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Dynamic Spectrum Sensing For 5G Cognitive Radio Networks Using Optimization Technique

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Abstract: - With increasing development of 5G technology, the rapid growth of various technologies and the growth of various wireless devices, demand for wireless spectrum becomes more urgent. Wireless communication technologies have been advancing rapidly, leading to the emergence of 5G communication systems .Spectrum sensing is the key model utilized to access the spectrum dynamically in CRN. Various researchers are done in spectrum sensing scenario and different methods are designed to perform the task of spectrum resource sharing. Most of the methods design a decision statistics for identifying the signal by analyzing the features of noise and signals. One promising approach to address the challenges of spectrum sensing in cognitive radio networks for 5G communication is the integration of deep learning with hybrid optimization techniques. By combining the power of deep learning algorithms with optimization methods, it becomes possible to improve the efficiency and accuracy of spectrum sensing in dynamic and diverse communication scenarios. One of the key advantages of MIMO-based spectrum sensing is its ability to exploit the spatial diversity inherent in the environment. By using multiple antennas at both the transmitter and receiver, MIMO systems can distinguish between signals arriving from different directions, thereby improving the accuracy of spectrum sensing. Moreover, MIMO technology also enables the cognitive radio network to utilize the available spectrum more efficiently. With the ability to establish multiple parallel communication links, MIMO-based cognitive radio networks can achieve higher data rates and improved spectral efficiency, especially in dynamic and challenging radio environments. Research in this field is focused on further enhancing the performance of MIMO-based spectrum sensing in cognitive radio networks through advanced signal processing algorithms and machine learning technique Spectrum sensing detect existence of primary users (PUs) and it becomes a main research topic of CRN in industry and academic domain. This research developed a new framework based on algorithm to progress the mechanism of spectrum sensing in the CRN by detecting the availability of free channel. The signal components are extracted from the received signal and thereby spectrum availability of detected through fusion center using proposed Feedback Artificial Optimization Algorithm-based Deep Q network. However, Simulation results show that the proposed multiple-input-multiple-output(MIMO) spectrum sensing method achieves good performance Cognitive Radion Network attains maximum probability of detection and minimum probability of false alarm as 70%, and 38% for Rayleigh channel.

Keywords: Machine Learning, Quantum Computing, Artificial Intelligence, Quantum Algorithms, Hybrid Approaches Cognitive Radio, Spectrum Sensing , 5G,Deep Learning Algorithms, Hybrid Approaches.

I. INTRODUCTION

Wireless communication technologies, particularly in the context of 5G networks, have shown significant growth and advancement. However, one of the key challenges in 5G communication systems is the scarcity of available spectrum resources. To address this challenge, dynamic spectrum sensing techniques have emerged as a promising solution [1]. These techniques allow wireless devices to intelligently detect and utilize unused frequency bands, optimizing the utilization of available spectrum resources while minimizing interference with other users. The use of dynamic spectrum sensing techniques in 5G networks can greatly improve performance by maximizing spectrum efficiency and addressing the coexistence issue. In this paper, we propose a joint optimization algorithm of dynamic spectrum access and coding .

This optimization algorithm aims to address the erasure of packets caused by dynamic spectrum access and realize cognitive spectrum collaboration among users in mass connection scenarios. By combining the cognitive technology of dynamic spectrum sensing with emerging coding technologies and machine learning, we can enhance the performance of 5G networks. Methods of dynamic spectrum sensing have become increasingly important in the field of wireless communication, particularly in the context of 5G networks, due to the scarcity of available spectrum resources [1].These techniques play a crucial role in resolving the coexistence issue and optimizing spectrum efficiency in future wireless communication systems. By dynamically sensing the available spectrum, 5G networks can adaptively deploy spectrum sensing configurations to optimize system performance in

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various scenarios. The proposed dynamic spectrum sensing technique aims to overcome the challenges of diverse 5G communication scenarios by combining reinforcement learning with spectrum sensing.

