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Bandwidth Allocation Schemes for Cognitive Radio Network

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Abstract

In the modern era, where colossal demand for high data rate fidelity and accessibility is crucial to be provisioned by service providers, many spectrum allocation and densification schemes proposed by Cognitive Radio (CR) have been adopted. In the endeavor to nullify the impact of noise and interference so that system capacity can be increased, multiple strategies have been proposed. To enable efficient communication, optimized usage of available radio resources is essential to meet the stringent requirements of 5G as envisaged by International Telecommunication Union (ITU) in the IMT-2020 standards. Therefore, there is a constant effort among researchers to disentangle the limitation of limited resources. The various groups involved in fostering and promoting the 5G wireless standard attempt to invent new innovative technologies so that utilization of the limited available spectrum resources can be donein a rational and proficient way. By employing features of cognitive radio wireless users are empowered to reconfigure optimally their operating parameters in consonance with the nearby radio environment. This paper critically examinesthe contemporary advancement in the field of cognitive radios and tries to address the pertinent issues while managing spectrum efficacy.

Keywords: *Bandwidth Allocation, Cognitive Radio, Wireless Communication, Spectrum Management, Spectrum Sharing.*

1 INTRODUCTION

In coming days, there is a possibility that internet trafficwould be too heavy and it will take a higher notch by a factor of 4.8 by the year 2022. It is expected that a different increment would be seen in low Internet traffic by a factor of 3.7. There will be a massive hike in networked devices and may reach a figure of 28.5 billion by 2022, compared to 18 billion in 2017. Mobile data traffic is expected to be 77.5 Exabyte per month by 2022[1].Hencethere is a need for technological advancement in wireless communication so that the available spectrum may be shared for proper coordination among multiple operators [2]. Further multicasting suggests a way where same content may be transmitted to a set of users as one-to-many communication mode on similar radio resources,which would be framed as a mechanism for frequency resource efficient for multimediacommunications [3]. While considering logical postulation, millimeter (mm) wave mobile broadband provides a possibility of 100 GHz new spectrum allocation that is 200 times higher than currently allocated spectrum for mobile communication below 3 GHz [4]. Having a low range of beam width signals transmitted by mm-wave mobile broadband have very low interference compared to wireless cellular systems; therefore it provides a better quality of service. To havemobile broadband applicationsin the range of frequencies 3–300

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GHz, the requirement of its bandwidth is fulfilled by mm-wave spectrum [5].

Researchers have adopted a smart way of communication through the wireless medium in the form of cognitive radio (C.R.), which has learning capability and also responds to its radio frequency (R.F.) environment.C.R. acquires knowledge and modifies its parameters for transmitting/ receiving of information to vary with the nearby environment [6]. By keeping a tab over the unused spectrum, to minimize the interference among users, it dynamically allocates it to the licensed users. As there is always an increment in losses during transmission of signals at the high range of frequencies, therefore it must be counteracted by appropriate techniques to be used such as beamforming and directional transmissions, resulting into intermittent channel quality [7].Authors in [7] have proposed that the C.R. may have some relevance to the C.R. users (CRUs) who are not authorized so that the identified "spectrum holes," can be used in an opportunistic scheme with the ultimate goal of improving the spectrum utilization.It usually happens that single users (SUs) run behind to get access of frequency resources while operators always think about how to increase the count of users therefore to trade-off these issues a time varying framework can be modeled to increase the spectral efficiency. Always there is competency for radio resources by secondary users (S.U.s) and access of users bythe service providers in such networks [7][8]. Authors et al. in [9] suggests that generally unauthorized CRUs tries to acquire the spectrum as per their need by the flexible selection of spectrum white holes to enhance spectrum utilization efficiency significantly. CRUs are designed in such a manner that they are intelligent enough to vary their characteristics to the wireless operating environment.To nullify the noise disturbance/ intercession at the level of primary users, an exemplar of multiple antenna zero-forcing (Z.F.) beamforming is implemented [10]. Authors et al. have proposed the way how to utilize a behavior model to inculcate outdoor millimeter (mm) wave communications between cellular cells and mobile terminal unit access within a cell to increase the efficiency of millimeter-wave propagation[11].

2 LITERATURE REVIEW

2.1 COGNITIVE RADIO

The term cognitive radio commonly refers to a system which is intelligent enough to perceive different parameters of its environment and after gaining such information to investigate opportunities in the existing frequency spectrum. Since primary users generally use available spectrum, therefore real-time monitoring of a range of frequencies that is licensed is being performed for secondary users who also exist along with primary users in the given cell [6][12].

