THERMAL AWARE HIGH THROUGHPUT ROUTING PROTOCOL FOR WIRELESS BODY AREA NETWORKS

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Candidate of **Master of Science in Computer Science** at the National University of Modern Languages do hereby declare that the thesis **Thermal Aware High Throughput Routing Protocol for Wireless Body Area Networks** submitted by me in partial fulfillment of MSCS degree, is my original work, and has not been submitted or published earlier. I also solemnly declare that it shall not, in future, be submitted by me for obtaining any other degree from this or any other university or institution. I also understand that if evidence of plagiarism is found in my thesis/dissertation at any stage, even after the award of a degree, the work may be cancelled and the degree revoked.

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ABSTRACT

Title: Thermal Aware High Throughput Routing Protocol for Wireless Body Area Networks

The Wireless Body Area Network (WBAN) is a branch of the Wireless Sensor Network (WSN) that uses biosensors continuously collect data about the human body. These biosensors implanted on the human body to monitor movement and each node in the network act in a group to route the data packet. Wireless routing protocols provide a route to distribute the information by making the route. However, in the routing protocol selecting the next hop node for data transmission consequently affects the packet delivery ratio (PDR) network's performance. Frequent use of the same node for packet transmission and unnecessary information distribution rise the temperature of the node, which causes heated node issue that could damages the human tissue. This research proposed protocol called Thermal Aware High Throughput routing protocol for wireless body area networks (TAHT) that uses multi-hop communication. It manages the network's route by data distribution initially. It estimates link quality for selecting the next hop from neighbor nodes. Also estimates the temperature to control the temperature rise and suspending the node based on predefined threshold and update the remaining energy status continuously to balance the energy. Moreover, the proposed protocol TAHT is compared with protocols name ERRS and TAEO, the simulation result shows that the proposed protocol TAHT controls the temperature dissipation by 5% as compared with the TAEO protocol while TAHT achieves 10% maximum throughput from TAEO and 20% from ERRS. TAHT increase 20% PDR by route planning as compared to ERRS. TAHT consumes 40% less energy as compared to TAEO and 20% from ERRS that improves network lifetime.

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LIST OF ABBREVIATIONS

PDR	-	Packet Receive Ratio
WBAN	-	Wireless Body Area Network
THAT	-	Thermal Aware High Throughput
GW	-	Gateway
QoS	-	Quality of Services
DF	-	Data Forwarder
CN	-	Coordinator Node
BC	-	Body Coordinator
SNR	-	Signal to Noise Ratio
RSSI	-	Receive Signal Strength Indicator
RSS	-	Receive Signal Strength
FLQE	-	Fuzzy logic base Link Quality Estimator
SF	-	Stability Factor
PRR	-	Packet Receive Ratio
ASL	-	Asymmetric Link
BSU	-	Body Sensor Unit
CRPBA	-	Cluster Based Routing Protocol

LIST OF SYMBOLS

Node_ID	-	Searching node ID
$count_{prr}$	-	Number of packet receive ratio in table
S	-	Sink
N_{cur}	-	Current node
Thr_temp	-	Temperature threshold
P.t	-	Packet temperature
P.e	-	Packet energy

LIST OF FIGURES

ACKNOWLEDGMENT

First of all, I wish to express my gratitude and deep appreciation to Almighty Allah, who made this study possible and successful. This study would not be accomplished unless the honest espousal that was extended from several sources for which I would like to express my sincere thankfulness and gratitude. Yet, there were significant contributors for my attained success and I cannot forget their input, especially my research supervisors, Asst. Prof. Dr. Sajjad Haider and co-supervisor, Asst. Prof. Dr. Moeenuddin Tariq, who did not leave any stone unturned to guide me during my research journey.

I shall also acknowledge the extended assistance from the administrations of Department of Computer Sciences who supported me all through my research experience and simplified the challenges I faced. For all whom I did not mention but I shall not neglect their significant contribution, thanks for everything.

DEDICATION

This thesis work is dedicated to my parents and my teachers throughout my education career who have not only loved me unconditionally but whose good examples have taught me to work hard for the things that I aspire to achieve.

CHAPTER 1

INTRODUCTION

1.1 Overview

In the modern era, sensors are devices that retrieve data by observing the environment in real-time (pressure, temperature, vibration, or movement; WSNs). Globally, WSN is worn in a wide range of fields [1]. Wireless body area network (WBAN) is a component of WSN that uses sensors to track and track the mobility of the body of an individual. As a result, WBAN has become more sophisticated due to the swift advances in sensor and communication technologies [2]. The sensors controlled via a network and according to IEEE standards, which include a WiFi, Bluetooth, and Zigbee-based network. Additionally, the same region is maintained by these network systems, here the regions are the human’s body that monitored by the sensors with the specific range [3].

The routing protocol for the WBAN frequently emerging invention that develops the network with cost essential cost essential sensors that are called body sensor units (BSU) in a network [4]. The sensor nodes likewise named body sensor units (BSUs). The data is assembled from these BSUs sent to the body control unit (BCU), from this unit, it is communicated to its accurate point through the base station. For instance, with next to no side effects of torment, patients are facing a gamble of genuine heart illnesses when their pulse is high. The consistent observation of related boundaries empowers productive components for anticipation and early admonition [5]. These nodes eventually create a network. To an extent, that transmits the data through a discrete routing protocol design. That codifies the routing protocol for WBAN i.e. (posture-based routing, temperature-based routing, cross-layer routing, cluster-based routing, and QoS-based routing) [6]. Here is an architecture of WBAN.

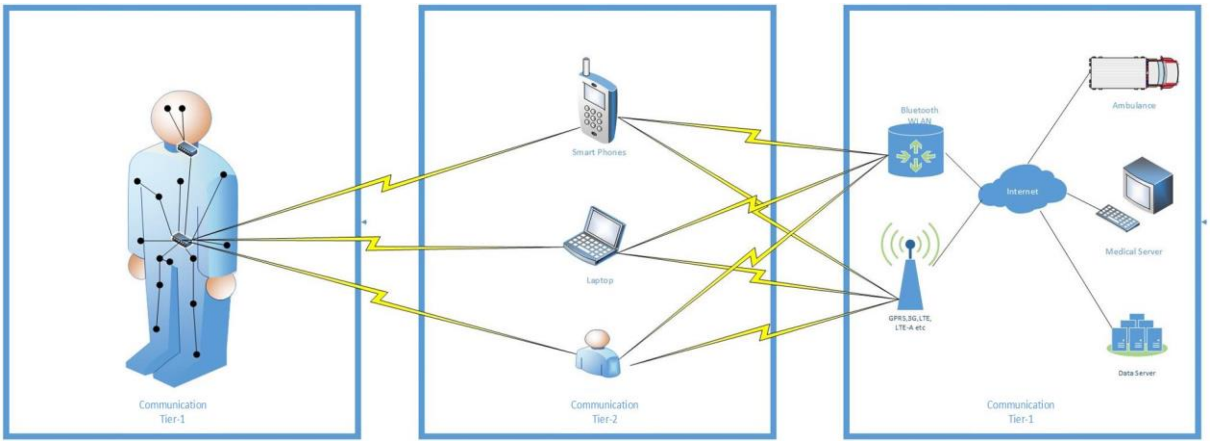


Figure 1.1: Architecture of Wireless Body Area Network

1.2 Motivation

Wireless sensor-based patient monitoring systems via WBAN has evolved and has brought out the revolutionary change in healthcare systems. WBAN technology has implemented in clinical research laboratories as well as medical test centers. A WBAN system can deployed at medical care units for old-aged people or at home for monitoring without affecting their day-to-day life activities. The advancement in sensors, wireless sensor network (WSN), WBAN, and the pervasive systems has taken healthcare to a new height. These technologies adeptly supported by Big Data technologies and different analytics that allows doctors for predictive diagnostics. The patients and medical care units far more engaged as never before.

WBANs tilized to monitor human wellbeing with restricted energy assets. It is important that a medical specialist for further analysis must reliably receive data sensed by nodes. Cluster Based Routing Protocol (CRPBA) facilitates to deal with the information transmission and correspondence among sensor nodes [7]. To improve the life span of the network, the cluster head randomly changed that improve the lifetime of network.

1.3 Application of wireless body area network (WBAN)

WBAN is a branch of WSN that has turned into a front area of exploration and advancement as it offers a colossal potential for development in medical care and checking [8]. Different applications of WBAN play an essential role in various fields.

1.3.1 *In the Medical field*

WBANs can give connection points to diagnostics, for remote observing of human physiological information, for the organization of medications in clinics and as a guide to restoration [9].

1.3.2 *The gaming sensors interface*

A gaming console where the information gathered for intuitive gaming and theatre setups associated with a gadget that gives information. The gaming applications would require remote devices to detect different body acts and contribute to them [10].

1.3.3 *Individual data sharing*

For example, in shopping, there are numerous applications in which information can store data utilizing WBAN sensors [11].

1.3.4 *The military applications*

WBANs incorporate observing humans' health, area, and temperature and hydration level [12].

1.3.5 *Secure validation*

This application depends on physiological and conducts biometrics plans, for example, facial examples, fingerprints and iris acknowledgment [13].

1.3.6 *Way of life WBAN*

WBAN can give offices the ability exceptionally distinguish every client and perceive client mindset and screen movement [14].

In wireless enabled network, monitoring the human body is an important research area in WSN. Heterogeneous sensors are deployed on the body that could emit heat radiation while sensing or transmitting the data and damage the sensitive tissue of the human body. These Heterogeneous sensor nodes are based on battery life [15]. The restricted constraints, i.e., temperature, and battery depletion, limit the stretch of the network lifespan. It is uncomfortable to replace the battery when the sensor nodes are implanted in the human body [16]. During transmission, network lifetime impact and temperature rise may drop packets to disturb the traffic, and a patient with a severe disease has delicate data. Therefore, sensed data has to be delivered without packet drop and with high transmission in secure routing schemes [17]. Moreover, radio signals are generated from wireless communication is also a cause of rise in tissue nodes[18].

