondary system) to user (secondary) and standard noise (Gaussian white), interference caused by secondary cells due to asynchronous data transmission. The study also performs quantification of interference due to transmission between two systems, while it is to be noted that all the sub-carriers will give rise to the interference for the 5G-based communication system. Apart from this, it should be noted that both OFDM and FBMC are the best approaches in the 5G communication system; however, FBMC can be stated to offer better protection against interference as their leakage of the spectrum is very less. Therefore, the analysis of interference assists in assessing the patterns of power dissipation over the subcarriers. The development of this model consists of constraint adoption, where three types of constraints. According to the first constraint, the cumulative cost of secondary cells is associated with the fact that the cumulative resource of all subcarriers over all cells should not be more than threshold power. The second and third constraint is associated with the accessibility of all subcarrier by individual unique users. The study considers the concept of optimization considers the fact that both continuous as well as discrete attributes could induce increased complexity; moreover ratio of any function of non-convex to the linear form of the function is always a structure related to non-convex form. It is believed that properties of interference from co-channel could represent all non-convex forms of characteristics. In order to maximize the performance of data transmission 5G networks, the proposed system considers that there is a uniform power distribution, which is followed by the proceedings of assigning sub-carriers depending upon the higher value of the signal to interference noise ratio. The proposed system also formulates a condition where the selection of subcarriers is carried out where the preliminary distribution of power is extracted by assigning the less amount of power over all the individual subcarriers. The assignments of the subcarriers are executed until it reaches the state of convergence. Apart from this, the proposed system considers various forms of attributes and conditions in order to perform optimization of the allocation scheme of resources. The next section discusses the algorithm that is constructed for computing the probability factor associated with resource allocation so that investigation can be carried out in a deeper stage.

D. Algorithm Implementation

The core aim of the proposed algorithm is to ensure a better form of allocation of the resource where the cognitive radio network plays a significant role in 5G networks. The algorithm takes the input of constraint factor of resource, binary coefficient, a configuration of the antenna, the value of an artifact, and the probability that finally leads to an outcome of the probability of allocating precise resources for given traffic as well as beamforming. The step of the algorithm is as follows:

Algorithm for Probability Calculation for Resource Allocation
Input: α, β, θ, γ, ψ, τ
Output: ϕ, χ
Start
init α, β, γ, θ, ψ, τ, ϕ, χ
For i=1: u
  For j=1: u
    Z→ α* β
  End
  ig(Z)→0
......re(Z)→√ ψ(i).norm(Z).
End
For m=1: c
  norm(θ)≤f_p. (√γ)
End
If (cond=u_{solved})
  ϕ →false
elseif f_p>1
  ϕ →false
Else
  ϕ →true
  χ→W
End

The brief explanation of the above algorithm is as follows: After initializing the users and amount of the data to be forwarded, the algorithm makes use of a convex optimization-based approach for better formulation of model mathematically. The algorithm considers three intrinsic variable beamforming mapping matrix, normalization attribute of constraint associated with resource, and reduction attribute of resource consumption. All the mobile users are considered, and computation is carried out for resources present in the channel system allocated on the basis of binary coefficient and antenna coefficient. The real and imaginary values are extracted from the communication channel that is allocated, which is further followed by normalization of all the constraints connected to the resource.

Upon comparing the normalizing attributed to constraint with the normalized value of it, the system can offer information associated with the saturation states.
The non-positive index is used for assigning the numerical value of the probability factor. The proposed algorithm infers that the state of the convex program in disciplined form is non-feasible if the assigned probability value is found to be higher than 1.

Table.1 Symbol Used

Symbol	Meaning	Symbol	Meaning
α	antenna configuration	γ	cut-off resource constraint
β	binary coefficient	ψ	signal quality constraint
θ	resource constraint	τ	artifact value
ψ	signal quality constraint	n	quantity of total transmit cognitive radio
u	number of users	c	quantity of resource constraints
f_p	fine-tuning parameter		

III. RESULT ANALYSIS

The proposed logic has been implemented considering 12 subcarriers considering 4-6 numbers of cells and the equivalent number of users too. The study considers the channel capacity of 15 kHz, considering the range of the cells as 2 kilometers. The analysis has been carried out over MATLAB, where comparative analysis is done with respect to existing schemes that emphasize resource efficiency, like in the proposed system. The existing schemes used for comparison are energy harvesting [31], scheduling approach [32][33][34], and bio-inspired techniques [35][36].

Table.2 Signal quality analysis

Resource allocation schemes		Signal quality (Probability)
Existing approaches	Scheduling using MIMO	0.6
	Energy harvesting	0.3
	Bio-inspired techniques	0.47
Proposed system		0.7

Table.3 Processing time comparison

Resource allocation schemes		Processing time (Sec)
Existing approaches	Scheduling using MIMO	0.40
	Energy harvesting	0.65
	Bio-inspired techniques	0.58
Proposed system		0.32

The analysis shows that i) energy harvesting scheme [31] doesn't offer maximized device connectivity but it supports peak traffic condition and higher applicability, ii) scheduling based scheme [32][33][34] offers better supportability to both peak traffic condition and maximized connectivity of device but it doesn't offer higher applicability. Existing bio-inspired based techniques [35] [36] has similar performance to the energy harvesting scheme, whereas the proposed system offers all the supportability towards higher applicability, higher device connectivity, and also supports peak traffic condition. The outcome shown in table 2 and 3 shows that the proposed system offers a better quality of the signal, and also it takes reduced processing time. The core reason behind this outcome is that the proposed system carries out dynamic computing using convex optimization principle towards better convergence rate that lowers the dependencies towards network attributes. On the other hand, existing approaches use too much of the iterative attribute for improving the resource allocation in the 5G network, and therefore the processing time shoots up while signal quality degrades. Hence, the proposed system offers a better balance between good signal quality and reduced processing time.

IV. CONCLUSION

This paper has presented a discussion about the resource allocation scheme using cognitive radio technology in 5G networks. Following are the contribution of the proposed study: i) A novel analytical scheme capable of boosting the data transmission rate over 5G networks, ii) Reduced resource dependencies owing to the usage of convex optimization scheme, iii) A perfect balance between resource allocation and transmission efficiency, iv) Proposed system offer higher signal quality in presence of artifacts in wireless medium and lower algorithm processing time to prove the reduced computational complexity associated with it.

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