Thebelow-mentioned credentials must be possessed by cognitive radio, for efficient spectrum utilization:

Aware: The capacity to be cognizant of its environment. A CR node keeps track of space parameters and spectral characteristics of users so that available resources could be allocated more efficiently.

Adaptation: As per user need enhances, the best available frequency resource is to be selected for fulfilling his needs.

Cognition:It includes recognition of ever-changing parameters of the spectrum environment [6] [13].

C.R. is a system that may be aware of its environment, examine it, kept for use as needed, and fulfill user needssuitably. Further as proposed by authors in[14]for perfect allocation of bandwidth, Fuzzy rules may be implementedhaving the foundation on following entities which have prime importance as the rate at which users are approaching whether they are licensed/unlicensedand the presence of the channel those are unoccupiedwithin the system. A fuzzy system based on hierarchy may be adopted for efficient allocation for a range of frequencies to S.U.s that depends on the intensity of real-time traffic. Further to enhance the CRN's performancesuitablyMultiband cognitive radio networks (MB-CRNs) are adopted, and reduction in handoff frequency gives better maintenance of channel [15].

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2.2 COGNITIVE RADIO CHARACTERISTICS

The pronounced increase in a measure of the quality of service (QoS) and channel capacity in networks of wireless communication is acutely got its limitationdue to sufficient availability of energy and bandwidth, which are the primary resources for efficient communication [16]. ThereforeC.R. may be adopted as cutting-edge technology for a future mode of communication through wireless medium and intelligent networking, which can enhance the efficacy of limited network resources in a flexible manner [14][17].

It is essential that all the relevant information must be obtained before any alteration in environmental parameters.The feature of C.R. having awareness about waveform to be transmitted, radio resources, the band of frequencies, types of networks, a geometric dimension of surroundings, set of rules for communication to be active and so on id commonly referred to as cognitive capability [18]. Authors identified that"self-configuration, self-optimization, self-protection, and self-healing" may be evolved by utilizing techniques of Data analysis [19]. After gathering relevant informationfrom the radio environment, devices associated with C.R. try to change their transmission parametersdynamicallyas per observation made on occurring variations inenvironment and so attainoptimum improvement in performance that is termed as reconfigurability [20].

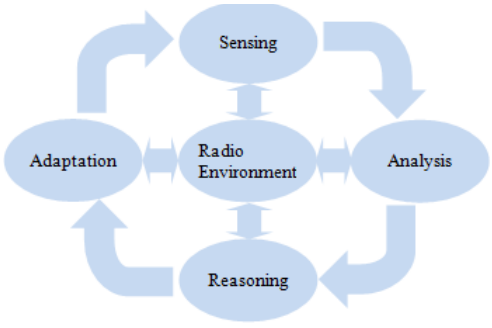

Fig.1 Cognitive Radio Duty Cycle

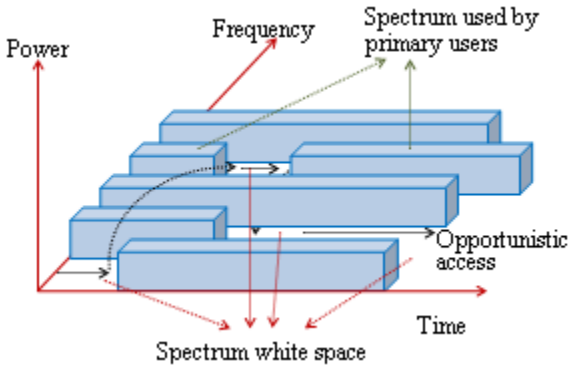

Fig.2. Spectrum sensing for white space

2.3 COGNITIVE RADIO FUNCTIONS

As illustrated, Fig. 1 depicts some primary functions performed by CR. The functions include how to detect white space in the spectrum, how to select the best available range of frequencies. The coordination required to access spectrum with other users and to vacate the frequency whenever a primary user become noticeable in C.R. duty cycle is also depicted [13][21]. CR duty cycle comprises the following functions:

- To sense the spectrum and analyze it;
- To manage spectrum and perform mechanism of handoff;
- To allocate spectrum and share it.

While we adopt the techniques for sensing and analyzing the spectrum, C.R. can detect the presence of white space in frequency spectrum (see Fig. 2), that means a specific range of frequencies is not in use by the primary users, and make suitable arrangement for utilizing the spectrum. Further, to avoid the generation of interference due to transmission by SUs it is the responsibility of CR to identify primary user's mode of transmission whether it is active or not [13][22].

