OPTIMAL ENERGY-EFFICIENT TRANSMISSION FOR HYBRID SPECTRUM SHARING IN COGNITIVE RADIO NETWORKS

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Abstract : *This paper explores optimal energy-efficient transmission within hybrid spectrum-sharing frameworks in cognitive radio networks, which have become increasingly vital due to the surging growth of wireless data traffic. As conventional equipment struggles to keep pace with expansive network requirements, energy efficiency has emerged as a primary design parameter, critically influencing both operational costs and quality of service. Utilizing cognitive radio technology, which enables dynamic adjustments of transmission parameters based on environmental conditions, this study unveils an Energy-Harvesting Spectrum Sharing (EHSS) model aimed at minimizing power consumption while maximizing data integrity and service delivery. Simulation results based on a network of 100 nodes demonstrate improved metrics such as Packet Delivery Ratio (PDR), end-to-end delay, throughput, and optimal energy utilization, emphasizing the significance of effective energy conservation strategies in current wireless systems. The findings elucidate the necessity for innovative design approaches that prioritize energy efficiency, aiming to address both ecological concerns and the demands of a growing user base while providing a roadmap for future development in cognitive radio technologies*.

IndexTerms -**Eenergy-efficient transmission, energy harvesting, energy efficiency, cognitive radio networks.**

I. INTRODUCTION

Optimal energy usage in wireless communications is increasing largely due to exponential network expansion, particularly the explosion of wireless data traffic, which is a key impetus for this research. This trend may reduce the energy efficiency of ICT networks and intelligent technology.

A recent study has shown a gap between high network development rates and past equipment efficiency advances, anticipated to expand over the next few decades. Even with the best-case scenario expected advancements in optimum energy efficiency, current technologies are unlikely to be adequate to regulate optimal energy use over the long term. Quality of Service and Optimal Energy Efficiency should be accomplished without interruptions while allocating bandwidths in wireless networks, which are inherently dynamic.

The increasing optimum energy usage is regarded as one of the greatest obstacles associated with the deployment of wireless networks. Wireless applications such as multimedia and interactive services employ a high data rate, resulting in excessive power consumption. The optimal energy expenditure may be decreased or used as effectively as feasible. Diverse technologies and designs have been used to address the difficulties posed by high power consumption.

The ideal energy efficiency has become a crucial design parameter for wireless networks due to environmental and economic considerations. To reduce the network operator's operating expenses, the power consumption of a network rises as its access point density grows. The rising battery capacity of wireless terminals does not meet consumer expectations. It is possible to extend the lifespan of the ideal energy source by using optimal energy conservation strategies and technologies. Maximum use of ideal energy does not always equate to optimal energy being utilized effectively and efficiently. Nonetheless, this phase must specify that the budgetary constraints should not exceed the maximum [7].

The need for connection, data throughput, and service quality cannot be met by raising a base station's transmit power (BS). Increasing the transmit power improves the signal intensity and interference received by a base station (BS) that is not transmitting data. This results in the signal-to-interference-plus-noise ratio (SINR), which significantly influences service quality. Cognitive radio is an emerging technology in which the network or wireless node dynamically modifies transmission and reception characteristics based on environmental sensors [1]. Cognitive radios can detect their surroundings and adjust to resource limitations.

CR identifies the spectrum with the least interference, combining numerous channels to obtain a high transmission rate. During data transmission, it conserves energy and preserves the Signal-Noise ratio.

This study focuses primarily on optimum energy efficiency considerations fundamentally driven by the tradeoff between optimal energy consumption and feasible Quality of Service This study aims to achieve the quality-of-service standards while decreasing the ideal energy demand.

II. EHSS MODEL

The conventional Communication system uses a single-packet delivery method, and senders share available bandwidth depending on the size of the packets. The primary purpose of this study is to discover the optimal nodes for transmitting data from the source in a wireless environment without incurring any delays.

