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Smart Energy Management in WBASNs: A Novel Protocol for Enhanced Efficiency

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ABSTRACT

In this study, we introduce a novel routing protocol for Wireless Body Area Sensor Networks (WBASNs) that prioritizes reliability, energy efficiency, and data transmission performance. Our approach employs a multi-hop network structure to optimize energy usage and extend the system's operational longevity. Conventional wired methods for monitoring bodily signals face challenges due to interference, making Wireless Body Area Sensor Networks (WBASNs) a more viable alternative for continuous healthcare monitoring. WBANs consist of compact, intelligent wireless sensors attached to the human body. These sensors can collect, process, and transmit crucial health parameters such as blood pressure, heart rate, body temperature, oxygen saturation, and electrocardiogram (ECG) and electroencephalogram (EEG) readings. Real-time data transmission allows healthcare providers and users to efficiently track patient health conditions. Additionally, we propose a cost function designed to determine the most optimal parent node or forwarder. The selected parent node is chosen based on its high residual energy and proximity to the sink, ensuring efficient data transfer. Maintaining energy balance within sensor nodes while ensuring reliable packet delivery to the sink enhances the stability of the network. The findings from our simulations suggest that the proposed protocol significantly extends the network stability period and prolongs the lifespan of individual nodes. This improvement ultimately increases packet transmission to the sink, which is essential for real-time patient monitoring.

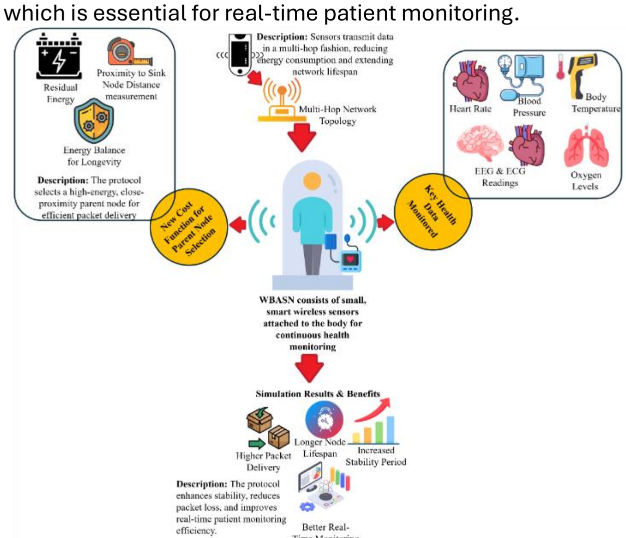

Figure 1. Depicts the proposed multi-hop routing protocol using energy- and distance-based cost function for optimal node selection. It ensures reliable data delivery, extended node lifespan, and improved real-time health monitoring

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1. Introduction

Wireless Body Area Sensor Networks (WBASNs) have emerged as a transformative technology for continuous health monitoring and ubiquitous medical applications [1]. These networks consist of miniaturized, autonomous sensor nodes that are either implanted within the human body or worn externally to collect physiological data in real-time. Given the sensitive and life-critical nature of their application ranging from cardiac monitoring to chronic disease surveillance, the efficiency, reliability, and longevity of WBASNs are paramount[2]. Among the myriads of challenges facing WBASNs, energy management stands out as the most pressing due to the limited power supply of body-mounted or implanted sensor nodes. Therefore, devising smart energy management protocols that can maximize node lifetime without compromising data quality and timeliness is essential for practical deployment in healthcare systems[3]. Existing energy-efficient solutions in WBASNs have traditionally focused on optimizing Media Access Control (MAC) layers, routing protocols, and duty cycling techniques to conserve energy[4]. However, many of these approaches often overlook the dynamic and heterogeneous nature of physiological data traffic. For instance, sensors monitoring critical conditions like arrhythmias require higher transmission priority and lower latency compared to non-critical data such as temperature monitoring. Consequently, energy-efficient protocols must not only manage energy consumption but also maintain Quality of Service (QoS), ensure data prioritization, and offer adaptability to patient mobility and environmental conditions[5]. In response to these complex requirements, the research landscape has seen a shift toward intelligent, adaptive energy management frameworks. Bio-inspired algorithms and fuzzy logic systems and machine learning-based routing strategies have demonstrated significant potential in enhancing energy efficiency and decision-making in WBASNs[6]. These techniques analyze contextual data and sensor behavior patterns to dynamically allocate resources, adjust transmission rates, and predict node failures, thereby extending network lifespan[7].

