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A Survey on Dynamic Resource Allocation in Cognitive Radio Networks

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***Abstract*—** In cognitive radio networks (CRN) an efficient spectrum allocation is a very big issues because of its lack of spectrum demand. Resources in CRN should be allocated based on dynamic access methods with respected to sensed radio atmosphere. A primary research challenge is that how should be allocated or assigned available unused spectrum to unlicensed users. The fitting portion of unmoving recurrence range existing together intellectual radios while amplifying all out transmission capacity utilization what's more, minimizing impedance is required for the productive range use in CRN. The technique for settled range portion came about to less range usage over the whole range. In this article we study the different fitting algorithms and present comprehensive analysis of each method used to improve the effective utilization of unused spectrum in CRN.

***Keywords*—**Cognitive Radio; Energy; OFDM; Resource Allocation; Spectrum sensing

I. INTRODUCTION

The cognitive radio is an emerging new technology to improve the effective utilization of radio spectrum by secondary networks when the primary users absent. License is required for function of a specific frequency spectrum. More often than not range stays unused and it is additionally hard to discover it. The apportioned range has been not used legitimately. It differs with the following aspects such as time, frequency and geographical locations. The radio frequency spectrum can assign limited users simultaneously in practice. For the expulsion of the range shortage and the unutilized range band, Cognitive radio (CR) and Dynamic range access (DSA) innovation has been presented. A radio or framework that detects its operational magnetic force atmosphere and may powerfully and self-rulingly amendment its radio operating parameters to change framework operation, as an example, expand output, moderate obstruction, encourage ability, access secondary markets. In cognitive terminology the higher priority is assigned to the primary user for accessing a specific part of the radio spectrum. The lower priority is assigned to the secondary user [1].

The idea of intellectual radio was first authoritatively introduced by "Joseph Mitola" III, at the Royal Institute of Technology in 1998 and distributed later in an article by "Mitola and Gerald Q. Maguire, Jr", in 1999.
Hykins defined the cognitive radio is "sensible remote association skeleton that is awake to its encompassing surroundings (i.e., outside world) and uses the technology of considerations by-building to find out from the surroundings and adapt its internal states to applied mathematics variations within the incoming RF spur by creating corresponding changes in bound functioning limitations (e.g., transmit-power, carrier-frequency, and modulation strategy) in period of time, with two primary objectives in mind, extremely reliable communication whenever and where needed; efficient utilization of the spectrum of radio frequency". The impedances, for occasion, range distinguishing and geolocation capabilities are prevented by using white space device technology [2].

CR includes a capability that senses near surroundings and dynamically adjusts its radio parameters to speak with efficiency. To improve an effective utilization of a spectrum by allowing secondary user should utilize the primary users licensed spectrum during primary user idle. In CR primary users have higher priority to sensing a specific radio spectrum. Secondary users have lower priority to sensing a specific radio spectrum. Radio frequency spectrum hole identification is essentially important to improve effective utilization of unused available spectrum by secondary network. The following diagrams shows cognitive radio networks and spectrum hole management architectures.

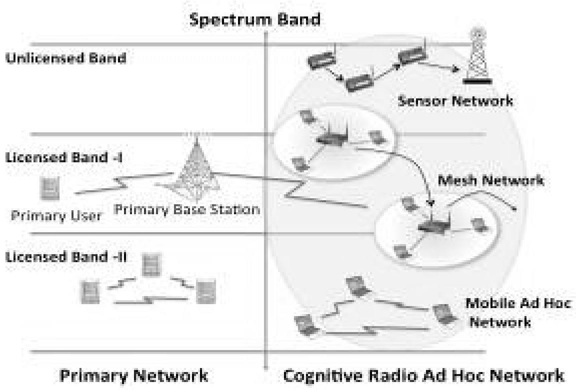

Fig. 1 Cognitive Radio Ad Hoc Network

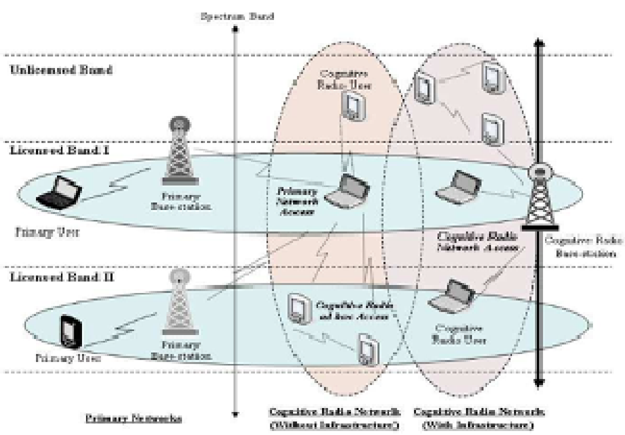

Fig. 2 Cognitive Radio Network [2]

