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EFFICIENT ENERGY AND QOS BASED ROUTING ALGORITHM FOR WBAN

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Master of Science

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EFFICIENT ENERGY AND QOS BASED ROUTING ALGORITHM FOR WBAN

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Signature

DEDICATION

I give thanks and adoration to Almighty God for His unconditional grace, love and sustenance towards the successful completion of this study.

I would like to dedicate this dissertation to my parents Mr. and Mrs. Ojelade, without whose support I would not have been able to complete this work. I would also like to thank my siblings and friends for their relentless support and encouragement during the time of conducting this research.

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ABSTRACT

EFFICIENT ENERGY AND QOS BASED ROUTING ALGORITHM FOR WBAN

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In this study, a Novel architecture comprising a sink node is designed to minimize power consumption as well as improve quality of service (QoS) of wireless body area network (WBAN). It is an emerging subfield of Wireless sensor network (WSN). In the quest to enhance the network lifetime and QoS, we utilized MAC protocol to classify the physiological attributes into normal and critical data. A routing protocol known as Efficient Energy and QoS (EEQ) algorithm is implemented to transmit the normal data through the shortest and appropriate route. According to the EEQ algorithm, the weight value is considered based on parameters such as network lifetime, link stability, throughput, residual energy, packet drop and delay. The data is conveyed through the path having the highest weight value. However, the data is encrypted using RSA algorithm. In order to compare EEQ with other existing protocols, a number of simulations is executed on OMNet++ software to show that the proposed work outperforms other related research works.

Keywords: WBAN, Network Lifetime, Link Stability, Throughput, MAC-Protocol

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LIST OF ABBREVIATIONS

WSN	:	Wireless Sensor Network
BSN	:	Body Sensor Network
QOS	:	Quality of Service
WBAN	:	Wireless Body Area Network
IoT	:	Internet of Things
WHO	:	World Health Organization
MAC	:	Medium Access Control
EEG	:	Electroencephalography
LOS	:	Line of sight
ECG	:	Electrocardiography
EMG	:	Electromyography
SIMPLE	:	Stable Increased Throughput Multi-Hop Protocol for Link Efficiency
IM-SIMPLE	:	Improved Stable Increased Throughput Multi-Hop Protocol for Link Efficiency
EMRP	:	Evolutionary based Multi-hop Routing Protocol
M-ATTEMPT	:	Mobility Supporting Adaptive Threshold Based Thermal Aware Energy-Efficient Multi-Hop System
RE-ATTEMPT	:	Reliability Enhanced Adaptive Threshold Based Thermal Un-Aware Energy-Efficient Multi-Hop Protocol
Rx	:	Receiver
Tx	:	Transmitter
OMNET++	:	Objective Modular Network Testbed in C++
OEP	:	Optimized Exchange Protocol
ACK	:	Acknowledgement

1. INTRODUCTION

We live in a time when the advent of digital technology has permeated every aspect of our society. This progress has steadily influenced the healthcare industry over the twenty-first century, while improvements have primarily centered on supervised systems requiring the participation of healthcare practitioners.

In Western countries, old and retired guardians are generally admitted to Care Centers where they are given with accommodation and health care services rather than living with their offspring. A device that can continuously track the health of old and sick people while also exchanging physiological data with a physician and healthcare centers is in high demand.

However, a huge portion of the population was left in dismay coupled with the restriction on regular face-to-face healthcare as a result of the worldwide pandemic in 2020 and early 2021. The urgent intervention for digital transformation of medicine became a necessity by the government and health organizations to enhance research and development in e-Health and m-Health.

In recent times, there has been a tremendous rise in population and a typical person gets diagnosed with one or more ailments. Millions of people have died throughout the world as a result of deadly and chronic diseases including cardiovascular, cancer, asthma, and other difficult symptoms that appear late. A sophisticated advancement in recent biomedical technology called WBAN [1] is established. A WBAN is composed of miniature, low-cost, low-energy, intrusive, and non-invasive sensing nodes that are implanted or connected to the body and communicate over a short distance. According to some sources, WSN is a type of short-distance wireless technology [2]. WBAN is a technical term for measuring physical parameters and it is also used for monitoring any serious or severe occurrence in the human body [3]. These parameters include Electrocardiography (ECG), which measures the electrical activity of the heart, Electroencephalography (EEG), which measures the electrical activity of the brain, and Electromyography (EMG), which measures the electrical activity of body muscles, Blood Pressure (BP), Body Temperature (BT), Respiration Rate (RR) and Blood Glucose Level (BSL) and transmit the corresponding results via a communication network to a predefined base station. Similarly, the sensors in a WBAN are divided into three categories: physiological, bio-kinetic and environmental sensors [4]. Physiological sensors, for example, monitor physical attributes like blood pressure, temperature and glucose levels. Ambient sensors monitor external elements such as light, vibration, and pressure level, while bio-kinetic sensor measures speed and angular rate of variation during movement of the body [5]. WBANs have a wide variety of uses, which may be divided into medical and non-medical categories [6]. Sleep Staging, Asthma, Sports, Battlefield, Diabetes Control and Cardiovascular Monitoring are some of the medical applications of WBANs that may be worn or implanted. The non-medical application include: Entertainment, Consumer gadgets, Off-Body (built in houses), Lifestyle and Aerospace sectors etc. The design and implementation of WBAN might seem complicated and challenging due to resource constraints (such as limited power supply, memory, bandwidth and computation capabilities) and wireless transmission routes [7].

Health organizations as well as World Health Organization (WHO) approves the use of WBAN since good health is a major concern of every individual. According to WHO, cardiovascular disease, heart disease and diabetes might be the major cause of death across the world by 2030 [8]. The expense of healthcare for patients with severe health issues and diseases is rapidly growing according to the current survey [9]. To address complicated medical difficulties, reduce mistakes and total expenses incurred, modern healthcare companies employ advanced information technology and communication devices [8]. It is however feasible to use cutting-edge technology such as smart healthcare, telemedicine etc., for early detection and prevention of prospective health complications that may later arise in the lives of people.

Telemedicine is the application of cutting-edge telecommunication technology and engineering to provide patients with a variety of healthcare services [10]. Telemedicine enables the administration of medical services and other form of consultation to patients regardless of the distance or climatic condition, hence boosting medical access to rural regions. Smart healthcare has gained several attentions because of its unique features such as mobility, adaptability and simplicity of patient monitoring. In addition, it is well known due to its ability to enhance the healthcare sector using cutting-edge infrastructures. Tiny, intelligent, wearable sensors capable of being employed on the human body have been enormously produced as a result of the current breakthroughs in wireless communication and microprocessor technology [11]. WBAN sensors require energy to communicate with one another, hence each sensor is powered through a small battery. These sensors monitor changes in a patient's vital signs and communicate the corresponding information to the sink, which is in charge of coordinating all other nodes and providing data to the physician for analysis and immediate diagnosis. However, in WBAN [12], ensuring medical data security and confidentiality while transferring medical information may be a difficult problem. Most healthcare system might not be able to integrate with the advance system requirements for optimal performance as it lacks a trustworthy and predictable design on the premise terms of information transmission, security and access control mechanisms. As a result, in the quest to ensure effective monitoring and evaluation of patient vital signs, the design of a secured wireless network capable of providing unauthorized access which is in compliance with the government security and privacy standards is necessitated.

The traditional healthcare method is transformed into WBAN [13] when the healthcare application is paired with sensors usually implanted or connected to the body for physiological data collection. As a result, the design of a WBAN can provide greater value to human life by allowing for earlier identification and treatment [14]. The fundamental goal of a WBAN is to retrieve health related information from patients over a period of time, hence it requires a good routing scheme [15]. Due to the unique characteristics and limits of WBAN, such as energy reduction or overheating of implanted sensor nodes, designing a reliable, secure, and efficient routing protocol is a complex task. Energy efficiency and dependability are two of the most critical and difficult factors to manage. This is because energy efficiency and dependability have a significant influence on the total lifespan and stability of the network and application [16]. Dependability in this sense refers to the ability to transfer sensitive data to the sink node in a timely and unaltered manner. The stability period is the time taken by the initial sensor in the network to deplete. Since the nodes in a WBAN are powered using batteries, recharging or changing the batteries in many applications may be difficult, it is vital to conserve battery power in the case of persistent monitoring [7]. The demand for energy-efficient and trustworthy routing solution that can improve network stability and increase total network lifetime is still prevalent, thus allowing the goal of adopting a WBAN application to be met.

1.1 CONTRIBUTION

The goal of this study is to design an energy-aware routing technique for WBAN with the aim of enhancing performance by optimizing several metrics such as throughput, average network lifespan, and WBAN energy consumption.

This study further adds to previous work in terms of network longevity, throughput, and QoS by addressing the following issues:

- Create an optimal (reduce heat-rise and improved energy conservation to increase network lifespan) WBAN routing strategy by taking important indicators like node temperature and residual energy into account when picking a forwarder node.

- To develop a self-adaptive routing technique capable of picking other forwarder nodes when a node becomes unavailable due to heat or power outage.
- To design a scalable and lightweight system that meet the needs of a realistic healthcare application and can be integrated with a variety of other IoT healthcare apps.
- To protect the integrity of the patient's physiological data while also providing confidentiality and access control measures to critical medical information, the RSA algorithm will be used.

1.2 BACKGROUND AND MOTIVATION

Sequel to the rise in average human lifespan and health costs, developing a smart healthcare system in industrialized nations necessitates the effective use of readily available resources such as battery power. The use of biosensors is posed with practical difficulties such as node mobility, excessive power consumption, consistency, and efficient operation of the overall components. Energy-related qualities and their limits [17] must be considered while extending the network's performance since they include the properties of a working device. As a result of the unique importance of WBAN, current routing protocols designed for wireless sensor network routing methods doesn't cater for the lifespan of a sensor, which is determined by the battery size, detecting data, transmission distance, activities done and sensor node mobility. A device might last a few days or weeks depending on these factors. As a consequence, when the energy sent from the nodes is decreased, communication can take place for a reason, extending the device lifetime during critical and emergency situation. The importance of the proposed system is that it would provide instant, precise, and dependable communication [18] while consuming less energy in the network. Direct or in-direct data transmission is considered based on the distance between relay nodes to create a system that is extremely energy efficient.