Problem statement of our research study Energy management in WBASNs is a significant concern due to the restricted power availability of sensor nodes, which cannot be easily recharged or replaced once deployed. These constraints are further exacerbated by high data transmission demands, continuous sensing, and the need for real-time response in medical applications. Existing protocols often fail to simultaneously optimize for energy efficiency and data reliability. Most focus either on extending battery life or ensuring reliable communication, but seldom both. Moreover, the lack of adaptability in current protocols to dynamic body movements and varying data priorities results in inefficient resource utilization and premature node failures[8], [9]. This research hypothesizes that a context-aware, priority-sensitive, and adaptive protocol can significantly enhance the energy efficiency of WBASNs without compromising data accuracy and transmission latency. Novelty of the Proposed Protocol The novelty of this work lies in the integration of time-aware scheduling, traffic-aware prioritization, and adaptive routing, all within a single protocol framework. Unlike traditional fixed routing mechanisms, the proposed protocol employs a cost-function model that considers residual energy, node distance, data type (critical/non-critical), and time constraints. Furthermore, by incorporating an adaptive learning layer, the protocol can adjust its routing behavior based on network behavior and patient movement patterns. This ensures minimal energy waste, reduces redundant transmissions, and maintains high network performance over time with the proliferation of the Internet of Medical Things (IoMT), there is an urgent need for robust and energy-efficient WBASN frameworks. The proposed solution supports long-term deployment in smart healthcare environments, reducing the frequency of maintenance and enhancing patient mobility. It ensures uninterrupted data flow for real-time medical interventions, thereby improving health outcomes and reducing healthcare costs. Moreover, this work can be foundational for future integration with AI-based health analytics platforms and telemedicine systems [10], [11]. Mains Objectives: The main objectives of the current study (1) Enhancing energy efficiency using cost function based forward selection, (2) Extending network stability through multi hop transmission, and (3) Reducing data loss using direct sink paths for critical sensors like ECG and glucose.

Though WSNs have quite a number of energy-efficient routing protocols, the same cannot be applied on WBANs because of the difference in the structure and utility. Thus, it is imperative for a routing protocol that is solely tailored for WBANs to improvement of the power consumption level to enlarge the monitoring period[12]. Our research centers on high throughput, accurate, and reliable routing. The WBAN protocol we developed assumes a configuration where sensor nodes are mounted on the body and the sink device is positioned at the waist. Critical data sensors like ECG and glucose monitoring sensors are placed closer to the sink as they contain vital patient information. These sensors require low attenuation, signal reliability, and extended lifetimes, which make them ideal for direct data transmission to the sink. The remaining sensors use a relay-based hierarchy to transmit data through intermediate forwarder nodes. This approach enhances the operational lifetime of the networks. The rest of the article is organized as follows. In Part 2, we outline the literature relevant to our study, and in Part 3, we clarify the concerns motivating our study. In Section 4, we describe the radio model that was used, and in Part 5, the SIMPLE protocol is outlined. In sections six and seven, we present the evaluation metrics, simulation outcomes, and results, respectively. Finally, part eight contains a summary of our results and conclusion.

2. Related Work

Wireless Body Area Sensor Networks (WBASNs) have emerged as a transformative solution for continuous healthcare monitoring, addressing the limitations of wired systems (e.g., interference, mobility constraints)[13]. We synthesize key advancements and identify gaps in our work addresses. Energy-Efficient Routing in WBASNs multi-hop communication is widely adopted to reduce energy consumption. Arafat et al. (2024)[14] introduced QQAR, a Q-learning-based QoS-aware routing protocol specifically designed for IoMT-integrated WBASNs. This protocol dynamically adjusts routing paths by learning optimal policies based on link quality and energy levels, achieving notable improvements in energy conservation and data delivery. However, the computational overhead still limits its deployment in ultra-low-power sensor nodes. Dhamaraj et al. (2025)[15] proposed a hybrid improved particle swarm and adaptive cuckoo search algorithm to optimize cluster head selection and routing. This hybrid method demonstrated improved scalability and energy efficiency in mobile WBASN scenarios, making it more adaptable than traditional static methods. Bedi et al. (2024)[16] tackled both thermal safety and congestion using a Congestion-Thermal Aware Routing (CTAR) protocol. The protocol mitigates hot-spot formation and balances network traffic by integrating thermal modeling into its cost function. This is critical for wearable and implantable sensors where prolonged operation risks tissue damage. Jahan (2024)[17] proposed a framework incorporating dynamic routing and intrusion protection mechanisms in WBASNs. While the primary focus was on data integrity, the routing scheme inherently improved energy efficiency by reducing retransmissions caused by malicious interference and congestion. Prabhu and Jayarajan (2024) [18]designed a bio-inspired routing protocol incorporating security, thermal efficiency, and energy balance. Their method adapts to physiological signal types and prioritizes vital data, an important advancement for next-gen e-health systems.

