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Dynamic Resource Allocation in Cognitive Radio Networks – Priority Scheduling approach: Literature Survey

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Abstract— In this paper we presents a comprehensive literature survey of cognitive radio technology, focusing on its application to dynamic resource allocation, based on priority scheduling approach. Dynamic spectrum access provides resource sharing between primary users called licensed users (PUs) and Secondary Users called unlicensed users (SUs). An essential examination test is that in what capacity ought to be apportioned or relegated accessible unused range to unlicensed clients. The fitting bit of unmoving repeat range existing together learned radios while enhancing hard and fast transmission limit usage furthermore minimizing impedance is required for the profitable extent use in CRN. The system for settled extent segment came to fruition to less range utilization over the entire reach. In this paper we presented the different approaches used for dynamic resource allocation and scheduling in heterogeneous Cognitive radio networks.

Keywords—Cognitive Radio; Energy; OFDM; Resource Allocation; Spectrum sensing; Heterogenitive services

I. INTRODUCTION

The cognitive radio (CR) is an emerging technology because; it offers a limited frequency range resource naturally, so that we can make to enable the radio exploitation on its demand [1]. Software defined radio (SDR) lies at the art of the cognitive radio network and support to dynamically reconfigurable radio that can become accustomed its operating parameters to the neighbouring environment [2]. A license is allotted to every user to operate in certain frequency spectrum. Generally, the spectrum remains unused and it is very difficult to find the unused spectrum. The owed spectrums have not been utilized appropriately and it varies with time, frequency and geographical locations. Cognitive radio and Dynamic spectrum access technology have been introduced to minimize the spectrum scarcity and the unutilized spectrum [3].

CR is a programmable wireless system which can sense their circumferences and dynamically adjust their broadcast waveform, channel access method, effective use of spectrum, and required protocols for good network and application routine[1][2][5]. CR makes intelligent communication such as transmitting and receiving, and also identified which channels are used and not and transfer to unused channels. This approach minimizing interference with other users and make it optimal use of available radio frequency spectrum [5].we can formulate efficient utilization of the CR spectrum by allocate a secondary user (SU) to utilize a licensed frequency band when the primary user (PU) is absent. So the detection of spectrum hole is important as shown in Figure 1. [1][4][5].

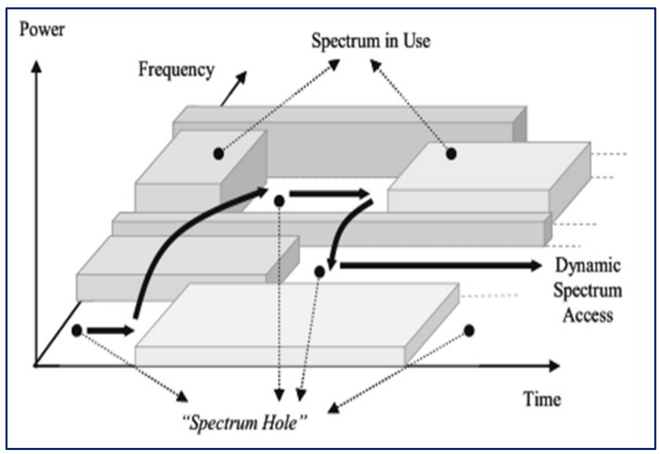


Figure 1. Spectrum hole technology[3]

In this paper, we presents as follows: Section I: Introduction, Section II: Dynamic spectrum access, Section III Dynamic Spectrum Access Technology, section IV Cognitive Radio Software, V different approach and section: VI conclusion this article.

II. DYNAMIC SPECTRUM ACCESS

The objective of Dynamic Spectrum Access (DSA) is that coexistence between primary (licensed users) and secondary (unlicensed) users, to minimize the fixed frequency limitation. The different models of DSA in CR have shown the following figure [2] [4] [6].