This approach allows for the adaptive deployment of spectrum sensing configurations, ensuring optimal system performance under multifarious scenarios in 5G communications [2]. Overall, dynamic spectrum sensing techniques are crucial in addressing the scarcity of spectrum resources in 5G communication systems. They enable intelligent detection and utilization of unused frequency bands, optimizing spectrum efficiency and minimizing interference. Therefore, integrating dynamic spectrum sensing techniques with cognitive technology, emerging coding technologies, and machine learning can significantly enhance the performance of 5G networks and pave the way for the realization of cognitive spectrum collaboration.

Dynamic spectrum sensing techniques not Dynamic also sensing the spectrum scarcity have been available a spectrum focal resources point in of 5G research communication. In systems the field also cover wireless communication especially for significant improvements in the context of performance 5G and CRN, efficiency. Due to the intelligently scarcity detecting of available utilizing spectrum unused resources, Frequency bands. These techniques play a critical crucial role in optimizing spectrum interference efficiency and optimizing resolving spectrum for the utilization. Furthermore, in spectrum sensing recent with years, cognitive Radio technology, integration emerging of coding cognitive technologies, and with dynamic machine learning. Spectrum holes has potential gathered for significant enhancing attention in Spectrum Sensing. The capabilities of combining 5G reinforcement networks. In this spectrum context the researchers in 5G aim next generation communication scenarios, to develop the adaptive joint deployment optimization strategies. The algorithm for dynamic spectrum sensing configurations, and ensuring coding optimal using system reinforcement performance learning across proposed diverse in 5G communication represents this significant approach advancement. Has this potential algorithm aims to address challenges caused by dynamic spectrum access and also cover the cognitive way spectrum for collaboration cognitive among spectrum users, collaboration in mass connection scenarios. Furthermore, It's the adaptive joint deployment optimization of algorithm proposed spectrum sensing.In configurations this ensures optimal spectrum holes system promise the performance for under addressing different scenarios coexistence issues in 5G communications CRN.

A spectrum efficiency is important in 5G CRNs. The crucial role of it to influences of emerging spectrum sensing technologies, such as machine learning narrowband to enhance wideband the spectrum performance sensing, of in 5G networks. Thus, position offering of a primary comprehensive users' solution and to enabling the secondary scarcity users to available spectrum access resources. Frequency channels integration of these advancements' reinforcement learning provide valuable and insights spectrum sensing techniques for researchers, and provide researcher into flexible approach for optimization.To targets adaptively for deploy spectrum sensing in configurations. Future contributing communications to the efficient potential utilization of dynamic spectrum resources sensing techniques in 5G communication systems.

It is moving forward, important to acknowledge ongoing exploration of the challenges, spectrum sensing limitations techniques, associated with their narrowband implementation and wideband Interference spectrum management. Spectrum sensing energy offers efficiency of valuable understandings security considerations for optimizing the targets.

These careful advancements addressed provide to researchers fully and realize researcher with the benefits opportunities to dynamic spectrum to develop a innovative sensing solutions in 5G CRN. The improve literature survey performance in the 5G CRN provides and a enable comprehensive cognitive understanding spectrum of collaboration.

In the state of exploration dynamic spectrum sensing techniques integration in 5G CRN. The challenges associated with diverse 5G communication scenarios and adaptively deploying spectrum sensing configurations, researchers are paving the way for the realization of cognitive spectrum collaboration and the efficient utilization of spectrum resources in 5G communication systems.

For the next generation network application, the radio spectrum and its availability is very important for the communication. The utilization of this radio spectrum effectively and efficiently is the crucial task for the network users. It is been observed that the spectrum utilization efficient & effectively in very less amount as per the available amount of the spectrum .

Integrating MIMO technology into spectrum sensing offers several advantages, including improved spatial diversity and increased detection reliability. By exploiting the spatial dimension of the received signals, MIMO-based spectrum sensing can enhance the detection performance in harsh and dynamic wireless environments. Furthermore, the use of multiple antennas at both the transmitter and receiver ends enables the extraction of rich spatial information, leading to more accurate sensing results.