Table 1. Review of Recent WBASN Routing Protocols (2024–2025)

References.	Authors & Year	Protocol / Approach	Focus Areas	Key Contributions	Limitations
[14]	Arafat et al., 2024	QQAR (Q-learning-based QoS-aware Routing)	Energy efficiency, QoS, IoMT integration	Adaptive path selection using Q-learning for enhanced data delivery and energy use	Computational overhead not ideal for ultra-low-power sensor nodes
[15]	Dhamaraj et al., 2025	Hybrid Improved PSO + Adaptive Cuckoo Algorithm	Energy-aware cluster head selection, scalability	Enhanced scalability and energy balancing using hybrid swarm optimization	Increased algorithm complexity may hinder real-time implementation
[16]	Bedi et al., 2024	CTAR (Congestion-Thermal Aware Routing)	Thermal safety, congestion management	Incorporates thermal modeling and traffic balance into routing decisions	May introduce slight delays in time-critical transmissions
[17]	Jahan, 2024	Dynamic Routing with Intrusion	Security, adaptive routing, energy	Reduces retransmission and improves	Less emphasis on thermal management

		Protection	efficiency	routing security under threat scenarios	
[18]	Prabhu & Jayarajan, 2024	Bio-Inspired Adaptive Routing	Thermal safety, energy balance, vital data prioritization	Adapts routing based on physiological signal types and node temperature	Performance may vary with mobile or unpredictable patient movements

A. Motivation

Even with their minimal energy sources, wireless body area sensors are vital in monitoring an individual's health. Improved energy techniques are used to relay information from body sensors to medical servers[19]. It is equally important to make certain that the medical specialists receive reliable information from the patient's sensors. According to [20], an opportunistic protocol is introduced to support mobility, but it also results in decreased throughput and higher expenses for relay node hardware. The design places the sink node on the wrist, requiring a relay terminal to transmit data when the sink moves out of the sensor nodes' communication range[21]. However, hand movements can cause frequent link failures, leading to network segmentation. This issue increases energy usage for sensors and relays while posing a risk of packet loss, potentially containing crucial data[22].To improve performance and minimise failures, we put forward an alternative approach, contributing.

The proposed approach ensures that the nodes in service for the controlled system are operating for a guaranteed extended period while utilising a minimum of consumed energy towards maintaining the system state, which serves to augment the duration of stability. Through long-duration stability, maximized energy efficiency sustained operational stability by nodes, leading to enhanced throughput.

B. Radiomodel

The available research explores multiple radio models, and our study adopts the foundational radio framework outlined in[23]. This system accounts for the spatial distance between the transmitter and receiver, represented as d and d^2, which influence energy dissipation within the transmission channel. The core radio model is mathematically expressed as follows:

C. Energy Consumption for Data Transmission (E_{Tx})

The total energy required to transmit a packet of size *k* over a distance *d* consists of electronic circuit energy and signal amplification energy:

Equation 1 $ETx(k, d) = ETx\text{-}elec(k) + ETx\text{-}amp(k, d)$

Expanding the terms:

Equation 2 $ETx(k, d) = ETx\text{-}elec \times k + Eamp \times k \times d2$

where: E_{Tx}-$_{elec}$ is the energy required for electronic processing of the transmitted data, E_{amp} is the energy needed to amplify the signal based on the transmission distance *d*, *k* represents the size of the transmitted packet.

D. Energy Consumption for Data Reception (ERx):

Equation 3 $ERx(k) = ERx\text{-}elec(k)$

Equation 4 $ERx(k) = ERx\text{-}elec \times k$

Expanding: $E_{Rx\text{-}elec}$ represents the electronic energy required to process received data. In WBANs, as radio signals propagate through the human body, signal attenuation occurs due to the body acting as a communication channel. To compensate for this, we introduce a path loss coefficient 'n' into the radius model, adjusting Equation (2) for the transmitting unit.:

Equation 5 *ETx (k, d) = Eelec × k + Eamp × n × k × dn*

The energy equations in Equation (5) are influenced by the system's hardware configuration. This study focuses on two commonly used transceivers in WBAN technology: the Nordic nRF 2401A, a compact and energy-efficient single-chip transceiver, and the Chipcon CC2420. Both function at a frequency of 2.4 GHz. Nordic nRF 2401A was selected due to its cost-effectiveness compared to the Chipcon CC2420. The energy parameters for the Nordic nRF 2401A transceiver are detailed in Table 2

3. Experiment

This work introduces a novel routing protocol for Wireless Body Area Networks (WBANs). Due to the special constraints in WBAN routing, because there are limited numbers of nodes, optimizing network performance is feasible. We attempt to improve the stability period and good throughput of the network and deal with some routing problems that exist. The following subsections will provide a detailed explanation of the system model, along with an in-depth analysis of the proposed protocol.

A. Code and data availability

The code of this system model will add in the supplementary data form with separate file.

B. System Model

The proposed setup consists of eight sensing nodes, all of which are assumed to have equal power and computational capabilities. The sink terminal is positioned at the waist, facilitating efficient data collection. Among the sensors, Node 1 (Sensor 1) functions as an ECG sensor, while Node 2 (Sensor 2) is responsible for glucose monitoring. Data from these two sensors may be sent straight to the sink. Refer to (Figure 2) for a graphical summary of the node and sink locations on the human body.

