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An Efficient Hybrid Analysis to Improve Data Rate Signal Transmission in Cognitive Radio Networks Using Multi- Hop

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ABSTRACT- Spectrum scarcity problems can be resolved with the emerging communiqué technologies known as cognitive radio (CR). Cognitive radio networks (CRNs) will give mobile users greater bandwidth via wirelessly heterogeneity design and dynamic spectrum acquisition methods. The Cognitive Radio Mobile Ad-Hoc Network (CR-MANET) idea of Adaptive Routing a new network paradigm may be realized by using the functions of spectrum management to overcome such difficulties. Secondary users (SUs) have the freedom to opportunistically explore and make use of the open spaces on licensed channels. When a primary user (PU) interferes with a licensed channel, this forces the SU to leave it and switch to an open channel. Because of the constant channel switching those results, SUs degrades as a result. In this result recommends a number of channels, number of hop CRN that uses a fuzzy decision-making system that is genetically optimized for channel selection, channel switching, and spectrum allocation. According to study, the suggested architecture achieves higher PDR, throughput, latency, and transmission time than fuzzy and genetic algorithms. Through simulations the result demonstrates significant improvements in data rate performance, making it a promising solution for enhancing communication efficiency in cognitive radio networks.

Keywords: Cognitive radio, Fuzzy and genetic algorithm, Cognitive radio networks, Ad-Hoc Network Cognitive Radio Mobile (AR-CRM).

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1. INTRODUCTION

A network of wireless cognitive radio devices is known as a cognitive radio network (CRN). These gadgets are environment-sensing and environment-adaptive. They take use of the licensed bands when they can. A gadget can look for a free frequency band to utilize if it discovers that the one it is presently utilizing is no longer accessible. So instead of remaining with one band, it may move around from band to band as the opportunity arises. 802.22 standard published by the FCC; CRN is now a reality for taking advantage of TV white spaces when they arise. Those who have access to licensed band is called as primary user (PU), whilst those who use licensed band sporadically called as secondary user (SU) [15].

Spectrum sensing, intelligent spectrum management and adaptive routing are all functions that can be performed by the function blocks that make up the Ad-Hoc Network Cognitive Radio Mobile (AR-CRM) [25].

A cognitive radio that can adapt to multifaceted, intelligent wireless communication systems that are crucial to meeting customer demands. A cognitive radio has two abilities:
(1) Environment detection, and
(2) Physical layer functionality adaptation.

Cognitive radio's two main goals are effective spectrum use and extremely reliable communications whenever and wherever they are required. One method is the cognitive radio, which may be used to cognitive networks. The term "cognitive radio network" raises to intelligent multiuser wireless communication systems which is believe radio-scene, excluding environmental fluctuations, offers communication between users through collaboration, and regulates optimal resource allocation to facilitate communication. The concept of a cognitive network refers to a cognitive procedure that can recognize the state of a network and then plan, choose and take action in response to those state changes. In order to integrate network functionality for cognitive networks and enable the cognitive process to adjust the network, the network must be software adaptable [13].

2. COGNITIVE CYCLE

The detection of the spectrum for white areas occurs during the sensing phase. Being able to access a frequency band in space that is unoccupied by major users the cognitive radio frequencies will utilize this region, which is open for the other broadcasts. The sensing phase picks up activity in both the available and unoccupied areas. It should be checked throughout the monitoring phase that there are no second users who are experiencing interference. It is necessary to accurately identify the white areas since the monitoring is real-time [9].