Another major concern with WBANs is reliability, which is determined by two factors: fast data delivery and data accuracy when received at the destination. The network's unreliability can have a direct impact on the quality of information retrieved from the patient being monitored. However, it can be dangerous if a life-threatening incident goes unnoticed. Our proposed technique, EEQ, assures not only dependable and efficient data transmission, but also balances the network's energy consumption, transmit data through secured approach and extending the total network lifespan and availability.

1.3 SCOPE OF THE RESEARCH

The study is outlined as follows: Section 1 contain the Introduction; chapter 2 is composed of the general study and chapter 3 contains the proposed work model. The performance outcome is evaluated in section 4, and the research is concluded with a discussion of future scope in section 5.

2. LITERATURE REVIEW

Various academics have contributed to the creation of a WBAN routing algorithm that is both dependable and efficient over time. The following are examples of alternative routing approaches for managing both critical and normal WBAN data:

To address the shortcomings of the SIMPLE protocol, the authors of [19] suggested the IM-SIMPLE technique for WBAN. The major purpose of the IM-SIMPLE protocol was to control mobility. In addition, a linear programming method is used to boost throughput. For typical sensor nodes, IM-SIMPLE employs a multi-hop communication mechanism to save energy. Using the TDMA scheduling technique, a sink node may select the forwarder node with the lowest cost function, and all other sensor nodes can transmit data to the forwarder node within their time slot. One of the strategy's significant drawbacks is the forwarder node's poor selection criterion. Due to its closeness to the sink, a next-hope node is frequently chosen; nonetheless, the power of such nodes drains quickly thereby resulting in unavailability of the node. In addition, since the IM-SIMPLE protocol pays less attention to connection quality and path-loss, the number of packets lost within a given time is greater than in SIMPLE [20].

The optimal route temperature routing protocol, which is based on a self-heat management mechanism, was devised by the authors in [21]. The protocol was created to select the optimum routing route while uniformly distributing heat across each node. The new protocol uses less energy in terms of QoS criteria and experimental result shows that it outperforms the two classic protocols. The authors in [22] introduced a unique WBAN protocol with sensor nodes in the front, rear and sides of the body. The EMRP is a genetic algorithm-based protocol that guarantees short communication lengths, minimum route loss and low energy consumption. The authors did, however, develop an optimized, cost-effective and energy-efficient routing protocol. The cost function was enhanced using a genetic procedure, and energy utilization in various modes such as active, idle and sleep were considered. The authors in [23] suggested a minimal hop routing technique for choosing the optimized next hop which is defined by the number of hops from the sink. Although this approach may meet the QoS need for minimal latency. Due to frequent data transfer and high energy consumption, it is easy for certain fixed nodes to quit the network, thereby resulting to poor network connection. The authors of [24] proposed M-ATTEMPT, a well-known thermal aware routing protocol. Data must be dispersed away from sensor nodes that may detect connection hotspots in this way. The quickest path is picked from among the several available possibilities. When many routes with the same number of hops exist, the one with the least amount of energy consumption to sink is picked. When a sensor node moves during a data collection cycle, a joint invitation request is sent, and a joint-request is permitted if the number of child nodes is less than three (3) after validating the parent's list of the child nodes. When sensor nodes detect a connection hotspot, packets are forwarded via a long alternative path, resulting in increased energy usage. Despite its benefits, when a sensor fails in M-ATTEMPT, there is no alternative option. Furthermore, instead of being situated according to their energy level, these sensor nodes are located based on their data rate.

To solve the drawbacks of M-ATTEMPT, the authors in [25] developed the notion of RE-ATTEMPT, a thermally unaware routing strategy. It uses a multi-hop transmission model in which the shortest path between sensors and sink nodes is chosen. Sensor nodes in the RE-ATTEMPT protocol exchange HELLO messages to discover all accessible routes. When a current path is unavailable, it chooses a less-than-ideal alternative to ensure reliable transmission. Due to the restricted amount of forwarder nodes, this strategy can prevent unneeded traffic from being relayed. However, since direct connection with the sink node increases the risks of packet loss owing to long-distance, it is not the ideal solution for ensuring low latency at the expense of energy and dependability [26]. To increase QoS metrics, the authors in [27] proposed an improved hybrid approach based on the Genetic protocol and Bat protocol as well as energy harvester method. The researcher in [28] proposed a system for detecting and prioritizing vital or emergency data for transmission above non-essential data. Each network sensor node was given its own method to do this. Another important energy-aware protocol that manages both constant and variable quantities of packets is the energy-aware peer routing technique, thus, it is utilized in the healthcare contexts.

The future of the WBAN, according to the authors in [29] lies in new technologies such as deep learning and big data, allowing it to provide optimal and timely treatments to patients in need. The numerous deep learning algorithms can analyze large quantities of big data. However, Edge computing, fog computing and cloud-WBAN are some of the new technologies used in WBAN. A new technology called fog computing was developed by the researcher in [30], the advanced technology can help in reducing delay, enhance storage capacity and provides additional services.

Further study is needed to achieve optimal improvements for sensor nodes to function at peak performance for longer duration. In essence, our main objective in this project include:

- To enhance network lifetime with optimum performance
- To enhance metrics of QoS such as throughput, residual energy, end-to-end delay etc.

2.1 CHALLENGES AND PROBLEM STATEMENTS IN ROUTING APPROACH FOR WBAN

According to this section, we discussed some challenges encountered during routing protocols in WBAN. Because this type of network transmits sensitive information and has an impact on patients' lives, picking the right path must be done with care. The following is a summary of issues encountered with WBAN routing protocols [31]:

2.1.1 Limited Energy

The nodes in WBAN are designed in small size in order to fit properly in/on the patient. It has a tiny, low-power battery. Thus, the power is limited. Consequently, the sensor nodes implanted inside the patient's body may require surgical operation to replace the battery. As a result, limited energy is a major challenge in this routing protocol.

2.1.2 Mobility

The main benefit of this network is that it allows for remote patient monitoring, allowing the patient to move freely within the network. However, determining a path and transferring data to the sink node are both difficult tasks in this process. Changing the network topology is another challenge with mobility. Meanwhile, the pathways to the sink node are dynamic.

As a result, we require a routing system that can effectively manage patient migration. Although many researchers assumed that the patient was lying in bed while few researchers have addressed the mobility problem.

2.1.3 Quality of Service

Sensitive data such as patient's health information requires adequate control measures. Therefore, Quality of service as a measure for maintaining such data must be put in place. Quality of service include other factors such throughput, latency, availability, speed, integrity etc.

2.1.4 Security

Security is very essential in this type of network and IoT devices in general. Therefore, we require an efficient routing protocol that fulfill criteria's such as data authenticity, confidentiality, integrity and availability.

2.1.5 Real time synchronization

Another challenge in WBANs is the implementation of real-time monitoring service for the patient. According to our proposed model, real time data synchronization is very imperative as any slight delay during transmission of critical data might result in high level risk or loss of life. For instance, patients with severe health condition or chronic disease requires real time monitoring.

2.1.6 Data management

Due to the volume of data retrieved or sensed at intervals in a WBAN, data redundancy or duplication might occur. Therefore, a data management tool must be considered in order to obtain data accountability and efficient data management.

2.2 CATEGORIES OF ROUTING TECHNIQUES IN WBAN

WBAN protocols can be classified into six categories, i.e., Temperature-aware routing approaches, cross layered routing protocol, cluster-based routing protocol, quality of service aware routing protocol (QoS), postural movement-based routing protocol and energy-aware routing protocol.

Temperature-aware routing approach

During the construction of a BSN, antenna radiation interference and absorption must be carefully considered. According to WBAN [32], the radiation emitted by sensors placed in or on the body in the process of transmission might cause health problems. Sequel to this effect, the authors established a rate-controlled model for the design of a WBAN. In contrast to the rate control, thermal-aware routing solutions must be addressed throughout the Intra-WBAN development phase. To avoid temperature increase and radiation, which are both detrimental to the patient, many thermal-aware relay techniques have been created.

The objectives and limitations of the current temperature-aware routing technique are listed in Table 1 below.

Table 1: Objectives and limitations of the existing temperature-aware transmission technique

Method	Objectives	Limitations	Domain
M2E2 [33]	The aim of this protocol is to convey packets away from hotspot area and extend the network lifetime in WBAN.	Increased temperature at the node.	Heterogeneous WSN's
RE-Attempt [25]	This protocol was intended to transmit packets and improve the lifespan of the network.	The network lifecycle is reduced	Homogeneous and Heterogeneous WBAN
M-Attempt [25]	This protocol was developed to transmit data packets away from hotspot area.	In the event of a hotspot, the ability to choose an alternative route was not successful. However, Load distribution on the node was not uniform.	Homogeneous and Heterogeneous WBAN
HPR [34]	To eliminate hotspot challenges in the network.	The network lifecycle is reduced	Heterogeneous WSN
THSR [35]	This protocol was aimed at reducing the node's temperature and avoid the creation of hotspot.	The network lifecycle is reduced	Heterogeneous WSN
RAIN [36]	To effectively route selection towards sink node through a random BSN.	Latency in packet delivery	In-vivo network of implanted sensors nodes

	Eliminate hotspot challenges in the network.		
LTRT [37]	To moderately reduce rise in temperature and increase packet rate and throughput.	The network life-cycle is reduced due to lack of hotspot prevention.	Monitoring system for cardiac patients
LTR [38]	To Eliminate the node temperature in a network and convey packets from the hotspot.	Packet throughput is reduced. The temperature of the node is increased and the network lifetime is reduced.	Monitoring system for cardiac patients

Cross Layered Routing

This protocol is mostly used to improve wireless sensor networks. The primary purpose of a cross-layer strategy is to enable layer synchronization without interfering with the operation of the MAC layer. Furthermore, cross-layer routing approaches boost network performance while alleviating network and MAC layer issues. The cross-layer routing protocols are classified into four types: Biocomm and Biocomm-D, TICOSS, CICADA, and WASP.

Cluster Routing

The two most critical parameters to examine in WBAN are temperature and energy. Cluster-based routing is a sort of WBAN routing that tries to minimize energy while prolonging the network life. By segmenting networks into sections, each of which represents a cluster, cluster-based routing minimizes node energy consumption. To build a communication head, these clusters are combined with a cluster head (CH). Data transmission, aggregation, and collection are all handled by the CH. Hybrid indirect transmission (HIT), AnyBody, and Cluster-based body are protocol (CBBAP) are some of the extant cluster routing techniques that have been studied in the literature [39].