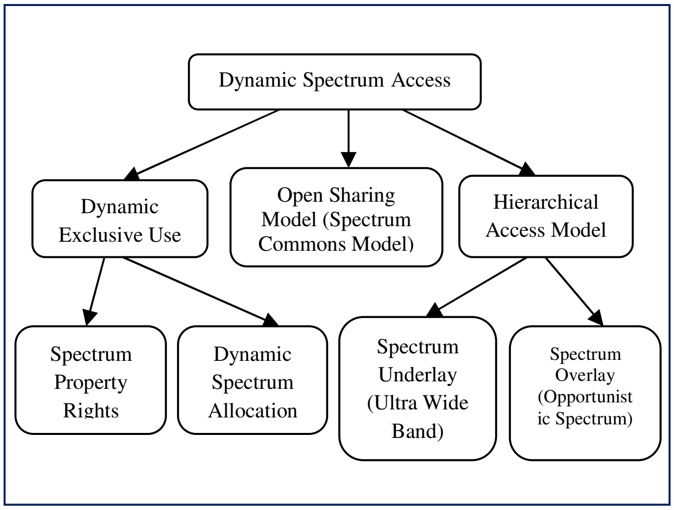


Figure 2. Taxonomy of Dynamic Spectrum Access

A. Dynamic Exclusive Use Model

The dynamic exclusive use model support to the present spectrum regulation policy, the spectrum bands are a unit licensed to services for exclusive use [2]. Its main objective is to introduce flexibility in spectrum allocation and usage. It also supports two approaches such as Spectrum Property Rights and Dynamic Spectrum Allocation [2].

Spectrum Property Rights

- Licensees to advertise and trade frequency band and to freely decide technology.
- Licensees contain the correct to lease or share the frequency band for profit, such behaviour isn't licensed by the regulation policy.

Dynamic Spectrum Allocation

- To improve frequency spectrum efficiency through dynamic spectrum assignment by exploiting the spatial and temporal traffic information of different services [2] [7].

B. Open Sharing Model

- All users have the same rights to use the spectrum.
  - *Uncontrolled- commons*
    - ✓ This maintained the uncontrolled commons model, no entity has exclusive license to the spectrum band.
  - *Managed-commons*
    - ✓ Supports to avoid the tragedy of commons by striking a restricted form of constitution of spectrum access.
  - *Private-commons*
    - ✓ Support to use of advanced technologies which enable multiple users to access the frequency radio spectrum.

C. Hierarchical Access Model

- It enabled Hierarchical Access Structure with primary and secondary users.
- This approach opens licensed spectrum to Secondary Users (SUs) while restricted interference alleged by primary users (licensees).
  - *Underlay*
    - ✓ This approach imposes malicious limitations on the transmission power of secondary users so that they operate below the noise floor of primary users. By dissemination of transmitted signals over a wide frequency band (UWB).
  - *Overlay*
    - ✓ This approach does not automatically impose malicious limitations on the transmission power of secondary users, but moderately on when and where they may transmit. It directly aims at spatial and temporal radio spectrum white space by allowing secondary users to identifying exploit local and immediate radio spectrum availability in a non-intrusive manner[2] [7] [10].

III. DYNAMIC SPECTRUM ACCESS TECHNIQUES

A. Game Theory Approach for Cognitive Radio Networks

- Game theory approach is a mathematical structure which contains a models, notations, functions and technology. Game theory support to analyse the iterative decisions performance of individual's interest about their own benefit.
- The mathematical structures of the game theory are used to analyse and designed the communication among the multiple decision makers [1] [4] [6].
- There are three main aspect game theory are
  - A finite number of decision makers or players are in every game functions are denoted by N.
  - A set of action, represented by Ai, for every player i; and

- A game theory set consisting utility or payoff ($U_i = A \rightarrow R$) functions for all players. The action of all players determined by A =$X_{i\varepsilon N}A_I$

- ***Cooperative Games:***

  Every player has to concern about all the overall benefits and they are not bothered about their own personal benefits. Some researchers like Yang C, 2010, Zhang J, 2009 used the game theory and to reduce the transmission power of SUs and generating interference to PU transmissions.

- ***Competitive Games:***

  All users are mostly concerned about his individual payoff and then all its decisions are made competitively and additionally selfishly. Existing literature, we found that Game Theoretical concepts have been widely used for spectrum distributions in CR networks (Niyato D, 2008) (Wang B, 2010) (Tan Yi, 2010), where the PU and SU take part in a game, behave rationally to choose strategies that maximize their individual payoffs.