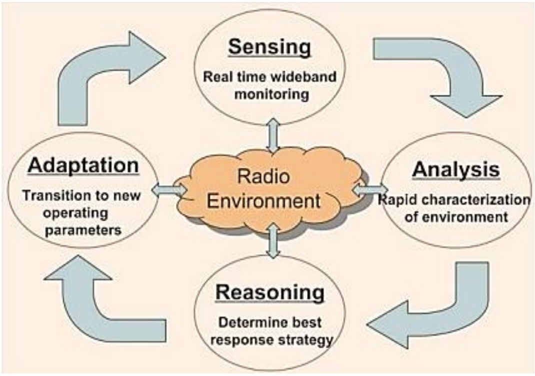

Figure 1: Cognitive radio cycle [9]

Sensing the spectrum stage is surveyed by identifying the white space with an appropriate frequency which is the best quality (utilizing QoS). Before the available white space may be deemed appropriate for the transmission, it must first fulfill a number of other standards. Secondary user is allowed to modify frequency band utilizing criteria if twice PU and SU are engaged in broadcast. The metrics used to assess the quality of the available frequencies are typically noise levels, losses, and mistake rates. It is essential to remember that all users have access to the frequency parameters (primary and secondary). After reviewing the settings, an appropriate frequency may be assigned for secondary users thanks to the cognitive radio's design. A typical radio network does not effectively utilize its spectrum efficiency. The benefit of cognitive radio is that it may use the same frequency for many transmissions [9].

3. TYPES OF COGNITIVE RADIO NETWORKS

As seen below are essentially kinds of Cognitive radio networks.

• Centralized CRN
• Decentralized CRN

Centralized-CRN: It's an Infrastructure-based system and SUs are handled by using a separate source station just for them. They have a wired back bone that controls the connections. The centralized -CRN's framework is depicted in *figure 2* below [10].

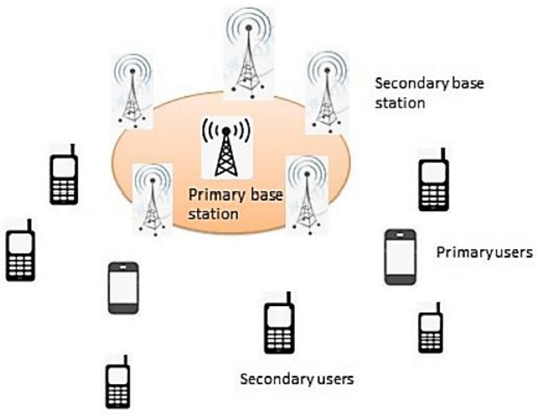

Figure 2: Centralized-CRN [10]

Decentralized-CRN: The Decentralized- CRN is framed in an adhoc fashion; Where SU's expanding communiqué in an adhoc manner. It usually operates cooperatively while scanning the spectrum. Multiple users can operate inside the unlicensed band thanks to this structure. The coexistence of IEEE 802.11 and IEEE 802.16 is a well-known example. The decentralized-framework CRN's is shown in *fig. 3* below [10].

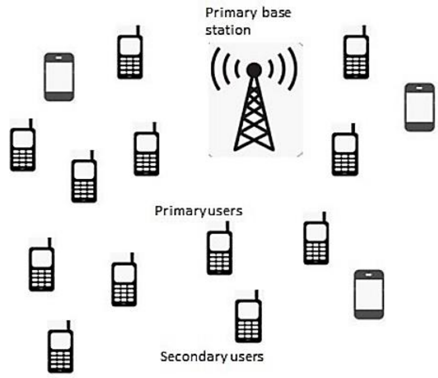

Figure 3: Decentralized-CRN [10]

4. FUZZY DECISION SYSTEM

Fuzzy logic, which is typically used to make judgments in situations when all the incoming facts are imprecise and qualitatively unclear, is sometimes denoted to be technique dealing solely with mathematically. The fuzzy set can lessen the fuzziness (imprecision) of real-time situation. According to the fuzzy-logic theory, a fuzzy set's membership requirements can't necessarily be true or false. We have mentioned below main parts described of a fuzzy-logic system [1].