Quality of Service Routing

To function, the QoS routing strategy relies on QoS measurements. It is a modular technique that appears difficult to enhance owing to synchronization and network density. WBAN regards patients' data (critical or normal) as extremely vital and guarantees that it is delivered quickly and securely using QoS methods. QoS relay method can be classified into two namely: delay-tolerant protocols and reliability-based protocols. The reliability-based protocol boosts throughput while reducing latency, and the delay-tolerant approach ensures that packets arrive on time. ENSA-BAN, RL-QRP protocol, multi-hop protocol with cost function CDR, ARBA, QPRR, and QPRD are the QoS-based routing techniques [40].

Postural Movement Routing

The postural mobility of the human body influences WBAN communication. Frequent bodily movement typically breaks the connection between nodes. Several studies have been conducted to estimate the cost function for effective sink routing. ETPA, PSR, DVRPLC, and PRPLC are examples of postural movement-based routing protocols [41].

Energy-Aware Routing

Node Energy conservation is a challenging task in WBAN. The battery size in a WBAN is tiny and compact, yet it requires relatively little power. Various energy-based transmission strategies were developed to improve the lifespan of networks by conserving electricity. To prevent message headers and reduce the amount of network control messages delivered and duplicate transmission, many known power-saving techniques are used. Co-CEStat, MEPF, RSSI, DARE, ESR, and SIMPLE are some of the energy-aware routing protocols [42]. In Table 2 below, the advantages and disadvantages of the present energy-aware routing protocol are summarized.

Table 2: Advantages and disadvantages of the existing energy-aware routing protocol.

Method	**Objective**	**Limitations**
SIMPLE	This method was intended to stabilize the power utilized by the nodes and subsequently obtain	Increase in packet drop.

	increased network throughput	
DARE	To decrease the energy used up by each node and eliminate node hotspot.	Varying load distribution.
ESR	To enhance the movement of patients and traffic load.	Reduction in network lifetime.
RSSI	To reduce energy consumption by applying QoS service.	Increase in packet loss.
MEPF	This method was developed in order to reduce energy consumed by each node by transmitting with less power.	High latency in network.

3. PROPOSED MODEL

In this section, we discussed explicitly on the proposed EEQ algorithm.

3.1 DESIGN ARCHITECTURE

The general operation of the proposed EEQ algorithm is divided into four working stages, as shown in Figure 1: Network deployment and initialization, forwarder node selection, data transmission and security and data processing and recommendation. The first three steps are necessary for initial data filtering processes for the targeted application (e.g., patient monitoring).

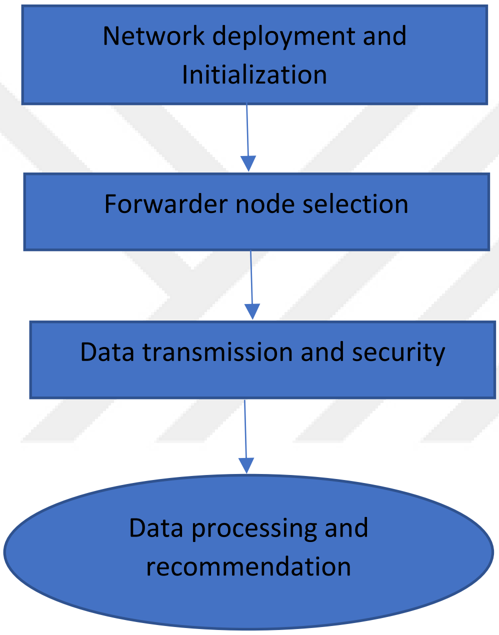

Figure 1: Architectural overview

System Model and Node deployment

Our EEQ-based model is made up of seven (7) different biosensors and a sink node. These biosensors are positioned in/on various areas of the front and rear sides of the body, with the sink which is located at the center. The position of the sink node is critical for minimizing line-of-site (LoS) issues that might disrupt network communication. Figure 2.1 depicts the general structure of the suggested model.

Sink node (SN): This node is configured to gather data from neighboring nodes and sends it to the server for further processing.

Body Sensor Node (BSN): These are microscopic devices that may be embedded or connected to the human body with the ability to fetch, analyze, and communicate signals to the sink node (SN). They have been programmed to differentiate between normal and critical data.

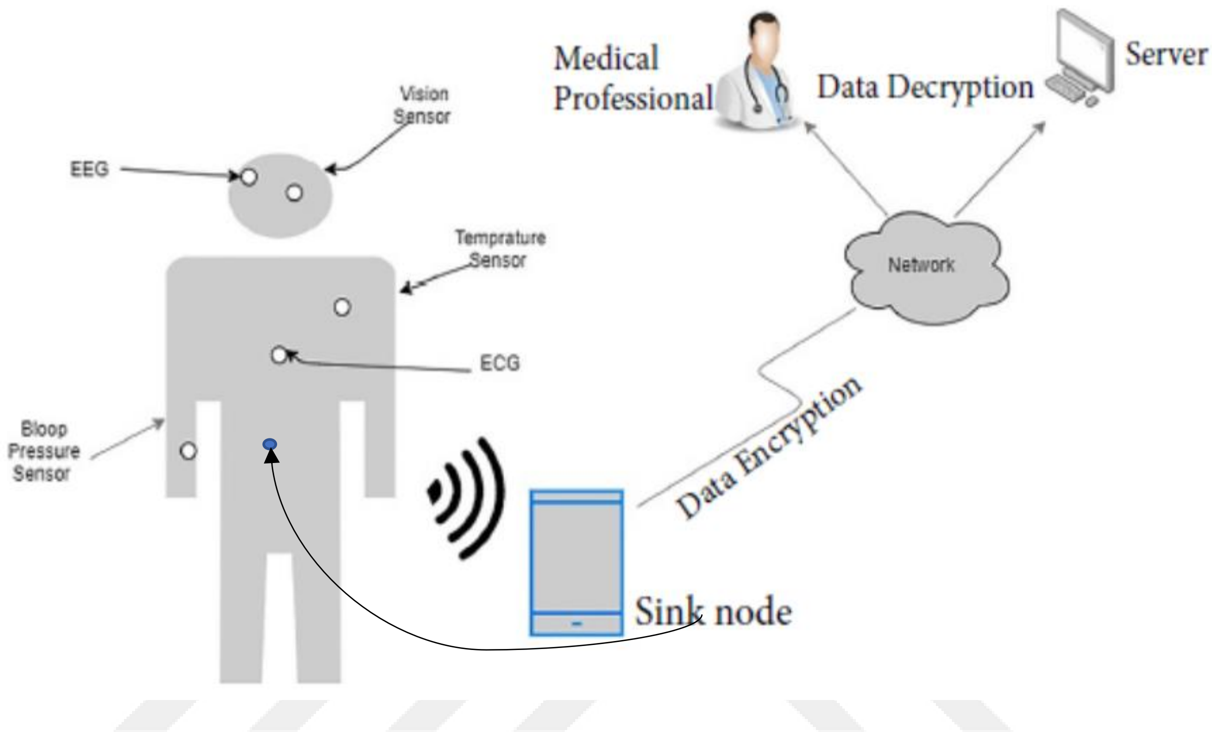

Figure 2.1: Model of the Proposed work (43)

The system model and network specifications reflect the kind of sensor nodes employed in our WBAN, as well as the transmission protocol used in EEQ. The system paradigm, as shown in Figure 2.2 is made up of two types of homogeneous sensor nodes and one heterogeneous sensor node that are positioned on the human body for optimal monitoring.

Homogeneous Nodes

- Critical Monitoring Sensor nodes — The sensor nodes shown in red are used for glucose monitoring and ECG. Because of their important nature, both sensors are critical monitoring biosensors with single-hop connection that are situated near the sink to aid direct transmission to the sink.
- Normal Monitoring Sensor nodes — Other physiological information is acquired by the remaining nodes.

Heterogenous Node

- Sink Node – The sink node gathers data from both critical and normal monitoring sensor-nodes and transfers it to a central repository.

