



ORIGINAL ARTICLE

# ENERGY EFFICIENT IOT HEALTHCARE THROUGH WIRELESS SENSOR NETWORKS

<sup>1\*</sup> S. Prasath, <sup>2</sup>K. S. Mohanasathiya, <sup>3</sup>V. K. Narendira Kumar

<sup>1</sup> Assistant Professor, Research Supervisor, School of Computer Science, VET Institute of Arts and Science (Co-Edu) College, Erode, Tamil Nadu, India.

<sup>2</sup> Assistant Professor, School of Computer Science, VET Institute of Arts and Science (Co-Edu) College, Erode, Tamil Nadu, India.

<sup>3</sup> Assistant Professor, Research Department of Computer Science, Gobi Arts & Science College (Autonomous), Gobichettipalayam, Erode, Tamil Nadu, India.

Corresponding Author Email: softprasaths@gmail.com

(Received 24 December 2025; revised 02 April 2026; accepted 11 May 2026)

## Abstract

Wireless Sensor Networks (WSN) often perform autonomous identification and management of the items of the physical world using sensor nodes distributed throughout the globe. These sensor nodes are powered by batteries using Internet of Things (IoT) and were important to the implementation of sensor nodes. Thus, it is necessary to decrease the amount of energy used in edict so as to increase the network life expectancy of healthcare systems. Consideration of the information flow observed is important when developing a WSN. Ideals of wireless technology like IEEE 802.15.4 are followed in order to facilitate data transfer. These specifications also provide optimal end to end connectivity and ideal pathways in the event of the application of the proposed Energy Optimization Technique. In order to achieve efficient data delivery to health care tracking, the suggested approach has enhanced the quality of data packet signal by 25 and has also contributed to the survivability of WSN. In order to demonstrate the efficiency of the suggested system in terms of the indicators of the quantity of the energy effectiveness, the existence of live nodes, packet distribution, and the communication latency in the system, the results of the experiment are compared to the state-of-the-art techniques.

**Keywords:** *wireless sensor networks; sensor nodes; energy saving; health care monitoring; internet of things*

## 1. Introduction

Smart healthcare is an innovation globally and also a technological advancement. The shift of the traditional healthcare to smart healthcare is a transformation of the disease-centric to the person-centric care, clinical to regional care, and generic to customized care. IoT-based smart healthcare is aimed at supplying the medical assistance needs of people [1-2]. Smart healthcare enhances the efficiency of local and medical services significantly. Smart healthcare is a case of smart infrastructure with linked phones to make far superior energy strategic choices [3]. IoT is a more recent method, compared to WSN. In other words, WSN can be actively employed as a part of an IoT system. An IoT device may have a large number of sensors interconnecting in a mesh network to help collect the information and transmit it to the Web through the routers [4]. As compared to IoT and WSN, it is not fully comprehensive. A WSN is a network consisting of wireless sensors only [5]. In case there is an interlinked device, then the system is not called a WSN anymore. This ceases to be the case with the IoT [6]. Any digital or electronic device capable of contacting the net in fact can be regarded as an IoT system. Sensor device networks do not need permission of remote healthcare professionals as smart gateways are available. By installing a smart gateway, the workload of the sensor node is minimized. This results in increased productivity and reliability. A case study of a Malaysian government hospital, and a summary of similar studies are also provided in the paper [7]. Towards the end, a framework is outlined as the central foundation on the protection of the IoT-based health systems against the existing security vulnerabilities. Mog computing [8] is one of the techniques that will help reduce the multi-hop data communication delay, resource management and enhancement of service dynamism within the healthcare industry. The study analyzed

and suggested the important big data infrastructure and services to be used in fog devices and big data analytics in healthcare [9]. The variables of the study were latency and resource use. The average transmission time in a health cloud is increasing as two or more healthcare systems use the same medium of communication [10]. The high pace of the development of the Internet of Things (IoT) has had a profound impact on healthcare by providing an opportunity to monitor patients at all times and on a real-time basis thanks to the connection of medical equipment. Healthcare IoT systems combine physiological monitoring devices, communication networks, and cloud computing to gather and process physiological information about the heart rate, blood pressure, temperature, and oxygen saturation. Wireless Sensor Networks (WSNs) are actively used in the area of IoT healthcare to enable data acquisition which is relatively inexpensive, flexible, and scalable. A WSN is a system of sensor nodes monitoring, processing and sending wireless information about health to a central gateway or cloud server. Nevertheless, sensor nodes can be supplied with battery resources which are usually limited, and the problem of energy efficiency is one of primary challenges. A high rate of transmissions of data, constant sensing and network overheads can soon exhaust node energy, lowering network lifetime and reliability.

Critical in this is energy efficiency in healthcare applications where continuous monitoring and integrity of data are needed. There is a risk that the loss of data, incorrect diagnosis, or slow medical response may occur as a result of node failures due to energy depletion, which can be fatal to the patient. That is why it is crucial to develop energy-conscious communication protocols, routing schemes, and data aggregation methods to extend the lifetime of the sensors and ensure high quality of healthcare services. The recent studies have been aimed at the optimization of energy consumption in the IoT healthcare system using some of the techniques like duty cycling, data compression, adaptive sampling, and energy-efficient routing. The objectives of these techniques are to minimize unnecessary transmissions and computational waste and provide dependable data delivery. Moreover, smart algorithms, and light models of machine learning are more frequently combined to forecast patient conditions and control network resources, further reducing the use of energy. The cloud and edge computing paradigm has also improved the energy efficiency of the IoT healthcare by offloading sensor node computationally intensive loads to the immediate edge devices or cloud servers. This minimizes on-node processing and communication, allowing real-time analytics at a reduced use of energy. Protection mechanisms of secure data transmission and privacy are simultaneously integrated in order to preserve sensitive medical data without a substantial impact on energy consumption. In this respect, the solution to the sustainable and scalable medical monitoring systems is energy-saving Internet of Things based on Wireless Sensor Networks. Such systems will be able to provide long network life, reliable health monitoring, and better patient outcomes by integrating optimized WSN architectures, intelligent data management, and cloud-assisted analytics. The issue of energy efficiency does not only improve the functionality of the system, but it also contributes to the implementation of IoT healthcare solutions in practice in the long term.

## 2. Related Works

The WSN enables the use of wireless transmitters and detectors in order to acquire information about a patient's body and send it live to the cloud infrastructure computer. The systems that are set to operate under energy constraints consume a lot of energy and lower the operational life of the systems [11]. The article provides real-time encoding technique, which conducts repetitive thresholding and estimation of wavelet transform to sparsely encode bio signals. This way, power and broadband usage is reduced. Some of the threats that IoT nodes in the health sector are vulnerable to include DoS attacks, man-in-the-middle attacks, Sybil attacks, spoofing, and information forgery [12]. This may make it difficult to determine a safe system that uses the minimal resources yet one that provides sufficient privacy despite the risks involved. Most of the power is used to complete the calculated procedures that are not essential in keeping the system running. Moreover, sensors have reversible functions as well as related systems, which means that there are more operations to be controlled by the centralized computer. This affects the model efficiency when a machine fails to replace or replenish the batteries that are in the device [13]. In this case, communication practices have been deployed and used applying WSN technology. This paper focused on hierarchy-based routing algorithms. This routing technique assumes that transmission is done through some endpoints since they are quite powerful compared to others [14]. The nodes that are created by hierarchical systems form cluster subgroups where all the components have generated

another. This type of clustering is easier to the administrator and far less energy consuming. The research estimates that these innovations improve the network life system although they are time consuming compared to other methods. Power consumption is one of the largest problems of the WSN technology [15]. WSN technology has two types of nodes that operate in it. The former one gathers and transmits information to other nodes; such a node consumes greater power. Second nodes are required to transmit these details to the base station. To improve these networks' structure, the procedures suggested by the author are called modified Geographic Adaptive Fidelity [16]. These are functioning well which involve the use of networks based on their geographical location. The alteration occurred when the networks of the technique were switched off since in that region, it switched off networks that carried out the same functions. Consequently, this increased the lifetime of the network [17]. Power management is one of the significant issues in the algorithms and protocols strategy of the WSN technology [18]. To create an energy awareness system, a number of procedures can be followed such as mobile nodes, scaled connectivity, path latency as well as minimizing routing protocol mechanism. The first type are routing protocols that are used with route-driven routing [18]. In these systems, the source transmits data to the subsequent destination in the path to the destination. The routing algorithm is route-driven and makes choices regarding the channel of data transfer depending on the state of excitability, position, and response time of the node [19]. Forster and Murphy proposed routing methods, which are routing methods based on reinforcement learning, FROMS and E-FROMS. FROMS is a multicast routing system that utilizes Q-learning. It considers hop count, duration, delay and battery capacity to select the best route between the basis node and the endpoint node [20]. The main weaknesses of this strategy are that the network has a limited lifetime and it has a major latency in communication.