B. Measurement based model for DSA in WLAN channel

Stefan Geirhofer and Lang Tong [8] proposed model is based on actual measurements in the 2.4 GHz ISM band using a vector signal analyser to collect complex baseband data. Moreover, they achieved data with good accuracy by applying Continuous-time semi-Markov model.

Their proposed system setup is shown in figure 3.

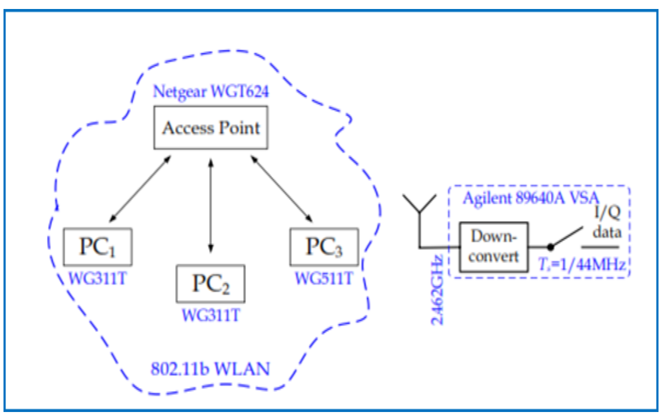


Figure 3. The Mesurement Setup [8]

The WLAN setup includes Net-gear WGT624 wireless router and three computers with wireless adapter cards (two Net-gear WG311T and one WG511T). The router operates in a 22MHZ frequency band around 2.462 GHZ (channel 11). The routers and workstations are resides in the same room resulting in a high signal-to-noise ratio (SNR) between nodes and no hidden terminals. Traffics were generated using the Distributed Internet Traffic Generator (D-ITG) [11], which allowed us to statistically characterize parameters such as inter-departure times and packet length. Their measurement based on two approaches. First, they could consider high rate UDP traffics from one workstation to the router (the other computers are turned off) to verify the operability of the setup. Consequently, they considered UDP traffics of constant packet length from all three computers with Poisson distributed inter-departure times at different rates. They engaged Agilent 89640A vector signal analyser to collect the complex data base band sample after confined the transmission of WLAN. The device that supports internally down converts 2.462GHZ to an internal IF frequency at a sample rate of 44MHZ [7].

C. *Dynamic Spectrum Access using a network coded cognitive control channel*

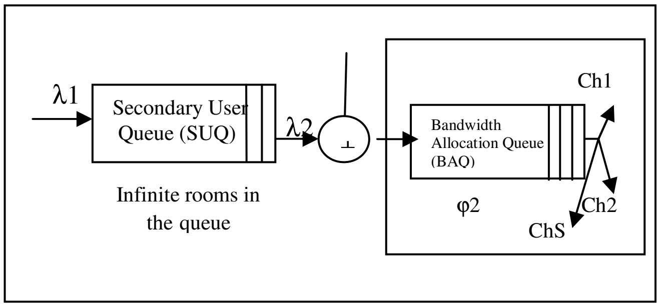
Dynamic Spectrum Access using a network coded cognitive control channel support to permit the users to make an effective communication from the available channels. It contains most important aspects of opportunistic spectrum accesses are

- Implementation of the control channel.
- Multi-channel medium access control.
- Primary user detection.
- Secondary users reuse the unused spectrum of primary uses.

Every secondary user visits all channels in the form of pseudo random fashion and exchange control information. Pre-deterministic algorithm is used to exchange information effectively from secondary users. In each allocation period primary users performed over all channels and keep track of the changing pattern of primary user's activity. The detection information gathered by each during an allocation period is to be disseminated to all users using the control channel. The same deterministic algorithm also support to cooperative detection. Dynamic resource allocation algorithm runs independently by all users and the transmission opportunity is assigns only on free channels. The network coding and cooperative techniques are to identify unused radio spectrum [7] [8].