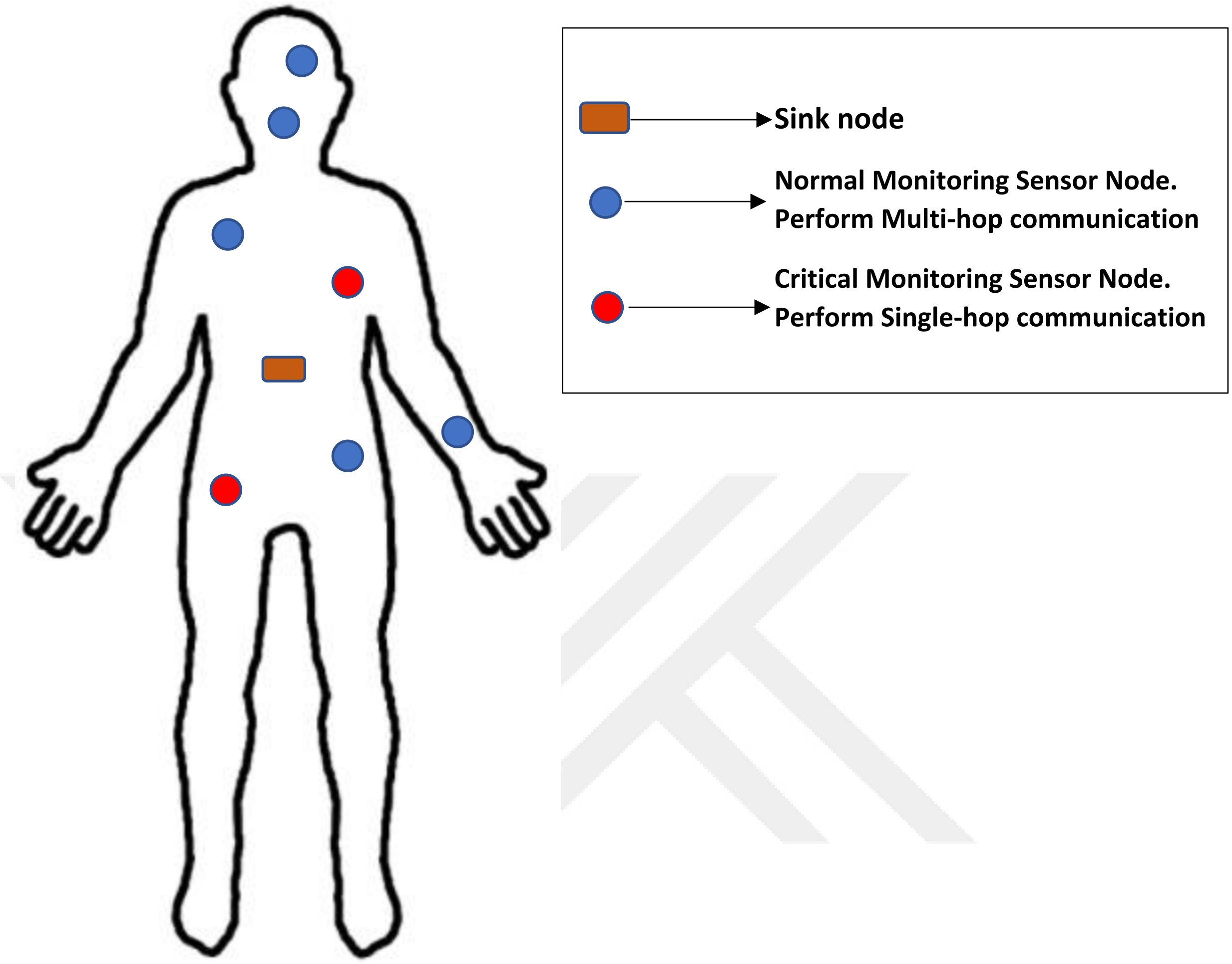

Figure 2.2: Node deployment and communication process

3.2 SETUP PHASE

According to our network model, the sink node is located in the center of the body. The nodes are distributed statically in a two-by-two-dimension body region. Each sensor has the same communication and power capabilities. We presume that the sensor nodes are placed uniformly and have communication ranges that are independent of the patient's body or moving organs. Sensor nodes employ wireless communication to relay the data to a central sink node. Sink is the principal hub node, in charge of all external communication. Each node in our suggested design is no more than two hops away from the sink node, according to the IEEE 802.15.6:20121 network topology. The location of each node and sink node is tabulated in table 3.

Table 3: Position of body sensor nodes

Node	X-axis (m)	Y-axis (m)
Sink	0.5	0.8
1	0.2	1.3
2	0.4	1.0
3	0.6	0.9
4	0.3	0.7
5	0.4	0.5
6	0.2	0.3
7	0.1	0.2

The x and y coordinates are taken into account while deploying sensors. Equation (1) below is used to compute the relative distance from one node to another:

$$D = \sqrt{(Xi - Xj)2 + (Yi - Yj)2} \qquad (1)$$

The optimum next-hop for sending data is assumed to be the node with the highest value.

3.3 INITIALIZATION PHASE

The network initialization process begins when sensor nodes are put on the human body, as illustrated in Figure 3 and sensor nodes are prepared for clustering arrangement through the following steps:

(a) The sink node sends out a HELLO message that includes its position, neighboring nodes' locations, and information about probable sink routes.

(b) When a sensor-node receives a HELLO packet, it modifies its routing table and sends an Acknowledgement Packet to the sink node, which contains information about the sensor node ID (SN ID), residual energy (SN RE), and location (SN LOC).

(c) The sink node stores the values of all deployed sensor-nodes that have acknowledged the HELLO message in its Information Table. The aforesaid network deployment and initialization step is depicted in Fig. 4's sequence diagram.

Each sensor node sends out a brief data packet with Id and location on the body. The node remembers the Id and position of the nearest node and broadcasts a brief packet containing the energy value, Id, temperature value and node position.

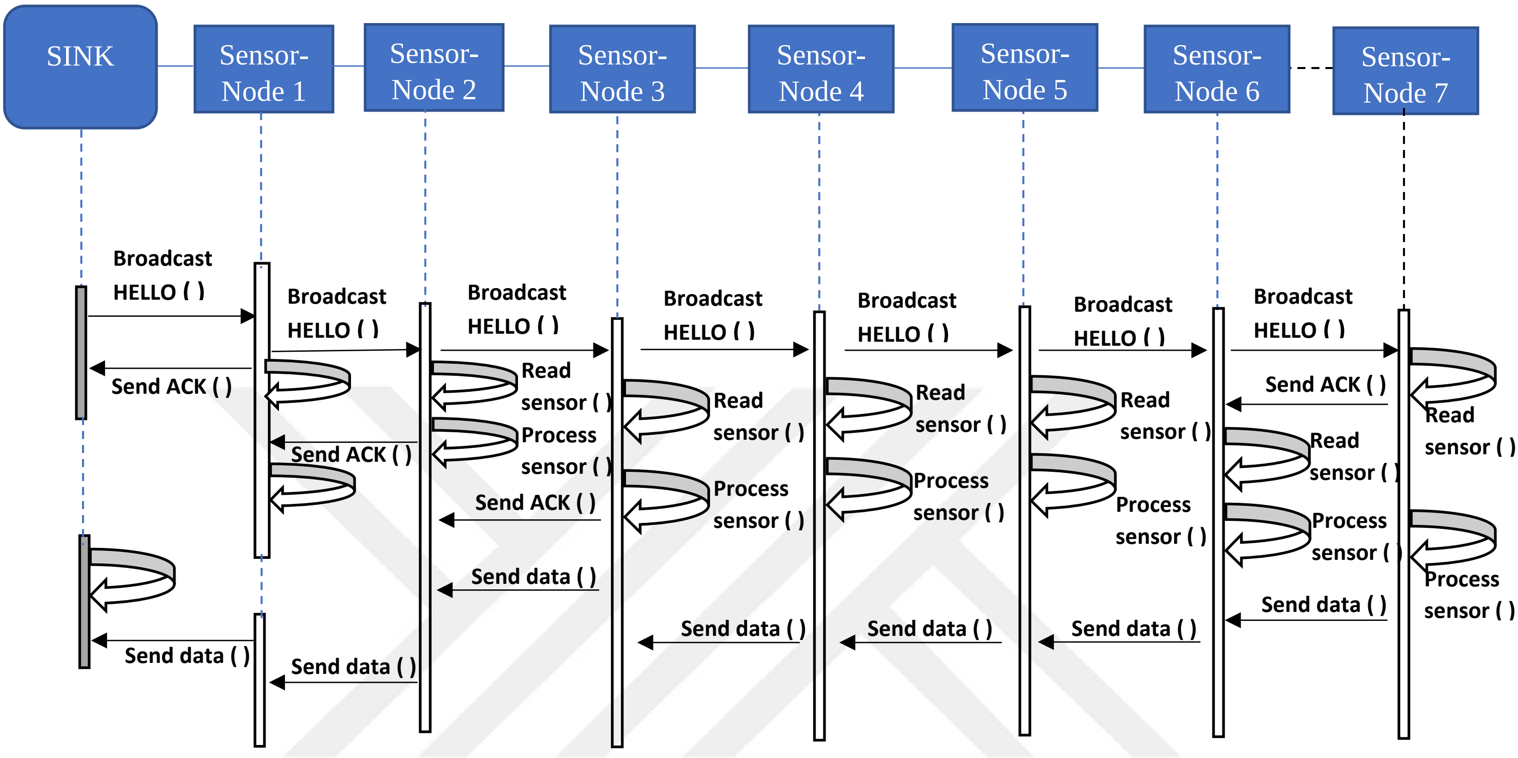

Figure 3: Sequence diagram of the network initialization phase

3.4 M-MAC PROTOCOL

The nodes are configured to gather physiological data in the human body and send to the sink node. A MAC frame is configured to filter the critical data packet from normal data packet in order to achieve energy efficiency and enhanced QoS. The normal data is denoted as 0 while the critical data is denoted as 1. The normal data is being routed using the EEQ algorithm while the critical data is conveyed to the sink and subsequently transferred to the central server. The physiological data is encrypted using public key cryptography before transmission from the sink node to the receiving end. At the receiving end, the authorized medical personnel decrypt the transmitted information using a private key.

M-MAC protocol: The protocol is utilized to establish energy-efficient, effective, low-cost and understandable wireless communication in close proximity to the body [44]. With respect to the proposed study, the MAC frame is configured to filter critical packets from normal packets to achieve energy efficient energy and enhanced QoS. A conventional MAC frame comprises of a 7-octet MAC header, a variable-length MAC frame body and a 2-octet frame check sequence (FCS). The MAC header is made up of four fields. The primary field, known as the frame control field consist of four octets. The receiver and sender ID fields, each with one byte, are the second and third fields, respectively. The BAN ID field, which contains one octet, is the fourth field.

According to the projected M-MAC, an additional field denoted as "data type" is merged with the frame control field. On the other hand, the MAC header retains its original 7 octets. The M-MAC is seen in Figure 4.

7 Octets				0 – 255 Octets	2 Octets
MAC Header				MAC Frame Body	FCS
Frame Control	Recipient ID	Sender ID	BAN ID		
3 octets	1 octet	1 octet	1 octet		

1 octet

Protocol Version	Ack Policy	Security Level	TK Index	BAN Security/Relay	Ack Timing/ EAP Indicator/First Frame on time	Frame Subtype	Frame Type	Data Type

Normal
Critical

Figure 4: M-MAC Format

The amount of criticality of the sensed data varies according to the diverse nature of BSN. For example, when a blood pressure sensor attached to the patient's body reads 140 mmHg or above, it is called Critical data (CD), while a blood pressure sensor that reads 90-139 mmHg is considered Normal data (ND). The binary form of the data types is displayed in table 1 in order to save overhead.

Table 4: Binary Form of Data Type Field

DATA TYPE	BINARY FORM
Normal Data	0
Critical Data	1

Efficient Energy and QoS (EEQ) algorithm: It's aimed to enhance the network lifetime and QoS by routing the normal data (ND) over the best feasible path utilizing multi-hop communication. The algorithm below is used to decide whether direct transmission or EEQ multi-hop-based transmission should be used.