The WSN framework of constant healthcare monitoring based on biosensors has been developed now. Context Sensors such as accelerometers, moisture sensors, kelvin among others will also be integrated into the WSN Network to support the process of aggregating information collected. There were several types of wireless biosensors designed using WSN design, i.e., ECG and Blood oxygen inundation [2021]. It is being developed with a lightweight WSN card on PDA enabling the device to collect, analyze and present sensor signals as well as reflect it as a router between BSN clusters and the PC system. The sensor information can be collected by the device and transmitted to a more permanent storage and pattern recognition over Wi-Fi/GRPS networks instead of producing a processed sensor result. A real-time remote monitoring cellular and mobile structure was developed. The system monitors and regulates the heart rate of patients and oxygen saturation levels of the blood using the ZigBee wireless technology. The pulse oximeter transmits its information to a computing device with a database in the WPAN area. Monitoring framework applications such as WSN are indispensable since they offer a number of advantages over other wireless frameworks, such as flexibility, higher productivity, power management, cost-efficiency, and processability. Wearable technology plays a major role in the detection, diagnostics, and prevention of diseases. Wireless devices and healthcare will also evolve and become more sophisticated with the added security of the patient. The advent of apparel biosensors has completely transformed the way of gathering and analyzing data. A number of studies have investigated how IoT and Wireless Sensor Networks (WSNs) can be implemented to monitor health with a focus on real-time data collection and remote patient treatment. Initial IoT healthcare models were majorly concentrated on wearable and implantable devices to check the body temperature, ECGs, and heart rate. Although these systems showed better monitoring of patients and a decrease in hospital visits, they frequently failed to consider energy efficiency, which resulted in the frequent replacement of the battery and the short lifespan of the network.

To overcome the energy limitation, scholars have offered energy conscious routing and clustering schemes of healthcare WSNs. Techniques like LEACH based clustering, energy efficient multi hop routing, adaptive transmission control techniques have been thoroughly researched to optimize energy use among the sensor nodes. Even though these methods were effective in extending the network lifetime, they tended to have scalability problems and higher latency, which is both a severe constraint in time-sensitive healthcare systems. They have been applied in predictive models that help in detection of anomalies, prediction of patient conditions as well as optimization of schedules of sensing thus minimizing unneeded data transmission. Most currently available ML-based solutions present extra computational complexity, even though they are successful, which may raise energy usage at the sensor

or edge level. More recent works have employed cloud and edge-assisted architectures to make IoT healthcare more energy efficient. Sensor nodes can run with low processing and communication costs by offloading computation to the edge devices or cloud servers. Although these architectures are better in scalability and energy saving, security, privacy, and network reliability issues are still open research problems. This also necessitates comprehensive energy efficient IoT healthcare systems that collaboratively optimize sensing, communication, computing, and security in WSN based systems.

### 3. Proposed System

The suggested IoT healthcare IoT is based on the Wireless Sensor Network (WSN) architecture that allows combining the physiological sensors, low-power communication modules, and cloud-aided data analytics. The system is meant to constantly keep track of patient health parameters and reduce power usage of sensor nodes. The general architecture is an arrangement of sensor nodes that gather data, a data aggregation gateway, and processing and storage on cloud and edge computing systems. The resources employed in the research encompass wearable biomedical sensors comprising of heart rate, body temperature, blood oxygen (SpO<sub>2</sub>) as well as blood pressure sensors. The sensor nodes are constructed based on a low-power microcontroller unit having a small memory and power storage. The wireless communication is provided by means of energy-efficient protocols like ZigBee or Bluetooth Low Energy (BLE) which are fitting in short range medical data transfer. A main gateway unit, which has Wi-Fi or cellular connectivity, gathers information by a series of sensor nodes and transmits it to the cloud. During the data acquisition stage, the physiological signals are sampled at adaptive rates depending upon the activity of the patient and the health status in order to minimize unnecessary sensing and transmission. It makes use of duty-cycling where sensor nodes can alternate between active and sleep states to save energy. In order to reduce the communication overhead incursion and enhance the data quality, noise and missing values are preprocessed locally prior to transmission across the WSN to enable a lightweight routing and data aggregation methodology. To support energy-aware communication, a lightweight routing and data aggregation strategy is employed in the WSN. The sensor nodes are used to send data to the gateway or through other nodes depending on the amount of residual energy status and distance to the communication. The aggregation is done by clusters to reduce redundant transmissions and cluster heads are dynamically picked to ensure that energy consumption is balanced throughout the network. The received data are stored and processed in the cloud and edge layer and processed by machine learning-based health monitoring algorithms. Through these algorithms, anomalies are identified, medical professional alerts are generated, and the trend of patient health is predicted. Senior nodes no longer need to work hard to process data and to send it to other network nodes by delegating the computationally intensive tasks to the cloud or edge servers and extending the lifetime of the network. Safe communication systems are incorporated to build data confidentiality and integrity without consuming a lot of energy. Energy consumption, the network lifetime, data delivery percentage, latency, and the performance of health monitoring are some of the metrics applied when assessing the performance of the proposed system. To confirm the efficiency of the energy-saving design, experimental analysis is done with different network sizes and with different patient activity conditions. The findings indicate that the suggested materials and procedures are useful in minimizing the energy consumption and at the same time, ensuring consistent and high-quality healthcare monitoring by utilizing Wireless Sensor Networks.

#### 3.1 Dataset Description

The data of the energy-efficient IoT healthcare system is the series of time-based physiological and network data obtained by the wearable sensor nodes applied in the patient. Every record is connected to the distinct patient and sensor identifier and a time to maintain the time continuity. The data contains essential health parameters including heart rate, blood temperature, blood oxygen saturation, systolic and diastolic blood pressure indicators which are crucial in continuous health monitoring and anomaly detection. To aid adaptive sensing strategies alongside the physiological data, contextual data is captured including the level of activity of the patient. Attributes relating to networks, such as the level of energy present in nodes, transmission delay and loss of packets are used to examine energy consumption and communication efficiency in the wireless sensor network. The designation of the anomaly is also offered

to differentiate between the normal and abnormal health conditions to allow the accurate evaluation of the performance of the proposed energy-efficient IoT healthcare framework.