The node is utilized to transport data if the previous transmission was successful. The CR node is used to detect nearby nodes, allowing for effective data transfer and efficient energy use.[2]
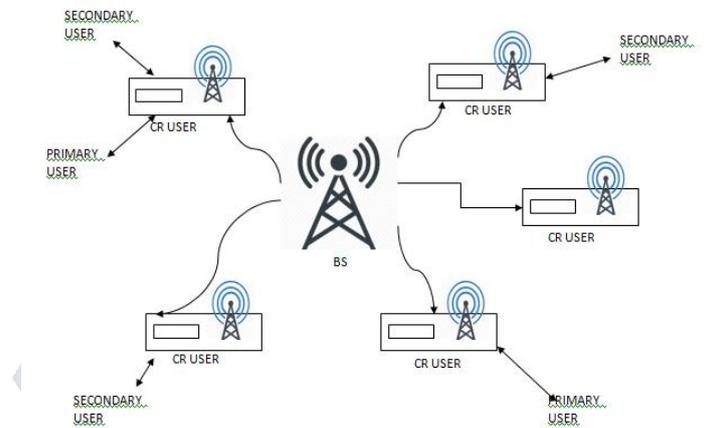

Figure 1.1   Cognitive Radio Network with CR Users and a BS

Cognitive Radio technology is used to address spectrum depletion and spectrum utilization challenges. However, it has inherent features that facilitate optimum energy usage. CR is a radio capable of modifying its transmitter settings depending on interaction with its operating environment to reason, plan, and determine future operations to fulfill various demands. Optimal energy efficiency may be effectively attained by detecting, reporting, and transmission scheduling to establish a balance between sensing precision and the transmission process.

Algorithm

Input: K the number of nodes denoted by N: A data set containing d objects

Output: A set of N as a node as optimal energy gained data

1.Initialize Network Load Balancer Module-> NLM

2. Arbitrarily select objects as point out of n data points(d>K)

3. For each transmission, i=0 from source denoted by S and destination denoted by R

4. Choose a marked node m, and unmark it

5. For all links (N,i1) -> (N,i2) do

6. If S > 0, On route discovery radio access as per routing protocols

7. Swap the first path with the new one with Load high -> yes

8. Return (xq,xq,x3,...xn,K packets to new broad castMAX}

9. Calculate the frequency adoption on Transmission optional energy Route on MAX and MIN

10 Transmit the data on route if path is valid

11. Computer total cost S of swapping path in initial nodes of an object n

$$TransmitNode\ Nm \sum_{t=1}^{\infty} Zj\left(Qri + \sum_{j=1}^{t} qij - qs * t\right)\ ta\ specific\ Time\ t,$$

where qi and Zj are sequence Time Z

Send the data line by line packet per threshold and wait time

Repeat steps until there is no change in the path as a consistent route

III. EFFICIENT OPTIMAL ENERGY OF COGNITIVE RADIO NETWORKS

As a result of the fast development of wireless communications, optimum energy efficiency in cognitive radio networks has emerged as a critical challenge for wireless networking. As cognitive radio networks comprise optimally energy-intensive components such as terminal nodes, base stations, and backbone networks, the longevity of the network depends on the quantity of ideal energy spent by these components throughout the various stages of communication. Therefore, effective energy saving should be considered in every cognitive radio network operation and planning aspect.

There are several techniques in cognitive radio networks to preserve optimum energy. One of them optimizes energy conservation at different cognitive radioactivity levels. Similarly, another reduces interference to an absolute minimum and obtains a high signal-to-noise ratio with the same transmission capacity. The sensing rate should be increased to conserve optimum energy and time while running in periodic sensing and active modes.

A. Why Optimal Energy Efficiency in Cognitive Radio is Critical

As the number of wireless devices and hardware increases, the demand for a more effective energy supply will continue to grow, as will the drive to develop more energy-efficient products. The burden to improve the optimal energy efficiency of cognitive radio networks rests not on the shoulders of the administrator but rather on those of the device manufacturers who must create and configure additional convincing solutions for the administrators to implement and the customers to purchase.