II. LITERATURE REVIEW

Cognitive radio (CR) is one of the solutions that are considered to be the most promising so far to solve the spectrum scarcity problem in wireless communication networks. Unlike traditional infrastructures, CR enabled devices have the operating ability of dynamic accessing and use of free spectrum bands, which may help to improve spectral efficiency. In a CR system, vacant spectrum bands are detected and used for operation by such devices in which spectrum sensing plays a mutually beneficial role. The cooperative sensing techniques are intended to combat spectral fading and shadowing as well as other channel impairments by merging information from varied sensing nodes. Overall, the research works as a foundation for the knowledge and insights of CR environments spectrum sensing techniques, which paves the way for the follow-up analyses and optimizations of the parameters.

A comprehensive review of the existing literature on MIMO-based spectrum sensing techniques for CRNs reveals a variety of approaches and algorithms proposed by researchers. From cooperative MIMO sensing to distributed MIMO sensing, there exists a diverse range of methodologies that aim to leverage the benefits of MIMO for spectrum sensing. By examining the strengths and limitations of these techniques, we can gain valuable insights into the current state of research in this field.

Moving forward, the research may encounter challenges related to practical implementation and scalability. It is essential to consider these factors and develop strategies to mitigate potential limitations in real-world deployment. Moreover, a comprehensive literature survey can provide additional insights and the latest developments in dynamic spectrum sensing techniques, offering a deeper understanding of the current landscape and future directions for research and innovation in this field. Through a literature survey, it has been found that there have been significant advancements in spectrum sensing techniques for cognitive radio networks.

Authors	Methods	Advantages	Disadvantages
Kaur, A. and Kumar, K. [34]	Decentralized Multi Multi-Agent Reinforcement Learning based resource allocation scheme	It enhances the performance in terms of network capacity, outage probability, and convergence speed.	It failed to consider multiple application requirements of CRs in cooperative CR networks.
Eappen, G. and Shankar, T. [35]	Multi-Objective Modified Grey Wolf Optimization (MOMGWO) algorithm	It showed higher performance with respect to the quality of the Pareto front.	Time complexity was higher.
Zhang, J. *et al.* [3]	Kernel-based spectrum sensing	It achieves much better performance than the traditional energy detector and p-norm	It is not much sensitive to parameters of Gaussian mixture noise.

		detector.	
Liu, C. *et al.* [4]	DNN based framework	It achieve almost the optimal detection performance.	High computational complexity
Eappen, G. and Shankar, T. [5]	Hybrid PSO-GSA	It showed higher performance in terms of transmission power, spectrum sensing bandwidth and power spectral density.	The extremely large value of the population size (e.g. 100) will increase the computational complexity of the optimization algorithms
Pan, G. *et al.* [29]	Spectrum sensing method based on deep learning and cycle spectrum	It has higher detection probability.	It has certain disadvantages, such as a single feature input.
Jothiraj, S. *et al.* [7]	Adaptive threshold-based dragonfly optimization model	It performs better in terms of detection accuracy and efficiency.	It further required to analyze the performance.
Reddy, S.S. and Prasad, M.S.G. [8]	Improved Whale Optimization Algorithm (IWOA)	It showed best performance based on delay, delivery ratio, performance, network lifetime, power consumption, and equity index.	It failed to analyze the performance with a greater number of nodes.

2.1 Limitation

While dynamic spectrum sensing techniques indeed offer potential benefits for optimizing spectrum efficiency in 5G communication, it's essential to consider opposing arguments regarding this approach. One of the main concerns with dynamic spectrum sensing is the potential for increased interference and congestion in the spectrum. As wireless devices dynamically access and utilize unused frequency bands, there is a risk of interference with other users who may be operating in the same spectrum. This interference can lead to degraded performance and reduced quality of service for all users sharing the spectrum. Additionally, the dynamic nature of spectrum access may result in higher levels of congestion, especially in densely populated areas or during peak usage times.

Another argument against dynamic spectrum sensing techniques is the complexity and overhead introduced in implementing and managing these dynamic access mechanisms. Dynamic spectrum sensing requires sophisticated algorithms and continuous monitoring of the spectrum to identify available frequency bands. This introduces additional complexity to the network infrastructure and may require significant resources in terms of computational power and energy consumption, potentially outweighing the benefits gained from spectrum optimization.