Attribute / Column	Data Type	Description
Patient_ID	String / Int	Unique identifier assigned to each patient
Sensor_ID	String / Int	Unique identifier for each wearable sensor
Timestamp	Datetime	Date and time when the sensor reading was recorded
Heart_Rate	Float	Heart rate measured by the wearable sensor
Body_Temperature	Float	Body temperature of the patient
SpO <sub>2</sub>	Float	Blood oxygen saturation level
Blood_Pressure_Systolic	Float	Systolic blood pressure measurement
Blood_Pressure_Diastolic	Float	Diastolic blood pressure measurement
Activity_Level	Categorical	Patient activity state (resting, walking, active)
Node_Energy_Level	Float	Remaining energy level of the sensor node
Transmission_Delay	Float	Time delay during data transmission
Packet_Loss	Integer	Number of lost packets during transmission
Anomaly_Label	Int / Boolean	Indicator of abnormal physiological readings

**Table 1:** Dataset Description

Patient_ID	Sensor_ID	Time stamp	Heart_Rate	Body_Temperature	SpO <sub>2</sub>	Activity_Level	Node_Energy_Level	Transmission_Delay	Packet_Loss	Anomaly_Label
P01	S01	2026-01-16 08:00:00	72	36.7	98	Resting	92	0.18	0	0
P01	S01	2026-01-16 08:01:00	74	36.8	98	Resting	91	0.19	0	0
P02	S02	2026-01-16 08:00:00	88	37.1	96	Walking	89	0.22	1	0
P02	S02	2026-01-16 08:01:00	92	37.3	95	Walking	87	0.25	1	1
P03	S03	2026-01-16 08:00:00	65	36.5	99	Resting	94	0.16	0	0
P03	S03	2026-01-16 08:01:00	68	36.6	99	Active	93	0.17	0	0

**Table 2:** Sample Data

The sample data also demonstrate the continuous collection of physiological and network-related information of wearable sensor nodes in an energy-efficient IoT healthcare system depicted in Table 2. A sensor reading at a specific point in time of a particular patient will be identified in a single row, and time-series monitoring of health statuses will be possible. The physiological condition of the patient under varying activity levels is reflected in such vital parameters as heart rate, body temperature, blood oxygen saturation, and blood pressure. In combination with health data, network properties such as node energy level, transmission delay and packet loss give an understanding of the efficacy and dependability of the wireless sensor system. The anomaly labels enable the distinction of the normal and abnormal health conditions and are helpful in the performance of the healthcare monitoring and the energy efficiency of the network behavior.

### 3.2 Energy Optimization Algorithm

An algorithm of transmitter power optimization and consideration of the static and time-varying properties of the network is introduced. Even though the EOA is an improvement of the optimum power control method, they both operate under different power allocation mechanisms. The mobile mote

system comprises a 256 kilobyte per second, IEEE 802.15.4 wireless radio, 8 channel A/D and an 8 MHz microprocessor to perform consigned processing of automated signals. A node-to-node transmission of the data is done using mesh network configuration. The technique proposed, which is vital in the application areas that are applied in the scenario, would offer fast and efficient transmission of data between the human physique and the recipient completion. The practice of medical systems is hence appropriate. Variables used in Energy Optimization Technique. Find the average received power strength (Rx) provided by which the weighted average of the signal power is Rx,

$$Rx = Relow + (1 - \delta 1) \times Rx \text{ ----- (1)}$$

$$Rx = Relow + (1 - \delta 2) \times Rx \text{ -----(2)}$$

The minimum example of obtained intensity values is low. Then utilize differential calculation to calculate the communication range.

$$\Delta_p = \begin{cases} 3 & \text{if } Rx < THL \\ -2 & \text{if } Rx < THRh \\ 0 & \text{if } THL < Rx < THRh \end{cases} \text{ ----- (3)}$$

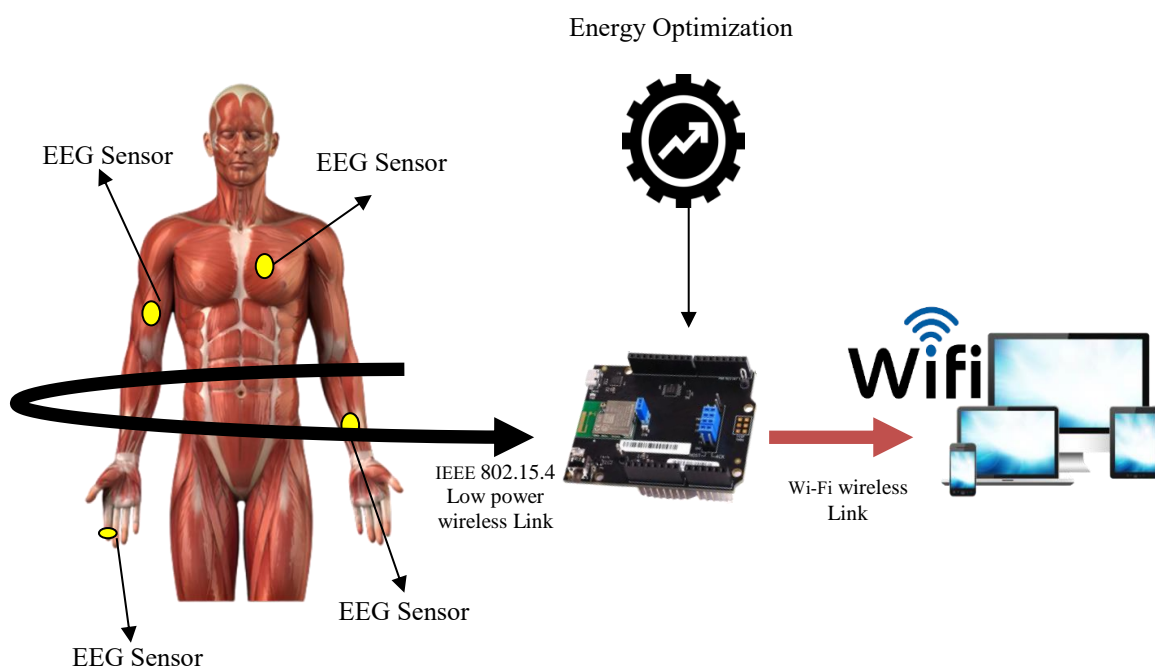
Using equation (4) to get the transmission rate by calculating the average channel capacity.

$$\sigma = \sqrt{\frac{1}{n} \sum_{k=1}^n (Rk - Rx)^2} \text{ k} = 1, 2, 3, \dots, n \text{ ----- (4)}$$

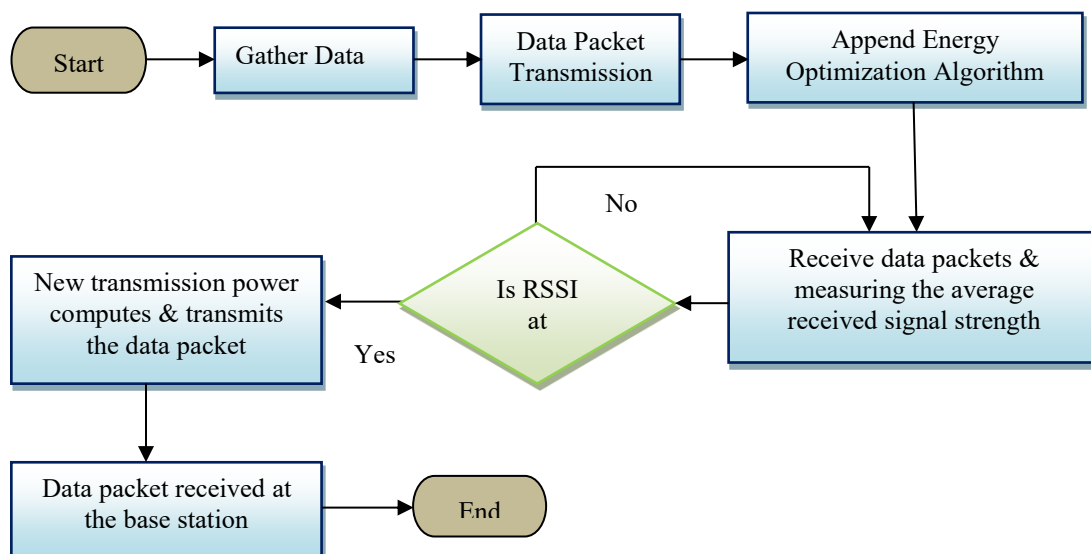
The following parameters remain used in formulas: Relow identifies a low transmission intensity obtained. Rate, Rx stands for average signal strength, 1, 2 for weight mean, THL for the lower limit, and THRh for a value greater, and n, Rk, and k for standard deviations. The calculation mentioned previously aids in boosting the receiver end signal strength. The formulas for the proposed Power Optimization Technique are generated using a calculation of transmission power. The received signal strength identifier ought to have more intensity (in dB). Equations (1) - (4) were used to effectively identify the signal maximum strength.