To quantify and reach specific QoS parameter essential task is to identify unused space in the frequency spectrum by the technique of sensing the spectrum. Further, the function of managing the frequency spectrum and performing handoff in C.R. is how to select the best available

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frequency band and hopping among the number of bands as per variation in characteristics of the channel by SUs to meet various requirements for efficient communication [23]. Now whenever a primary user wishes to start communication and tries to regain his/her frequency band, the secondary user has to transmit his/her data on another available band of frequencies, which was used earlier the same licensed band that is required by primary users.

3 RESEARCH DIRECTIONS

3.1 SPECTRUM SENSING

To access freely available frequency bands by SUsin CRNs is being fulfilled by Spectrum sensing, which is a primary function in CRnetwork. On behalf of statistical data collection from S.U.s authors proposed an optimum coordination basedaction plan for spectrum sensing. And basically the final decision is based on homogeneous and linear combination of statistical data collected from S.U.s [13][24].The characterisation to sense the frequency spectrum is being classified on behalf of following states, i.e., the signal containing information emitted by P.U., channel state having PU-SU and random interference in signal,isbeingdone by unified dynamic state-space model based on the observation made,composed by authors. As per independent characteristics of transitionthesignalemitted by P.U. and the articulation of channel try to progress in dynamic fashion [25].With the help of different techniques for identifying and sensing of P.U.s in C.R.s, the evaluation for measure of efficiency and limitation can be done effectively[26]. Rather it requires a very limited interval of time but still to be synchronised is a big challenge over a band of frequencies. The crucial part is detecting the level of energy requirement since it consumes a huge amount of time and at the same time suffering frominterferingsignalstherefore there is limit up to which energy detection could be possible [27].

3.2 SPECTRUM MANAGEMENT

Authors et al have proposed a mechanism which is organisingitselfin vibrant fashion so that to establish links with nearby C.R.s operating on available range of frequencycognitive radio units make an attemptto utilize the primary networks unused bands. Considering no primary user activity for frequency band selection, and the use of self-organizing maps (SOM) technique can generate the time dependent assigning strategy for channel on sub-bands byextracting and memorizing the ways in which the primary network are active similar to human brain [28]. Authors have suggested an algorithm for formulating a network which is going to cooperate and coordinateto increase the transmission of transmitter and receiver combination by adoptingmm wave R.F. to construct a multihop path through relays. A set of rules based on fuzzy logicare implemented for optimization the bandwidth allocation based on three prime factors such as: the rate at which users are approaching whether they are licensed/unlicensed and number of channels within the system those are free [24] [29].

3.3 SPECTRUM SHARING

Authors have proposed the best thing aboutCognitive radios is thatit may be operated in the same rage of frequencyhaving cooperation and coordination with nearbyso that it can diminish thetime of detecting and so agility improvement is achieved. At the secondary user transmitters (SU-TXs)the impact of having unsoundcharacteristics of communication link arising due toerroroccurrence during estimation of channel parameters is also taken into consideration.Nowtolimit the interference at the receiving side of primary usernon-variantand controlling parameters for power are adopted [27] [30].

For characterization of measuring the signal strength for an erratic network multiple operator based cellular network termed as mmWavehavingcoordination based basestations (B.S.s) are proposed and itscoverage probability is derived to meet certain constraints [31].For the analysis of performance measures of uplink users the dynamic time division duplexing enabled cellular networks for next generation using a stochastic geometry framework is proposed by author's et al [32].To authoriseandperformdifferent data streamsper

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user respectively, for multiple users MIMO ororthogonal frequency division multiplexing (OFDM) based CRNsit is beneficial to useoptimumprecoding and beamforming strategies toenhance the C.R. users rate subject to interference constraints [33].

To enable the S.U.s to use the spectrum which is licensed easily i.e. not used without any interfering signalwith P.U.s, authors proposed ahopped channel based CRN protocol for wireless networks in synchronizing fashion[34].Suffering from phenomenon of fading and being mobile in naturethe characteristics of wireless channels those are time variant is being considered while adoptingquality of service to be accessed by policy to be dynamic in nature. By performing mechanism to sense and select optimumrange of frequencieswhile taking a decision by observing channel state is determined by proposed scheme andimpact is that there isreduction in both the rate at which error is occurring in a frame and rate at whichlevel of energy to be consumed[35].