Furthermore, there are concerns about the security and privacy implications of dynamic spectrum sensing. As wireless devices dynamically detect and access spectrum resources, there is a risk of unauthorized access or malicious interference, posing security threats to the overall network.

In light of these opposing arguments, it becomes crucial to carefully weigh the advantages and disadvantages of dynamic spectrum sensing techniques in 5G networks to ensure that the potential benefits outweigh the potential drawbacks. While dynamic spectrum sensing offers the promise of optimizing spectrum efficiency, it is imperative to address the challenges and limitations to achieve a balanced and effective implementation in next-generation communication systems.

2.2 Aims, Objective & Challenges

The aims are to develop a superior scheme for determining the optimal spectrum sensing parameters in 5G cognitive radio environments.

Objectives

- To specify performance parameters for optimization, and then evaluate validity through analysis.
- To investigate the issues related to spectrum scarcity and spectrum heterogeneity and improve the reliability and efficiency of cognitive radio (CR) systems.
- To provide tools for decision-making in the optimization of spectrum sensing parameters to be able to deal with the anticipated spectrum shortages

Here are some of the issues faced by the existing methods are listed below:

•With an increase in SNR, sample count, and other factors, the detection performance of the kernel-based detector improves and it is less susceptible to Gaussian mixture noise characteristics number of receiver antennas [3].

• Even though the DNN based framework showed better detection performance, it faced higher computational complexity issues [4].

• The extremely large value of the population size increases the computational complexity of the optimization algorithms in [5].

2.3 Literature Gap

The literature gap in the earlier studies on the spectrum sensing parameters in cognitive radio environments is because few comprehensive works are solely dedicated to addressing the optimization problems for real-world scenario deployment. Several studies have investigated these techniques and algorithms as well as complexity and real-world constraints such as hardware restrictions, dynamically changing channels, and coexistence with legacy systems though. Moreover, the efforts to optimize deep learning models in terms of detection accuracy, energy efficiency, and computational complexity are not in depth. This type of system employing cognitive radio would benefit from the bridging of this gap.

III. PROPOSED METHODOLOGY

This research paper aims to propose a novel MIMO-based spectrum sensing methodology tailored to the specific requirements of CRNs. By leveraging advanced signal processing techniques and exploiting the spatial diversity offered by MIMO, our proposed methodology seeks to address the challenges inherent in spectrum sensing while maximizing the utilization of the available spectrum. The deductive approach of research used for this project. This approach involves constructing theories and hypotheses based on existing literature and theories, then following that with experimentation. The research methodology employed is virtual experimental, where the different sensing parameters of cognitive radio environments are experimented upon while the environments are controlled. With this approach, important variables can be controlled to observe their effects on system functions.

Primary intention of research will be to design and develop a multi objective functions for the spectrum sensing model using proposed Feedback Artificial Optimization Algorithm-based Deep Q network. The Spectrum Sensing is an important role in power efficiency in 5G CRN . In CRN in order to have high detection probability, periodic spectrum sensing is performed which consumes energy. This work concentrates for cooperative spectrum sensing in MIMO 5G cognitive radio networks considering the availability. In this research, availability of spectrum is detected using Deep Q network that is trained using proposed FAMA, which will be derived by the integration of Feedback Artificial Tree (FAT) algorithm [28] with Mayfly Algorithm (MA) [27]. The proposed method will be simulated in the MATLAB tool and its effectiveness will be analysed with the measures, like probability of detection and probability of false alarm.

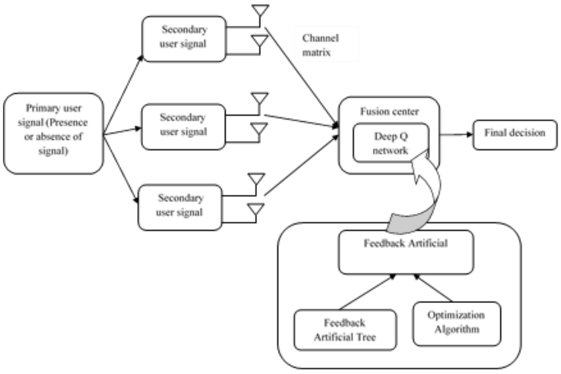

Figure.1 Block diagram of proposed method

The cooperative spectrum sensing model for the PU detection is the MIMO system is modelled as the binary hypothesis testing with null as well as alternative hypothesis corresponds to the absence as well as the presence of PUs [37]. The CRN contains fusion centre with X_a number of receiver antennas and X cooperating SUs with X_b antennas at every cooperating user. Let us consider $p_{d,m}$ as probability of detection, and $p_{f,m}$ as probability of false alarm of local decision rule of m^{th} user[37].