### 3.2 Architecture

The information is transferred to base stations in diverse applications such as safety and observation, ecological control, healthcare, and wildlife span environment supervision. When sensor-gathered data is sent it is transmitted to an IEEE 802.15.4 wireless approach, as depicted in Figures 1 and 2. It is based on Energy Optimization Technique to send the information to the mobile equipment through the Bluetooth connection. A crucial enhancement is to the transmission of information between people and base stations where in case an individual is displaying an abnormal behavior; the information is relayed to the relevant authorities to assist them in making the correct decisions.



**Figure 1:** Architecture of energy optimization algorithm



**Figure 2:** An energy optimization algorithm

The suggested technique flow diagram indicates that information originally was compiled by the sensor node. Thus, the data transfer of information packets took place by the use of the Energy Optimization Algorithm. The mean Received Signal Strength is then calculated as a way of determining the network packets received. In case of unusual conditions in a human body, the Received Signal Indicator objective measures the power of the transmitter and transfers the information to the base station. In case the evaluation of the wireless signal is wanting, however, it goes back to the calculation of data streams.

The general essence of the MATLAB software is to create a sensor system and apply an energy optimization method to enhance the performance of transmit power. The values and data sets used to set up the parameter settings used in the simulation could be located in Table 3. The characteristics are carrier signal, power ratings, Transmission Power Minimal and Optimum times, and data packet width and data transfer rate. Data transmission will be effective due to different values. The minimum value was set to the lowest at 0.006 Watts or 30 Decibels. The frequency band can be denoted in giga Hertz. In fact, the dimension of the region covered by the installed sensor networks should be mentioned as 100 x 100 meters. The proposed method utilizes 2.4 GHz Bands of channel frequency with 50Hz bandwidth. The recommended range of data transmission was 0 to 30 dBm.

Parameter	Value
Carrier frequency	2.5 GHz
Power levels(DBS)	(-30, -25, -15, -10, -5, 0)
Transmit power maximum	-30 dBm
Transmit power minimum	0 dBm
Time	100 ms
Data frame size	100 bytes
Data rate	256 kbps

**Table 3** Simulation parameters

### Algorithm

#### Step 1: Sensor Node Initialization

Let the wireless sensor network consist of  $N$  sensor nodes deployed on patients. Each node  $n_i$  is initialized with residual energy  $E_i(0)$ , sensing range  $R_s$  and transmission range  $R_t$

$$E_i(0) = E_{initial}, \quad i = 1, 2, 3, \dots, N$$

#### Step 2: Physiological Data Acquisition

Each sensor node continuously senses physiological parameters such as heart rate, temperature,  $SpO_2$ , and blood pressure. The sensed data vector at time  $t$  is represented as:

$$D_i(t) = \{HR_i(t), Temp_i(t), SpO_2_i(t), BP_i(t)\}$$

#### Step 3: Adaptive Sampling and Duty Cycling

To reduce energy consumption, adaptive sampling is applied based on patient activity and anomaly probability. The sampling rate  $f_i(t)$  is dynamically adjusted as:

$$f_i(t) = f_{min} + \alpha \cdot P_{anomaly}(t)$$

Sensor nodes switch between active and sleep modes using duty cycling:

$$DC_i = \frac{T_{active}}{T_{active} + T_{sleep}}$$

#### Step 4: Energy-Aware Clustering and Routing

Nodes are grouped into clusters to minimize communication overhead. A node is selected as a cluster head (CH) based on residual energy and distance to the gateway.

$$CH_i = \begin{cases} 1 & \text{if } E_i > E_{avg} \\ 0 & \text{Otherwise} \end{cases}$$

Routing decisions prioritize nodes with higher remaining energy:

$$NextHop = \arg \arg (E_j - d_{ij})$$

where  $d_{ij}$  is the distance between nodes  $i$  and  $j$ .

#### Step 5: Energy Consumption Model

The energy consumed for transmitting and receiving data is computed as:

##### Transmission Energy

$$E_{tx}(k, d) = E_{elec} \cdot K + E_{amp} \cdot k \cdot d^2$$

##### Reception Energy

$$E_{rx}(k) = E_{elec} \cdot K$$

where  $k$  is the packet size and  $d$  are the transmission distance.

#### Step 6: Data Aggregation and Cloud Offloading

Cluster heads aggregate data to remove redundancy:

$$D_{agg} = \frac{1}{M} \sum_{i=1}^M D_i$$

Aggregated data are transmitted to the gateway and forwarded to cloud/edge servers for further processing, reducing computation at sensor nodes.

#### Step 7: Health Anomaly Detection

An anomaly score is computed using threshold-based or machine learning models:

$$A(t) = \begin{cases} 1 & |D(t) - \mu| > \lambda\sigma \\ 0 & \text{Otherwise} \end{cases}$$

where  $\mu$  and  $\sigma$  are mean and standard deviation of physiological data.

#### Step 8: Network Lifetime Evaluation

The network lifetime is defined as the time until the first node exhausts its energy:

$$T_{Lifetime} = \min\{t: E_i(t) = 0\}$$

#### Step 9: Alert Generation and Energy Optimization

If an anomaly is detected, alerts are generated and transmitted with high priority. Otherwise, low-priority transmission is used to conserve energy.

### Outcome

The algorithm reduces energy usage by adaptive sensing, energy conscious routing, clustering, and offloading to cloud services and provides reliable and continuous healthcare monitoring. Physiological and network level optimization is greatly integrated, and this improves the network lifetime and system reliability. The suggested energy efficient algorithm of the IoT healthcare works with the idea of intelligently organizing sensing, communication and computation of the wireless sensor network to extend the network life span and maintain the reliability of health monitoring. At the beginning, sensor nodes are attached to a patient and constantly measure such physiological indicators like heart rate, body temperature, oxygen saturation, and blood pressure. Dynamic control of sensing and transmission activities in adaptive sampling and duty-cycling mechanisms is used to save energy by adapting to patient activity levels and likelihood of adverse health events. A strategy to use in routing and clustering of nodes based on energy awareness is then implemented, in which nodes with high residual energy and comfortable communication ranges are used to forward data, and hence to equalize network energy use. The aggregation of data in the cluster heads eliminates unnecessary transmissions and the aggregated data is offloaded to cloud servers or edge servers where the information is analyzed to identify anomalies and determine health. The algorithm is capable of saving a lot of energy through a combination of adaptive sensing, energy efficient communication, and cloud assisted processing, which ensures that a lot of energy is saved, lifespan of the network is enhanced and constant and quality healthcare data is recorded.