Whenever there is requirement for S.U.s to access the unused frequency slot in CRNs, by using the model for sharing spectrum among the S.U.s are put in actionon the basis ofTDMA, in which the S.U.s transmission are made able to utilize the free slot [36].As requirement of data to fulfil needs of mobile user is growing at very fast rate thereforea network build up based on gathered informationfrom surroundings being the best solution for wireless and mobile networks [37].A scheme to sense range of frequencies which can vary its characteristics and feature on demand is the best for CRNs is said to be adaptive in nature as it may be that it doesn't require any knowledge of P.U.s. And so it may vary the parameters even at the starting node of each frame [38].It may be the impact of channel fading that individual cognitive radio networksis not going toidentify the presence of a primary radio, which may be licensed user for certain range of frequencies. It is usual that to tackle the impact of channels those are not constructive in nature and devicesthose are not acting properly, we should try to adoptsome set of rules to sense the spectrum effectively that is also cooperative and coordinating in nature[39].To provide the services to S.U.s, authors suggested that it is also possible to divide the servicing area into feasible cluster ofSUs known as Neighbourhood Area Network (NAN) clustersinbasiccognitive radio based 5G communication network architecture. Further mathematical model has been presented by authors foravoidinginterference having two considerations such as the allocation based on whether it is fair or not and allocation based on whether it has the highest priority or the lowest priority[40].

After getting an estimation of the vastness of the frequency component and a true estimate of QOSauthor'set al have proposed a way through which pragmatic detection of frequency components is possible [41].Whenever there is no possibility for detection of primary signala secondary user has to put a check on licensed bands and opportunistically transmit so that it may access free licensed spectrum at the moment[42].As there is limitation on level of energy therefore CRNs is making use of energy efficient sensor nodes.The time span of CRN can be improved by the adoption of cooperative and coordination based switching of sensor nodes whenever there is requirement [43].Time slot allocation can be modelledby a general channel allocation modeltoimproveQOS of multiple types of multimedia traffic over centralized cognitiveradio network[44].

3.4 ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING IN COGNITIVE RADIO

While we try to make a machine to be Intelligent, Artificial intelligence always deals

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with following issues such as deduction, whether it is to be adopted or not , the technique through which a problem could be solved or not, the way in which information could be represented, and the methods to learn about environmental conditions. Authors have proposed a stochastic functionforevaluatingthenon-centric signals having basic understanding of Signal and Interfering signal [45].Sometimes it happens that electromagnetic algorithms are not capable to figure out the exact parameter in that caseAuthors have explored the issues occurring during estimation of Hidden Markov Model (HMM) parameters which are used to propose prototype a CRN [46]. The CRNs can be made more intelligent by the use machine learning algorithm as shown in Fig. 3 and can be expressed as follows:

(1)To sensesurroundings parameters,

(2) To observe the environment and analyseit,

(3) To Learn,

(4) To update the prototype hold the decision and keep the observed parameters for reforming theModelandachievingpreciseness in prediction of future,

(5) To take decision on issues such as how to manage resource allocationand how to regulateoccurrence of errors during data transmission [47].

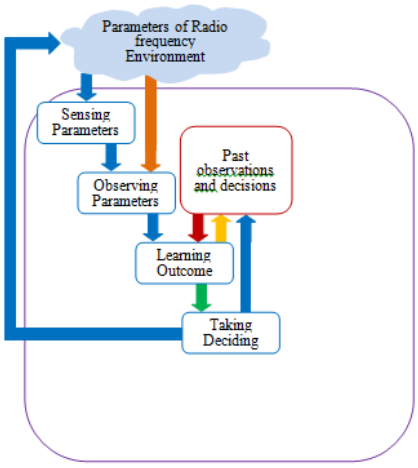

Fig.3. Steps performed in Machine Learning

Fuzzy logic, Genetic Algorithm, Reinforce Learning, Neural Network, Game Theory, Support Vector Machine, Markov Model may be validated to let the clients to unearth the issues and responding stochastically to augment the overall QOS[48][49].Authors have proposed different techniques usingmachine learning such as Generative Deep NeuralNetworks (GDNNs) to be aware of task to be performed, and try to incorporate enablingof flexible and dynamic management of spectrum [50].

4 CONCLUSION

This review paper presented different approaches considered for intelligent and efficient cognitive radio networks.It also put some focus on the use ofartificial intelligence and machine learning incognitive radio networks. It deals with the allocation of free frequency band to the secondary user so that the overall efficiency can be increased by adoption of proper spectrum sensing and spectrum management schemes.

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