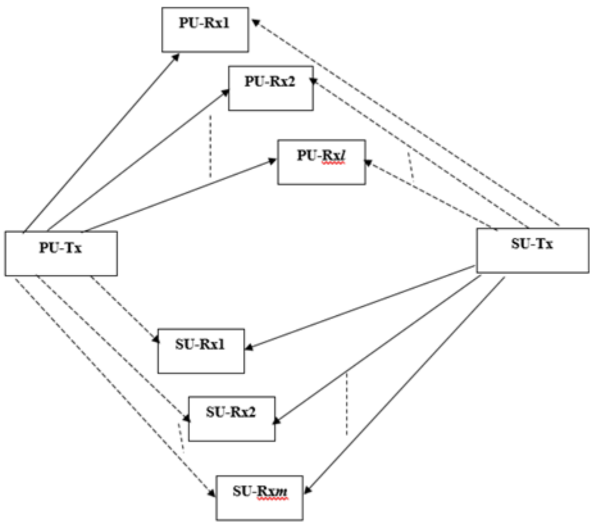

Figure 2 Block diagram of 5G Cognitive Radio Network(CRN)

When the m^{th} secondary node made a decision, the node transmit the set of A vectors $g_m(h) \in \Re^{X_b \times 1}, 1 \le h \le A$, corresponds to local decision with regards to the absence or the presence of PU to fusion center. In the below figure, matrix G_m is generated by stacking all the set of A vectors $g_m(h), 1 \le h \le A$ corresponds to decision as, $G_m = [g_m(1), g_m(2), \ldots, g_m(A)]^B \in \Re^{A \times X_b}$. Let matrix G_m send towards fusion center get the values of $G_m = P_0$ or $G_m = P_1$ corresponds to decision of absence $\aleph_0$ or presence $\aleph_1$ of PU, respectively. Under the non-antipodal signal with $A = 2$ and $X_b = 2$, matrix $P_0 = 0_{2\times 2}$ and P_1 is selected as orthogonal matrix $[1 \quad 1; \quad 1 \quad -1]_{2\times 2}$ that is $P_1 P_1^B = AC_2$. Accordingly, local performance for m^{th} secondary user that is $p_{d,m}$ and $p_{f,m}$ is expressed as, [37].

$$p_{d,m} = pr(G_m = P_1 \mid \aleph_1) \tag{4}$$

$$1 - p_{d,m} = pr(G_m = P_0 \mid \aleph_1) \tag{5}$$

$$p_{f,m} = pr(G_m = P_1 \mid \aleph_0) \tag{6}$$

$$1 - p_{d,m} = pr(G_m = P_0 \mid \aleph_0) \tag{7}$$

It is stated that number of antennas located at PU as well as detection mechanism utilized at every cooperating SUs are arbitrary. Accordingly, received signal $J_m(h) \in \Re^{X_a \times 1}$ at fusion centre that corresponds to vector $g_m(h)$ send by m^{th}, $1 \le m \le X$, SU at m^{th}, $1 \le h \le A$, instant over the orthogonal MAC is specified as,