1.4 Constraints in WBAN routing protocol

In the following section, different constraints discussed including energy consumption, transmission range, node motility, sensing range, node suspension, scalability.

1.4.1 *Energy Consumption*

In WBANs, it's challenging to expand the network lifetime. As the network depends upon sensor monitoring the human body, sensor nodes sense the data and transmit it to the sink through different routing techniques and forward it to a personal digital assistant (PDA) [19]. The network's energy depletes quickly and shrinks the network [20]. Sensor nodes exchange information with neighbor sensor nodes and update the routing table. Thus, there should be a minimum energy-utilizing mechanism for remote energy usage and a mechanism where each node’s routing table updates after a specific battery usage.

1.4.2 Node Motility

In WBAN, sensors are fixed on the human body. Somehow, the movement of the human body can create a challenging situation in which the route has to update, resulting in connection loss [21]. Therefore, the limited network requires a motility prediction model and route planning.

1.4.3 Sensing and communication Range

Some essential factors that affect the performance of the network. In WBANs, sensors connect wirelessly and deployed over the human body that senses the data forward it to PDA and use radio signals to communicate with each other. The average communication range is 10m with 10kbps bandwidth, which affect the bandwidth that leads to congestion in an emergency [22]. Therefore, a communication range with high bandwidth is required.

1.4.4 Node Suspension

In WBANs, when the node's temperature exceeds the threshold and energy depletes, it reaches the end. The node is suspended, shrinks the network, and causes traffic congestion[23]. Thus, an algorithm that controls the node’s temperature and repeated energy updates expend the network lifetime.

1.4.5 Scalability

In WBANs, sensors sense the sensitive data highly influenced by changes in body condition [24]. Therefore, the network should be efficient enough to fluctuate with environmental changes.

1.5 Problem Background

Real-time monitoring and data transfer are constrained by the demanding WBAN infrastructure. Numerous research that have already been done have produced a variety of WBAN-related protocols. Body sensor nodes must cooperate with their neighbors, share data, and pass it to the sink node efficiently to achieve the best results. On the other hand, the typical network protocol uses a lot of energy, suspends the temperature-sensitive nodes, and is unable to govern data transmission with a high packet delivery ratio (PDR). The typical network had some imposed limitations that resulted in end-to-end delays in data forwarding and route planning during emergencies. The nodes close to the sink are heavily engaged in packet transmission, which depletes their energy and raises their temperature node retransmits the data, which prompts the loss of essential data from the neighbor node.

Nodes in WBAN plays an important role in collecting data and forwarding it to the sink node. First these nodes establish a between other sensor nodes. However, it is difficult to establish a link, which is reliable, and enhance the efficiency of the network in terms of packet delivery ratio (PDR) and better link quality. In TAEO, for forwarding the data the forwarder node selected based on temperature, distance and energy. It also doesn't gives any guarantee to establish a reliable link [19].

In WBAN nodes has limited battery, which reduces the network lifetime and performance of network. As ERRS [25] selects forwarder node and rotate the forwarder node that take enough energy that is not required. It also put burden on the specific node that its battery depleted early in transmission. It is necessary that to control the excessive energy consumption or it affect the network.

Temperature of a node is another issue that effect the network's transmission and human tissue. The technique used in TAEO controls the temperature by tissue damaging but this technique behave different on different parts of body [19].

Hence, for packet delivery ratio (PDR), energy and regulating temperature, effective computing frameworks such as a thermal aware routing mechanism needed for efficient routing and data transmission. Moreover, nodes can communicate with others efficiently using wireless routing paths and relay data. Which can affect in terms of packet drop, traffic collusion and retransmission of data.

1.6 Problem Statement

In WBAN, the radio links between nodes are involved in data communication. However, the body movement may results in broken links that increase packet drop and retransmission. Such retransmissions lead to the temperature rise along with energy. Moreover, data packets are normally flooded in the transmission area of the nodes and many nodes in that area become eligible for data forwarding. Hence, packet collisions are inevitable. Increase in temperature of node beyond the specified limit may cause tissue damage and duplicate transmission also cause increase in heating node and energy consumption.

1.7 Research Questions

i What metrics could use for the selection of an appropriate next hop to enhance packet delivery ratio, throughput, and network lifetime?

ii How unnecessary or duplicate packet transmission can decreased to reduce energy consumption and node heating issue.

1.8 Aim of the Research Objectives

In a wireless body area network (WBAN), objects like blood pressure, body movement, and heart rate recorded for information usage transferred to the internet cloud to allow authorization for emergency measures. While sending emergency messages, packet delivery ratio (PDR) has an impact on time-sensitive sensing and monitoring applications. For optimal throughput and temperature control in this delicate area, good link quality and minimum delay are required. A bumpy delivery of important and time-sensitive data packets might be disastrous and result in enormous loss. In order to maintain link quality and a high packet delivery ratio in WBAN, this research intends precisely control the temperature to avoid heated nodes. Network performance will improved by establishing the link between nodes to choose the next hop nodes and defining the threshold for heated nodes that prevent suspending the nodes in the network. As a result, PDR will increase and achieve a high throughput packet transmission.

1.9 Research Objective

i. To design and develop a scheme, that utilize link quality in the selection of the next hop node to increase packet delivery ratio, throughput, and network lifetime.
ii. To design and develop a scheme, that suppress duplicate transmission to enhance energy consumption and reduce heating of sensor node.

1.10 Thesis Organization

This thesis is organized is as follows:

Chapter 2 will render comprehensive state-of-the-art schemes and algorithms for thermal awareness and high throughput protocol for WBAN that presented in current research. It includes a detailed overview of all the existing work and describes how this study distinguishes itself from the existing schemes. Also contains categorical discussion, a detailed comparative analysis of state-of-the-art technologies and their research limitations that lead toward new research direction.

Chapter 3 will present the methodology and description of plans that how to solve the identified problem and detailed the operational framework and verification of the proposed algorithm. It introduces the novel thermal aware high throughput routing (TAHT) protocol for WBAN. This prototype provides an increased packet delivery ratio (PDR), reduces unnecessary packet transmission for increased throughput, and restraints the node’s temperature. A simulation framework presented for the performance evaluation of TAHT protocol, and it considers the performance metrics of the simulation. Extensive simulation put into NS-2 to get accurate and effective results. Also, analyzes different phases in THAT protocol for WBAN to manage the temperature and establish the high-quality link between nodes for data transmission without loss.

Chapter 4 will provide the experimental evaluation to prove the validity of thermal aware high throughput routing protocol for WBAN in detail. It discusses the results of the experiments and presents a comparative analysis of these results with other schemes. It explains the results presented in multiple graphs from the simulator and logs files.

Chapter 5 will sum up the contributions of this research work. It also discusses the gaps in the proposed prototype, which lead to further directions for future work and attracts innovative researchers to benefit from it.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This chapter presents literature review of different WBAN routing protocols. The analysis of these schemes presented in terms of energy efficiency, low packet delivery ratio (PDR), link quality, temperature control and different communication techniques. The basic idea, working, merits and demerits discussed in table 2.1, and research gaps in the literature highlights and lead to the new direction. That proposes a new method for thermal aware high throughput routing protocol for WBAN.

2.2 Multi-Hop Routing

The proposed multi-hop WBAN construction scheme [9][26][27][28]. Gateway is supposed to be 'Tier 0'. Therefore, the sink node of WSN that accumulate data from other nodes, and 'Tier 1' subscript can directly communicate to GW also relay data from Tier 2 to GW. 'Tier 2' subscript has large distance from GW Author make clusters that consist of one tier 1 node and multiple tiers 2 nodes. GW broadcasts routing entry to its neighbors, neighboring nodes update their routing table and rebroadcast it. They are marked as Tier 1 nodes and nodes that receive the tier1 (parent) node routing table will be Tier 2 child nodes. The child node listens to the message head by the parent node. It checks the RSSI value if the value is low defined threshold for a certain limit of child node tries to find the control message of another node that is strong to its legacy parent that provides mobility support and links failure tolerance features.

In [18] Develop a weighted, QoS-based, energy and Temperature aware routing protocol (WETRP). In which multi-hop communication in WBSNs increases the network lifetime. The WETRP protocol encompasses sensor nodes, relay nodes, and a gateway node. Relay node estimates temperature by several forwarded/received packets. The forwarder node selected on a minimum of the cost function. The weights assigned according to the temperature to assure traffic load is equally distributed. For route selection, it must observe the temperature and energy thresholds. In addition, the route maintained at any time during packet transmission and might be inactive due to a hotspot, or energy deficit node. WETRP's energy and temperature awareness display less temperature rise at high data transmission rate. Moreover, throughput is decreasing as the network load reaches (100kbps) and the network strains wireless links.

Temperature Aware and Energy Optimized (TAEO) routing protocol that solves the thermal and hotspot problem [19]. It starts working by broadcasting the message that contains location, energy, temperature, and node identifier. By this, each node has the information of its neighbor nodes. If the temperature of any node exceeds its threshold level that may cause tissue damaging. While routing the Data Forwarder (DF) temperature estimated if the temperature is below the threshold level then it allows for transmission otherwise DF dropped for some rounds. Scheduling the data transmission and assigning time slots each node. TAEO consumes low energy as compared to other datasets and increases the number of rounds with a low-temperature rise. On the other hand, TAEO is not performing efficiently in terms of throughput.

DSCB Dual sink approach using clustering in body area network [4] and iDSCB use clustered technique that enhances the body nodes dual sink approach [20]. It begins with initializing with node distribution then forming clusters of nodes then allotting the time slot, examining the data, and developing the hop-distance benchmark for the forwarder node. That reduces the end-to-end delay and high throughput and shows a 6.59% of improvement from the previous algorithm. While at the initial time, it suffers from more delay due to the development of the hop distance benchmark. Al-obaidi M A D, et al. developed a scheme that reduces energy consumption and enhances the network lifetime through the addition of sleeping mode in the SIMPLE protocol. It uses single-hop and multi-hop schemes for forwarding the data. First, it chooses the parent node that accumulates the data and forwards it to the sink node while a selection of the node could affect the energy consumption. For balancing the energy consumption, SAMPLE selects a new parent node based on the low-cost function. Then classify the sensors into critical and non-critical sensors and data. This scheme provides reliability and integrity to WBAN, and provide the scheduled sleep mode. But the packet could be dropped in sleeping mode [29].