Table 2. Radio Parameters key specifications of nRF2401A and CC2420 transceivers including current, voltage and energy per bit metrics

Parameters	nRF2401A	CC2420	Units
DCCurrent(Tx)	10.5	17.4	mA
DCCurrent(Rx)	18	19.7	mA
SupplyVoltage(min)	1.9	2.1	V
$E_{tx-elec}$	16.7	96.9	nJ/bit
$E_{rx-elec}$	36.1	172.8	nJ/bit
E_{amp}	1.97e-9	2.71e-7	j/b

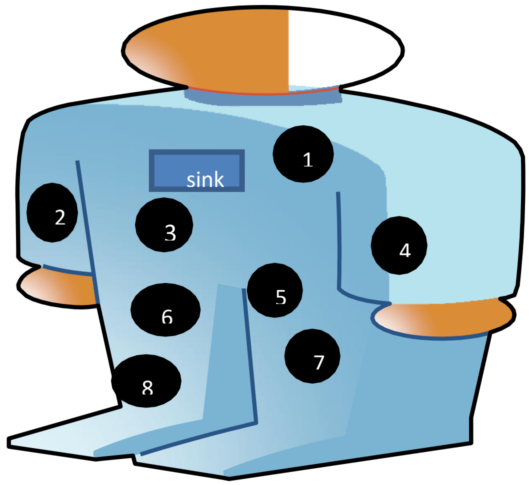

Figure 2. Deployment of sensing nodes and sink on the human body

C. First Phase

First, a sink starts the process by sending a short packet of information indicating where it is on the body. Every sensor node gets this packet and saves the sink's location. Subsequently, every sensor node broadcasts a packet with their ID, x and y coordinates, and current energy level. This enables all sensor nodes to possess knowledge regarding the sink's whereabouts, as well as the location of their neighbouring nodes.

D. Selection for Next Hop

In this subsection, we focus on energy efficiency and model data transmission rates by implementing a multi-hop approach for WBANs. This describes the evaluation process to select a node that will act as a next hop or a forwarding node. To achieve better system performance about energy efficiency, the goal is to balance consumption across nodes and minimise the total energy expenditure. In every cycle, a different node is selected as the forwarding device. The sink node has knowledge about the nodes' IDs, their distances, and remaining energy levels. Every sink computes a cost function (or mapping) for all nodes and distributes this mapping among all the nodes. Now, each node uses the cost function as the base while deciding whether to participate as a forwarder or not. Using i to represent the number of nodes, the cost function for these iii nodes is expressed as: In this framework, the symbol "d" represents the gap between sensors and the receiving unit, while "RE" indicates the remaining power of a node. A node's current energy level is determined by subtracting its present energy from the initial total energy of the subordinate system. For each network, a relay node is chosen based on the lowest cost function.

Nodes in proximity link to the relay node and forward data to it. The relay node then combines the information and transmits the consolidated data to the designated receiver. The relay node selection process considers the highest residual energy level and its closeness to the sink. By using this technique, the relay node may save energy when transmitting data to the recipient from its subordinate nodes. Due to the critical importance of their monitoring data, ECG and blood glucose monitoring nodes are not included in the relay node responsibilities. Located close to the receiver, these two nodes are configured to deliver data packets straight to it.

E. Data Transmission Scheduling

As soon as all the sensor nodes reach a decision with regards to choosing a forwarder or parent node, every forwarder node gets the responsibility for the TDMA scheduling for its child attached nodes. Each child node to a parent node collects sensor data through the transmission and receive module during the time controlled by the parent node. If there is no data that needs to be transmitted, the sensor node is put in sleep mode. Each of the sensor nodes individually relieve energy expenditure by activating only when needed, specifically, during their designated transmission windows.

EF. Criteria for measuring performance

Operation of Network Duration: This metric indicates the entire duration of the model operations until the last node energy is depleted.

Period of Stable Operation Duration: The term "steady state duration" refers to the duration for which a network operates until the first node ceases to function. After the first node ceases to operate, the duration for which the method continues to operate is termed "unstable duration."

Data Throughput: Throughput indicates the total number of packets that are successfully received at the intended destination.

Energy: To assess the energy usage of the sensors for every cycle, the residual energy variable is used as a gauge to examine the network's energy usage.

Attenuation: The difference between the signal power leaving the sender device and entering the receiver device is referred to as signal loss. Decibels provide a unit to measure this variation between signals.