Recently, a hazardous atmospheric divergence has become an important element that cannot be disregarded. Most government offices, network specialist cooperatives, network device manufacturers, and consumers are now concerned about wireless devices' ideal energy efficiency. Improving optimum energy efficiency in cognitive radio networks has several implications. Nonetheless, most of them concentrate on configuration, green interchanges technique, and reserve funds regarding cost and end-user fulfillment and pleasure[6].

The greater the optimum energy consumption in a wireless system, the greater the heat because optimal energy consumption in wireless devices generates heat. Heat is emitted when a cognitive radio client is in conversation. If the system becomes overheated, it will begin to fail and may be completely or partially destroyed. A very massive cooling system may be necessary to reduce the temperature, but this is not suitable for portable wireless devices. A relatively big cooling system will demand extra ideal energy for operation, resulting in increased heat. Due to these design concerns, there is a need for wireless networking systems to be more energy-efficient.

Consequently, using optimum energy efficiency protocols in cognitive radio networks may reduce optimal energy consumption and be easily validated by these standards.

Base stations demand a great deal of optimum energy to transmit and receive wireless signals. A reduced amount of heat will be emitted by wireless components in base stations using an efficient optimum energy utilization protocol. If less heat is generated, less ideal energy will be required to maintain the base stations' natural temperature. This allows the service provider to save money on electricity.

IV. PERFORMANCE METRICS

The performance metrics used to evaluate the optimal energy efficiency in wireless networks are discussed in the section.

1. Packet delivery ratio

PDR is the measure of the number of data packets delivered to their destination. This depicts the level of data supplied to the destination as computed using the algorithm.

$$PDR = \left(\sum\_i \llbracket packet\ delivery \rrbracket \right) / \left(\sum\_i \llbracket packet\ sent \rrbracket \right) \times 100$$

The PDR is used to survey concepts inside the framework. It refers to the measurement of packets in the network and describes the quantity that will be transmitted from source to destination at a certain speed. It is known as a delivery ratio.

2. End to End delay

End-to-end delay describes the median time it takes an information packet to travel from the source to destinations across a network. It also accounts for the delay resulting from the route identification process and the backlog in the transmission of data packets [3].

$$Delay = \sum i \frac{(Arrival\ time - Send\ time)}{} \sum i\ Total\ number\ of\ connections\ and$$

$$Its\ Average\ Delay = Total\ Delay / Total\ number\ of\ packets\ received .$$

3. Throughput Ratio

Throughput is the mean speed at which messages are successfully delivered across a communication link. Throughput is often quantified in bits per second, data packets per second, or time slots. Throughput is also known as data rate or bandwidth.

$$(\textbf{Throughput} = \left(\sum\_i \llbracket \textbf{Packet delivered} \rrbracket \right)/\textbf{Delay})$$

where delay in time at sending packets are $delay = \sum I\ Packet\ arrival - packet\ start\ time$

To provide a high-quality service channel for transmitting real-time data to the gateway, it is essential to meet the end-to-end latency requirement.

4. Transmission Ratio

Network performance, referred to as transmission, is quantified by the ratio of packets received by the receiver to the packets sent by the source.

5. Utilization of Optimal energy

Utilization is the primary method of measuring asset performance and determining business success.

V. **SIMULATION RESULTS**

This section and phase offer simulation findings based on the performance of the EHSS framework. The experiment included 100 randomly arranged nodes within a 1000×1000 meter square region. TABLE 1.1 shows the key simulation parameters utilized in this experiment.