Heterogeneous Gateway-based Energy-Aware multi-hop routing protocol (HMGEAR). [22] design enhanced Heterogeneous Gateway-based Energy-Aware multi-hop routing protocol (HMGEAR) [30] that is based on the heterogeneous nodes head node selected on the residual energy. The network is the combination means union of Base Station (BS), Gateway (GW), Heterogeneous nodes (H0), and Set of Heterogeneous nodes (He) [31]. It works based on dividing the network into four threshold distances. While proposed, it consists of two phases, the setup phases (deployed nodes in four regions and elect the cluster), and steady phases (which way the data is transmitted and energy consumption). This scheme improves the residual energy, throughput, and network lifetime.

The author [23] developed Adaptive Thermal-Aware Routing(ATAR) protocol for WBAN. It starts from the initialization phase in which the distance of each node calculated by hop-count and is apart into rings and each ring has several nodes. The R1 nodes connected to each node of R2 and so on. After that transmission of data performed. This proposed approach enhances the throughput however because of the fastness temperature of nodes raised.

Khan RA, et al. [24] proposed a stable network that consumes low energy. The network proposed by using eight sensor nodes. The sensor's initial energy is 0.5 J and the threshold energy is 0.1 J. The sink node informed about the identity and the energy status. The cost function of any sensor is calculated. The forwarder node selected based on the shortest distance. The packet received ratio at the sink is high compared to other data sets if the availability of sensor nodes.

An approach that also uses a multi-hop technique with the Castalia WBAN simulator [32]. It provides better performance as compared to the direct delivery method. The reliable data transmission and dynamically choosing the next hop node was proposed by Qu Y, et al.[27], and uses a multi-hop technique. The abnormal data that is exceed its threshold requires reliable data transmission. The dynamic routing achieved on the bases of the priority of data. That successfully transmits the data to the sink node however with low throughput and consuming huge time. That depletes the energy faster.

A reliable, power efficient, and high throughput routing protocol for WBAN [33]. The network initialized with the placement of biosensors throughout the body. The sink on-air is the packet containing the location of the sink only and each node on-air is the packet containing id, location, and energy. So that each node knows its neighbors. Based on energy for data transmission parent elected. The cost function calculated by the sink and every forwarder node. It scheduled the nodes by time division multiple access (TDMA). So the depletion of nodes can minimized. However, it cannot count the expected transmission count (ETX).

Maymand LZ, et al. [34] proposed a thermal aware routing protocol with two thresholds. Both used for increasing and decreasing the temperature of the sensor. The working method begins with a hello packet and then a neighbor table maintained by each node having parameters neighbor node, Residual Energy, Temperature, Hop Count. The rate of temperature estimated and an algorithm used to select the next-hop neighbor. This scheme provides a High packet delivery ratio (PDR), low delay, and energy consumption. The issue may arise when the temperature of the node goes up and difficult to level down.

In [35] Designed An Optimal Energy Consumption Artificial Bee Colony (OEABC). It works in a way that it begins with residual energy is 50 and the path is selected by a hopping scheme for data transmission. As compared to ORABC is performing better than the Genetic and Ant Colony Algorithm in consuming energy and convergence ratio. While the first 50 iterations consume high energy rather than 100 or 150.

WBAN protocol that consumes less energy and controls the thermal impact on tissue. It works in a way that Transceivers and receivers are transmitting the data. The transceiver contains a frequency synthesizer, modulator, amplifier, and oscillator. On the other hand, the receiving model also contains this subsystem. Then it estimates the route cost, which links quality, energy consumption, and thermal change that contains the setup and data transmission phase. Finally, the routing model is proposed. It increases the throughput balance of the packet collision. In the future, different network simulators are used to test the scheme [36].

A priority-based energy-efficient routing protocol (PERA) for WBAN [37]. It prioritizes the data transmission according to the importance of data. The proposed scheme has four steps, it begins with airing a Hello packet having the location of the sink, and by multi-hop routing, and each node knows the location of the sink node and its neighboring nodes. For forwarding the data, the maintained table route selected. After that time division, Multiple Access (TDMA) periods assigned to each node then all nodes start sensing data. On this basis, the slot assigned to each node can forward data accordingly. It has high throughput and minimum path loss. Due to batteries, it cannot gather all the information.

A temperature heterogeneity energy (THE) routing protocol. The network consists of one coordinator node (CN) separated from the body and a set of nodes attach to the body [38]. The material used to prevent heat is Nikel. For data transmission, standard priority level 6 assigned to nodes that transmit data directly to CN, and for normal nodes standard priority level 5 and transmitted to the parent node (PN). While transmitting the normal traffic (priority level 5) if the temperature exceeds from threshold (37degree) it immediately changes the priority level 7 and directly forwards the data CN. The proposed network performs better in terms of lifespan and high throughput in low temperatures. As the temperature rises, the throughput of the network would be slow.

Energy Efficient Sustainable Network that uses Network Optimization Technique (EFS-NOT) [39]. The initialization of the network begins with Hello Packet by the body coordinator (BC) so the network established between the nodes. After that, continuous monitoring results in storage issues. It can be resolved by using data compression (by using Huffman) and data encrypted using the smart grid and decrypted. The is selected after encryption and decryption For energy efficiency using an Adaptive Scheduling Protocol, that switch the nodes from active to sleeping can minimize the energy consumption. The new system performs better in terms of network, transmission rate, and latency, and reduces packet-dropping rate. Future work will expand the network with different technologies.

In [40] developed Dual Forwarding Selection Technique (DFST) that expands the network lifetime, throughput, and stability period. That divides the network into two groups and the forwarder node selected from nodes in each group meaning the upper and lower part of the body divided into groups. In dual forwarder selection nodes, it initialized with forwarding the HELLO packet (parameter with ID and location). Then the forwarder node selected and if the distance far it consumes high energy then the stability factor decreases. Time slots allocated through the time division multiple access (TDMA) protocol. Finally, the pathway is selected for data transmission by multi-hop communication or directly. In the future, the developed technique can expanded by security.

A routing protocol that selects the relay node based on four levels that begins by observing nodes' position, as some are dynamic while others are static. The second is to evaluate the distance between the nodes through RSSI. The third level to reckon is the Direction of arrival (DOA) based on the multiple signal classification (MUSIC) algorithm. Lastly, selecting the relay node based on fuzzy rules (if else condition applied). It performs better in terms of latency, throughput, end-to-end delay, and PDR. Due to battery usage, their lifespan is limited. [41].

ZITA [42] designed a cost-based routing protocol that improves timeliness, link quality, temperature control, and energy efficiency for the transmission of data. While transmission consumes the energy by controlling voltage oscillator, frequency synthesizer, modulator, and power amplifier. At receiving end, the component as mentioned before consumes energy. The energy exhaustion will depend on the data-receiving rate. A specific Absorption Rate (SAR) in Watt per Kg (W/kg) measures the heat absorption rate. The system's cost measured through hop count, queue length, power consumption, and delay. In addition, the thermal cost calculated by the node's transmission and receiving activities. Then the list of neighbors selected on the bases of residual energy. ZITA selects an efficient forwarder node that sends directly to the sink nodes by Zapf's law (is to balance the energy depletion rate). Nevertheless, it increases the node's heat rate while moving and decreases the delivery ratio in multi-hop routing.

Reddy K V, et al. [43] developed an energy-efficient communication protocol for WBAN. The communication between the base-station by single hop. It used clustered-based routing containing one CH and elect CH randomly. With the short distance between BS, and a high signal-to-noise ratio (SNR), energy, the next CH would be that node. CH accumulate the data and forward it to the base station. The proposed protocol longs the network lifetime, throughput, and energy for various nodes. Nevertheless, it is a difficult small network.

In [44] proposed an energy-efficient computing technique for the transmission of data emergency scenarios. The system model structure based on three stages (initialization and data sense, selection of coordinator nodes, scheduling, and data communication stage). As the network starts from the hello packet from the sink an acknowledgment signal transmitted to the sink from a node in response so that all nodes would be aware of their neighbors. To balance the energy consumption use the cost function which based on distance and residual energy for the coordinator node. If not have, the ability to communicate then the cost function value is for the link used. On this cost, the function coordinator node is decided. After that, the data transmission is scheduled and given the time slots so the traffic managed without loss of any packet and transmission delay. At transmission time, the node will be active and if there is no data for transmission then the node remains idle. It improves in terms of stability period, lifetime, throughput, and energy consumption. However, cannot differentiate between the data in real time during emergency time.

Abdu A I, et al. designed an energy-aware QoS-Guaranteed WBAN (EQ-WBAN), and the network consists of sensor nodes (SN), Coordinator (CR), and sink node (SN), E-SN. IA-MAC (fixed length MAC header, fixed length frame check sequence, variable-length frame body) is examining the traffic type through SMNN (a classifier that classifies the traffic into normal or emergency traffic.) with single and multi-hop routing. GSS (this scheme allows idle sensing time) is doing a sleep schedule to reduce energy consumption. PWD (both single and multi-hop transmission are performed) is an algorithm that plays an important role in routing. The proposed scheme enhances the network lifetime, and throughput, and reduces the delay, energy consumption, and dropping packets. But can't secure from spoofing, jamming attacks, and eavesdropping [45].

A hybrid AHP-TOPSIS protocol for selecting relay nodes [46]. It starts with the deployment of nodes on the body and finding the relay node by sink nodes that forward the hello packet in the transmission range that would contain residual energy, traffic load, hop distance, and no. of neighbors. Then weights assigned using the AHP weight method. Next is to find the relay node first all the data is transmitted to the relay node and the radio is off so that it consumes less energy at receiving signals and use AHP-TOPSIS to find the compatible nodes based on the information. It provides flexible relay node selection. But, it can't be used in postural movement and mobility of sensors.