Algorithm for the proposed EEQ multi-hop-based transmission

Initialization: Node n = {1,2,3,4,5,6,7}

Initialization of Sink Position

Sink broadcast its position and all nodes store it

Check if all body sensor nodes are placed properly

Node n E N broadcast the ID, position, residual energy and QoS message

Calculate distance D for each neighbor node

Calculate path loss PL based on distance D

Sense data

If (data type = 1)

    Transmit to Sink

Else

    (Data type = 0)

    Check for the following parameters P {

    identify all neighbor nodes n

    Calculate max. residual energy of all nodes

    Check for link stability

    }

If (P = True)

    Select the best routing path

    Select the forwarder node

    Send data to Sink

Transmit data from Sink node to the server via intranet or Internet

End if

End

The EEQ routing method select the next feasible node based on its weight value using equation (2). Where Wi is the weight value of node, REi is residual energy, LSi is link stability, D is the distance between two nodes, and DSi is the distance to sink. The node with the greatest weight value is regarded to be the best next-hop for data transmission.

$$W_i = (RE_i + LS_i) - (D + DS_i) \qquad (2)$$

Path loss model

The electromagnetic signal weakens or loses power as it travels from source to destination. The amount of energy lost during transmission is affected by distance and a variety of other variables. Attenuation due to the distance that electromagnetic signals flow through the medium is the loss that we will include in our model. The transmitted power in the network is affected based on mobility and other body components. Equation (3) below depicts route loss equation at a starting point of d0.

$$PL(d0) = 10\log10\,(4\pi fd)2/c \qquad (3)$$

Where f is denoted as the frequency and c is the speed of light.

3.5 ROUTING PHASE

Multi-hop communication provides for hop-by-hop conversation. As a forwarder node approaching the sink, the neighbor node with the maximum weight value will be picked. The kind of packet in the transmission queue determines the next-hop node. The sensor in conventional data traffic continuously checks and delivers data on a regular basis. This operation will only be applied to sensors that are not critical to the patient's survival. For example, a blood pressure sensor will continually detect data but will only transmit it to a sink at a predetermined time interval known as the data aggregation time interval.

If a data packet is tagged emergency at this time frame, it will not be collected. Instead, the data packet will be designated as critical data and transmitted over the emergency channel. When the data aggregation time interval expires, the sensor will examine all stored packets and filter the lowest, highest, and average value data packets. This is known as filtering. The sensor will only send these three filtered packets to the sink. Data aggregation and filtration processes will minimize individual sensor energy consumption, network traffic load, and network lifespan.

3.6 DATA SECURITY

The Internet has become such a phenomenon that many organizations including hospitals today cannot function without it. However, the Internet exposes organizations to a wide range of dangers that did not previously exist. Organizational data and resources are accessible from computers and IoT devices across the world through the internet. Despite the fact that governments across the globe are implementing rules and regulations to reduce the so-called "Cybercrimes", the nature of cybercrime and the wide digital environment make apprehending the attackers challenging.

Another important area of study is the security issues in wireless sensor networks. WSNs are often exploited by an adversary as a result of the communication channel, environment, and node vulnerabilities. Security assaults can be active such that an adversary may attempts to change or fabricate nodes and data content, leaving traces in the network that may be tracked while in a passive attack, an adversary does not attempt to modify or fabricate nodes or data content.

Security is very essential when dealing with sensitive data such as patient’s physiological data. This can be accomplished by introducing a technique for encrypting and decrypting the patient’s physiological data. An Asymmetric cryptography called RSA algorithm is employed in the proposed work. The asymmetric key encryption technique makes use of two distinct keys which are private and public keys (45). Using the public key, the plain text is converted to encrypted text. This single operation is known as "encryption," and it is performed by the sender. The receiver then decodes the cipher text using the private key, which is referred to as "decryption." The recipient only knows the private key with the explicit aim of keeping the private keys discreet. On the contrary, the public key is accessible to the users. The public key is used to ensure that the message is originated by the designated party and that it is secret. The sender's encrypted text can only be decoded with the recipient's private key. Messages can be sent in a secure manner as data from the public key is insufficient to decipher the cipher-text. As a result of the above-mentioned desired viewpoint, we used asymmetric key cryptography in our proposed technique (45).

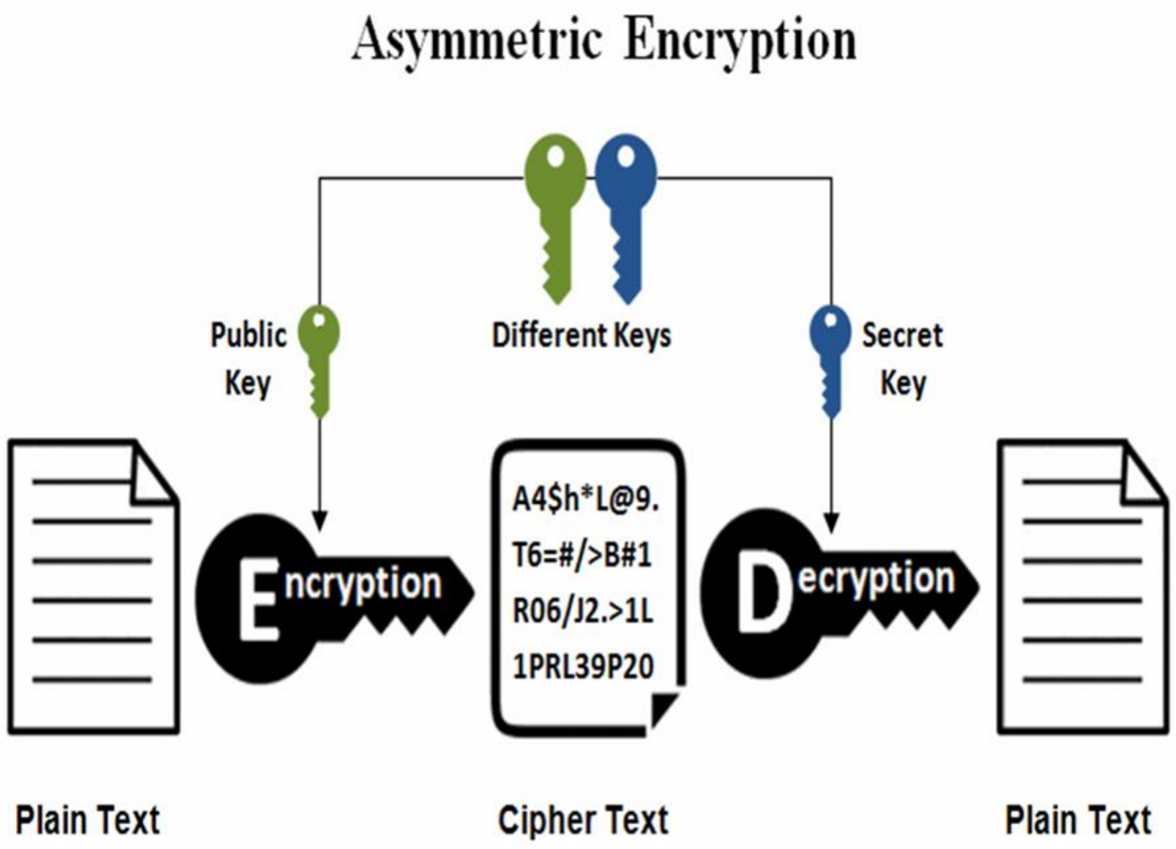

Figure 5: Asymmetric encryption (46)

According to our proposed work, the patient's physiological data is encrypted using a public key during transmission from the sink node to the server, the data is decrypted by authorized medical personnel (Doctor) using a corresponding private key.

In the proposed RSA method, three prime integers (x, y, and z) are expected to be utilized to produce the common modulus n. The prime numbers are added to n to form a new variable that is used to encode and decode data. The application of new variables for encryption and decryption improves data transfer security.

Key Generation:

Pick three random prime numbers: x, y, and z.

Calculate n=x*y*z.

Calculate Ø(n) = (x-1)(y-1)(z-1)

Calculate Kpu:

1gn <Kpu< n

(Kpu can also be a co-prime to n)

Compute d:

If x > y THEN n-x < d < n

If x < y THEN n-y < d < n

(d must be co-prime to n)

- A general formula to find d: Kpu * Kpr mod(d) = 1

Kpr is found using the formula: Kpr * Kpu = 1 *mod (d)

Encryption:

c = m*Kpu mod (d)

Decryption:

m = [c*Kpr mod (d)] ½

Where,

Kpu: Public key

Kpr: Private key

m: Plain Message

c: Cipher Text

The proposed RSA algorithm is further illustrated using a flow chat as shown below in figure 6.