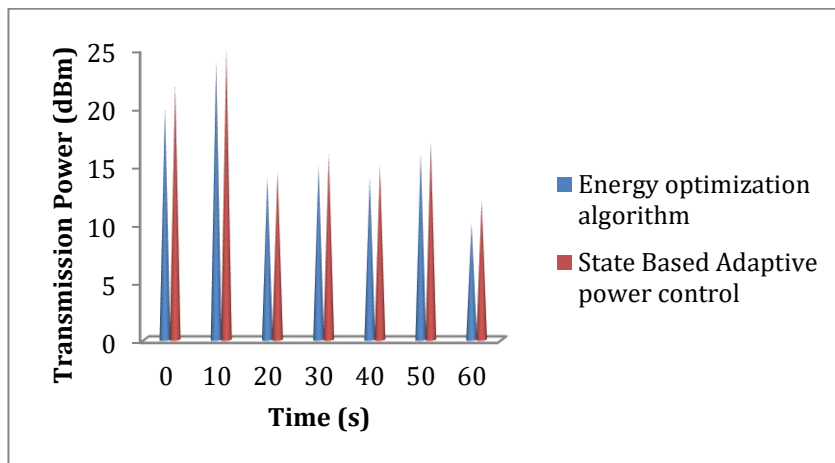
#### 4. Result and Implementation

The energy-efficient IoT healthcare system experimental setup was aimed at assessing performance of health monitoring and energy consumption of a wireless sensor network operating under a wireless network environment. Several wearable sensor nodes were installed on patients and they had physiological sensors that monitored the rate of heart, body temperature, blood oxygen saturation and blood pressure. The individual sensor node was made up of a low power microcontroller, biomedical sensors, and a wireless communication module running on a power efficient protocol. The sensor nodes sent the data gathered to a local gateway node that served as a consolidator and sent the data to a cloud server to store and analyze it. The sensor nodes were made energy-aware by using energy-aware routing, adaptive sampling and duty-cycling mechanisms to minimize power consumption. The system was subjected to various patient activity conditions and network scales to examine energy consumption, network longevity, transmission delay and accuracy of health monitoring.

Component / Module	Hyper parameter	Value / Setting
Sensor Node	Initial Energy	2.0 J
	Sampling Rate (Min-Max)	0.5-2 Hz
Duty Cycling	Active Time	30%
	Sleep Time	70%
Communication Protocol	Transmission Power	0.5 W
	Packet Size	512 bytes
Clustering Mechanism	Cluster Head Selection Rate	5%
Energy-Aware Routing	Distance Weight (Ⓜ)	0.6
	Energy Weight (Ⓜ)	0.4
Data Aggregation	Aggregation Interval	60 seconds
Anomaly Detection	Threshold Factor (Ⓜ)	2.5
Cloud Analytics	Training Epochs	50
	Learning Rate	0.001
	Batch Size	32

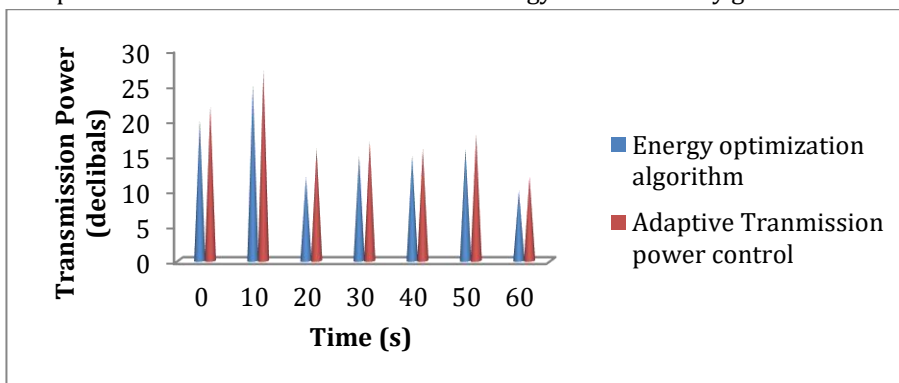
**Table 4:** Hyper-parameter settings

The hyper-parameterization of the proposed energy-saving IoT healthcare system had been chosen appropriately to attain an optimal trade-off between energy saving, reliability of the communication, and precise health monitoring as illustrated in Table 4. The sensor nodes were deployed with a constrained energy and they were configured to work with adaptable sampling rates in order to minimize the redundant data capture. The duty-cycling parameters were optimized to ensure that nodes spend more time in sleep and as a result, the power consumption is greatly reduced. The hyperparameters in communication like transmission power and packet size were selected to provide certainty of the data delivery without causing a waste of energy. The parameters of clustering and routing were adjusted such that more emphasis was given to nodes having residual energy and shortest transmission path thus balancing the network load. The intervals between data aggregation were optimized to minimize redundant transmissions and the anomaly detection thresholds were also optimized to capture the abnormal health conditions without too many false alarms. Learning parameters such as learning rate, batch size and epochs were optimized at the cloud-level, since the model converged well, yet remained computationally efficient. As shown in Figure 3, the Energy Optimization Technique, as compared to the Adaptive Maximum Transmission Regulation and State-Based Dynamic Adaptive Control, is effective in providing high-speed distribution with low data rates. The range of transmission was measured in decibels on the Y-axis, and the length of time in milli-seconds on the X-axis. Transmitted power of up to 25 dBm was used. The concept of Energy Optimization Algorithm is compared to the existing protocols such as the State Based Adaptive Optimization Technique and Adaptive Transmission Power Control Method. The suggested solution is fairly successful in the utilization of reduced signal strength.

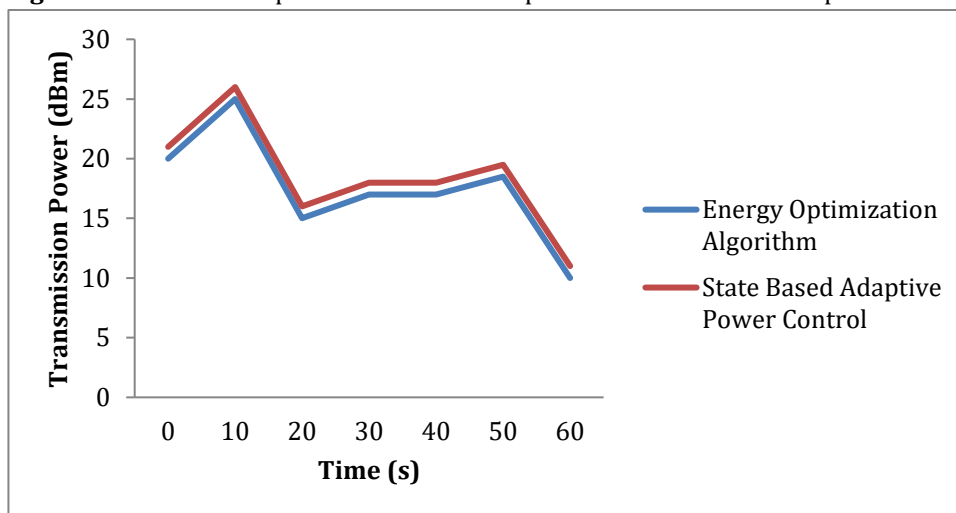


**Figure 3** Transmission power utilization

Comparing with the adaptive control techniques of state-based, Figure 4 depicts the means through which the Energy Optimization Technique provides the dominant rate transmissions with low statistics rates. The Y-axis showed transmit power in dB, whereas the X-axis showed the duration in milliseconds. The transmitted power up to 25 dB was employed. As compared to State Based Adaptive Power Control Techniques and Energy Optimization Algorithms, which provide good bandwidth and Figure 5 depicts that the transmit power has consumed less amount of energy with efficiency gains.