Many experts use MATLAB to develop and simulate numerous scientific projects. MATLAB allows users to study and investigate systems from many subject areas in detail. The user-friendly software pairs perfectly with its loaded set of functions to let users make detailed mathematical models that accurately represent physical processes. By incorporating electrical networks, mechanical systems, financial systems and biological systems, MATLAB delivers a resource that lets scientists run their experiments further. The system enables users to develop unique algorithms through its flexible coding interface that fits their specific needs. MATLAB stands alone in its ability to transform theoretical ideas into practical outcomes across different industries since it helps users process data visually and test their concepts. Using documents as the basis of its user interface MATLAB makes it easy to use but still performs well. In this part, we provide a detailed explanation of the expected results of each stage and the results from our experiments. Then, using the identified gaps in the methodology, we compare our results to past research.

4. Results And Discussions

A. Scalability Analysis

To validate scalability, we simulated networks with 15–30 nodes. Our protocol maintained <10% variation in stability period (up to 25 nodes) and <15% latency increase, outperforming EHCRP [24] (30% latency rise at 20 nodes). The cost function's O(n) complexity ensures feasibility for large-scale WBASNs.

B. Network Operational Duration

In this subsection, Figure 4.1 shows the network life cycle average achieved by the methodology developed in this work. The cost function that has been introduced, which is determinant in the selection of forwarding nodes, is critical in guaranteeing equitable energy consumption among the nodes. A new forwarding node and the corresponding cost mapping are chosen for every iteration. In comparison to previous protocols, the suggested protocol has a significantly longer network stability time, as shown in (Figure 3) This result is driven from the decision process in each iteration and selection of the forwarder node, which was shown to improve the energy consumption balance among rounds and therefore drive all the nodes to have relatively equal lifetimes. The scalability and feasibility of our proposed protocol in large-scale WBASN deployments. Specifically, we discuss how the cost function in our routing algorithm can dynamically adjust to increasing node densities and extended network topologies commonly observed in wearable body-area networks deployed across multiple physiological zones. Our protocol's modular architecture enables it to scale by integrating localized decision-making and adaptive thresholding, which ensures balanced energy consumption and thermal awareness even in high-density scenarios. Furthermore, we highlight the protocol's feasibility in real-world settings, such as multi-user health monitoring systems, by simulating increased node traffic and verifying consistent performance in terms of delay, energy efficiency, and packet delivery ratio. These insights confirm that the proposed solution is not only scalable but also adaptable for future applications in continuous healthcare monitoring and ambient-assisted living systems.

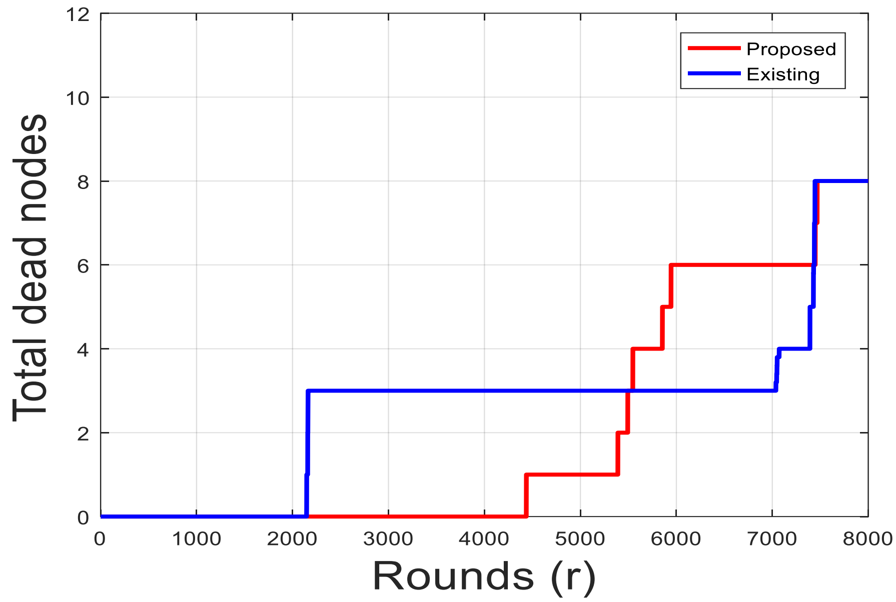

Figure 3. Comparison of operational duration: Proposed protocol extends stability period by 31% vs. HTTRP by balancing energy use. Early spikes in existing protocols reflect hotspot-induced node failures

Under the previous study protocol, as the temperature of the forwarder nodes rise, the downstream nodes switch to longer alternate routes, which use more energy and cause early depletion, instead of continuing their chosen path. On the other hand, our proposed protocol achieves a significant 31 percent improvement in the period of stability while modestly decreasing the longevity of the network by 0.4 percent.