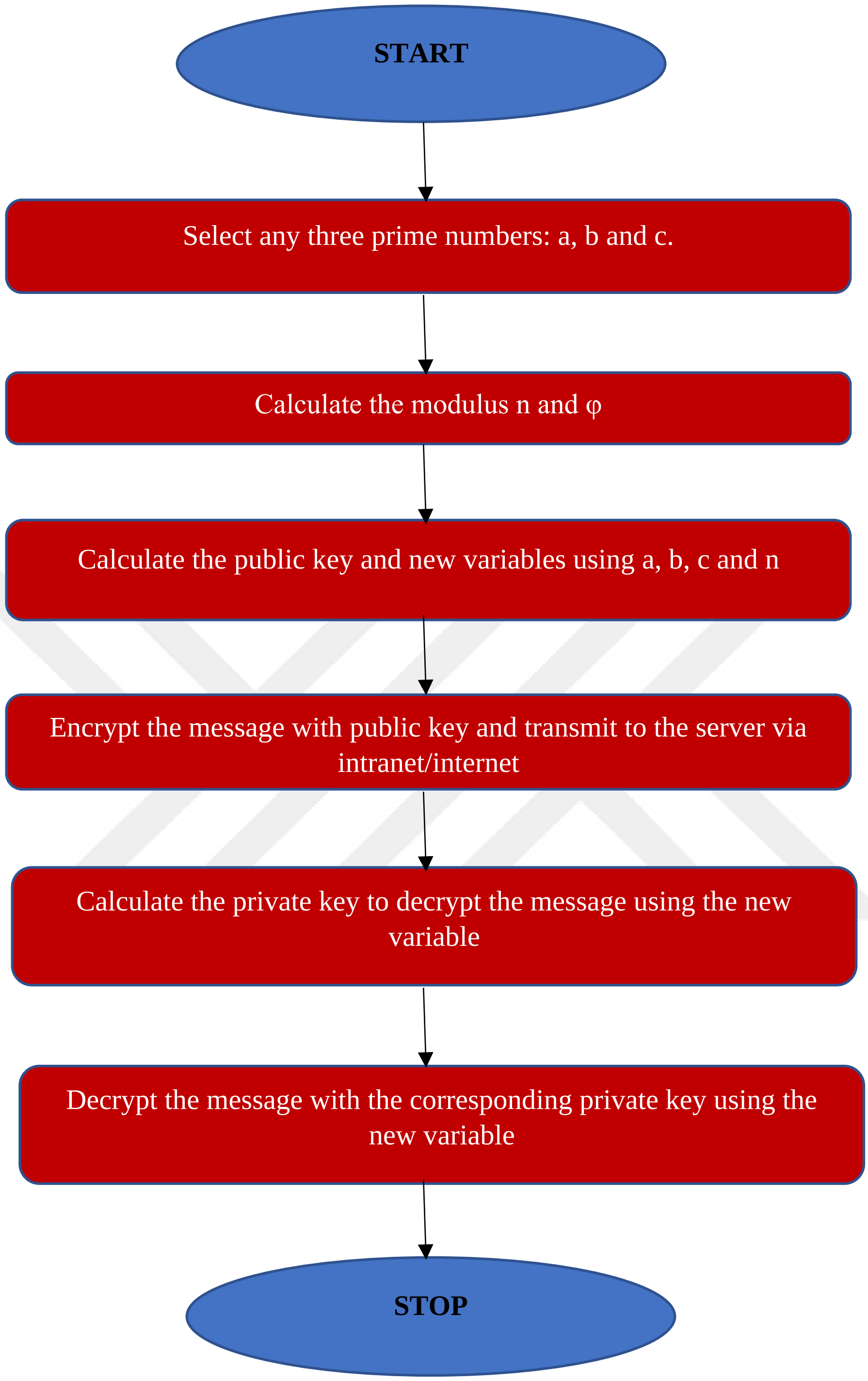

Figure 6: RSA Flow chart

4. RESULT EVALUATION AND SIMULATION

We utilized the OMNet++ simulator to assess the projected scheme's performance and contrast with other techniques. The OMNet++ simulator incorporates a number of frameworks including Castalia, which is designed particularly for WBAN. Hence, it is simple to use and adaptable with built-in analytic tools, sophisticated graphical and interactive environment for evaluating WBAN algorithms and applications. Outlined below are few primary assessments and parameters that was envisaged to accomplish with the simulation:

Firstly, an experiment will be conducted to determine the network stability period and total network lifetime. The purpose of this experiment is to see if our suggested method can increase network lifetime and improve network stability period.

Secondly, studies will be carried out to determine network throughput in terms of packets sent to the sink and packets discarded. To assess dependability in terms of network throughput, we will study the number of packets received and the total number of discarded packets out of a total number of sent packets during the data transmission phase.

Thirdly, compute and assess overall energy usage during and after the data collection and transmission phase. The goal is to determine if energy usage is uniform or unequal.

Finally, the network latency must be evaluated. The length of time it takes for a packet to transit from the source node to the destination node is referred to as delay.

This experiment is designed to test the network's dependability on the basis of quick and continuous data transfer to the sink.

4.1 SIMULATION PARAMETERS AND RADIO ENERGY MODEL

We compared the efficiency of the proposed EEQ algorithm to the iM-SIMPLE and RE-ATTEMPT protocols [19, 25] using a simulated network constructed in OMNet++. Furthermore, as shown in Figure 2b, two types of homogeneous sensor-nodes (critical monitoring sensor-nodes and normal monitoring sensor-nodes) are connected to the body with one heterogeneous node (sink node) for optimal tracking. The sink is situated at the center of the body. Individual sensor node in is assigned an initial energy (Einitial) value of 1.0 J, " Ω" indicates the threshold value of Weight Factor of current forwarder node, transmission energy (ETXproc) is 15.4 nJ/bit, and transmit amplifier energy (ETXproc) is 1.89 nJ/bit/m2, as shown in Table 1. Furthermore, the packet size (k) for different applications might vary depending on the nature and magnitude of the detected data. WBANs often employ Nordic nRF 2401A and Chipcon CC 2420 wireless radio transceivers [47]. A comparison of several characteristics of these two radio transceivers is shown in Table 5. The energy specifications of the Nordic nRF 2401A transceiver, which is a single chip, low power transceiver, was utilized since it uses less power than the Chipcon CC2420, as shown in Table 6.

Table 5: Comparison between CC2420 and nRF2401A transceiver

Parameters	**CC2420**	**nRF2401A**
DC current (TX)	15.0mA	9.5mA
DC current (RX)	18.3mA	17mA
Minimum supply voltage	2.0v	1.8v
E_{TXproc}	92.5nJ/bit	15.4nJ/bit
E_{RXproc}	171.5nJ/bit	35.2nJ/bit
ε_{amp}	265nJ/bit/mn	1.89nJ/bit/mn

In the literature, many radio models have been employed. We have, however, employed a first-order radio model to evaluate the performance of several WBAN methods [48]. This paradigm includes mathematical equations for data transmission and reception, making implementation simple [49]. The transmission distance in WBANs is short, and the transceivers can be in direct line of sight with each other if there are no major barriers or shadowing.

Furthermore, the energy loss owing to the square of the distance d2 between the transmitting and receiving nodes is included in this model; As a result, it is best suited for the proposed EEQ since it takes distance into consideration while calculating the weight factor for forwarder node selection. The energy spent transmitting and receiving energy to process k number of bits across a distance d, is calculated using the equation below:

$$E_{TX}(k,d) = E_{TXproc}.k + \varepsilon_{amp}.k.d^2 \qquad (4)$$

$$E_{RX}(k) = E_{RXproc}.(k) = E_{RXproc} \qquad (5)$$

ETX is the total energy consumed to transmit a packet containing k no. of bits (in Joules) over a separation distance d in these equations. The receiver's energy consumption is measured in ERX.

The energy necessary to power the electrical circuits are E_{TXproc} and E_{RXproc} respectively. The energy consumed by the amplifier circuit is denoted as ε_amp, whereas the energy lost owing to channel transmission is denoted by d2. The human body, which contributes to attenuation of radio signals in WBANs, serves as the communication channel.

4.2 PERFORMANCE METRICS AND EXPERIMENTAL RESULTS

We conducted different experiment by considering the essential performance metrics highlighted below:

- Network Lifetime
- Stability Period
- Throughput
- Residual Energy
- End-to-End Delay

Considering the above metrics, simulation-based tests were carried out with the aim of assessing the efficacy of the projected EEQ algorithm likewise comparing with other previous procedures such as iM-SIMPLE, RE-ATTEMPT and NoAlgorithm routing protocols. The simulation result is shown in table 6 below.

Table 6: Simulation Information

Parameters	**Values**
Simulation Time	3 minutes
Transmission power	10mW
Buffer capacity	32
Data rate	1024
Number of super frame slots	16
Frequency	20MHz
Packet size	2Kb
MAC header length	32
Number of sink node	1
WBAN standard	IEEE 802.15.6
Simulation area	1280 x 760
Packet interval	4s

Transmission energy consumption	3 nJ/bit
Slot duration	1s
Pay load	Max. 2000 bytes
Transmission rate	5 packets/s

4.3 NETWORK LIFETIME

The estimated number of iterations initiated at the inception of the operation to the passage of every node in the network is referred to as network lifespan. Figure 7 shows the difference between the suggested network lifetime and other related works. According to the proposed research, network lifetime is described as the period whereby the last node in the network dies. As shown in figure 7, NoAlgorithm dies after 40 seconds, RE-Attempt after 75 seconds, iM-SIMPLE after 110 seconds and EEQ after 170 seconds. “NoAlgorithm” is when no algorithm is used.

Data is transferred without classification or consideration of the best way to convey data in NoAlgorithm, therefore energy is rapidly exhausted. RE-Attempt uses a limited set of criteria to select the best path, however it is unable to significantly increase network lifetime. The retransmission of data in iM-SIMPLE consumes energy. Our proposed method provides improved network lifetime than other similar works because of its ability to classify data and select optimum path by considering various characteristics.

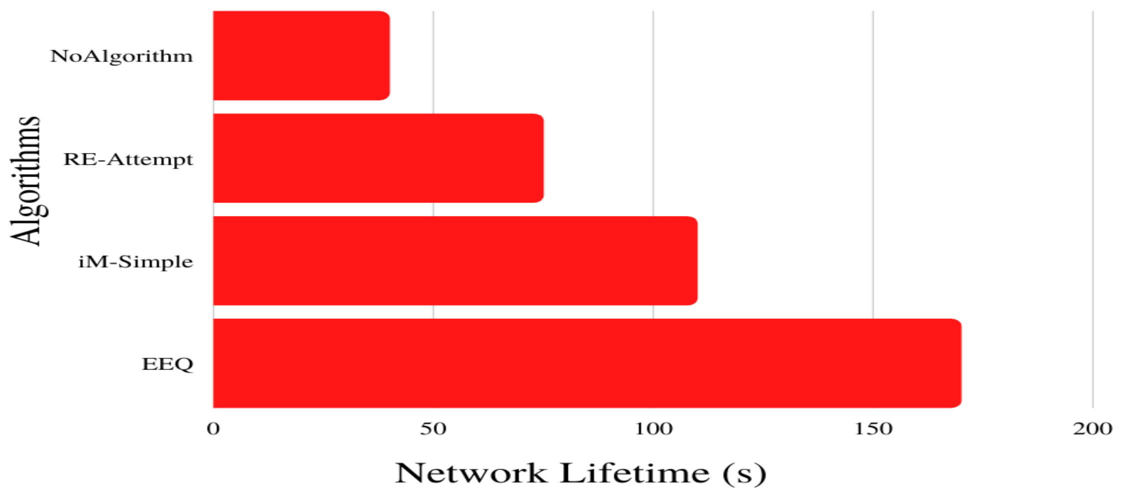

Figure 7: Network lifetime comparison

4.4 NETWORK STABILITY PERIOD

The stability period in WBAN is the time it takes for the network to run from the time it first starts until the time the network's first node dies. After the first node dies, the remaining operational time is referred to as the unstable phase. The amount of data to be sent and the parameters for selecting forwarder nodes have a big influence on the network's stability period.