- Fuzzifier: The initiate data is initially prepared for fuzzification using a fuzzifier and specified membership functions. Now, the input, which is originally took the form of crisp values, is being transformed into fuzzy values [1].
- Fuzzy Knowledge Base: This FDS element is where all of the input membership functions that define input variables, all of the outcomes membership functions that describe outcomes control variables and the fuzzy link amongst input and outcomes are stored [1].
- Fuzzy Rule Base: The FDS's fuzzy rules base contains the information necessary to understand how the entire process works.

  This element assigns the connection between the fuzzy input and the crisp outcomes [1].
- DE fuzzifier: The DE fuzzifier unit helps to obtain the relationship between input and output from the fuzzy rules base unit in order to transform the fuzzy value to crisp outcome values [1].

5. GENETIC ALGORITHM

GA is an evolutionary meta-heuristic optimization approach built on the principles of crossover, mutation, and reproduction in genetic evolution. A soft computing method called GA is used to tackle the overall optimization problem in order to address optimization issues. GA's primary goal is to improve results using its several phases, including selection, crossover, and mutation. The effectiveness of a GA depends on how well the search operators are designed and integrated into the algorithm [1].

5.1 Literature Review

V. Noel Jeygar Robert, K. Vidya, "Genetic algorithm optimized fuzzy decision system for efficient data transmission with deafness avoidance in multihop cognitive radio networks", Springer, 2021 [1], in this paper, cognitive radio networks (CRNs) will demonstrate how wireless heterogeneity designs and dynamic spectrum acquisition techniques may provide mobile users with more capacity. The changing nature of the spectrum that is accessible and the various needs for a wide variety of applications, however, provide obstacles for CRNs. These issues can be solved by the functions of spectrum management, enabling the realization of a new network paradigm. The empty areas that exist in licensed channels can be opportunistically explored and used by secondary users (SUs). (PU) interferes with the licensed channel, this forces the SU to leave the channel and switch to an unoccupied one.

Amjad Ali, Laraib Abbas, Muhammad Shafiq, Ali Kashif Bashir, Muhammad Khalil Afzal, Hannan Bin Liaqat, Muhammad Hameed Siddiqi, And Kyung Sup Kwak, "Hybrid Fuzzy Logic Scheme for Efficient Channel Utilization in Cognitive Radio Networks", IEEE Access, 2019 [2], In this research, cognitive radio (CR) technology is presented as possible approach to effective spectrum utilization, allowing CR devices, also known as secondary users (SUs), to opportunistically take advantage of white spaces present in the permitted channels. When SUs sees the principal user has arrived, they must promptly leave the licensing channels and move to other channels that is open. If channel switching occurs repeatedly, the SU's performance suffers significantly. Additionally, in brain-powered CR networks (CRNs), when sensing info is not only erroneous and faulty but also heavily ambiguous, making channel-switching judgments based on clear reasoning is not the best course of action. The authors of this work planned (FLB-DSS) that handle channeling switching and channeling selection in tandem to increase total throughput of CRNs.

Rajiv Kumar Berwer, Santosh Kumar, "Multi Channel Based Clustering in Cognitive Radio Networks", IEEE, 2017 [3], In this research, Cognitive Radio Networks (CRNs) are capable new technology that enable Unlicensing users (Second User) to fill spectrum gap and change the CR device characteristics as anticipated to use free channels without interfering with licensed users (primary users). Nodes are organized into local groups for efficient communication via clustering, a topology management approach. The goal is to achieve scalability and stability, as well as support channel access and channel sensing, which are essential for CR operations. A method for cluster generation is planned in this paper. Our technique consists of two phases; in the first, Node with highest degree in its neighbourhood is chosen the cluster leader. The cluster is formed in second stage when the remaining nodes link appropriate cluster leaders by swapping a finite number of messages.