$$J_m(h) = \mathbf{B}_m g_m(h) + q_m(h) \tag{8}$$

where, $\mathbf{B}_m \in \Re^{X_a \times X_b}$ denotes channel matrix of MIMO with every element $k_m(x, y)$ of matrix $\mathbf{B}_m$ shows fading coefficient among y^{th} transmitting antenna of m^{th} SU and x^{th} receiving antenna of the fusion center. However, l^{th} row of channel matrix $\mathbf{B}_m = \left[k_{m,1}, k_{m,2}, \ldots, k_{m,X_a}\right]^B$ is defined by $k_{m,l}^B \in \Re^{1 \times X_b}$. Accordingly, vector $q_m(h) \in \Re^{X_a \times 1}$ denotes circularly symmetric additive white Gaussian noise that is showed as identically separated and independent with the value of zero mean such that covariance matrix is represented as, $\mathbf{S}_q = E\{q_m(h) q_m^B(h)\} = \lambda^2 C_{X_a}$ [37]. To simplify the process, received signal $v_{m,l}(h)$ of above equation at l^{th} receive antenna of fusion center, $1 \le l \le X_a$ is modeled as,

$$v_{m,l}(h) = k_{m,l}^B g_m(h) + q_{m,l}(h) \tag{9}$$

Here, vector $J_m(h)$ of Eq. (8) is represented as $J_m(h) = \left[v_{m,1}(h), v_{m,2}(h), \ldots, v_{m,X_a}(h)\right]^T \in \Re^{X_a \times 1}$. However, the term $q_{m,l}(h)$ implies l^{th} element of noise vector

All channels are assumed to be subject to Rayleigh Channel and assumed that independent identically distributed.

This work expects to give the best outcomes in recognizing spectrum holes through a careful examination of the spectrum sensing parameters in the 5G cognitive radios environment. Research is coordinated in a deductive manner, with experimental design utilized as an experimentation method inside the system of positive research reasoning. Through the innovation of factors, reproductions, and tests, the study estimates the exhibition of the cognitive radio under various boundary settings. Appropriate validation mechanisms help to maintain the accuracy and reliability of the outcomes, in this manner working on their credibility. Subsequently, this work works on the field's collection of information concerning cognitive radio and offers supportive signs on how the spectrum sensing parameters can be successfully tuned for effective spectrum usage.

IV. 4.RESULTS AND DISCUSSION

4.1 Practical Implementation Considerations

In addition to theoretical advancements, practical implementation considerations for dynamic spectrum sensing techniques in 5G networks should be further investigated. This includes the development of cost-effective and scalable solutions for spectrum sensing, as well as the design of efficient algorithms for spectrum sensing data processing and decision-making. Furthermore, the integration of dynamic spectrum sensing with network slicing and edge computing concepts can enable tailored spectrum management and resource allocation for diverse 5G services and applications.

4.2 Experimental setup

The simulation of the developed Deep Learning based system is done in MATLAB tool with windows 10 OS, intel processor, and 4GB RAM.

4.3 Comparative methods

The proposed model is evaluated with the existing models, like Kernel based spectrum sensing [3], DNN [4], Cooperative reinforcement learning [33], to show how much improvement the proposed model attained in the communication scenario.

4.4 Analysis with Rayleigh channel

Fig. 3 shows analysis of detection probability. At SNR of 5dB, detection probability acquired by kernel-based spectrum sensing, DNN, cooperative reinforcement learning, deep learning, Analysis portrayed with false alarm probability is shown in figure

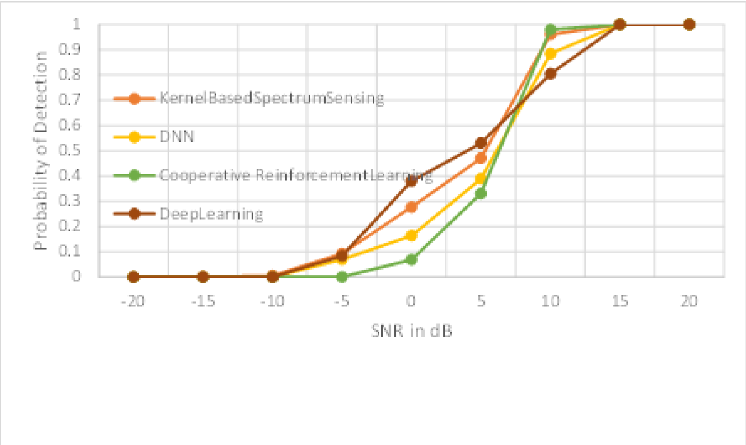

Figure. 3. Analysis by Rayleigh channel- probability of detection,

Fig.4 For the SNR value of 5dB, the probability measure captured the value for kernel-based spectrum sensing, DNN, cooperative reinforcement learning and deep learning.