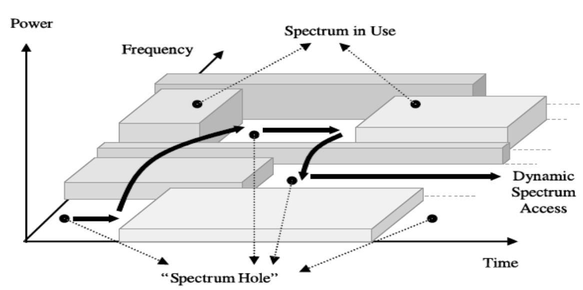

Fig. 3 Spectrum hole technology [3]

Rest of in this article we present brief discussion about cognitive radio in section II, dynamic spectrum access in section III, brief discussion of Game theory approach for cognitive radio and few comparative studies in section IV, few comparative studies and brief discussion on fuzzy logic for cognitive radio networks in section V, comparative study and analysis of DSA in section VI, And conclusion in section VII.

II. Cognitive Radio

Cognitive radio is a novel solution skill. Its task is that to allocate available spectral opportunities in dynamic fashion. CR definition was intellectually defined by "Joseph Mitola" was "a radio or system that senses, and is aware of, it's functioning atmosphere and can dynamically and autonomously adjust its radio operating parameters accordingly", according to this definition CR have two key features are the cognition capability and the reconfigurability [4].

A. *Cognitive Capability*

The cognitive radio has such a capability to sense and collect the unused radio spectrum at a specific location or time intervals and then provide the communication without any harmful interference to the other users [5].

B. *Reconfiguraity*

Radio spectrum, dynamically changes the role based on its environment constrains. Resembling radio frequency, broadcast control, modulation scheme, communication protocol without any adaptation of the hardware environment to be changed based on its surrounding characteristics [6].

The following figure shows the functional architecture of a cognitive radio Fig.4.

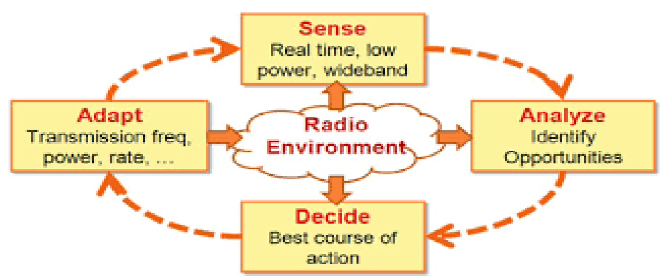

Fig. 4 Functional architecture of cognitive radio

The functional architecture of the cognitive radio cycle contains three major parts are spectrum sensing, spectrum analysis and spectrum access decisions.

1. *Spectrum Sensing*

It detects the licensed primary users and determines the remaining available radio spectrum from the specified location. This improves the effective utilization of the licensed spectrum and avoiding collision with the primary users. To improve the detection probability, there are numerous techniques should be used during signal sensing. Its major role is to determination of signal from the primary transmitter whether it is present or not.
There are different techniques

- Matched filter detection

- Energy detection
- Cyclostationary feature detection

2. Spectrum Analysis

This method is used to every range gap ought to be portrayed considering the time-fluctuating radio environment and as well as the essential client action.

3. *Spectrum Decision*

When all the examination of range band is done, suitable range band is be chosen for the present transmission considering the QoS prerequisites and the range attributes. As per client necessity the information rate, data transfer capacity is resolved then as indicated by choice guideline proper range band is picked.

4. Spectrum Mobility

In this procedure CR changes its recurrence of operations to utilize the range in element way to work in the best accessible recurrence band. When essential client shows up, current channel condition turn out to be more awful so range portability emerges. Because of this range portability range handoff emerges.

5. Spectrum Sharing

It is the real test of the open range use. There is a coordinated access with other users. This system comprise of five noteworthy strides: range detecting, range portion, range access, transmitter-beneficiary handshake, range portability.

III. DYNAMIC SPECTRUM ACCESS

Dynamic spectrum access (DSA) is new technologies which support to dynamically implement the available spectrum hole with deficient rights to use spectrum, accordingly changing situation and targets: obstruction made changes the radio's state, changes in ecological requirements. DSA supports two types are cruel obstruction brought on by breaking down gadget and destructive impedance created by malevolent client. In DSA, the users can access a specific radio spectrum within defined time intervals or location.