Hamza Khan, Sang-Jo Yoo, "Multi-Objective Optimal Resource Allocation Using Particle Swarm Optimization in Cognitive Radio", IEEE, 2018 [4], In the multi-channel ad hoc cognitive radio networks presented in this study, the viable data rate for Secondary user (SU) and essential sensing parameter value are channel dependent. Wireless channel gain and principal activity are unique to each channel. SUs have different standards for energy efficiency and data traffic. The appropriate resource allocating strategy and dynamic MAC frame configure for a multi-channel ad hoc cognitive radio network are established in this study. Their dynamic resource allocating model is represented as a constrain optimized problematic with many objectives utilizing particle swarm optimization (PSO) method.

Shribala Nagul, "PDDT: Path discovery for end-to-end data transmission in Cognitive Radio Ad-Hoc Networks", IEEE, 2020 [5], In this research, Cognitive Radio (CR), which provides dynamic spectrum channel supply, is one of the key technologies offered to address the evolving trends. However, the main issue with this Cognitive Radio Ad-Hoc Networks (CRAHN) is challenge of establishing a direct route between nodes. As a result, the route must be established with few channels in series. To fully utilize the resources, a path must be constructed over a few channels in series, which necessitates dynamic channel allocation. As much distance inside the network will be avoided as a result. The crucial subject that is being explored in this research is multi-channel broadcasting route with highest Quality of Service (QoS) condition for CRAHN. Through adaptive evolutionary algorithms that look at the available multi-channel pathways, the intended technology is evaluated. QoS measurements are taken into account in the fitness function. The effectiveness of the intended model demonstrates the study's results. There is a strong likelihood that this model will significantly.

5.2 Flow of System

1. Set Initial Parameter for Design Wireless Sensor Network.
2. Node Movement and Randomly Optimize Route from Cluster.
3. Based on Distance optimize node and selection of SU & PU.
4. Observe and analysis on Multi-hop Node for discovers Optimize node and Route.
5. Apply Fuzzification on data and apply Rule Parallel for optimize Route and handshake data between node.
6. Apply Defuzzification on data.
7. Selected Optimized Node Apply on GA.
8. Optimize again Route and Node Selection and Routing time analysis using GA (Objective).
9. Finalize the route based on iteration and tune it based on best route optimization.
10. Work on performance analysis.

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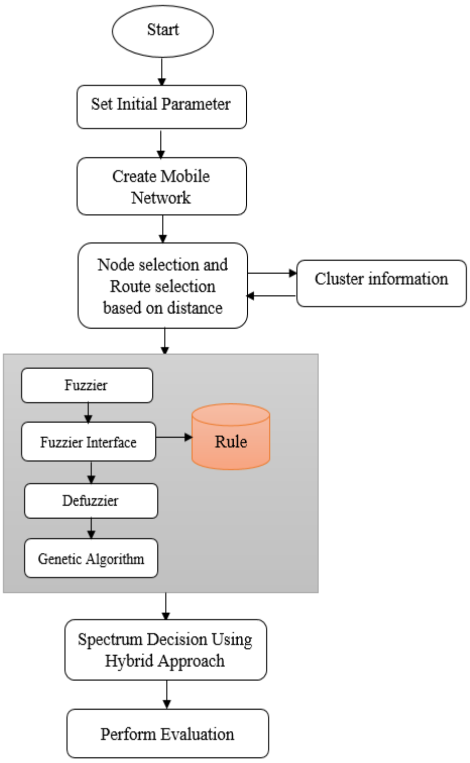

Figure 4: Flow of System

5.3 Mathematical Analysis

Multihop cooperative spectrum sensing's time frame is broken down into four subframes: data transmission time (Tt), reporting time (Tr), reporting time (Tc), and reporting time (Ts) of cluster members to respective CHs. the whole frame duration may be expressed as follows:

$$T=Ts+NmTc+MTr+Tt \quad (1)$$

Where M shows total cluster used in the network, and Nm is sensor used in the m-th cluster, which is biggest cluster in the wireless sensor Network. Pd and Pf Shows a throughput and energy consumption of node, and energy efficiency may all be used to evaluate the effectiveness of cooperative spectrum sensing. The objective is to achieve the highest detection performance with the least amount of network energy consumption while preventing the chance of a false alert from rising over a certain level.