D. *Markovian Queuing Model centralized architecture for DSA*

Central controller plays an important role of bandwidth allocation to intended users in centralized architecture of Markovian queuing approach. These technologies support to get all information of unused spectrum hole and minimized the hidden problem. One transceiver is dedicated to control among the SUs. Second a SDR based which inspect the availability of spectrum in its neighbourhood. In infrastructure, forwards the spectrum holes information to the base station. In infrastructure forwards the spectrum holes information to less master/controller. The unused available channels bandwidth is owed to SU. The equivalent queuing diagrams as shown in figure.



S rooms in the queue (including served request)

Figure 4. Queuing model for DSA in CR network [10]

E. A Fuzzy Logic Based Spectrum Access Method

A fuzzy is a multi-valued logic and it will take more input parameter to take decision. For an example some determining input parameters are signal strength, node velocity, secondary user velocity, spectrum efficiency and distance between the primary licensed and secondary unlicensed user [11][14].

IV. COGNITIVE RADIO SOFTWARE

Obviously, software system of cognitive radio involves the essential function to perform its capabilities. The essential functionality of software organization of cognitive radio would be discussed below [2].

A. The radio Hardware

- It precise the self-configuration capability of signal processing device and it also contains radio frequency circuitry.

B. Software modules

- Software modules with codes are loaded into electronic devices.
- The software modules can define its interface to other software components.
- Common language is used to describe its interfaces naturally.
- Obviously, the common language practice gives more flexibility and reliability
- Examples: Field Programmable Gate Arrays (FPGAs), Digital Signal Processors (DSPs), or embedded general purpose processors.

C. Middleware

- Middleware layer is support to minimize the particulars of specific devices and software modules to common abstractions.
- Example:
  - o Setting the transmitting frequency of the radio frequency circuitry
  - o Setting the encryption key of a software module
- Creating a middleware system will require progress of a frequent model for a wide range of hardware/software modules.

D. Logical Radio Layer

- Logical radio layers process of an action as depends on the hardware and software to act like multiple radios available links.
- Example: The radio would support communications on numerous frequencies, time slots, or CDMA codes, each of which looks like an autonomous link.

E. Device Manager

- Device manager performs the following operations
  - ✓ Software Radio is loaded into hardware components.
  - ✓ Sets-up the logical radios.

F. Configuration Manager

- Configuration manager on the physical layer and manages application loading into hardware.
- It also interacts with modules libraries below to determine which radio modules are needed to meet user requirements.

G. Module Libraries

- The libraries modules are nothing but the collections of radio functions
- Example:
- Modulations (AM, FM, BPSK, QPSK, etc.)
- Error control
- Encryption
- Adaptive algorithms
- The libraries modules are made with a multiplicity of tools
- Example:
  - General purpose compilers, cross compilers, hardware design languages, and FPGA design tools.
  - Coordinating the multiple sources that may go into building a specific module is a challenging task.

H. Rules Engine and Policies

- The operations of the radio is very limited due to regulatory, geographical, or physical constrains the policies are used.
- Policies should be usable independent of a particular radio.
- To interpret policies and to determine the allowed operation (device managers, logical radios, middleware, and hardware drivers) a "rules engine" is used.

I. Smart Controller

- It governed radio resources interface with in the wireless networks.
- It enhanced wide range of radio communication and wireless networking services.
- It provides reliability, and robustly manages all the components that compose up a cognitive radio.