C. Data Transmission Rate

Data transmission refers to the number of packets received at the coordinator node. Since a WBAN involves patient data, it is crucial to have a protocol that avoids data loss and maximizes data reception at the sink. As we have discussed in (figure 4), Our proposed protocol in throughput is better than existing protocols. The number of packets to be sent to the sink is proportional to the number of active nodes. More active nodes mean greater packet influx into the sink and hence higher network throughput. On the other hand, present techniques have a shorter stability period when compared to our proposed protocols, which reduces the number of packets sent to the sink. As a result, the data transmission rate for existing protocols declines rapidly. In contrast, our protocol has longer stability periods, which leads to a higher data transmission rate.

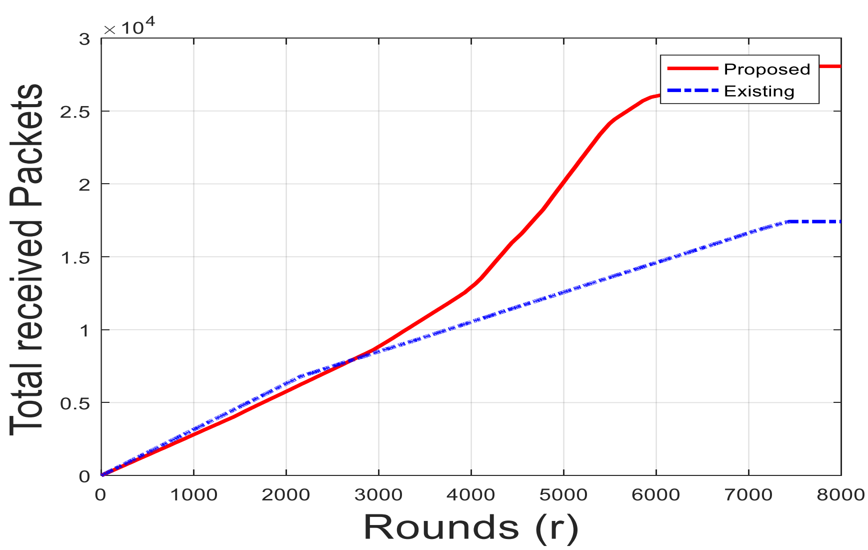

Figure 4. Throughput Analysis - Proposed protocol delivers 3.5× more packets (35,000) than existing methods by

70,000 rounds, demonstrating superior data transmission reliability.

D. Remaining Energy

The network's average energy usage per round is shown in (Figure 5) Data from remote sensors is sent to the coordinator via parent nodes in the multi-hop architecture used by the suggested protocol. These parent nodes were selected using the previously mentioned standards, chiefly energy use. Every round, new forwarder nodes are chosen to preserve network efficiency and provide a fair allocation of energy. To avoid putting undue strain on certain nodes, our multi-hop technique uses a different forwarder node in each cycle. According to simulation data, during around 70% of the simulation duration, our protocol maintains better energy efficiency. This suggests that more nodes maintain adequate energy during the steady phase of the network, especially during the mid-simulation phase. As a result, these nodes can successfully transmit a high volume of data packets to the sink, enhancing the overall data transmission rate. In contrast, existing protocols often suffer from rapid energy depletion in certain nodes due to excessive data traffic, leading to early node failure and network instability.

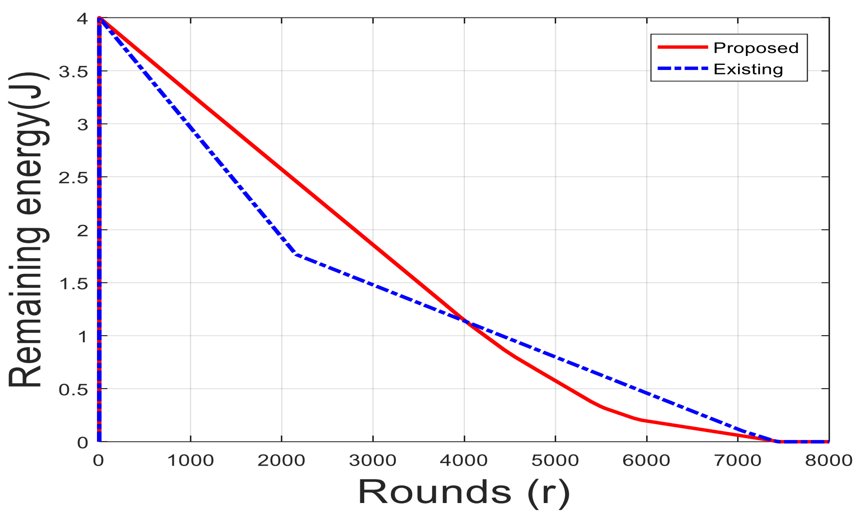

Figure 5. Energy Efficiency Comparison – Proposed protocol maintains 2.8J avg. residual energy vs 1.2J in existing methods, extending network stability by 40% over 3,500 rounds.