5.4 Cluster Grouping

All users in network using Fuzzy Clustering Algorithm widely employed in pattern recognition the Main Objective Attributes and Function:

$$\min_{\lambda ij,mj} = (v_{Eq}) \quad (2)$$

Where,

$$v_{Eq} = \sum_{i=1}^{N1}\sum_{j=1}^{M1}\lambda_{ij}^{q}\left\|\gamma_i - m1_j\right\|^2 \quad (3)$$

Here,

M=clusters used in Network,

Q= Fuzziness Component >1,

i_j= membership Function of the i[th] node in cluster, (0>= i_j<=1)

m_j = center of cluster j

Based on Iteration use objective function to update the membership value of i_j with cluster centroid m_j for fuzzification.

$$\lambda_{ij} = \frac{1}{\sum_{h=1}^{M}\left(\frac{\|\gamma_i - m1_j\|}{\|\gamma_i - m1_k\|}\right)^{\frac{2}{q-1}}} \quad (4)$$

And

$$m_j = \frac{\sum_{i=1}^{N}\lambda_{ij}^{q}\cdot\gamma_i}{\sum_{i=1}^{N}\lambda_{ij}^{q}} \quad (5)$$

When the termination requirements, which are k+1ijkij, are satisfied, the iterative optimization comes to an end. In this case, k is the iteration step. Additionally, Algorithm 1 illustrates the cluster formation description.

First Cluster Formation Algorithm

1: Initialization: membership values $\mu i, j\forall h$=1, 3, 5, 7...N $M\forall i$=1, 3, 5…N

2: Initialize cluster

3: while $\{\lambda_{ij}^{k+1} - \lambda_{ij}^{k}\}<\sigma$ do

4: for j= Integer range

M= Integer range

5: $m_j = \frac{\sum_{i=1}^{N}\lambda_{ij}^{q}\cdot\gamma_i}{\sum_{i=1}^{N}\lambda_{ij}^{q}}$

6: end for

7: for i=Integer range. $N1$=Integer range

8: for j= Integer range. $M1$=Integer range

9. where is λ_{ij}^{k}

10. if $mode\left\|(\gamma_i - m1_{j)})\right\| > 0\ then$

11: Calλ_{ij} as

12: $\lambda_{ij} = \frac{1}{\sum_{h=1}^{M}\left(\frac{\|\gamma_i - m_j\|}{\|\gamma_i - m_k\|}\right)^{\frac{2}{q-1}}}$

13: which is λ_{ij}^{k+1}

14: end_1

15: end_2

16: end_3

17: end_4

New estimated objective function

$$\Psi_j^{(m1)} = \max_{CH}\left(\frac{\beta_j^{(m1)}\gamma_j^{(m1)}}{\alpha EPL_j^{(m1)} + (1-\alpha)EPL_{FC}^{(m1)}}\right) \quad (6)$$

Here $\beta_j^{(m)}$ = Residual energy of the j^{th} node

$\gamma_j^{(m)}$ = Signal to noise ratio of the channel

$EPL_j^{(m)}$=Estimate path loss

$EPL_{FC}^{(m)}$ = the path loss,

α = weight function

The $EPL_j^{(m)}$ is defined as

$$EPL_j^{(m)} = \frac{\sum_{i=1}^{N_m} PL_{j,i}^{(m1)}}{N_m} \quad (7)$$

Here, Nm = No of Sensor.