V. COMPARATIVE ANALYSIS

TABLE I. COMPARATIVE ANALYSIS OF DSA IN CRN

Years of Publication	Algorithm Used(Methodology)	Result
2010. [12].	Game approach- Two-tire game approach. RA-Game: Every PU chooses the expected quantities of sub-channels to reach the highest payoff. PS-Game: Every PU advertises his unused radios to SUs nearby, which is made as an auction game. Distributed algorithm autonomously distributes PUs and SUs. It covers Nash Equilibrium	Maximize the utilization of entire network resource. Relay scheme improves the throughput of SUs. *Future Direction* Extend our approach to multiple cells and more relays
2013 [13].	Novel Resource allocation framework based on bandwidth power minimization approach Iterative water-filling scheme also used	The future framework recovers the utilization of spectrum by striking an optimum balance between the consumed power and bandwidth.
2012 [15].	Stackelberg game Approach is used. An iteration algorithm based on price updating	The proposed scheme improves energy efficiency significantly in heterogeneous wireless networks with femtocells and cognitive radios.
2013 [16].	The framework for multi-SU resource allocation game with Nash bargaining solution (NBS) under the cognitive radio scenario (CR-MSU-NBS game) – sum of pair wise is used	Fairness and throughput are improved 33.4%
2013 [17].	Dual decomposition technique. Suboptimal low complexity algorithm.	Performance is significantly improved due to the deployment of multiple antennas at the SUs.
2013 [18].	Jointly designing sensing paraments and resource allocation algorithm used. An iterative algorithm also used.	Throughput and fairness improved significantly.
2013 [19]	Compressive Sensing technique named Finite Rate of Innovation in a Cognitive Radio Network (FRI) used	Proposed technique is Improved the performance in a fair resource allocation for cognitive radio networks. *Future Direction* To improve the radio spectrum utility performance using different scenario and architecture in CRN
2014 [20].	centralized algorithm used for our comparison benchmark, and a distributed algorithm used to assign spectrum channel with fairness	Proposed algorithms are very efficient in coordinating transmissions in a MIMO-CRN. *Future Direction* We can incorporating CR with MIMO and achieve efficient performance
2013 [21].	Proposed a very general scheduling model accomplishing goals such as making frequency, time slot, and data rate distribution to secondary users with possibly numerous antennas, in a heterogeneous multi-channel and multi-user scenario. Heuristic algorithm	Achieved performance in terms of both total throughput and fairness for varying number of secondary users, frequencies, antennas, and window size. *Future Direction* To plan estimate calculations, which have hypothetically provable execution assurance, to

	used for fair schedulers	address the reasonable
2012 [22].	proposed Hybrid Opportunistic Scheduling Algorithm	Achieved user fairness and Optimal growth rate for the secondary throughput.
2013 [23].	Evolutionary game framework An entropy based coalition formation algorithm	Achieved effective and flexible throughput. It achieves a high detection probability and a low false alarm probability. *Future Direction* Intend to jointly consider the two Problems of which action to take and which channel to sense. As a secondary user may want to decide which action to take based on the channel it needs to sense.
I2012 [24].	Lagrangian dual methods used for solve the optimal power utilization. Discrete Stochastic optimization method is used to solve the joint power and channel allocation It can track the changing radio environment to dynamically allocate the resources.	Diminished the computational multifaceted nature with defective channel detecting. It has provided quick optimal coverage during SUs sensing the channels It has provided the significant performance of throughput under the calculation of sensing error *Future Direction* Focus on joint access control method and dynamic resource allocation to maximize the total system capacity and minimize the interference to PU when there are sensing in the secondary networks.
2013 [25].	Distributed Consensus Algorithms is used to solve the problem of distributed common control channel allocation among the cooperative neighbour CRs.	Network capacity and spectrum sensing efficiency are significantly improved during the comparative analysis with sequence-based rendezvous scheme.
2016 [26]	Cross-layer approach called TCP-Freeze-CR technology	ST(Secondary Transmitter) with TCP-Freeze-CR can send about 10 times more packets than ST with standard TCP
		Future Direction Basic vitality recognition instrument just to detect essential transmission, and configure the test system where SUs never neglect to identify essential transmission.
2015 [27]	New approach called Virtual Prioritized Slice (VPS) algorithm is used to improve the scheduling of resources for Real Time (RT) and Non-Real Time (NRT) traffic.	Improved the performance significantly (reducing the blocking of real-time flow and improving the throughput of non-real-time flow). *Future Direction* To improve the performance of queuing approach
2012 [28].	barrier-based method is used to achieve the optimal power distribution	Achieved the optimal solution with an almost linear complexity, much better than standard techniques. Efficiency also improved *Future Direction* The case of imperfect channel state information, the presence of multiple users using the same sub channels and the interference among multiple primary cells should be investigated, to make the proposed RA algorithms more promising for applications.
2010 [29]	Proposed a suboptimal priority based resource allocation algorithm for the multiservice 2-hop OFDMA systems.	The proposed scheme performs better than the fixed allocation. Proposed suboptimal algorithm significantly reduced complexity compared to the optimal algorithm.
2012 [30]	Proposed two new load adaptive radio resource allocation techniques for the heterogeneous network	Provided the best performance improvement Improved the capacity of the networks This proposed algorithm might have enhanced the capacity of the system by a significant margin.
2014 [31].	Dynamic Resource Allocation Management Algorithm (DRAMA)	It accomplished the better use of accessible ranges. It uses the unused assets