Al-obaidi M A D, et al. [29] developed a protocol that reduces energy consumption and enhances the network lifetime through the addition of sleeping mode in the SIMPLE protocol. It uses single-hop and multi-hop schemes for forwarding the data. First, it chooses the parent node that accumulates the data and forwards it to the sink node while a selection of the node could affect the energy consumption. For balancing the energy consumption, SAMPLE selects a new parent node based on the low-cost function. Then classify the sensors into critical and non-critical sensors and data. This scheme provides reliability and integrity to WBAN, and provide the scheduled sleep mode. However, the packet could dropped in sleeping mode.

Energy Optimized Congestion Control based on Temperature Aware Routing Algorithm (EOCC-TARA) [47]. It proposed a Software Defined Network (SDN) for WBAN (The network model of WBAN has layers. Layer 1 consists of Intra-WBAN communication. Layer 2 creates an Inter-WBAN communication. Layer 3 communicates beyond WBAN to store the data in cloud storage or else.). The temperature of each node is analyzed and calculated individually or the whole network. Now the energy estimated by using parameters Residual energy, link quality, multi-objective cost function, congestion control model, and path loss. Finally, the route selected. It provides high throughput, minimizes the path loss, and therefore packet is also minimized, and the hotspot issue overcome. Nevertheless, this network has a mobility problem.

High Throughput and Thermal Aware Routing Protocol (HTTRP) that reduces the temperature of sensors and controls energy consumption. It starts from the transmission of the Hello packet and each node maintains its neighbor table. Network divides the data into two types (emergency data and normal data). As emergency data needs an urgent response so it is directly sent to the sink node. While in normal natured data through the multi-hop scheme. The data transmitted to its nearest neighbor node and so on. However, while transmission, if the neighbor node suspended due to low energy or temperature, and exceeds its predefined threshold then sending node finds the second nearest node from the maintained table. It minimizes energy consumption and diversifies the route. Nevertheless, packets could dropped due to the continuous use of the same path for transmission and congestion occur [48].

In [49] developed a high throughput, reliable, power efficient protocol for wireless body area network. The deployment of nodes and sink nodes placed in the center of the body. After that, on air, the packet contains the position and ID of the node to its neighbors. In addition, scheduled the data transmission through time division multiple access (TDMA), frequency division multiple access (FDMA), and code division multiple access (CDMA). It consumes energy while the sensor forwards them to the sink node and receives the notification packet from the sink node. It uses single-hop and multi-hop routing for the transmission of data. However, it would not allow the body to move to make the whole network shut down.

An increased throughput with an optimized Sink (ITOS) [50]. The sensors that applied to the body has some critical nodes like ECG and glucose sensor that are directly forwarding the data to the sink. The location of the sensors depends upon the functionality of the sensors. The sink node forwards the hello packet to each node on the network and acknowledgment signals are air by the nodes on receiving the hello packet. The selection of the next hop node elected based on ID, residual energy, cost function, and distance of node before every round for the forwarder/next hop node. While it decides whether the data is directly forwarded to the sink or through the forwarder node. It improves the throughput and the lifetime of the network while it cannot enhance the stability of the network.

2.3 Cluster Based Routing

In [16] worked on a meta-heuristic clustering protocol to find the suitable cluster head for transmission of data. In this method, clusters made in uniform sets of nodes so that the energy consumption is balanced. The researcher used the phenomena of an ant for probing the food called pheromones. Likewise to detect the suitable shortest path for communication between nodes or CH and nodes. Cluster members transmit data by multi-hop or by direct transmission. While transmitting the data node's temperature should considered to balance, the energy consumption and each time new path should be taken .To find the suitable path if the value of cluster head is less than this is the optimal path for data transmission.

An optimized cluster-based routing protocol using a genetic approach [51][52]. It works in a way that measures the physiological value of the human body [53]. It performs better in terms of energy dissipation and throughput. While performing low in terms of network availability, secure localization, dependability, and data confidentiality.

A protocol that increases the network efficiency with the phases of cluster formation, cluster head election, and routing operation. It performs better in concern of energy consumed. However, it leads to higher delay if the wrong cluster head elected and if any packet could not reach the sink node that also failed to retransmit the packet [54].

Energy efficient and reliable routing protocol (ERRS) that improves stability and reliability [25]. This scheme has four phases that begin with the deployment of two types of homogeneous sensor nodes (critical and normal sensor nodes. Sink on air the Hello packet has location, neighbor location, and information about the route and each node maintains its routing table. Then forwarder node is selected is based on distance from the node and residual energy and weights are assigned to the information the clustered-based routing used for data forwarding. For data transmission, data scheduled using Time division multiple access (TDMA) that assigns time slots. Sink also monitors the forwarder node if weight reaches the threshold (predefined) then that FN suspended for energy storage. The forwarder node's packet handling rate (PHR) calculated by using send array and receive array. Nevertheless, the scalability and mobility occurred.

In [55] developed a genetic algorithm-based cluster protocol. In cluster-based routing nodes gather data and forwarded it to the cluster head. That accumulates the data and transmits it to the base station in multiple clustering rounds. For selecting the CH in each round, GA-LEACH randomly selects from nodes according to the predefined threshold value (between 0 & 1). Each node calculates the distance from the source and BS called part of the fitness function. So the CH selected for this fitness function. The proposed algorithm can maintain a longer lifetime. However, the throughput, end-to-end delay, and packet delivery are slow.

Energy Efficient Sustainable Network that uses Network Optimization Technique (EFS-NOT) [39]. The initialization of the network begins with Hello Packet by the body coordinator (BC) so the network established between the nodes. After that, continuous monitoring results in storage issues. It can be resolved by using data compression (by using Huffman) and data encrypted using the smart grid and decrypted. The is selected after encryption and decryption For energy efficiency using an Adaptive Scheduling Protocol, that switch the nodes from active to sleeping can minimize the energy consumption. The new system performs better in terms of network, transmission rate, and latency, and reduces packet-dropping rate. Future work will expand the network with different technologies.

A cooperative routing protocol (CRP). The multiple sources (sensors) that monitor the human body and several relay channels that dispense different pathways for data transmission and eradicate points of failure. If a failure occurs in one relay then the remaining relays would have to receive, create, and forward the excessive packets to the destination in increasing the aggregative transmission time. It uses CRP in MATLAB, which has a set of nodes that generates data that transmitted to the destination. Then the scheduling processed. The data is processed and analyzed Critical data (this data s directly transmitted to the physician) and normal data (this data directly transmitted to the database). This way the criticality of data scheduling minimized. This way the network's security level, fault tolerance, and computation time are improved. The deficit increases if the delay is five times [56].

Fuzzy based Energy Efficient and Low SAR (specific absorption rate) routing protocol (FEELS) that uses clustered-based routing [57]. By assigning weights according to SAR's sensitivity from 1-4. As the proposed scheme used clustered based protocol, the cluster head selected for data transmission. The node has a low bitrate and has the permission directly send the data to the hub. The reliability of the link is measured by received signal strength (RSS) [41]. It improves end-to-end delay, lifetime, and stability. Nevertheless, the latency is low as compared to the other two protocols.

Fuzzy Energy Budget based Vikor-MADAM protocol (EB-Fv-MADM) that selects the cluster head dynamically. The steps initiate node deployment and then ranked the nodes by Fuzzy- VIKOR-based compromise node ranking. Each cluster node calculates the three nodes' attributes in its attribute packet. That packet transmitted to the sink. It turns the value from attributes to fuzzy grades very low, low, medium, high, and very high. These grades defined as Triangular Fuzzy numbers. The sink node determines the Fuzzy Positive ideal solution and Fuzzy Negative Ideal Solution. It provides 93.80% of throughput along with an end-to-end latency of 9.595ms. The proposed program did not eliminate cross-channel interference in real life [58].

In [59] proposed a block chain-assisted delay and energy-aware healthcare monitoring (B-DEAH). It distributes the key to each patient having parameters id, password, location, and biometric records because the patient moves dynamically. For routing, cluster heads selected based on the residual energy and MOORA algorithm s used for selecting the CH. After that, contention window size (CWS) created by residual energy, RSSI, and distance. Patient Block Agent (PBA) searched using four-Q-Curve, which accumulates the data and forward it to entities. Then the data classified into three classes of packets (periodical, fault data, name, and emergency). The packets encrypted through extended- a present algorithm that is a small-size block-cipher-encryption algorithm. Finally, the route selected for data forwarding. It improves packet loss rate, residual energy, end to-end delay based on periodic and authentication time and reliability. In the future, investigate the problem of BAN, and MAC scheduling to manage the energy of each sensor.

Energy-efficient routing and QoS- supported traffic management protocol (ERQTM) for software-defined wireless body area network (SDWBAN) [60]. This scheme has two correlated algorithms energy-efficient routing algorithm and a QoS traffic management algorithm that regulate the no. of clusters needed. For the energy consumption model SDN, allot time slots through TDMA. However, the posture of the patient's body affects the radio signals for this path loss model used. For energy efficiency, CH elected to reserve energy consumption. Generic Algorithm resolves the multi-objective based scheme. It gives the high transmission rate and end-to-end delay is low, and residual energy is efficient. It cannot do cross-layer intersections.

In [61] designed an Energy Budget based Multiple Attributes Decision Making protocol (EB-MADM). The proposed scheme's first stage is localization, after the deployment of sensor nodes distance of nodes calculated before each round using receive signal strength indicator (RSSI). TDMA used to air the message. The second phase is to elect the cluster head dynamically. In this process, it calculates the cost based on the residual energy While transmission of data between the child node and parent node. Then estimate the energy budget and elect the best cluster head. After that, the data sensed through sensors. The child node forwards the data to the cluster head or sinks node. After the accumulation of data also including the datum packet (which contains child node ID and data), it is sent to the sink node. This scheme prolonged the lifetime, stability period, and throughput. However, it has to implement in the real-time environment of WBAN.

Fuzzy logic-based clustering protocol that routes the data for WBAN. After deployment, the distance estimated by RSSI. Moreover, the sink node forwards the hello packet. Therefore, each node calculates the distance between the sink and other nodes. Then the cluster head elected on basis of residual energy and cost function value. Moreover, the energy packet forwarded to the sink on that information the cluster selected. Weights assigned by the sink based on the importance of using a Genetic Algorithm (GA). This scheme stabilizes the network and is highly reliable. However, could not control the cross-channel interference and QoS performance. [62].