And $EPL^{(m1)}{}_{j,i}$= Estimate path loss between i^{th} and j^{th} node

$$EPL_{j,i}^{(m)} = 10nlog10(ER_{j,i}^{(m1)}),$$

Where $ER_{j,i}^{(m)} = \left\| \gamma_i^{(m1)} - \gamma_j^{(m1)} \right\|$ Shows distance between nodes

$$\gamma_i^{(m)} = \left\{ Ex_i^{(m1)} - Ey_i^{(m1)} \right\},$$

For i^{th} sensor node,

$$\gamma_i^{(m)} = \left\{ Ex_j^{(m1)} - Ey_j^{(m1)} \right\}$$

The path loss between the Cluster Head of the m^{th} cluster and FC is given as

$$EPL_{FC}^{(m1)} = 10nlog10(ER_{FC}^{(m)}), \quad (8)$$

Where $ER_{FC}^{(m)} = \left\| \gamma_i^{(m)} - \gamma_{FC} \right\|,$

Here X_J= PU & Y_J = SU.

Averaging value of each group (cluster) before select PU.

$$\lambda(S_{PU(avg)}) = \begin{cases} 0, & S_{PU(avg)} \le 1 \\ \frac{S_{PU(avg)}-b}{b-a} & a < S_{PU(avg)} \le b \\ \frac{S_{PU(avg)}-b}{c-b} & b < S_{PU(avg)} < c \\ 0, & S_{PU(avg)} \ge c \end{cases} \quad (9)$$

$$F(x) = W_1 \cdot S_{PU} + W_2 \cdot B_{PU} + W_3 \cdot C_{PU} + W_4 \cdot P_{SU} + W_5 \cdot D_{SU} \quad (10)$$

In this equation define weight factor of each group (selected cluster) take a part in channel (Routing Establishment from one node to another node) and hybrid approach of equation represent novelty factor of proposed system.

$$\text{Channel utilization} = \left(\frac{BW_{SU}}{BW_c} \times 100 \right) \quad (11)$$

Calculate channel utilization during selection of primary and secondary node.

Table 1: Simulation Parameters

Simulation Parameter	Value
Simulation Area	1000 x1000
Simulation Time	10-200
No of PUs	5
No of SUs	10 -120
Packet Size(bytes)	1024

6. SIMULATION RESULTS

Figure 5 indicate overall power spectral density of complete system. *Figure 6, 7 & 8* provide results of simulation like parameter PDR (Packet Delivery Ratio), Transmission Time & Throughput respectively. Where handoff and throughput indicates successful transmission take place. Transmission time is total time required to switch the channel.

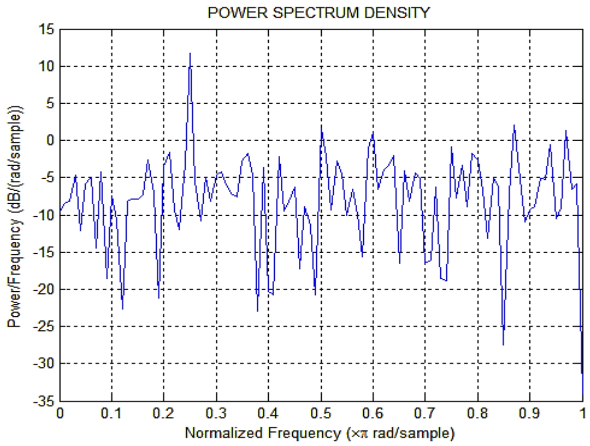

Figure 5: Spectrum Density

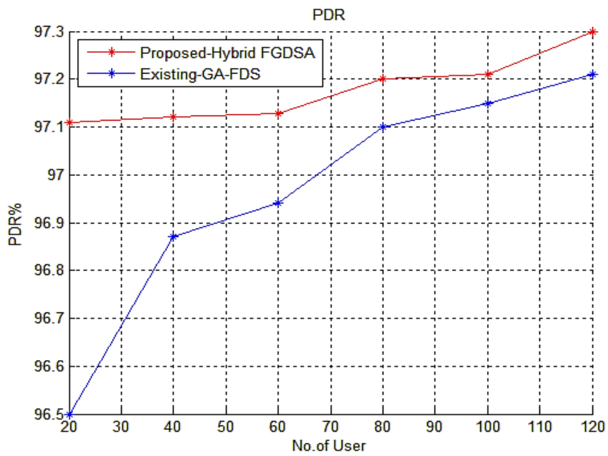

Figure 6: PDR (GA-FDS = Genetic Algorithm Fuzzy Decision System)