Parameter	Value
Simulator	NS2
Node quantity	100
Simulation Time	30 sec
Channel	Wireless Channel
Type Traffic	CBR
Range Transmission	100m
Mobility Model	Random Waypoint
Covered simulation area	1000 * 1000 m
Node Speed	20 m/s
Interface Type	Queue
Type of Mac Protocol	802.11 Ext
Packet Size	512 MB
Queue length	250
Radio Propagation Model	Two Ray Ground

Table 1.1 Simulation Parameters

Each node has a starting ideal energy of 5 joules and is regarded non-functional when its optimal energy level approaches zero. Each packet contains an ideal energy field, which must be updated throughout packet transmission in order to determine the average optimal energy[4].
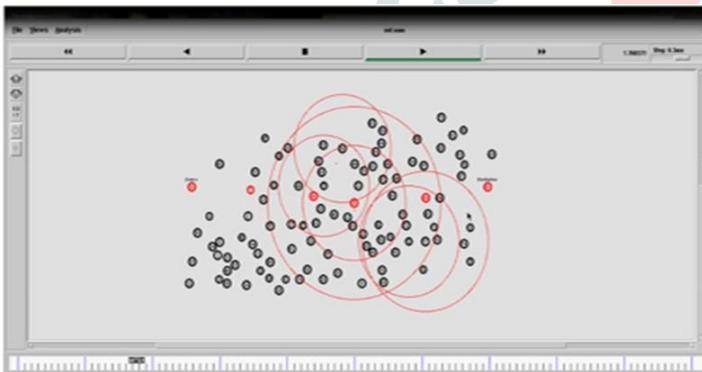
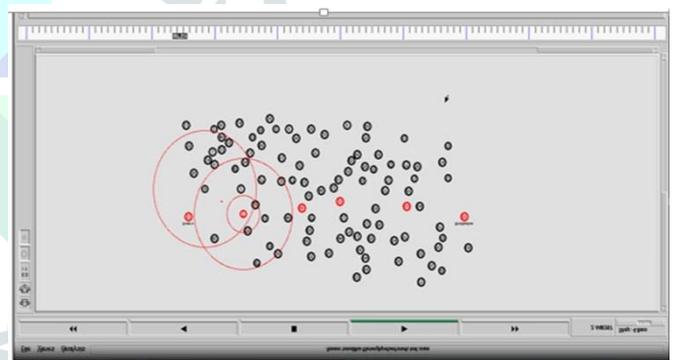**Figure 1.2   Optimal energy Distribution**

Figure 1.3 Transmission Optimal energy

Figure 1.2 depicts each node's best energy allocation throughout the runtime

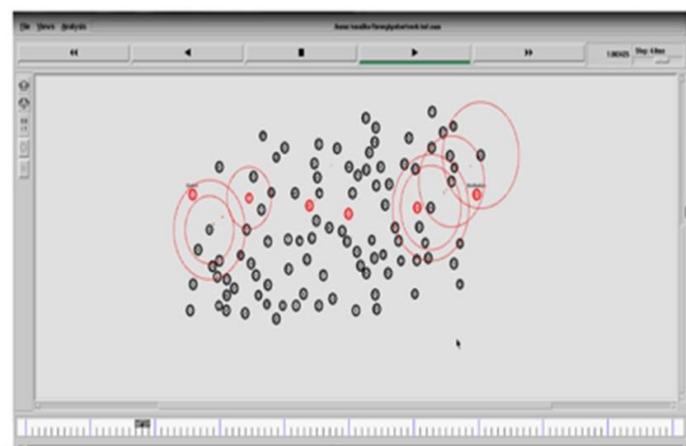Figure 1.3 shows how to choose access nodes for safe data transfer