Clustered based for inter-body interference for BANs. It is a transmission between two networks by CH uplink and both share the same frequency band. The interfering CH causes interference of desiring CH. Brock fading during transmission link randomly changes from one to another. Nevertheless, assumed that each sensor in the network encounter flat fading. In addition, outage events occur due to the capacity of the current encryption rate being low. All the parameters mentioned during the fixed threshold. It is simultaneously applicable. However, cannot overcome the energy consumption issue [63].

2.4 On-Demand Routing:

In [64] proposed routing protocol of WBAN that is Energy Aware and Stable Routing protocol (ESR). Its purpose deployed in hospitals and distributed communication. This scheme worked in a way that discover the best path for data transmission. As it assures a stable network however with high-energy consumption.

A data-centric routing for Intra WBANs that modifies on-demand routing. [65]. The researcher used two types of the network model that is data centric with and without relay nodes. In without, sensors are implanted inside the body, use limited transmission power, and behave as forwarder nodes [66]. It forwards the sensor data to the body coordinator (BC). It categorizes into different types like Daley sensitive data (DSD), Reliability Sensitive Data

(RSD), and Normal Data (ND) [67]. It performs better in delay and reliability. The future work is to increase the Packet Delivery Ratio (PDR).

Link-Quality Aware and Thermal Aware On-Demand Routing (LATOR) protocol [68]. Which improves the Packet Delivery Ratio (PDR) and prevents overheating of nodes. LATOR has phases i.e. Route request (RREQ) and Route response (RREP), Route Maintenance and Route Error (RERR) performed. As compared to other protocols i.e. LTOR, all the functionality is the same rather than controlling the temperature nodes examine the Link Quality Information (LQI). LATOR switched node when the node heated until its temperature is down. The LATOR has a 73.10% of packet delivery ratio while LAOR has a 74.89% with no temperature control scheme.

Temperature link-reliable, delay-aware routing protocol (TLD-RP). The system starts from network initialization by forwarding the Hello packet to nodes so that its neighbor known. For delay minimization, the transmission of packets periodically and path quality estimated. The path quality estimator leads to a reliable and stable link for transmission. QoS-aware route discovered by exchanging hop count to routing metric. Moreover, source node checks its routing table for the route if the route exists then it transmits to the destination or sends the route request (RREQ) to downstream nodes. After the route maintained if there is, any heated node or QoS shortage or failure of link for this route error (RERR) message is on or for immediate action. It improves in throughput, delivery ratio, and end-to-end delay. However, no improvement in QoS-aware routing protocol[69].

2.5 Comparison Of Existing Routing Protocols

Table2.1: Comparison of Existing Routing Scheme

Reference	Method	Pros	Cons
Multi-hop Routing			
Bhangwar, A. et al. [18], 2019	Weighted, QoS-based, energy and Temperature aware	WETRP's energy 10% and temperature 10%	Throughput is decreasing as the network load

	routing protocol (WETRP).	to 20% awareness display less temperature rise at high data transmission rate.	reaches(100kbps) the network pressure wireless links
Iyobhebhe, M. et al. [20], 2022	Dual Sink Approach using Clustering in Body Area Network (iDSCB)	It improves the end-to-end delay by 3.16%. Also improves the throughput by 6.59%.	Buffer traffic state will be consider to that reduces the number of dead nodes.
Chavva, S. et al. [21], 2019	Multi-Hop Routing	It improves throughput 12%, more residual energy 5%, reduce path loss less than 10%.	It preforms under due to cumulative minimum path loss.
Jibreel F, et al. [22], 2022	An enhanced Heterogeneous Gateway-based Energy-Aware multi-hop routing protocol (HMGEAR)	Improves the residual energy 30%, 20% throughput, and network lifetime.	Its nodes are dead as compare to other dataset and it reduces the lifetime.
Jamil F, et al. [23], 2019	node calculated by hop-count and is apart into rings and each ring has several nodes	It p6erforms 10% efficiently with throughput.	However temperature of nodes raised. because of the fastness
Khan RA, et al. [24],2018	An energy efficient and stable network.	Packet receive ratio (Throughput) is 30% high.	However single hop for critical data sensors which slower the PDR and consumes high energy.

Nururrahmah A, et al. [32], 2019	An adaptive approach for selecting forwarder node	Perform better in packet delivery ratio and energy consumption	Can't move dynamically during the daily life experiment scenarios
Qu Y, et al. [27], 2019	The reliable data transmission and dynamically choosing the next hop node.	Successfully transmits the data to the sink node.	However with low throughput and consuming huge time.
Nadeem Q, et al. [33], 2019	Routing protocol for WBAN.	It is reliable, power efficient, and high throughput routing protocol.	It can't count the expected transmission count (ETX).
Maymand LZ, et al. [34], 2017	thermal aware routing protocol with two thresholds	This scheme provides a High packet delivery ratio (PDR) 4%, low delay 6%, and 5% energy consumption.	The issue may arise when the temperature of the node goes up and s difficult to level down.
Yan J, et al. [35], 2018	Optimal Energy Consumption Artificial Bee Colony(OEABC)	ORABC is performing better than the Genetic and Ant Colony Algorithm in consuming energy and convergence ratio.	While the first 50 iterations consume high energy rather than 100 or 150.
Ahmed G, et al. [36],	Thermal aware, energy-efficient, and	It increases the throughput	In future the proposed protocol can

2019	reliable routing protocol	balance of the packet collision.	be implemented on simulator like NS2, OMNET, and OPNET.
Ahmed G, et al. [37], 2017	priority-based energy-efficient routing algorithm (PERA)	It has throughput and 10% path loss.	Due to batteries, it can't gather all the information and consumes 30% more.
Ahmed O, et al. [47], 2020	Energy Optimized Congestion Control based on Temperature Aware Routing Algorithm (EOCC-TARA).	It provides 50% throughput, the path loss, and therefore packet is also minimized, and only 10%hotspot issue.	But this network has a mobility problem.
Bouldjadj S, et al. [48], 2020	High Throughput And Thermal Aware Routing Protocol (HTTRP)	It consumes 50% energy less and diversifies the route.	The packets could be dropped due to the continuous use of the same path for transmission and congestion occur.
Selem E, et al. [38], 2019	temperature heterogeneity energy (THE)	The proposed network performs 5% better in terms of lifespan and 15% high throughput in low temperatures.	As the 10% temperature rises the 10% throughput of the network would be slow.
Kamruzzaman M M, et al. [39],	Energy Efficient Sustainable Network	It performs better in terms of	In future this technology s

2022	that uses Network Optimization Technique (EFS-NOT).	network, 40% transmission rate higher than other, and latency, and reduces 20% packet dropping rate.	incorporate with big data, machine learning, deep learning, and block chain.
Rahman H, et al. [40], 2022	Dual Forwarding Selection Technique(DFST)	That improves network lifetime, throughput, and stability period.	In future network lifetime can be improved and security techniques can be implemented.
Shunmugapriya B, et al. [41], 2022	Routing protocol based on relay node selection	It performs better in terms of latency, throughput, end to end delay, and PDR.	Due to battery usage their lifespan is limited.
Roy M, et al. [42], 2022	cost-based routing protocol ZITA	It improves timeliness, link quality, temperature control, and energy efficiency for the transmission of data.	It increases the node's heat rate while moving and decreases the delivery ratio in multi-hop routing.
Reddy K V, et al. [43] [64], 2021	Energy-efficient communication protocol for WBAN	The proposed protocol longs the network lifetime, throughput, and energy for various nodes.	But it is a difficult small network.

Abdu A I, et al. [45], 2019	energy-aware QoS-Guaranteed WBAN (EQ-WBAN)	The proposed scheme enhances the network lifetime, and throughput, and reduces the delay, energy consumption, and dropping packets.	But can't secure from spoofing, jamming attacks, and eavesdropping.
Kaur S, et al. [46], 2021	AHP-TOPSIS	It provides flexible relay node selection.	It can't be used in postural movement and mobility of sensors.
Al-obaidi M A D, et al. [29], 2020	Energy consumption reduction and enhances the network lifetime through the addition of sleeping mode in the SIMPLE protocol.	It provide the scheduled sleep mode.	The packet could be dropped in sleeping mode.
Dakhel, et al. [49], 2019	high throughput, reliable, power efficient protocol for WBAN	It uses single-hop and multi-hop routing for the transmission of data.	It wouldn't allow the body to move to make the whole network shut down.
Soni S, et al. [50], 2017	Increased throughput with an optimized Sink(ITOS)	It improves the throughput and the lifetime of the network.	It can't enhance the stability of the network.
Clustered Based Routing			
Nabavi, S. et al.	The efficient schemes	The	By selecting nodes

[16], 2020	in enhancing lifetime as well as scalability of the wireless sensor networks is clustering	temperature of the sensor nodes embedded in the body doesn't increase over time and tends to be constant.	with low temperature may risks the patient. High energy consumption reduce lifetime of network.
Umare A, et al. [51], 2018	Genetic Approach to discover the energy consumption	It performs better in terms of energy dissipation 10% and throughput 10% to 20%.	While performing low in terms of network availability, secure localization, dependability, and data confidentiality.
Boudargham n, et al. [54], 2018	The scheme that increases the network efficiency	It performs better in concern of 40% less energy consumed.	Due to wrong cluster head higher delay. Also fail to retransmit it.
Ullah F, et al. [25], 2021	Energy efficient and reliable routing scheme(ERRS)	It improves stability and reliability.	The scalability and mobility issue occurs.
Nayak P, et al.[34], 2017	GA-LEACH	It can maintain 20% longer lifetime.	The are relatively throughput, end-to-end delay, and packet delivery are slow.
Oleiwi S S, et al. [56], 2022	Cooperative routing protocol (CRP)	The network's security level, fault tolerance, and computation time are improved.	The deficit increases if the delay is five times.