Furthermore, the network's operational lifetime is directly influenced by the stability period. The entire network operating lifespan will be enhanced if the stability period is prolonged.

As shown in figure 8, NoAlgorithm dies after 9 seconds, RE-Attempt after 46 seconds, iM-SIMPLE after 72 seconds and EEQ after 98 seconds.

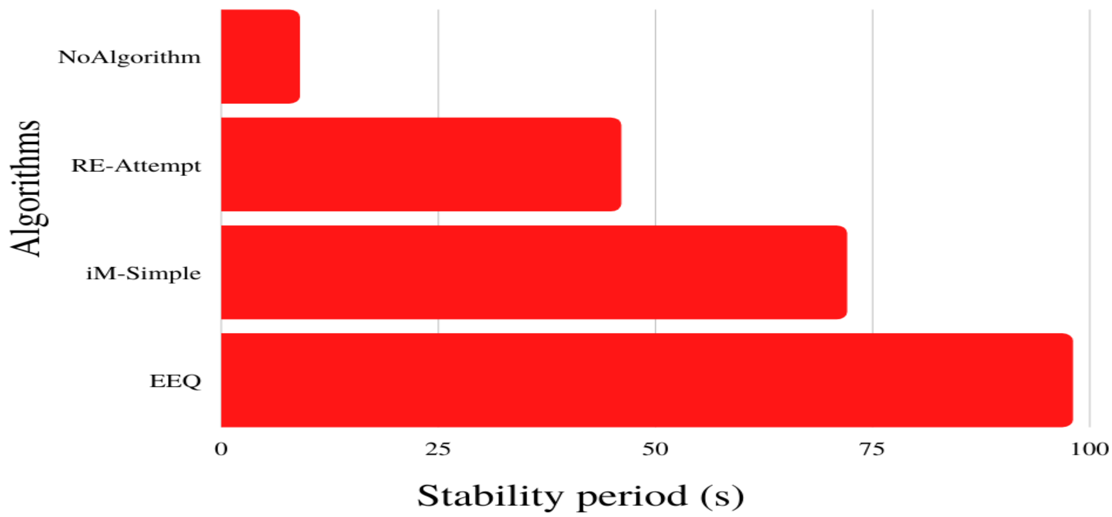

Figure 8: Stability period comparison

4.5 THROUGHPUT

The amount of successful packets retrieved at the sink is called throughput. Comparing RE-ATTEMPT and NoAlgorithm algorithms (as shown in Figure 9), our proposed work achieved great throughput. The remaining sensor nodes in the network that are still operational determine the overall number of packets forwarded to the receiving end. Since it transmits regardless of the relevance of data or network quality, NoAlgorithm reached a throughput of 21kbps. As a result, a great deal of data is lost. RE-Attempt, on the other hand, achieved a throughput of 58kbps, which is much greater than NoAlgorithm but lower than iM-Simple. Finally, the proposed EEQ method achieves a throughput of 97kbps due to packet drop, thus the best data transmission path is selected.

Mathematically, it can be expressed as:

$$Throughput = \frac{Packet\ size}{Transmission\ Time} \qquad (6)$$

Figure 4 depicts a difference in the throughput of our proposed work with other similar algorithms such as [44] and "NoAlgorithm".

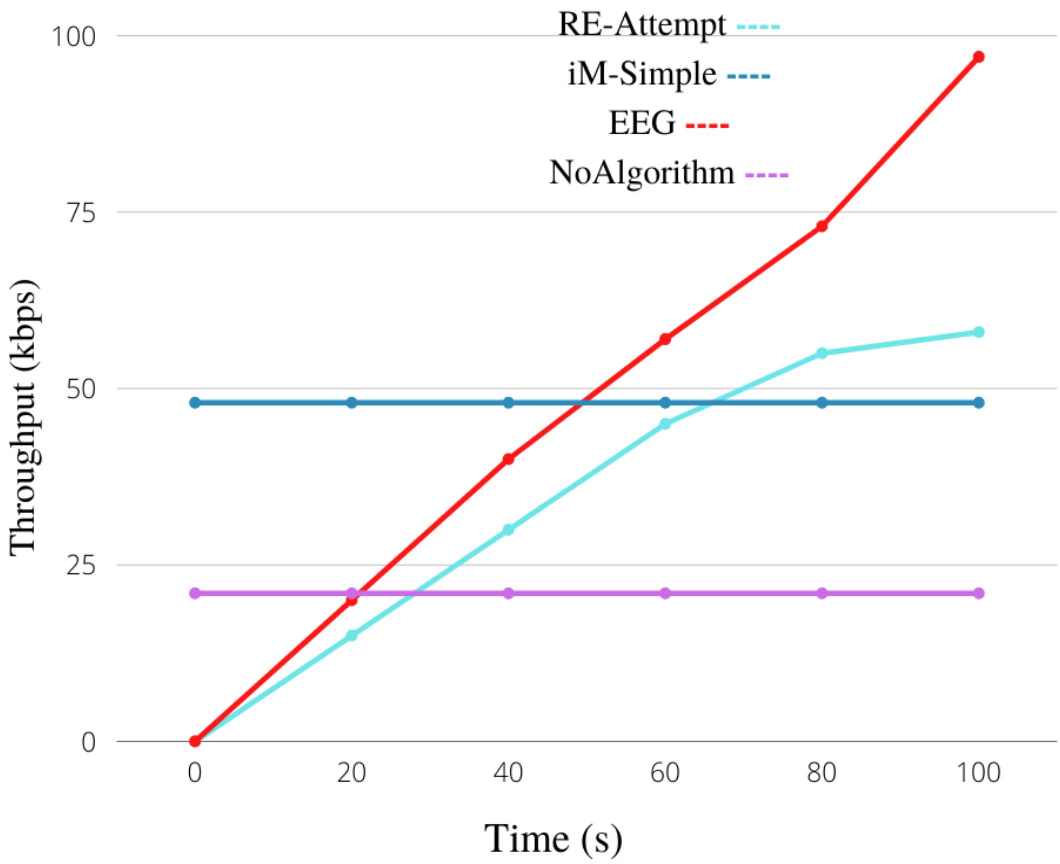

Figure 9: Throughput comparison

4.6 RESIDUAL ENERGY

It is the initial energy minus the energy consumed in a node. Each cycle assesses the total energy consumed in the network which is measured in joules (J). The average residual energy decreases as the number of iterations increases as shown in Figure 10. Our suggested protocol consumes little energy and hence adds greater power to the network as a whole. Critical packets are being transmitted directly due to its level of criticality, allowing the central node to broadcast more data packets while eliminating redundant packets. The cost value determines the optimal forwarder node for effective transfer of data at the next hierarchical level. The EEQ algorithm outperforms the earlier SIMPLE and M-ATTEMPT techniques based on the energy consumed by the nodes (see Figure 10).

The residual energy can be computed by considering Equation (7):

$$\mathrm{Eresi} = \mathrm{Einitial} - \mathrm{Eused} \quad (7)$$

Where Eresi is the residual energy in the neighboring node, Einitial, is denoted as the initial energy, Eused is the energy consumed.

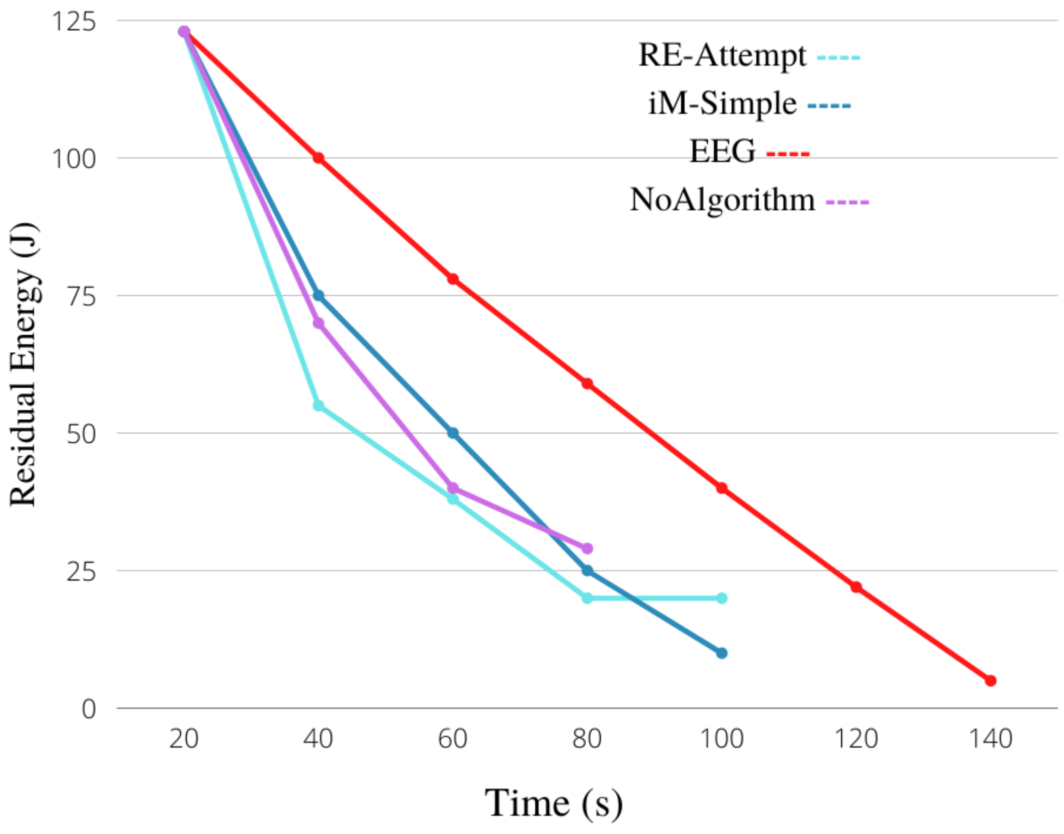

Figure 10: Residual Energy comparison

4.7 PACKET DROPPED

Information packets are rejected when the communication connection capacity falls below the given value, which is required for successful data transmission and reception throughout the communication process, according to the random uniformed model. Due to the sensor nodes' mobility surroundings, the quality of the communication path among them changes. On the energy competency parameters, the variation result to packet drops considerably. To compute packet drop, we utilize a variable packet loss probability of 0.3, which varies from 0.3 to 0.7 depending on the routing strategy employed in their research. Depending on the value supplied, the path between the communicating nodes is taken into account in order to conduct successful transmission. Consequently, the estimated value of packets emitted by the sensor nodes does not tally with the expected value of packets retrieved. In comparison to existing routing protocol approaches, the averaged packets delivered to sink, averaged packets received at sink and averaged packets lost are shown in figure 11.