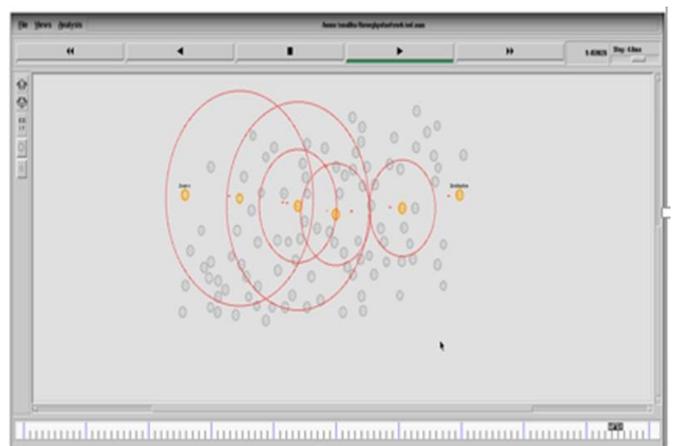**Figure 1.4 Data Transmission**

Figure 1.3 Transmission Optimal energy

Figure 1.4 depicts a model for the replication of the power equivalent of areas in nodes of a network throughout data transmission.

The amount of power used during the transfer of data from the source node to the node of destination is shown in Figure 1.5. Data is sent quickly and securely from the source node to the destination node.
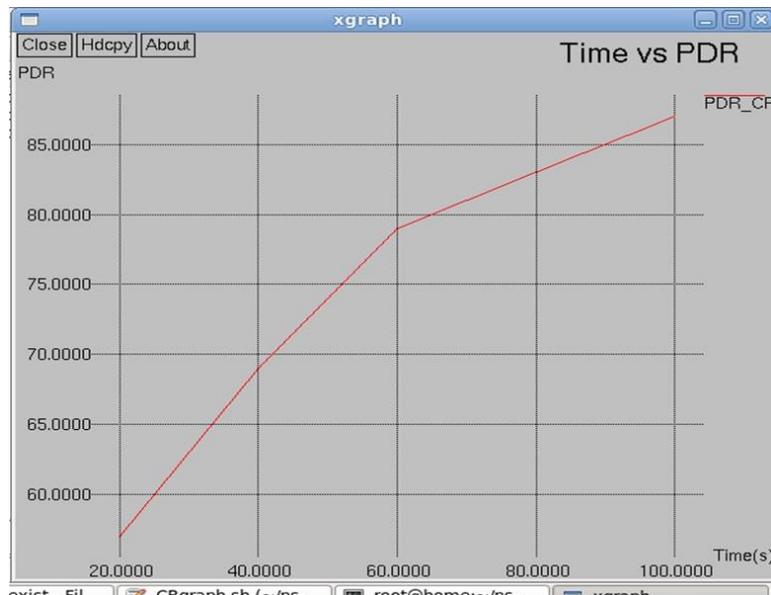

Figure 1.6 Packet Delivery Ratio

Figure 1.6 illustrates how data transported from source to destination node in the EHSS process reduces packet delivery ratio. It explains how the network's nodes' packet delivery ratio increases power consumption.

The packet delivery ratio fluctuates with their traversal rate when there is a high volume of traffic. The data will be able to reach its target with a delivery ratio ranging from 20% to 40%. Using the Cognitive radio, the nodes gather and send the data that the sensing nodes have collected to the destination node.