Zadoo M, et al. [57], 2022	Fuzzy based Energy Efficient and Low SAR(specific absorption rate) routing protocol	It improves end-to-end delay, lifetime, and stability.	But the latency is low as compared to the other two protocols.
Choudhary A, et al. [58], 2022	Fuzzy Energy Budget based Vikor-MADAM Algorithm(EB-F_v-MADM)	It provides 93.80% of throughput along with an end-to-end latency of 9.595ms.	The proposed program didn't eliminate cross-channel interference in real life.
Anbarasan H S, et al. [59], 2022	Clustered based routing	The block chain-assisted delay and energy-aware healthcare monitoring(B-DEAH)	It improves packet loss rate, residual energy, end to-end delay based on periodic and authentication time and reliability.
Samarji N, et al. [60], 2021	Clustered Based Routing	energy-efficient routing and QoS-supported traffic management scheme(ERQTM)	It gives the high transmission rate and end to end delay is low, and residual energy is efficient.
Choudhary, et al. [61], 2019	Energy Budget based Multiple Attributes Decision Making Algorithm(EB-MADM)	This scheme prolonged the lifetime, stability period, and throughput.	It has to be implemented in the real-time environment of WBAN.
Choudhary A, et al. [62], 2020	Fuzzy logic-based clustering protocol	This scheme stabilizes the network and is highly reliable.	It couldn't control the cross-channel interference and QoS performance.

Jameel F, et al. [63], 2017	Inter-body interference for BANs	It is simultaneously applicable.	But can't overcome the energy consumption issue.
On-demand Routing			
Smail O, et al. [64], 2016	Energy Aware and Stable Routing protocol (ESR)	Best path for data transmission.	Frequent changes of topology exhaust the batteries performance.
Bangash J. I. et al. [65], 2015	Data-centric routing for Intra WBANs	It performs better in delay and reliability.	The future work is to increase the Packet Delivery Ratio (PDR).
Caballero E, et al. [68], 2020	Link-Quality Aware and Thermal Aware On-Demand Routing (LATOR) protocol	LATOR switched node when the node is heated until its temperature is down.	The LATOR has a 73.10% of packet delivery ratio while LAOR has a 74.89% with no temperature control scheme.
Memon S, et al. [69], 2021	temperature link-reliable, delay-aware routing protocol(TLD-RP)	It improves in throughput, PDR, and delay.	But no improvement in QoS-aware routing protocol

2.6 Research gaps and directions:

In the WBAN routing protocol, we have inspected different routing protocols in existing research work. Based on the analysis of the state-of-the-art literature in a multi-hop routing protocol, some issues mentioned in the above table have not been focused on. The following are the issues that are investigated;

- Multi-hop-based approach is the most suitable for forwarding the data packets. Where appropriate, links are established based on the nearest neighbor nodes. However, to TAEO to maintain these links are not guaranteed to be reliable due to traffic collusion, packet drop and retransmission [19].

- Massive data transmission from the different nodes on the same route leads to packet drops and low packet delivery ratio (PDR) [19].

- ERRS protocols does not offer a network stability with respect to energy balancing scheme when a node shares information continuously with its neighbor nodes [25]. Routing table updates continually that shrinks the network lifetime.

- If temperature exceed in the network which effect the human tissue and also the network performance. In TAEO, the technique which is used behaves different on different body parts which leads to unreliability [19].

For thermal aware high throughput routing, a number of protocols have been put forth, with the most crucial considerations being energy efficiency, body temperature, link quality, packet delivery ratio (PDR), energy updates, network architecture, and sensing power. In broad terms, WBAN research is expected to monitor the body in real time and use such information to take reasonable precautions. Also, address the accuracy of schemes that depend on the parameters like data sensing, temperature monitoring, route planning, and traffic management between sensor nodes, energy consumption and updates. In a high throughput protocol, the nearest neighbor nodes are chosen to transmit information needed for route planning, while setting the farthest node could cause in end-to-end delay, poor connection quality, and packet loss.

Based on the aforementioned conclusion, the current research suggests a thermal aware high throughput routing protocol that should be capable of effectively monitoring the human body and estimating the link quality for batter route planning, an algorithm to control energy usage. Additionally, it ought to improve PDR and shorten end-to-end latency in real-time.

2.7 Summary

In this chapter, existing routing protocols discussed. The analysis of this presented in terms of energy efficiency, low packet delivery ratio (PDR), link quality, temperature control and multi-hop techniques. The basic idea, working, merits and demerits discussed in Table 2.1, and research gaps in the literature highlighted and lead to the new direction. That proposes a new method for thermal aware high throughput routing protocol for WBAN.

CHAPTER 3

METHODOLOGY

3.1 Overview

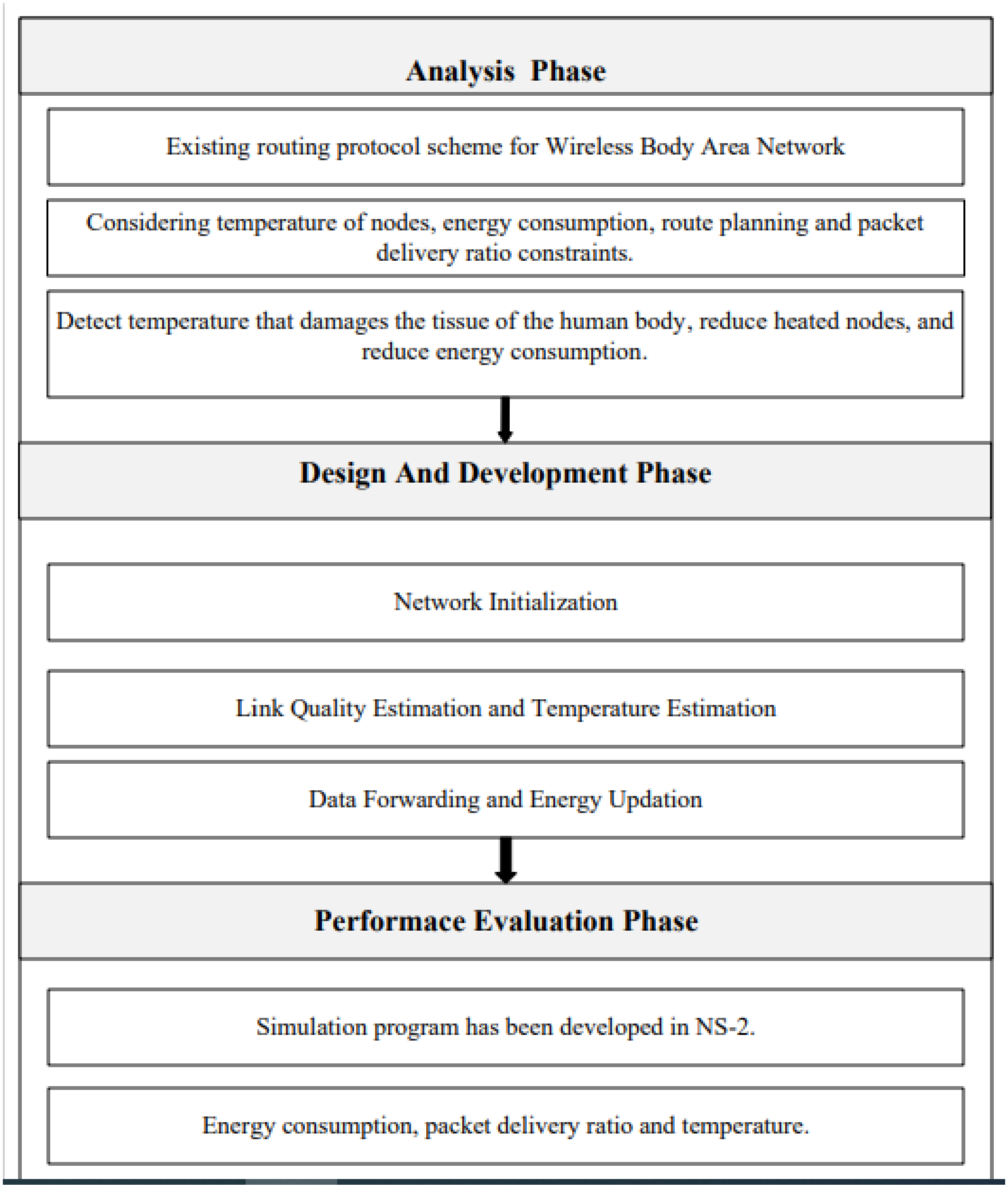
This Chapter proposed a novel mechanism for thermal aware high throughput (TAHT) routing protocol for WBAN. This technique intended to monitor the temperature and energy of sensors by defining threshold and link quality by manipulating metrics. The principal is to build a mechanism that selects the energy-efficient and low-temperature node from its neighbor, end-to-end delay, and network lifetime in a wireless body network environment. Consequently, the proposed solution generates the strategy to bring about set objectives. In the second phase, the most stable route for the next hop will elected by analyzing and integrating the lower cost value. For cost value, link quality computed before data forwarding using four metrics, the selected route performs better in terms of end-to-end delay. The third phase is to balance the energy of the network because the continuous use single node often causes the death of nodes, which limits the performance and reduces the network lifetime.

3.2 Operational Framework

Thermal aware high throughput (TAHT) routing protocol designed to avoid hotspot issues and the Packet Delivery Ratio of WBAN. The operational framework divided into different phases shown in Figure 3.1. In the first phase, understand the existing scheme and identify the challenges involved in the pursuit of developing an enhanced energy-efficient

Routing protocol that eventually leads to problem formulation. The second phase diverse the limitations found during the exhaustive survey and the steps required for the designing of the TAHT protocol. Finally, the third phase evaluates the performance of the developed protocols against the state-of-the-art and well-known routing protocols regarding energy consumption, end-to-end delay, and network lifetime and packet delivery ratio.

Figure 3.1: Operational Framework



3.3 Research Design and Development

This section will design and develop the TAHT routing protocol that is to be composed of network initialization, link quality estimation, route planning, and maintenance phase.