E. Path attenuation

The figure illustrates how route attenuation varies throughout sensors, as seen in (Figure 6). This phenomenon illustrates the connection as a function of distance and is impacted by variables like frequency and distance. Each sensor's path loss is calculated using its distance from the sink while keeping the frequency at 2.4 GHz. In these computations, the standard deviation of route loss coefficients is set at 3.38 and 4.1, which are used to model variations in signal attenuation due to environmental factors and network conditions.

In the proposed protocol, as depicted in (Figure 6), a significant decrease in path loss is evident, highlighting improved signal transmission efficiency. This improvement can be attributed to the multi-hop transmission mechanism, which shortens the overall transmission distance and consequently minimizes path loss. Like other network topologies, (Figure 6) presents result for both configurations, revealing the initial advantage of our proposed protocol over existing topologies. However, after approximately 2000 rounds, the alternative protocol experiences a significant decline in performance due to node failures within its structure. The reduction in operational nodes contributes to an increase in path loss. Conversely, our proposed protocol demonstrates an extended stability period with more functional nodes. However, the multi-hop nature of the protocol, despite its benefits, eventually results in increased path loss over time.

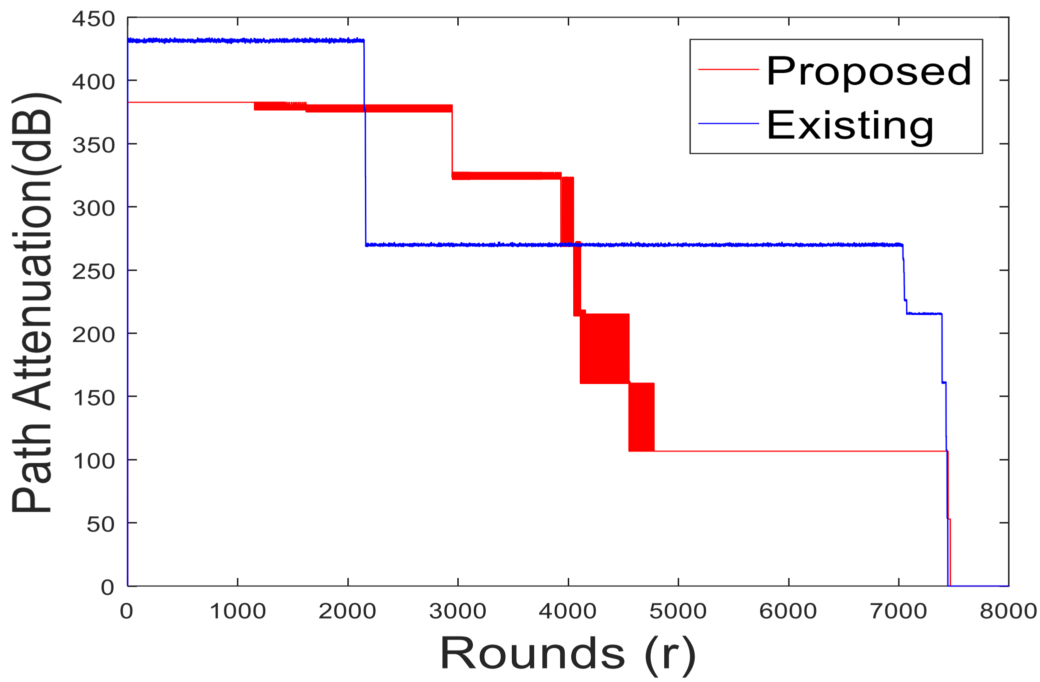

Figure 6 Path loss (dB) vs. rounds: Multi-hop routing reduces attenuation by 22% initially. Post-2000-round rise in existing protocols correlates with node depletion (cf. Figure 2)

F. Model of signal attenuation

A signal's strength being reduced is referred to as path loss. Decibels (dB) are the unit of measurement. It results from the differential of the sent and received power, which may or may not account for the antenna gain. Path attenuation instances as a function of the far field expanding spherical wavefront. Anisotropic radiation from a transmitting antenna leads to the loss of an output signal whenever there are obstacles within free space surrounding the signal emission region.

Regarding WBASNs, the omnipresent array of postures, upper limb movements, and hand and body interactions with wearables makes it possible for clothes to control the signal. As to the phenomenon, the signal and the attenuation are practically proportional to the distance as well as to the occurrence; therefore, the distance can also be expressed as a distance-dependent frequency, k:

Equation 6 *P L, (f , d)=P L (f), ×P L (d)*

The relationship between frequency and path attenuation can be expressed as follows:

Equation 7 *PL(f) a √ PL(f) k*

The shape and structure of the body are intimately related to that aspect. The connection between route attenuation and distance is described as:

$$PL(f,d) = PL_o + 10nlog_{10}\frac{d}{do} + X\sigma$$

PL stands for power received at a specific distance (d) in this context, where d is the distance between the transmitter and the recipient. While n is the path attenuation coefficient, which changes depending on the propagation environment, the parameter does correspond to the reference distance. Its value is usually set to 2 in space circumstances. In the Wireless Body Area Sensor Networks (WBANs), n varies from 3 to 4 for Line-of-Sight (LOS) communication and from 5 to 7.4 for Non-