A greater packet delivery ratio cannot be achieved using the conventional approach. Using cognitive radio technology instead of the conventional approach has reduced the packet delivery ratio, according to the simulation findings. From the source to the destination, the cognitive radio node detects the data that needs to be received and processed.
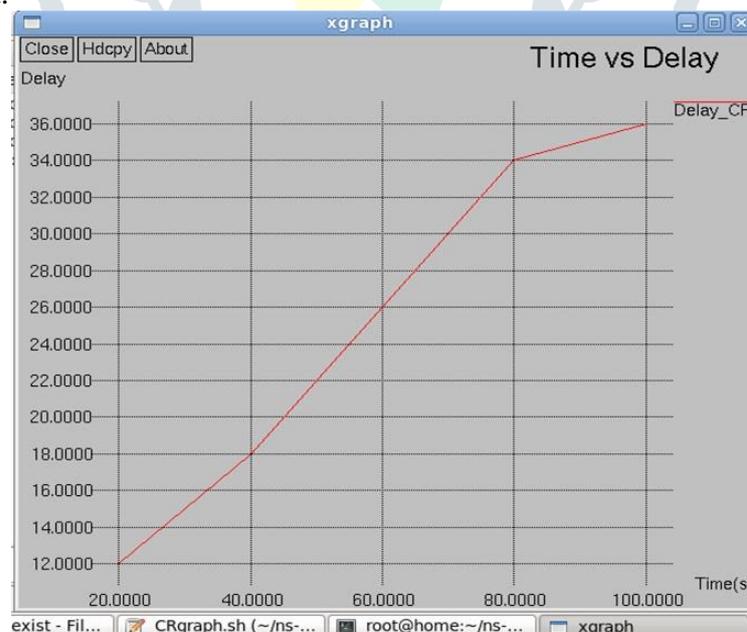

Figure 1.7 End to End Delay

Figure 1.7 shows that when the amount of data packets rises, the end-to-end latency decreases. The bandwidth usage displays the maximum data rates of the node's transceiver and receiver. Noise in the system has an impact on the maximum data rate when communicating.
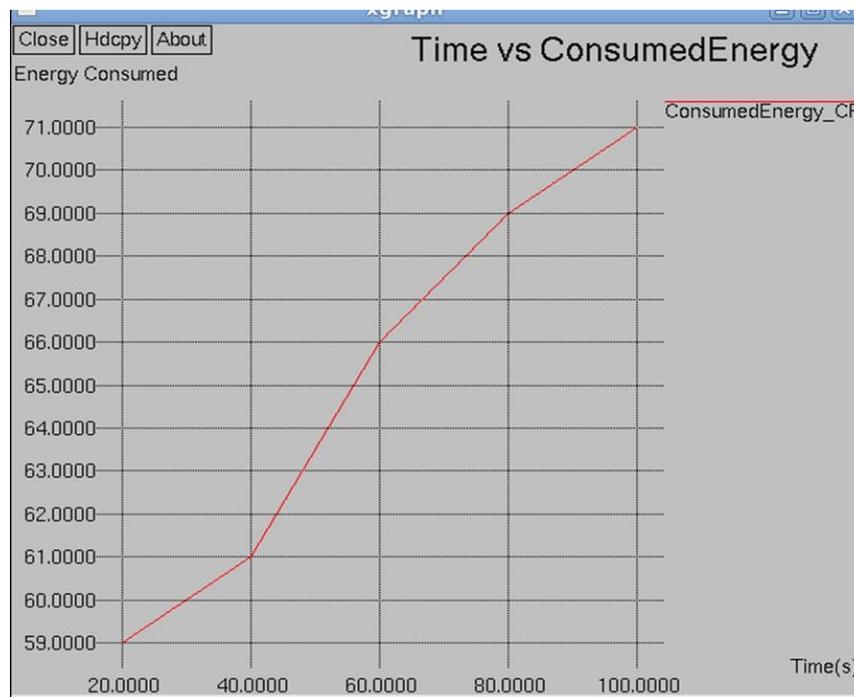
Figure 1.8 Optimal Energy Consumed

The proportion of total ideal energy consumption for real data transmission rises every outcome interval, with reception being generally minimal in these systems due to infrequent occurrences. The ideal energy needed for sensing events is often a fixed amount and is beyond control. Therefore, the most efficient energy used to maintain the communication system is the main factor in controlling energy consumption to prolong the network's lifespan. Enhancing the longevity of energy-constrained event-driven networks is a successful method to improve performance. Nodes may drastically minimize energy usage by entering a sleep mode when there are no events. Figure 1.8 shows the process of optimal energy consumed during the data transmission.