3.3.1 Network Initialization

To design TAHT-based WBAN, the first sensor nodes and sink nodes initialized for transmission behavior. In the network initialization phase of TAHT protocol, the information distributed to the whole network to set up the route. The sink node broadcast the "Initial Packet" message that information is disseminating its node's ID, temperature, time stamp, and energy to its 1st-hop neighbors. The nodes receive the packet and store the information. The nodes further broadcast the packet to its 1st-hop node and so on. So all the nodes maintain the routing table that contains the information about neighbor nodes as shown in figure 3.2.

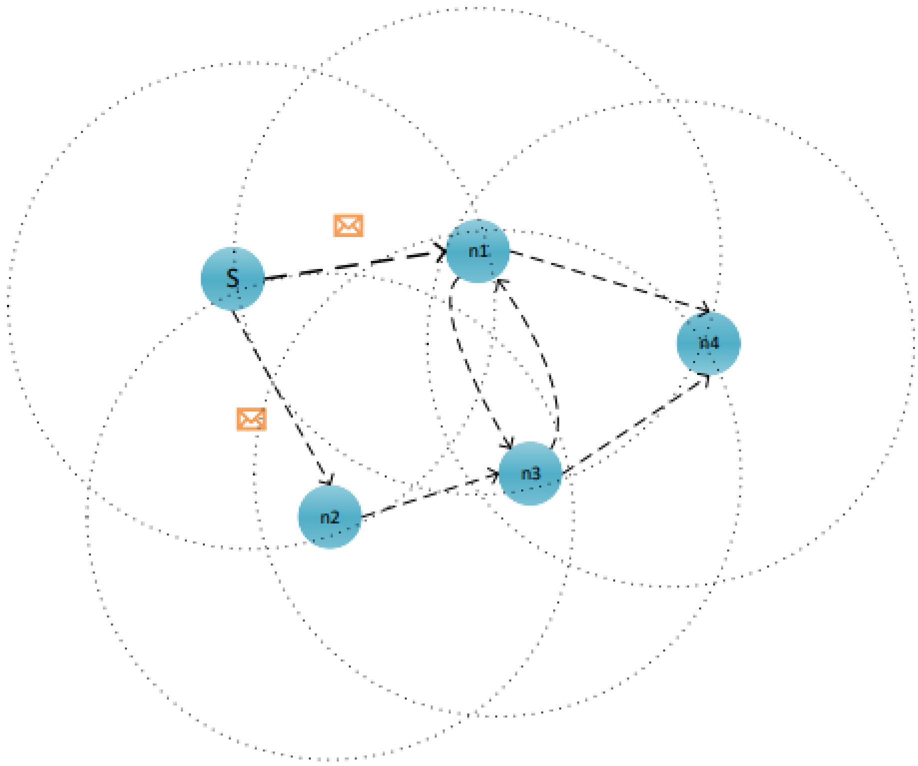


Figure 3.2: Information Distribution

3.3.2 Link Quality Estimation

The patient's mobility frequently causes the link quality to fluctuate. Selecting an uninterrupted connection for data forwarding becomes increasingly difficult in wireless networks where radio waves channels are particularly subject to depletion, noise, and multipath impact, as well as environmental conditions. In order to evaluate the link quality between the first hop neighbors, the node's link quality calculated using a fuzzy logic-based link quality estimator (FLQE) [71]. Where Four metrics are estimated by FLQE for the quality of link: the signal-to-noise ratio (SNR), the stability factor (SF), the link asymmetry (ASL), and the packet receive ratio (PRR). The actual quality calculated for each metric. Five packets with the node id and timestamp required by FLQE must forwarded to neighbors in the direction of the sink. FLQE estimates multiple link quality on the channel level and packet level. Moreover, FLQE reduces end-to-end delay and reduces the retransmission for the successful delivery of the packet.

3.3.3 Temperature Estimation

The temperature of the nodes mounted on the patient body and continuous processing increase the temperature of the nodes and tissues. Due to thermal dissolution, the smaller temperature ignored. The thermal dissipation from nodes influences the patient's tissue. It also raises the issue of network stability and lifetime. In TAHT, the node's temperature measured by defining a threshold. If any node in the network is heated and exceeds from threshold level heated node will suspended for the upcoming three or more rounds until its temperature reaches the threshold level.

3.3.4 Data Forwarding and Energy Updating

In TAHT, this phase begins with route planning as each node will have a temperature, link quality, ID, and energy of each node based on these parameters i.e. energy, temperature, and link quality for cost calculation for route selection. Temperature profound effect on TAHT network's link because an increase in temperature does suspend the nodes for transmission, resulting in a heavy load of traffic and a low packet delivery ratio (PDR). In TAHT, each node selects the nodes from 1-hop neighbors in the direction of the sink based on cost. The energy utilization affects the cost value, which means the node having higher energy will have the highest priority and low-cost value in the routing table. Consequently, the forwarder node selects the node having the highest energy, low in temperature, adds its ID to the data packet and overhead the packet as shown in figure 3.3.

For energy balancing, TAHT keeps the forwarder node informed of the remaining energy of their 1-hop neighbors in figure 3.4. Although the forwarder node only receives the information of its range. This helps to select next hop node based on their energy, temperature and link quality. During this process of forwarding and receiving data packet energy decreased. This mechanism balances the energy, attains a long lifetime of the network, and reduce the energy consumption while processing, forwarding and receiving data packet.

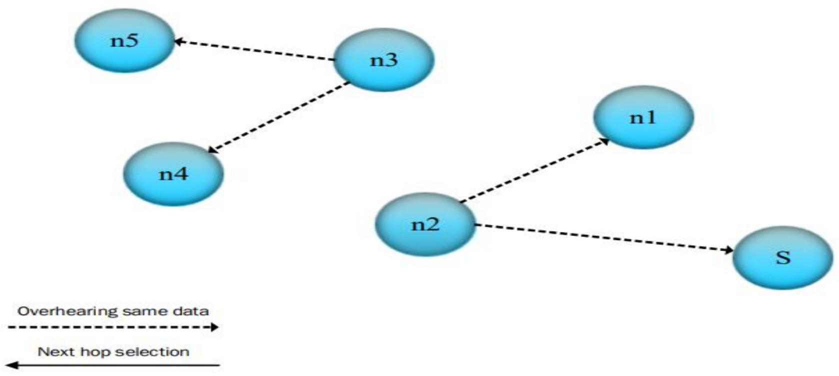


Figure 3.3: Update After Overhead the Packet

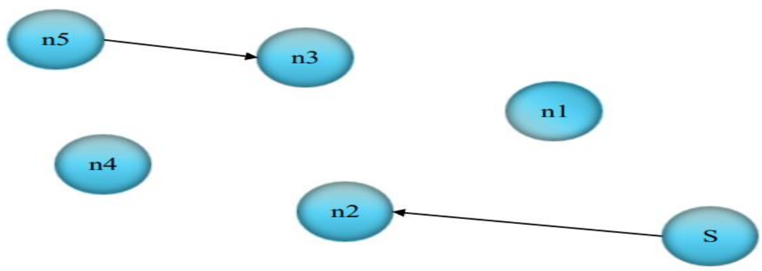


Figure 3.4: Energy Balance

3.4 Simulation Framework

The environment of THAT protocol has been calculated using comprehensive experiments. The simulation managed in combination with thermal aware high throughput in WBAN. NS-2 simulator that provide support for WBAN. NAM is an extension of NS-2 simulator used to add animation. Table 3.1 shows the parameter and environment setting for THAT. The simulation setup consists of 2m x 2m network area and total 11 sensor node are deployed including 1 sink sensor node. TAHT uses wireless network interface type with CBR traffic type. Simulation begins after setting all the simulation parameter to evaluate the TAHT and is compared with protocol such as ERRS [25] and TAEO [19].

3.4.1 Simulation Parameters

To estimate the performance of TAHT protocol the sampling method consider the following evaluation metrics packet delivery ratio, throughput, number of dead nodes, temperature rise, and network lifetime.

Table 3.1: Simulation parameter for TAHT

Parameters	**Values**
Area of simulation	2m x 2m
Number of sensor nodes	10
Number of sink sensor nodes	1
Transmission range of a sensor node	50cm
Propagation Model	TwoRayGround
Network Interface Type	Wireless
Traffic Type	CBR
IEEE 802.15.4 Standard	Default Value
Simulation Time	1000 sec
Temperature Threshold	(36-40) °C
Initial Energy	50 J
Energy Threshold	20% of initial energy

3.4.2 Performance Metrics

1) ***Throughput (T):*** When packets successfully delivered from the source node to the sink node, throughput is determined. The expression that follows can utilized to calculate throughput. An optimized throughput increases the performance of the network [4].

$$T_{avg} = \frac{p\_size}{\text{time}} \tag{3.1}$$

Where p_size node's data packet size and time taken for sending data packet to sink.

2) ***Packet delivery ratio (PDR_{avg}):*** shows the difference between the number of packet sent to sink and number of packet sent to nodes from each possible routes, and its equation is shown below [25].

$$PDR_{avg} = \frac{P\_rec}{P\_sent} \tag{3.2}$$

P_rec is total number of packet received at sink node and *P_sent* is total number of packet sent from source node

3) ***Number of dead nodes:*** Employs a stable network. The stability span is the time from the beginning of network operation until the death of the last node. The frequency range has an immediate influence on the network's durability [25].

4) ***Temperature rise ($Temp_{avg}$):*** The nodes that are highly involved in data transmission could raise temperature due to heavy traffic. So we define the threshold vale to control the temperature of nodes [19]. The average temperature of the node calculated as follow.

$$Temp_{avg} = Thr\_temp - N_{cur}\_temp \tag{3.3}$$

5) ***Network lifetime (N_life):*** Influenced by energy consumption, which calculated as the difference between the starting and ending levels of energy. The average network lifetime is calculated by following expression [70].

$$N\_life_{avg} = \frac{\sum_{i=1}^{n}(E\_s - E\_f)}{n} \quad (3.4)$$

Where i is number nodes, *E_s* presents the starting energy with respect to b data packets and *E_f* final energy

3.4.3 Limitations and Assumptions

i. It assumed that all the nodes are static and every node knows the position of other nodes.
ii. Including sink all the sensor nodes are heterogeneous and sink is assumed to have unlimited battery power and processing capability.
iii. Sink node is placed at the center of the human body and is responsible for transmission of data packet.
iv. In the beginning, all nodes have equal energy.
v. First, hop sensor nodes of sink node forward data to sink using single hop.