- Screen range to see which frequencies have no other radio action (i.e. they are definitely not being utilized by anybody).
- Agree with other element range access gadgets in the system which frequencies will be utilized, by means of same beforehand approved normal channel.
- Being conveying on the concurred recurrence band.
- Continue to screen the range for endeavors other client to get to this range.
- Change recurrence groups and alter power as essential [5-10].

IV. GAME THEORY APPROACH FOR COGNITIVE RADIO NETWORKS.

Game theory is basically mathematical functionality called mathematical tool. It support to analyzed and make it multiple decision maker when it is interact with multiple users. Three major components are used in this system.

- N: denotes a finite set of players.
- Ai: denotes a set of action for every player i, and
- Ui : A → R: denotes payoff/utility function which measures the outcome of every players i determined by actions of every player, $A=Xi\ \varepsilon_N Ai$, these strategic game is denoted by ‹N, (Ai); (Ui)›.

Four modules of game theoretic radio spectrum sharing are Non-Cooperative sharing games, Economic games, auction games and mechanism design, Cooperative games, and Stochastic games.

- Non-Cooperative sharing games: Nash Equilibrium Methods of solution is used.
- Economic games, auction games and mechanism design: rationality and equilibrium approach is used.
- Cooperative games: determines how to utilize and distribute the spectrum resources, further it has Bargaining games and Coalitional games.
- Stochastic games: it is the extension of Markova decision process is used to achieve proper payoff function, Efficiency of equilibrium, Issues in mechanism design, Issues in stochastic games, security

Publication Year	Proposed-Methodology	Result
2016 [11]	• A three-phase game approach is investigated utilizing in reverse incitement; the stages incorporate getting range, picking the Spectrum service provider (SSP) channel appropriation and satisfying the end clients' range demands. • Nash equilibrium is used in the game between SSP and its end users.	• Achieved optimal maximize the utility of both SSPs
2016 [12]	• Stackelberg game approach is used	• Achieved a significant

	between the licensed network and an actor node act progressively and wisely to handle the recurrence designation issue and makes the hidden HWSN work in a self-composed way.	improvement of throughput of victim licensed nodes with slightly decreasing network total throughput.
2015 [13]	• They proposed Normal Collaborative Spectrum Sensing (NCSS) based on coalitional games.	• Significant achievement of sum-utility by 20% • The cost of minimal 2.3% loss in energy efficiency.
2012 [14]	• They proposed Chinese restaurant game	• Achieved sensing accuracy and channel quality
2012 [15]	• They proposed non-transferable utility coalition graph game (NTU-CGG) based resource allocation scheme	• Achieved significant system fairness and throughput
2013 [16]	• They proposed stochastic game are Distributively implemented	• Achieved significant performance and reduce information exchanges
2015 [17]	• They proposed cooperative game (CG) in a characteristic form	• Achieved the best balance among fairness, cooperation and performance in terms of data rates obtained by SUs.
2013 [18]	• They proposed new spectrum sharing scheme by using the Bayesian game approach and share spectrum bands based on the double auction protocol.	• Dynamic and flexible solution is provided with significant improvement.
2013 [19]	• They proposed a new spectrum sharing scheme is on the repeated auction model. • Bayesian game also used	• Dynamic and flexible solution is provided with significant improvement.

Table 1: comparative analysis of Game theory approach

V. Fuzzy Logic for Cognitive Radio Networks.

Fuzzy logic gives some approach to get the determination to a disadvantage fundamentally in light of off base, boisterous, and deficient data. Typical rationale utilizes a gathering of fluffy participation capacities and aberrant tenets to get the answer that meets goals intriguing. Typical rationale administration contains fuzzifier, typical rationale processor and defuzzifier. The fuzzifier is utilized to plot the specific inputs by making them fluffy, the typical rationale processor gives partner unique thought motor to incite an answer bolstered sets of predefined tenets, furthermore the defuzzifier is connected to change over the response to genuine yield.

It has ambiguous logic. A few info parameters territory unit acclimated take the decision like separation, sign quality, velocity and range intensity region unit alluded to as information parameters. The likelihood of accepting call is gathered if the channel that offered by nuclear number 94 signs are high and separation between nuclear number 94 and SU is low. In the event that the space is modest, the rate will expand the likelihood of the range getting to is a considerable measure of [20][21][22].