Throughput is the aggregate number of packets received per second by the endpoints of all multi-hop flows in the network while conserving energy efficiently [5]. The parameter for comparing ideal energy usage in this phase is the total energy used for transmission and reception per correctly received packet, which is growing.
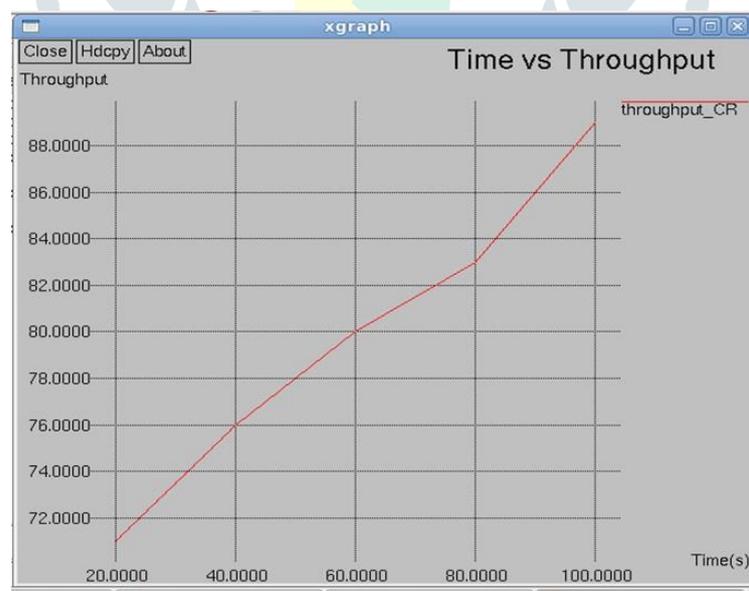

Figure 1.9 Throughput

Within the EHSS project, the data transmission rate rises as the throughput is optimized, as shown in Figure 1.9.
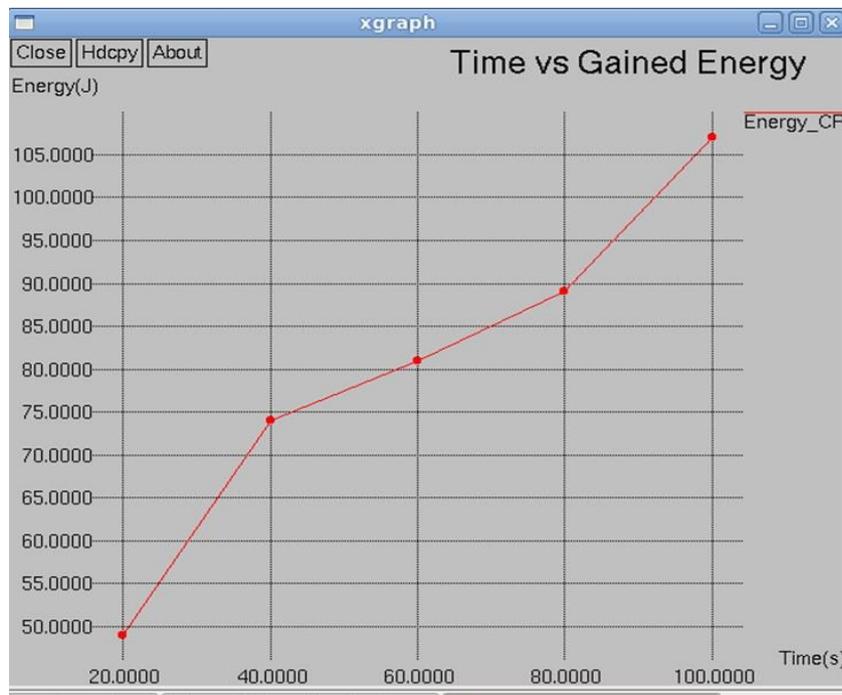
Figure 1.10 Gained Optimal energy

Figure 1.10 shows how much optimal energy has been gained from the EHSS work with maximized throughput.