	is proposed	and guarantees a predominant level of administration for the meandering clients. In light of the limit streamlining, it helps MBS to offload abundance activity that lessens large scale femto-impedances and raises the system execution which is appropriate for higher organization densities of femtocell. *Future Direction* Future exploration will concentrate on the range renting elements of mixture access femtocell system.
2011 [32].	Optimal time-sharing and power allocation policy Quantized spectrum sensing mechanism approach.	Achieved efficient time and power resource management between the secondary users.
2010 [33]	The heuristic optimal resource allocation algorithm. Suboptimal sub-channels and power allocation algorithm	The proposed algorithm significantly improved the system performance.
2010 [34].	Two classes of heuristics are proposed : Adaptation of a class of multistep heuristics policy. Novel approach called selective greedy algorithm.	Achieved good performance.
2010 [35].	Partially Observable Markov Decision Process (POMDP) is proposed.	TCP throughput significantly improved if the lower-layer parameters in CR networks are optimized jointly. *Future Direction* Consider different parameters in CR systems, for example, vitality utilization and security, in the proposed structure.
2010 [36].	Myopic sensing policy is proposed	Lower and upper limits on the presentation of the myopic policy are obtained in closed-form, which characterize the scaling behaviour of the achievable throughput of the multi-channel opportunistic system. The approximation factor of the myopic policy is also analysed to bind its worst-case performance loss with respect to the optimal performance. *Future Direction* Determining the optimality conjecture of the myopic policy and generalizing the results to stochastically non-identical channels by investigating Whittle index policy.
2010 [37]	Entirely distributed and scalable cooperative spectrum-sensing scheme based on recent advances in consensus algorithms is used.	Achieved sensitivity in detecting the primary user's presence and robustness in choosing a desirable decision threshold. *Future Direction* Rearrange the information arrangement of location insights from every auxiliary client to spare the remote transfer speed. Vitality identification does not function admirably for spread-range signals; different methodologies will be examined to manage such systems.
2009 [38].	They projected Goal-programming approach and Rate-requirement calculation mechanism	Achieved better performance than existing algorithm.
2009 [39].	Opportunistic scheduling algorithm Lyapunov Optimization with collision queue.	Proposed algorithm provides an explicit performance guarantees.
2008 [40]	Conformation control algorithms for spectrum underlay in CDMA networks is used	The result had shown the impacts of different system, QoS and interference constraint parameters on the network performance.
2008 [41]	Novel joint power/channel	Proposed system achieved the improved overall network throughput and