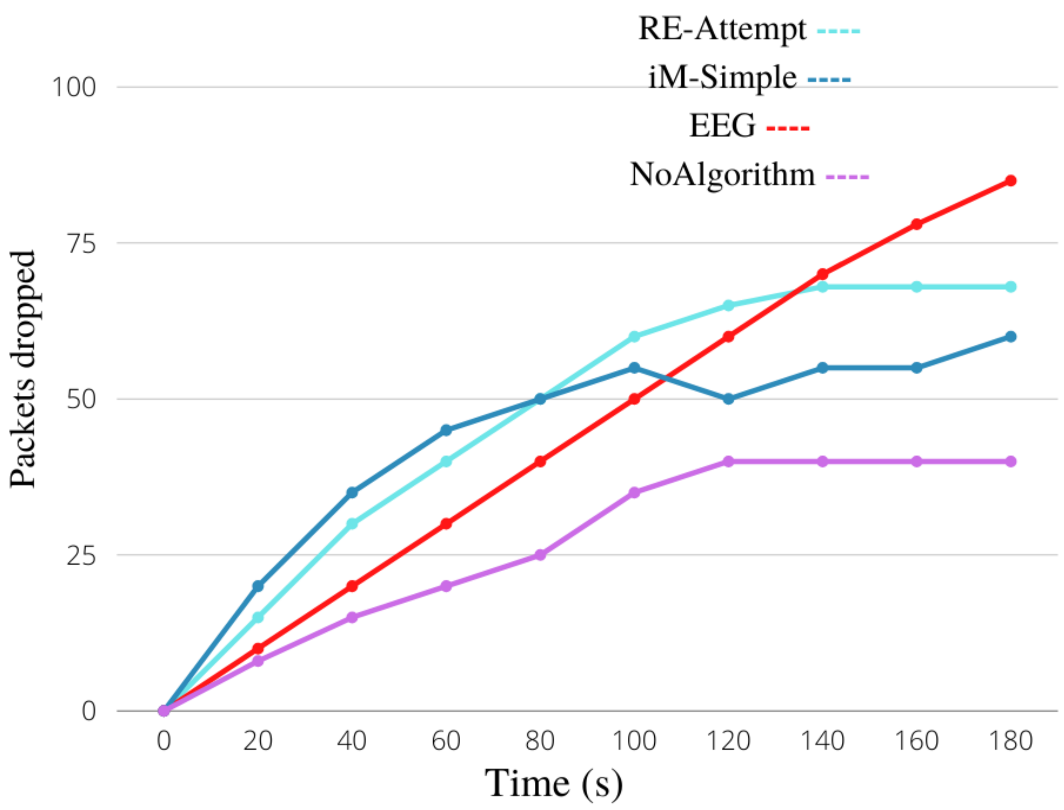

Figure 11: Analysis of averaged packets dropped.

4.8 END-TO-END DELAY

It is the estimated period required by a packet to travel from its origin to its end point. Since WBANs are employed to track crucial health issues in the human body, therefore end-to-end latency is minimized to avoid errors. The identified data in WBANs should be transmitted to the designated end-point without further delay. Given the implication of end-to-end latency, we aimed to keep it minimal. Figure 12 illustrate the outcomes of the end-to-end simulation. According to the result generated, the EEQ algorithm is observed to have sustained the lowest end-to-end latency. EEQ performance was nearly comparable to that of its counterparts at first, but it later improved in comparison to its contemporaries. The proposed design performed a great estimation by conveying critical data during the initialization stage, as a result, it is compared alongside others protocols. However, at the 660th iteration, the end-to-end latency in EEQ reduced noticeably and dropped to 140ms, while its contemporaries had more communication latency.

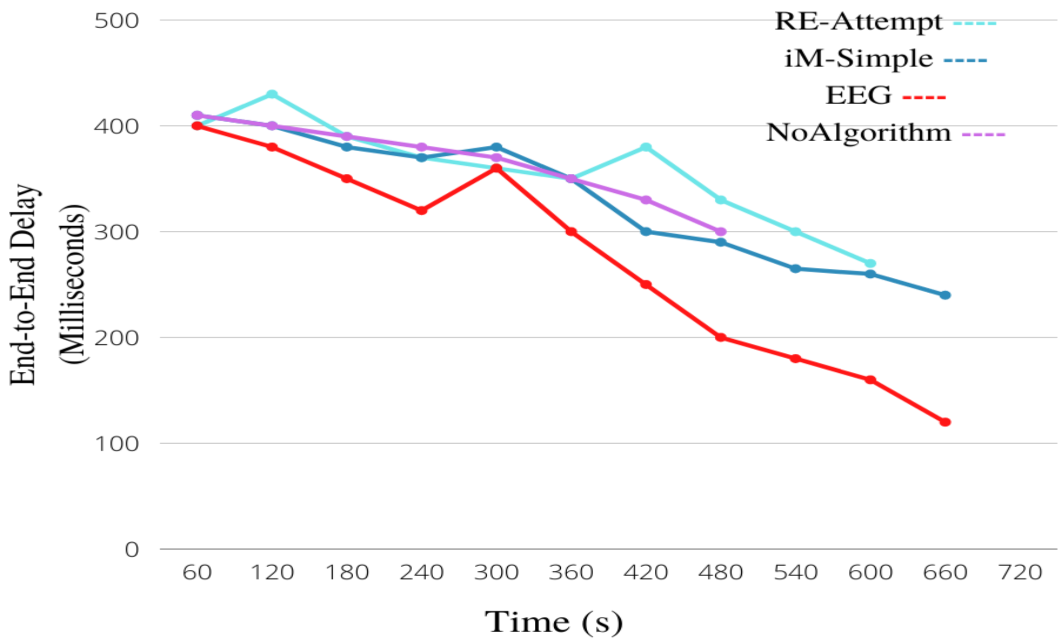

Figure 12: End-to-End Delay Comparison

Result Analysis

Table 6 shows the value and efficiency of our proposed algorithm. When compared to the other criteria, the EEQ algorithm performs well and produces better results.

4.9 COMPARATIVE ANALYSIS OF THE VARIOUS ROUTING PROTOCOLS IN WBAN

A comparative study depicting the differences between the various WBAN routing protocols is shown in table 7 below. The aim, method employed for the routing protocol, throughput and challenges have all been used to make comparisons among the different protocols.

Table 7: Comparative analysis of related routing protocols in WBAN

PROTOCOL	AIM	METHOD	THROUGHPUT	CHALLENGES
RE-ATTEMPT [50]	In each round, load distribution and energy usage are consistent.	Nodes are deployed with respect to their energy values and LPM.	Medium	Inadequate stability
M-ATTEMPT [51]	Data from a hotspot connection is discarded	Application of hotspot and TDMA	Medium	Multi-hop routing and mobility are not supported
SIMPLE [52]	Increase throughput while reducing energy usage.	Each nodes have the same amount of power and computation capability.	Average	Does not support mobility
iM-SIMPLE [19]	Increase throughput while reducing energy usage.	Each node has the same amount of power and computation capability	Average	Lacks the ability to support mobility
DMQoS [53]	End-to-end path discovery and maintenance in	Localized routing is used to create a	Medium	Network traffic is increased

	a homogeneous manner	modular architecture		
EPR [50]	To minimize energy usage and stabilize network traffic	Select the next hop with respect to the node's residual energy	Average	Limited operation
EERDT [54]	Maximize node lifespan by picking CH based on the fundamental cost-effective function.	Transmission is done based on hierarchy	High	Does not support mobility
ESR [55]	Retain node residual energy	Uses an objective approach to choose the most energy-efficient pathways.	Medium	Limited to medical application
PEA [56]	Boost the lifespan of each node	Select node based on the level of criticality of the data	High	Another relay node is chosen each time a change in the node position is observed
Proposed EEQ	Minimize energy consumption, provide data security and enhance data transmission	Filter packets and select forwarder node based on its weight value	High	Does not fully support mobility

5. CONCLUSION AND FUTURE SCOPE

This study aims to provide an Efficient power and QoS based multi-hop transmission procedure in WBAN to improve network longevity and quality of service. To assure data delivery to the sink, the design utilizes a single sink node with direct and multi-hop transmission. Data is identified before to transmission, and the Modified-MAC protocol (M-MAC) divides it into normal and crucial categories. To eliminate delays that might lead to unanticipated events, critical packet is transferred to the sink after classification. In the event of normal data, the EEQ protocol is utilized to determine the optimum channel for data transfer. Consequently, the classified information is encoded using the RSA technique. By considering parameters such as network longevity, stability, throughput and latency, the recommended simulation result was compared to other protocols including RE-ATTEMPT, iM-SIMPLE, and NoAlgorithm. This approach reduces network energy usage by removing duplicate packets and optimizing the routing algorithm. Patients are constantly watched and instantaneous information from the network allows the doctors to acquire a complete understanding of the health status of the patient.

As a consequence of the advent of improvised transmission technique that addresses efficient energy, storage, and memory limits, new prospective uses for WSNs are being proposed. We broaden the discussion to encompass a larger variety of WSN applications, with a particular emphasis on wireless energy transfer, efficient localization, and mobility in WSNs. In wireless energy transfer, these systems rely on piezoelectric principles, laser beams and radio waves, inductive coupling and microwaves.

In the future, potential features that can further enhance the application of WSN such as Wireless sensor networks with effective localization and mobility, wireless energy transfer and Internet of people should be considered. In addition, sleep-scheduling should be implemented to evaluate how much energy can be saved, as well as to minimize packet loss and enhance overall network performance.

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