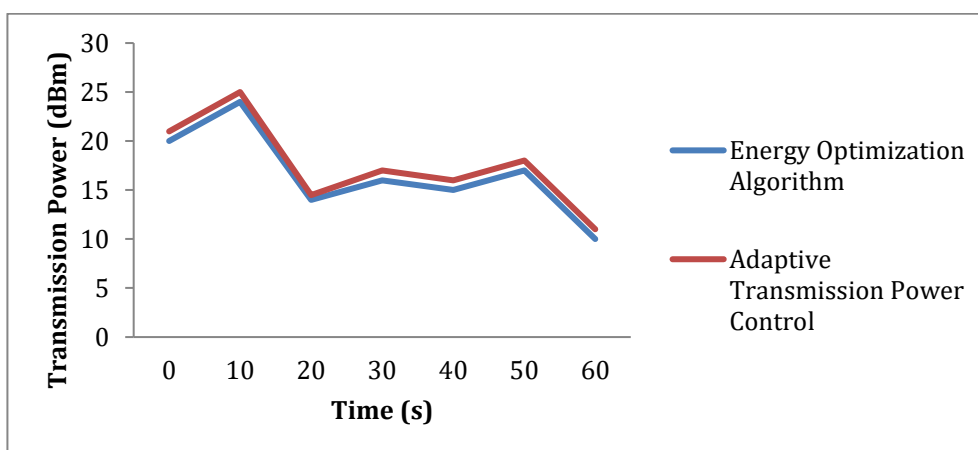


**Figure 4** Transmission power utilization comparison of state-based adaptive control



**Figure 5** Throughput comparisons concerning bandwidth

Comparing ESA with Adaptive Transmission Power Control that ESA provides well and Figure 6 indicates that transmit power consumes less energy and the performance is improved. Bandwidth can be used up to 25 dB of transmission capacity. Data on transmission power was shown on the Y-axis in decibels, and the time on the X-axis on a scale of seconds. Efficiency is used to assess the energy consumption of it and the latency between a human and the transmitter.

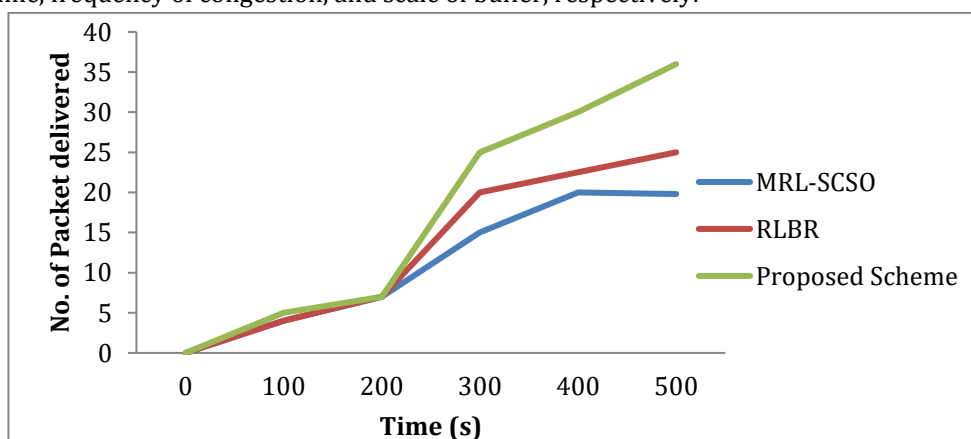


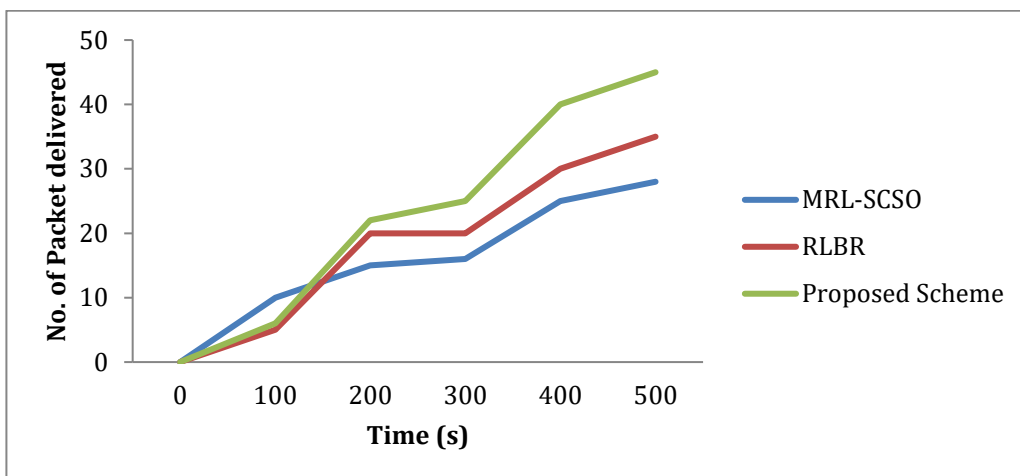
**Figure 6** Throughput comparisons for not using bandwidth

#### 4.1 Simulation Results

This is compared with the results of the proposed scheme that are simulated on networks with MRLSCSO and RLBR found after the network simulations have been run in ns3.29 software. Simulations with the simulation tool are being run on an Intel Core i3 Central Processing Unit that has a computational efficiency of 3.07 GHz and Ubuntu 20.04. 8 GB of RAM is used to run the simulation. In the first scenario, super nodes and sensor nodes have been arbitrarily placed at 100 points in a monitoring area of 100 square meters and 100 sensor nodes are arbitrarily placed in the surveillance area with the BS being placed in the middle of the networks and at the fixed dimensions.

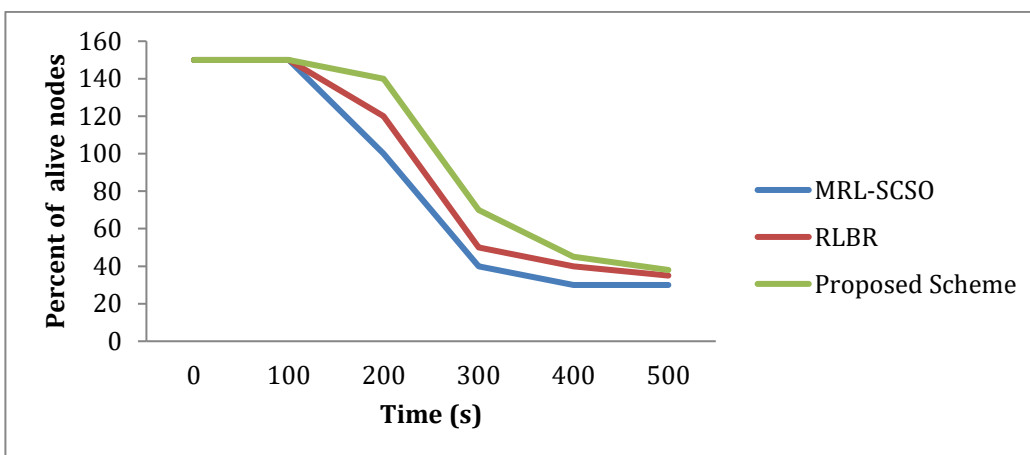
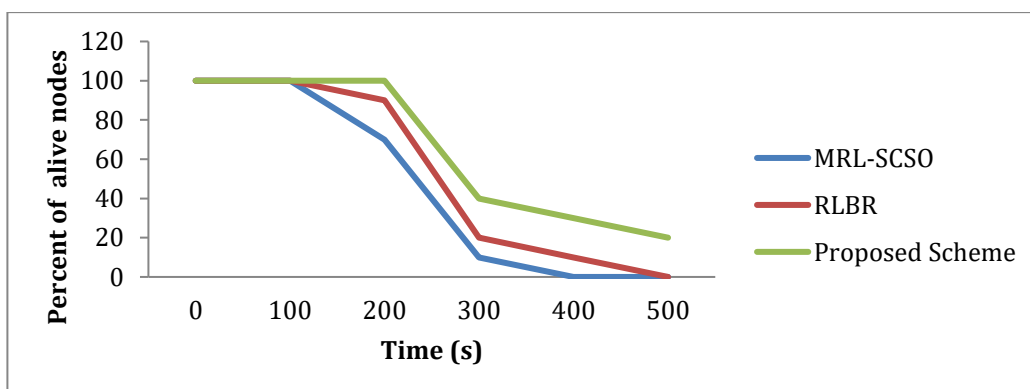
Figure 7 depicts the transmission of packets across delay. As Figure 7(a) shows, the proposed system provides 45% of the packets compared to RLBR, and 85% of the packets compared to MRL-SCSO. This is a proposed strategy where the number of deliveries is increased by 44.4 percent and 85.1 percent regarding RLBR and MRL-SCSO respectively as shown in Figure 7(b). The DRA-based information routing process is responsible for achieving the enhanced delivery of packets because it involves the calculation of the optimal route of data transmission based on numerous variables, which include remaining energy, waiting time, frequency of congestion, and scale of buffer, respectively.