The transmission ratio is calculated by dividing the number of successful detections by the total number of assaults in the EHSS technique. The calculation has been determined as follows:

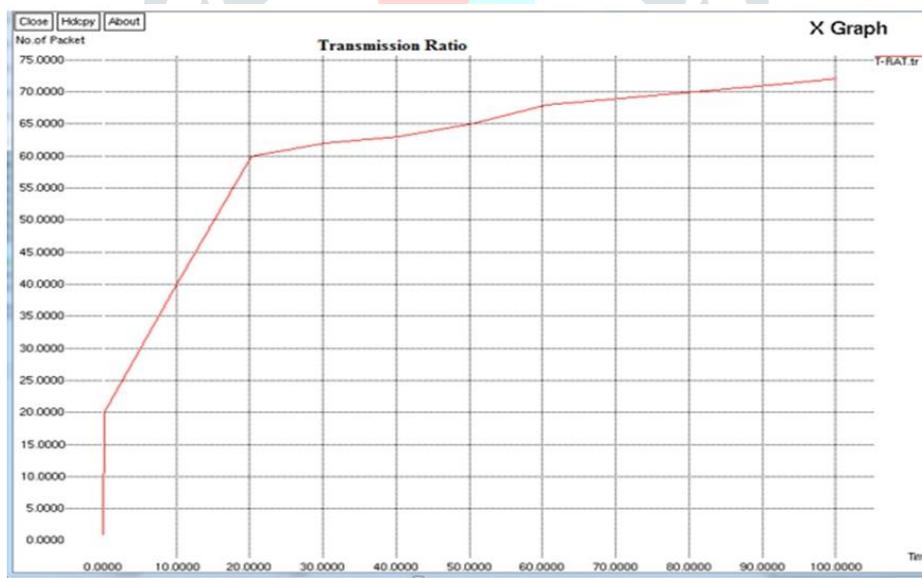$$\text{Detection Accuracy} = \frac{X}{Y} \times 100$$

Figure 1.11 Transmission Ratio

Figure 1.11 illustrates the transmission ratio percentage of the structured node transferring from source to destination in radio access technology. The destination node chooses the dependable node based on factors such as remaining ideal energy gain of up to 72%, throughput, cost, and hop count, excluding pheromone value. Subsequently, the answer is sent back to the source node via the chosen route. The source forwards all packets to the destination using the most efficient route to enhance radio transmission energy efficiency.

Figure 1.12 Optimal Energy Utilization

Figure 1.12 demonstrated that implementing optimum energy efficiency techniques enhanced both energy efficiency and throughput, thereby enhancing the performance of all users. Optimal energy usage minimizes interference and decreases throughput loss. Regular packet exchanges are necessary to sustain these neighbouring connections, resulting in a substantial overhead to maximize the transmission range of radio signals. Characterizing the performance of topology boosts lifespan utilization by up to 66%. This step requires precise knowledge of neighbours' x-y coordinates. The EHSS system produces high utilization as per the transmission constraints.

VI. CONCLUSION

Efficient energy use is a key focus in the rapid advancement of wireless networks due to the many stakeholders' concerns over design, eco-friendly technology, expenses, and user pleasure. [8] As the number of nodes grows, the speed of each node likewise rises, impacting the end-to-end latency. The quantity of packets used for data transmission and various transfer modalities is determined by the amount of the data being sent. The EHSS study shows that a higher packet error probability is directly related to larger packet sizes, leading to an elevated transmission ratio.

Cognitive radio depends on new and unique technologies and algorithms. It may result in increased optimal energy utilization. Optimizing the optimal energy efficiency of cognitive radio networks diminishes ecological effects and reduces network expense to empower prudent green cognitive radio. As a result, one of the most important criteria for a functional cellular cognitive radio network would be high optimal energy efficiency. The logical outcomes are valuable for choosing an outline structure like the power control system, subject to arranged climate and required performance goals

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