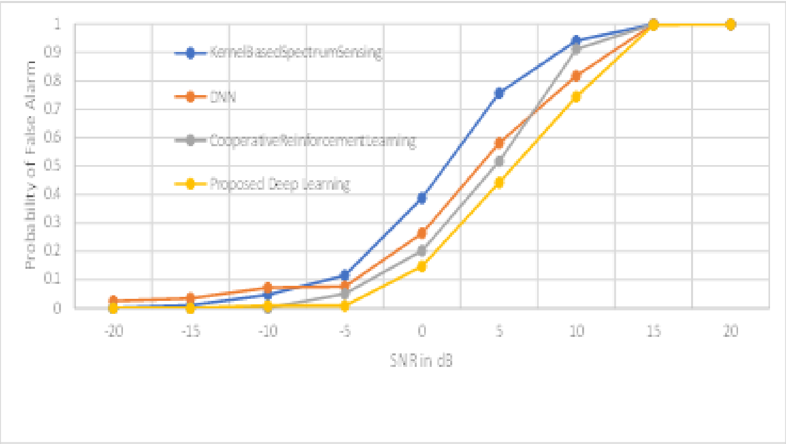

Figure 4 Analysis by Rayleigh channel- probability of false alarm

Fig.5 signifies analysis with ROC. For the probability of detection of kernel based spectrum sensing, DNN, cooperative reinforcement learning and

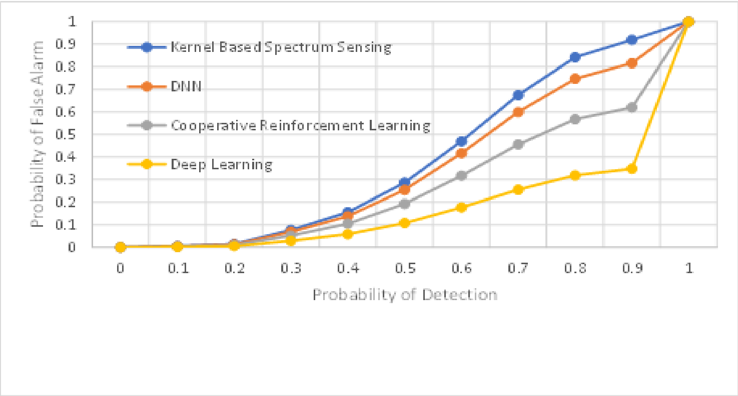

Figure 5 Analysis by Rayleigh channel -ROC

V. 5.CONCLUSIONS

In conclusion, the use of dynamic spectrum sensing techniques in 5G networks is essential for optimizing system performance, maximizing spectrum efficiency, and addressing the coexistence issue. By combining these techniques with cognitive technology, emerging coding technologies, and machine learning, we can further enhance the performance of 5G networks and enable cognitive spectrum collaboration. Overall, dynamic spectrum sensing techniques play a crucial role in addressing the challenges of diverse 5G communication scenarios by adaptively deploying spectrum sensing configurations. Through a comprehensive review of existing literature and the development of simulation-based methodologies using MATLAB, this research has contributed valuable insights into the optimization process. The results draw the prospects of the suggested technologies' potential to improve the capacity of cognitive radio to find and use the available spectrum resources. Here, the signal received at the receiver end is used to extract the components that includes energy of signal, test statistics, and Eigen statistics. Accordingly, the signal components are fused at the fusion centre by employing the weight factors such that the value of weight parameter is determined using Mayfly Algorithm. However, the proposed approach attains maximum probability of detection and minimum probability of false alarm as 0.70, and 0.38 for Rayleigh channel.

In future studies, the limitations should be considered and more optimization strategies researched to validate the findings through practice. Moving forward, further research in the field of dynamic spectrum sensing should focus on the development of advanced algorithms and protocols for real-time spectrum management in 5G networks.

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