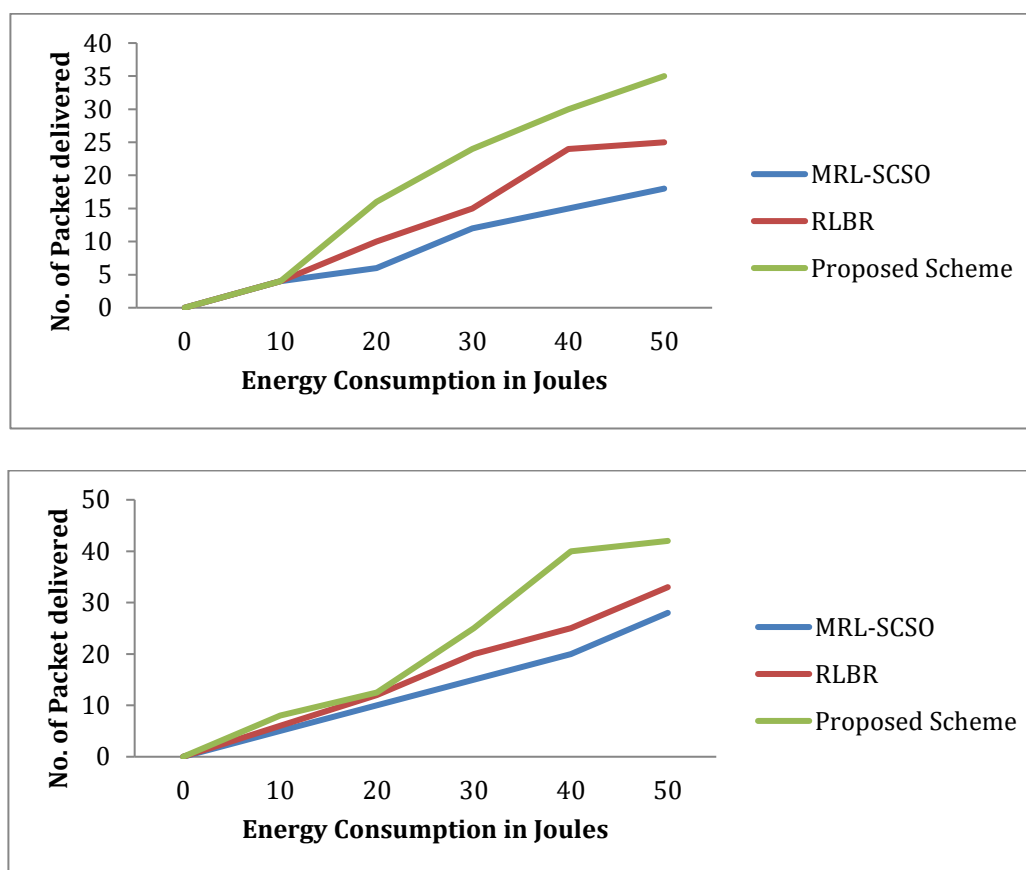


**Figure 7:** Packet delivery. (a) 100 sensor nodes. (b) 150 sensor nodes

Figure 8 illustrates the active network nodes in different timeframes. As shown in Figure 8(a), the proposed scheme increases the number of alive nodes up to 66% compared with RLBR and up to 75% compared with MRL-SCSO. As shown in Figure 8(b) the number of alive nodes increases up to 67.2% with the proposed technique as compared to RLBR and 75.4% as compared to MRL-SCSO. The results prove that the initial node mortality of the proposed scheme is longer than the mortality of other innovative methods that evaluate the system reliability. The result is the usage of uneven cluster formation strategy (load-balanced).