	allocation scheme A price-based iterative water-filling (PIWF) algorithm.	reducing the average power consumption.
2008 [42].	Proposed techniques are capped multi-level (CML) water-filling algorithm and a recursive decoupled power allocation algorithm	Achieved significant throughput and performance.
2007 [43]	Novel multi-reservation multiple access (MRMA) scheme is proposed.	MRMA can occupy a larger number of real-time traffic streams compared with FPLS while satisfying their access delay bounds.
2016 [44].	Stackelberg equilibrium or Stackelberg price game approach	Accomplished a huge execution of the traditional unicast and multicast plans in CRNs while accomplishing a close ideal execution tantamount to the comprehensive pursuit plan.
2016 [45].	Stackelberg game misusing the cognitive radio (CR) technology to utilize those scarce resources in CRN.	The proposed methodology can essentially enhance the throughput of casualty authorized hubs with somewhat diminishing system all out throughput.
2015 [46].	Dynamic spectrum learning and access (DSLA) scheme is proposed. A new low complexity VDF is proposed. Interpolation and Modified Frequency Transformation based VDF (IMFT-VDF) used.	Proposed algorithm achieved power-efficient and suitable for battery-operated cognitive radio terminals.
2016 [47].	They are analysing this situation from a game theoretic perspective and model the coexistence of CRNs with heterogeneous spectrum as a non-cooperative, recurrent spectrum sharing game.	They utilized the concept of *price of anarchy* to measure the efficiency of these solutions under selfish behaviour from CRNs.
2015 [48]	Proposed a user mobility prediction algorithm. A novel bandwidth utilization optimization technique and Hybrid Genetic Algorithm also proposed	Achieved required performance by network utilization, throughput, and QoS quality in the heterogeneous wireless networks.
2016 [49]	Proposed fuzzy algorithm based on decision making multiple criteria. Used particularly a selection of a backup channel in spectral mobility. Also proposed a benchmarking of performance of the two spectrum handoff models: Analytical Hierarchical Process and the proposed Fuzzy Algorithm.	Achieved an effective frequency channel selection. The results show a reduction of the rate of channel changes in contrast to the AHP selection method. The developed Fuzzy Algorithm based on multiple-criteria decision making is an instrument for decision-making that improves efficiency for the selection of spectrum opportunities.
2012 [50].	Proposed a novel pre-equalization stage for Spatial modulation (SM) which allows mitigating the fading e□ect of the wireless channel.	The proposed algorithm achieved significantly enhances the performance of SM. *Future Direction* To abuse spatial opposing qualities at the beneficiary not just to enhance the execution of SM. This is conceivable because of the additional degrees of opportunity presented by the numerous radio wire components accessible at the recipient yet continually keeping the many-sided quality to a tractable level, permitting the framework to be executed.
2013 [51]	Proposed priority-based traffic scheduling approach	The prioritized system provides optimum solution compare through the system where all types of traffic are preserved the same in terms of SG traffic delivery.
2014 [52]	They proposed queue-based channel assembling strategy for multi-channel CRNs. Two queuing approach is used to improve different types of traffic through distinct	They obtained significant improvements like increase the capacity of the secondary network and spectrum utilization whereas reducing blocking probability and forced expiry probability.

	priorities. Markov chain algorithm also used.	
2010 [53]	They proposed a modified proportional fairness scheduling algorithm with interruption factor (MPF-IF)	Achieved better QoS guarantee for secondary users' traffics and more fairness for secondary users.
2011 [54]	They proposed generalized analytical framework based on the pre-emptive resumption priority M/G/1 queuing theory.	The generalized analytical framework can illustrate the general performance of connection-based channel usage and help evaluate QoS performance in various traffic conditions and achieved a significant improvement of throughput.
2013 [55]	Dynamic channel selection approach is proposed. The pre-emptive resume priority (PRP) M/G/1 queuing network model is used to characterize the spectrum usage behaviours in secondary and primary users.	Proposed scheme with the equal data delivery rate and a slight increase in service time at the light traffics reduces the connection commotion rate of secondary users significantly.
2014 [56]	They proposed channel accessing scheme with priority queue. Primary task is, real-time message scheduling in cognitive radio networks that maximizes the packet transmissions before they exceed their deadline (delay tolerance).	Proposed scheme Minimised the interference to licence users and to maximize transmitted packet there should be trade-off between sensing time and transmitting time. And also specified that the interference to primary user is not depending on priority system. Achieved a significant throughput.

VI. CONCLUSION

In this article we have presented a comparative study and analysis of dynamic resource allocation in heterogeneous services in cognitive radio networks. In this literature survey we studied different technique used to achieve best performance over secondary networks, effective resource utilization, channel allocation throughput, delay; power consumption etc., each method provides better performance based on them approaches. In future, we can combine dynamic resource allocation and priority scheduling to achieve a better performance of priority based heterogeneous CRN.

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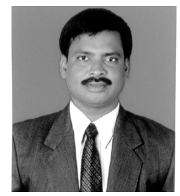

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