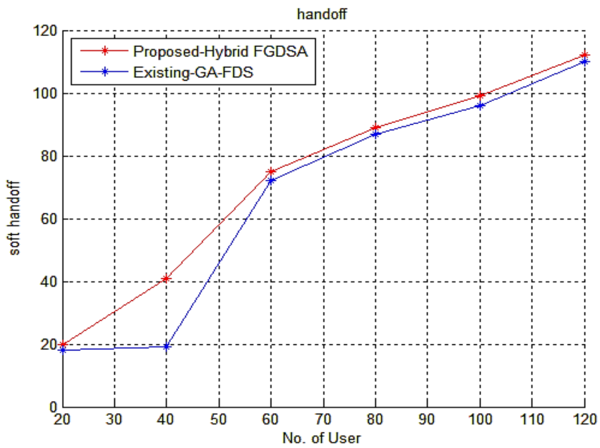

Figure 7: Handoff

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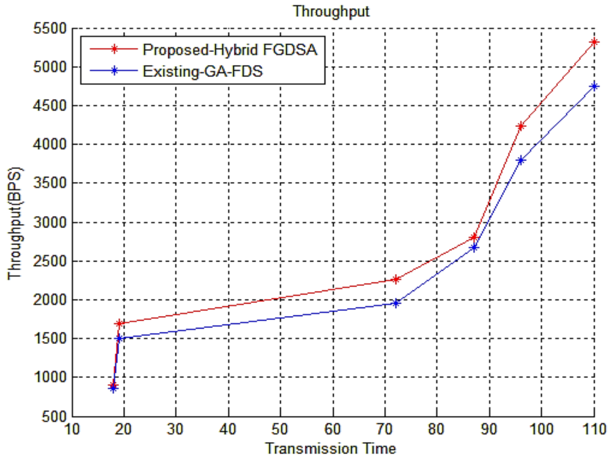

Figure 8: Throughput

Table 2: Simulation Results

No. Of Users	PDR	Throughput (BPS)	Transmission Time
20	97.02	900	18
40	97.12	1698	19
60	97.181	2260	72
80	98.20	2800	87
100	98.22	4239	96
120	98.234	5311	110

7. CONCLUSION

The fuzzy genetic algorithm and fuzzy logic are both used in this paper's work on the hybrid FGDSA (Fuzzy Genetic Decision System Analysis) technique to infer relationships. At this stage, the research included an overview of the problem, its context, the architecture of the FGDSA system that had been created (complete with extensive module descriptions), as well as the mathematical model that served as the foundation for the solution strategy that had been built. A few general performance assessments made using the FGDSA method were also reported in the research. The suggested architecture on the basis of the choice of the primary user and the secondary user, work on route discovery and route optimization. Along with different routes that have been discovered and analyzed based on node distance and location in order to connect a node to a selector or an optimizer, fuzzy rules are used. The GA is used to examine a node's availability in a cluster and the potential of additional nodes as well as the route for information flow between source and destination. As a consequence of the work done on the parameter results, it has been demonstrated that the suggested model outperforms the existing system. as based on result analysis it prove that proposed system gives better throughput and packet delivery ratio than existing system as our proposed system provide PU selection base on location, weight and Rule based selection of cluster. The scientific contribution of proposed approach enable better utilization of available spectrum resources and offer higher data rates for secondary users, leading to more efficient and reliable communication in dynamic and heterogeneous wireless environments. In future work on other parameter like latency, energy or other parameter using different methodology.

Conflicts of Interest: Declare conflicts of interest or state "The authors declare no conflict of interest."

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