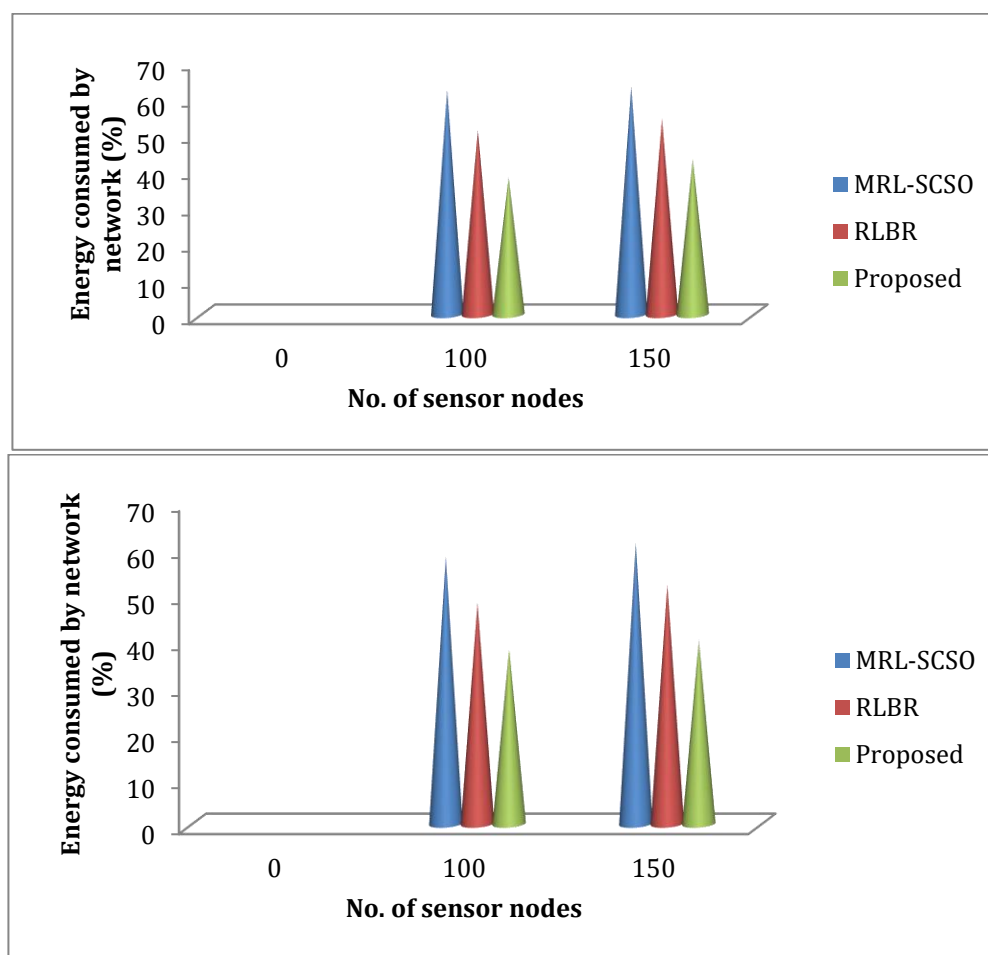


**Figure 8.** Alive nodes. (a) 100 sensor nodes. (b) 150 sensor nodes.



**Figure 9:** Energy efficiency. (a) 100 sensor nodes. (b) 150 sensor nodes.

Figure 9 reveals the quantity of packets sent to the BS concerning the different network energy conditions. Figure 9(a) shows that the proposed system can consume more energy up to 40 percent compared to RLBR and up to 89 percent compared to MRL-SCSO. As can be seen in Figure 9(b), the proposed method achieves a maximum of 88.3 percent energy efficiency, compared to MRL-SCSO, and 41.5 percent energy efficiency compared to RLBR. The rationale is that super networks are still serving as a CH and an intelligent DRL-based process is employed to identify the optimal path that the packet is to be transmitted over. The suggested method as well uses a Multi objective intelligence approach to enhance the amount of packets reaching the BS in the case of inter-cluster networking through a multi-hop data routing connection. Figure 10 illustrates the energy consumed by systems that have different node counts. Equal and unequal demands on the super nodes are determined by the standard deviation of masses when compared with the total number of the sensor nodes of the network. As it can be demonstrated based on Figure 10(a) and (b), the proposed technique consumes less energy, as compared to other more modern techniques. The reason is that the sensor networks were added to the nearest CH based on the least distance and the best remaining power. Besides, the suggested multi-goal DRL-based routing protocol reduces significantly the communication overhead in the data routing interval, and therefore, the energy consumption of the network is reduced.



**Figure 10:** Energy consumption of the network. (a) Equal load. (b) Unequal load

## 5. CONCLUSION

In the context of choosing the high energy transfer, the performance of the detector network is influenced by the change of the transmission range and the corresponding power transmitted. In comparison of the proposed Energy Optimization Technique with the method of adaptive transmit control management and state-based adaptive control management techniques, the efficacy of increasing the packet data transmitting was identified as 25 percent. The Energy Optimization Technique has enhanced the power consumption, the frequency of data transmission and minimized the use of batteries. When it comes to packet transportation, the power efficiency, the transmission latency followed by the number of alive nodes in the system, the simulated outcomes show that the given method is superior to the contemporary approaches, particularly in the case of RLBR and MRL-SCSO. The suggested approach is useful in raising the power consumed in solicitation areas. A possible development is the identification of the security-based data transfer in WSN when it comes to healthcare insurance surveillance.

### Conflict of Interest Statement

There is no conflict of interest

### Data Availability Statement

Data not available due to commercial restrictions

### Ethical Approval

Not applicable

### Authors' contributions

A: Methodology, Writing- Original draft preparation.

B: Visualization, Investigation, Supervision

C: Reviewing and Editing.

**Funding**

No funding

**REFERENCES**

- [1] Tyagi, S. K. S., Goswami, P., Pokhrel, S. R., & Mukherjee, A. (2021). Internet of things for healthcare: an intelligent and energy efficient position detection algorithm. *IEEE Transactions on Industrial Informatics*, 18(8), 5458-5465.
- [2] Behera, T. M., Samal, U. C., Mohapatra, S. K., Khan, M. S., Appasani, B., Bizon, N., & Thounthong, P. (2022). Energy-Efficient Routing Protocols for WSN: Architectures, Strategies, and Performance. *Electronics*, 11(15), 2282.
- [3] Gurram, G. V., Shariff, N. C., & Biradar, R. L. (2022). A Secure Energy Aware Meta-Heuristic Routing Protocol (SEAMHR) for sustainable IoT-Wireless Sensor Network (WSN). *Theoretical Computer Science*, 930, 63-76.
- [4] Garikapati, P., Balamurugan, K., & Latchoumi, T. P. (2022). K-means partitioning approach to predict the error observations in small datasets. *International Journal of Computer Aided Engineering and Technology*, 17(4), 412-430.
- [5] Bangotra, D. K., Singh, Y., Kumar, N., Kumar Singh, P., & Ojeniyi, A. (2022). Energy-Efficient and Secure Opportunistic Routing Protocol for WSN: Performance Analysis with Nature-Inspired Algorithms and Its Application in Biomedical Applications. *BioMed Research International*, 2022.
- [6] Thirukrishna, J. T., Aishwarya, M. V., Mansi, S., Mounisha, B., & Naksha, K. (2021). Efficient data Transmission in WSN using wearable sensors for Healthcare Monitoring. *International Journal of Advance Research and Innovative Ideas in Education*, 7(2), 446-457.
- [7] Tagare, T. S., & Narendra, R. (2022). Performance Analysis and Assessment of Various Energy Efficient Clustering-Based Protocols in WSN. In *Computer Networks, Big Data and IoT* (pp. 137-153). Springer, Singapore.
- [8] Chelliah, B. J., Latchoumi, T. P., & Senthilselvi, A. (2022). Analysis of demand forecasting of agriculture using machine learning algorithm. *Environment, Development and Sustainability*, 1-17.
- [9] Chen, F., Wang, A., Zhang, Y., Ni, Z., & Hua, J. (2021). Energy Efficient SWIPT Based Mobile Edge Computing Framework for WSN-Assisted IoT. *Sensors*, 21(14), 4798.
- [10] Ajmi, N., Helali, A., Lorenz, P., & Mghaieth, R. (2021). SPEECH-MAC: Special purpose energy-efficient contention-based hybrid MAC protocol for WSN and Zigbee network. *International Journal of Communication Systems*, 34(1), e4637.
- [11] Ramasamy, K., Anisi, M. H., & Jindal, A. (2021). E2DA: Energy efficient data aggregation and end-to-end security in 3D reconfigurable WSN. *IEEE Transactions on Green Communications and Networking*, 6(2), 787-798.
- [12] Tripathi, K., & Agarwal, S. (2021, September). Energy Efficient Clustering Scheme to Improve the Lifespan of WSN. In *2021 9th International Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions) (ICRITO)* (pp. 1-5). IEEE.
- [13] Monica, M., Sivakumar, P., Isac, S. J., & Ranjitha, K. (2022, April). PMSG based WECS: Control techniques, MPPT methods and control strategies for standalone battery integrated system. In *AIP Conference Proceedings* (Vol. 2405, No. 1, p. 040013). AIP Publishing LLC.
- [14] Saha, D., Devi, G. N. R., Ponnusamy, S., Pandit, J., Jaiswal, S., & Bhuyan, P. K. (2022, October). Application of Nanotechnology in Neural Growth Support System. In *2022 IEEE 2nd Mysore Sub Section International Conference (MysuruCon)* (pp. 1-6). IEEE.
- [15] Raviprasad, B., Mohan, C. R., Devi, G. N. R., Pugalenti, R., Manikandan, L. C., & Ponnusamy, S. (2022). Accuracy determination using deep learning technique in cloud-based IoT sensor environment. *Measurement: Sensors*, 24, 100459.
- [16] Obaid, A. J. (2021). Wireless sensor network (WSN) routing optimization via the implementation of fuzzy ant colony (FACO) algorithm: towards enhanced energy conservation. In *Next Generation of Internet of Things* (pp. 413-424) Springer, Singapore.
- [17] Gupta, S. K., & Singh, S. (2022). Survey on energy efficient dynamic sink optimum routing for wireless sensor network and communication technologies. *International Journal of Communication Systems*, e5194.
- [18] Qu, Z., Xu, H., Zhao, X., Tang, H., Wang, J., & Li, B. (2021). An Energy-Efficient Dynamic Clustering Protocol for Event Monitoring in Large-Scale WSN. *IEEE Sensors Journal*, 21(20), 23614-23625.
- [19] Ahmad, N., Shahzad, B., Arif, M., Izdrui, D., Ungurean, I., & Geman, O. (2022). An Energy-Efficient Framework for WBAN in Health Care Domain. *Journal of Sensors*, 2022.
- [20] Gupta, P., Tripathi, S., & Singh, S. (2021). RDA-BWO: hybrid energy efficient data transfer and mobile sink location prediction in heterogeneous WSN. *Wireless Networks*, 27(7), 4421-4440.