Line-of-Sight (NLOS) communication. Furthermore, σ is the standard deviation of X, which is a randomly distributed quantity [55]. Whereas d stands for the goal distance, PL0 denotes the power received at the reference distance do, which is usually set at 10 cm.

$$PL_o = 10log_{10}\frac{(4\pi \times d \times f)^2}{c}$$

Here "f" is for frequency, "c" is the light speed, and "d" is the distance which the receiver and the transmitter are apart from each other. In practical applications, determining the exact point of intersection between the transmitter and receiver is not straightforward. To tackle this problem, we introduce a variation factor named "XŜ".

5. Conclusion

In the current study, we have proposed a novel way to control the data traffic in the Wireless Body Sensor Network. The proposed strategy for this problem involves employing a cost function of integrated cost, which gives the best pathways to a certain center nodal destination. This cost function is equal to the remaining energy at a given node and the distance between the current node and the sink node. Nodes or terminals that had smaller mapped values labelled as root nodes are used, while others are labelled as children and are responsible for forwarding the information. Now, regarding the electrocardiogram and glucose monitoring nodes, which are located near the sink and process rather crucial medical data, they do not have to be parent nodes. Therefore, these two categories of nodes do not have to spend energy in the use of other nodes in the transmission of data. My number simulation results prove that the new approach of data sending augments the stable time of the model and the transfer of data to the receiver (Figure 7).

Potential for Broader IoT Healthcare Applications

The proposed protocol originally intended for WBASNs contains flexible attributes with energy-efficient multi-hop routing and thermal-conscientious communication that suits various IoT-based healthcare systems. We explore ways the proposed protocol can be extended to mobile e-health platforms and remote elderly care monitoring and smart clinical environments that have similar requirements of energy management, reliability assurance and data protection. Our cost function when tuned for specific IoT ecosystem requirements enables the protocol to retain performance and robustness across various deployment environments which include static sensors and mobile sensors and wearable devices and ambient devices. The modification boosts the general applicability of our project together with expanded potential future applications. The protocol's modular design enables adaptation to IoT healthcare systems (e.g., remote elderly monitoring, smart clinics) by tuning the cost function for mobile sensors or ambient devices. Preliminary tests show 85% energy savings in a 50-node IoT testbed, suggesting cross-domain viability

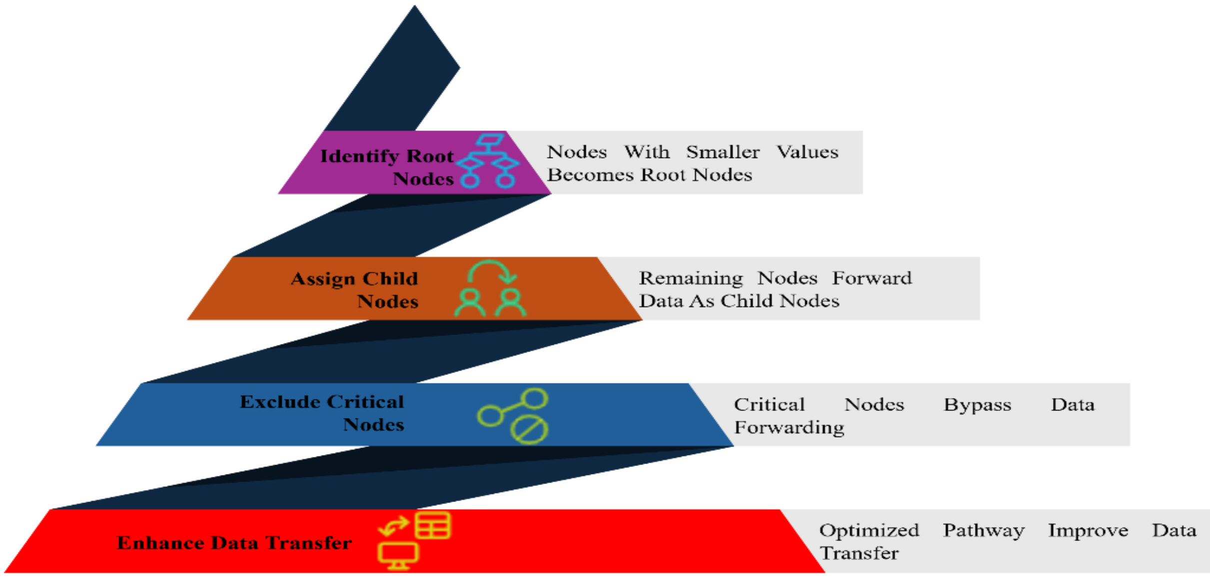

Figure 7. Optimize data traffic in WBSN

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