Publication Year	Proposed-Methodology	Result
2016 [23]	• Using fuzzy logic they mighty discover the range of Fuzzy C-Means (FCM) clustering on energy detection based cooperative spectrum sensing (CSS) in single primary user (PU) cognitive radio network (CRN). •	• Improved the ability of sensing and efficient energy gain.
2015 [24]	• fuzzy based fusion rule is used and it support to take a decision with its own parameters	• Achieved a better performance under probability of detection and probability false alarm.
2015 [25]	• They proposed ranking channel approach according to behaviour of primary users on the channel and RSSI value. • For achieving *candidate* channels list and backup based on priority scheduling are implemented by using fuzzy-logic-based algorithm	• Achieved a good performance networks.
2013[26]	• Evolutionary algorithms are used to achieve the optimization solution of problem in a multi-objective framework. • A fuzzy logic based strategy also used	• Achieved significant overall performance
2013 [27]	• An adaptive fuzzy logic	• Achieved

	framework based plan for agreeable range detecting without the requirement for from the earlier system data, for example, the clamor change, channel state data, and qualities of existing essential signs	outperforms the equal-gain combination based scheme, and matches the optimal soft combination scheme in terms of sensing accuracy.
2015 [28]	• They proposed the technique that by adding a Hopping Sequence (HS) module to the detectors based on a fuzzy logic system (FLS).	• They achieved enhanced outcome of performance.
2014 [29]	• They proposed fuzzy neural decision making technique	• Achieved significant improvement in sensing accuracy by exhibiting higher probability of detection.
2015 [30]	• They proposed prioritized spectrum allocation technique based on fuzzy logic	• Achieved performance using the four input parameters priority, path loss, and node velocity and spectrum efficiency.
2014 [31]	• They proposed fuzzy neural decision making algorithm.	• Achieved significant improvement in sensing accuracy by exhibiting higher probability of detection.
2010 [32]	• They proposed coexistence beacon protocol (CBP) with The fuzzy logic control (FLC) spectrum sharing algorithm	• Achieved to improve resource utilization and fairness.

Table 2: comparative analysis of fuzzy logic

VI. COMPARATIVE STUDY AND ANALYZIS OF DSA.

Publication Year	Proposed-Methodology	Result
2010 [33]	• RA-Game and PS-game approach	• Achieved throughput gain significantly
2003 [34]	• Control algorithm is used	• Achieved good throughput and fairness
2008 [35]	• Heuristic algorithm is used	• Achieved good performance
2008 [36]	• Lyapunov Optimization resource allocation algorithm is used	• Achieved significant performance
2008 [37]	• novel Multi-Channel Contention Graph (MCCG) algorithm	• Better throughput and fairness
2014 [38]	• spectrum resource utilization maximization scheme	• Better throughput
2010 [40]	• Dynamic Spectrum Access scheme	• Significant performance
2015 [41]	• New approach	• Performance improved
2007 [42]	• Game-theoretic approach.	• Better heterogeneous network performance
2016 [43]	• convex optimization methods	• significant performance
2016 [44]	• novel cooperative sensing scheme	• better performance
2016 [46]	• Stackelberg game algorithm is proposed	• optimal performance
2016 [47]	• Stackelberg game algorithm is proposed	• Significant improved throughput.
2015 [48]	• Nyquist band improvement algorithm.	• Power consumption improved
2016 [49]	• Distributed correlated equilibrium algorithm	• Significant throughput improvement
2016 [52]	• Fuzzy logic algorithm	• Significant channel selection accuracy
2016 [56]	• Markov chain and the matrix-analytic algorithm	• Significant performance improved
2010 [57]	• Discrete Time Markov Chain (DTMC) model.	• Maximum Throughput
2012 [58]	• Sleep scheduling mechanism – to control battery power • Centralized sleep scheduling mathematical model- control traffic. • Spectrum-driven sleep scheduling algorithm.	• Significant gain improved through the traffic holding rate and energy efficiency.
2015 [59]	• Practical medium access control protocol.	• Provides significant throughput gains with respect to baseline solutions.
2016 [60]	• Multiuser-diversity-based interference alignment.	• Gain of effectiveness.

Table 3: comparative study and analysis of DSA

VII. CONCLUSION

In this writing survey, we have exhibited different strategies of element range access in subjective radio systems. We contemplated the different strategies for executing procedures and results. At last we introduced near examination of asset allotment by element access technique. Every strategy could have been accomplished noteworthy enhancements like throughput, execution, productivity, channel designation, effective use of unused radio range are abridged.

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