3.5 Thermal Aware High Throughput Routing Protocol For Wireless Body Area Network (THAT)

The proposed TAHT scheme overcome the shortcomings of route planning for link quality and thermal detection to control the suspension of nodes and data forwarding and energy balancing. The proposed model is able to detect the sensitive data and forward it in real time. The consist of four schemes (i) Initial Network Development (ii) Estimation of Link Quality

(iii) Estimating Temperature (iv) Forwarding Data (v) Energy Equilibrium. As shown in figure 3.5.

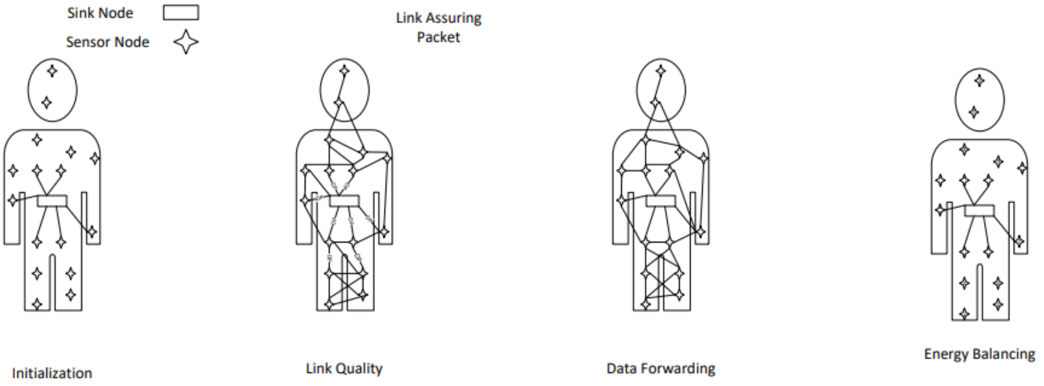


Figure 3.5: Network Architecture of TAHT

3.5.1 Initial Network Development

In Thermal Aware High Throughput (THAT), the First phase is to initialize the network by distributing the Initial packet between nodes in the network, so each node knows its neighbors. Hence, a reverse path is establish in hop-by-hop manner, from each node to the sink. TAHT locally compute the information about neighbor nodes by forwarding Initial packet. The format of the Initial packet is shows in the Figure 3.6. Forwarder ID is unique to identify each node and Energy is use to present the remaining energy of the node while Temperature presents the forwarder node temperature. The time taken by the packet to send is calculated using Timestamp information.

Initial Packet

Packet Type (8 bits)	Sender ID (16 bits)	Energy Remainning (16 bits)	Temperature (32 bits)	Timestamp (32 bits)

Figure 3.6: Initial Packet Format

The sink node at the center and sensor nodes are implanted on different organs of the body that senses the data and forwards it to the sink in a multi-hop manner. The network starts from the distribution of information by sending an Initial packet to its 1-hop node in its range. On receiving the Initial packet sensor nodes forward an acknowledgement signal to the sink and store the received information in the routing table. This node further broadcast the message to its neighbor in each direction then all 1-hop neighbor nodes note the information and maintain a routing table. This process continues until all nodes store information about their 1-hop neighbor nodes.

As the information distribution is complete, the next phase is to estimate the link quality. Fuzzy Logic Link Quality estimation (FLQE) tool metric as performed in the section below. For reducing the end-to-end delay by reducing the retransmission and increasing the packet delivery ratio (PDR). Therefore, at the starting of route planning and data forwarding node calculate energy, temperature and link quality.

3.5.2 Estimation of Link Quality

TAHT uses FLQE out of many estimators that integrate four metrics and provides separate property individually. Packet Receive Ratio (PRR) smooths the temporary changes for successive PRR, Asymmetric Link (ASL) that calculate the difference between the packet received from source to destination and inversely. The stability factor (SF) calculated for changes in PRR numerous times, and the signal-to-noise ratio (SNR) calculated on received packets.

$$FLQE(\alpha, W) = \alpha \times F\,LQE + (1 - \alpha) \times LQ \tag{3.5}$$

α is constant and the range is from [0-1], w represents the number of the received packet, and LQ combines the four metrics [71].

$$LQ(W) = 100 \times \mu(i) \tag{3.6}$$

Here 100 is the highest and best case and 0 is the lowest and worst case of $\mu(i)$ [71].

$$\mu(i) = \beta \times \min(\mu PRR(i) + \mu ASL(i) + \mu SF(i) + \mu SNR(i)) + (1 - \beta) \times \text{mean}(\mu PRR(i) + \mu ASL(i) + \mu SF(i) + \mu SNR(i)) \quad (3.7)$$

$\mu(i)$ is a subset of link quality, β is a constant and its range is [0-1] [71].

It proven that FLQE is a reliable estimator among others link estimators and it has the advanced feature of SNR and stability factor. According to FLQE formula by [71].

FLQE calculate link quality using Link assuring packet contains only timestamp and ID of potential neighbors. As shown in Figure 3.8. Link assuring packet exchanged between source and receiver to compute the link quality. FLQE uses five packet but in absence of certain information, FLQE ignores and compute four metrics and link quality. Following is the scheme for link quality estimation.

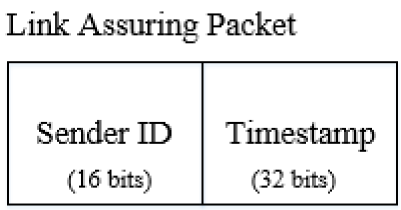


Figure 3.8: Link Assuring Packet Format

Table 3. 2: Notation and their Description

Symbol	Description
C	Packet count
ć	Time counter
F	Frequency
SL	Source level of the signal at a given frequency f
NL	Noise level at the receiver over a given frequency f.
TL	Transmission loss is the total reduction in signal intensity over a distance l at frequency f.
DI	DI is Directivity Index

Algorithm 3.1: Link Quality Estimation scheme in THAT

```
FLQE packet Received
if node_ID Exist In T AB then
        Cancel Previous Waiting_Time & Start_New Waiting_Time
        c ← c + 1      //  update packet count,
    ć ← ć+ 1      //  update the time count
        SNR = SNR+(SL−T L−NL+DI)   //  Calculate SNR values for each packet
   if (ć ≠ c) then    //  time counter is not equal to packet counter
        PRR = PRR + α.PRR/(ć−c)  //  calculate increment in PRR value
   end if
   if (ć >= 5) then    //   counter ć to receive packets is completely expired
      Countprr = Countprrmode5     //  history of packet received ratio
      PRR[Countprr + +]  =  c/ć
   SF = Σ(PRR[0 : 4])/5    //  calculate stability factor
      Call_FLQE_Calc     //    call the FLQE calculation function(calling sub-function figure 3.8)
   end if
Else
    Drop_Packet   //   node doesn't exist in routing table
end if
if Wait_Timer_Expired then   //  if a packet is not received in given time
    ć ← ć + 1   //   Increment time counter
   if (ć ≠ c) then   //   time counter is not equal to packet counter
   PRR = PRR− α.PRR/(ć −c)   //   calculate reduction in PRR value,
   end if
   if (ć >= 5) then  //  counter ć to receive packets is completely expired
   Countprr =  Countprrmode5  //  history of packet received ratio
      PRR[Countprr + +]  =  c / ć
     SF = Σ(PRR[0 : 4])/5    //  calculate stability factor
      Call_FLQE_Calc   //   call the FLQE calculation function(calling sub-function figure 3.8)
   end if
else if
if (ć < 5) then   //  incase of any packet loss
     Reset & Start_New Waiting_Time
```

33 **end if**

In link quality estimation scheme, on receiving FLQE packet from a node initially it determines in routing table weather it exists or not. If it exists in the routing table of destination node, it eliminates the previous waiting_time and starts waiting_time with the forthcoming packet. On other hand, it simply discard the packet. It also update the packet count c and time count ć. The Signal-to-noise ratio (SNR) compute link quality for each packet received. A receiver determines if ć = c to estimate the increase and decrease in Packet Receive ratio (PRR). If the packet received successfully, PRR increase otherwise PRR decrease if packet is not received on time. Second, it checks the time for five FLQE packet is expired or not by check in the value of count, ć. Stability factor calculated over history of five PRR and stored the value in array. Then the Call_FLQE_Calc called for FLQE calculation as shown in Algorithm 3.2.

Complexity of Algorithm 3.1

For above Algorithm, time complexity is given by T (n). At first, it's a general statement taking constant time i.e. O (1). The first conditional statement runs for 't' constant time so it is given as O (t). The next conditional statement in step-7 takes constant time given as O (1). In next step-14, it checks the condition up to 5, each statement in the body of this conditional statement execute for constant time, so total cost it will take is O (5t). In next the statement executes for once i.e. O (1). In else case, from step 19-28 each statement executes for once so it takes O (t) time. Step 31-32 also takes O (1) time. Therefore, the sum of total cost given as below.

$$\mathrm{T}(n) = O(1) + O(t) + O(1) + O(5t) + O(t) + O(1)$$

$$\mathrm{T}(n) = O(t)$$

Where't' is a constant, hence, reducing the higher terms to low the overall time complexity of the algorithm 3.1 is O (1).

Algorithm 3.2: FLQE estimation (Call_FLQE_Calc)

```
W here i = 1, α = 0.9, β = 0.7, w = no. of packets = 5 and Flqe seed = 100
μ(i) = β ×min(PRRμ(i)+ASLμ(i)+SF μ(i)+ SNRμ(i)) + (1 − β) × (PRRμ(i) + ASLμ(i) + SF
μ(i) + SNRμ(i))/4  //   calculate member function
LQ = 100 × μ(i)   //    calculate link quality
FLQE(α, W) = α × 100 + (1 − α) × LQ  //  FLQE metric calculation
  return FLQE value
```

If packet not received at time ć expires then packet count c will it but ć increase d by 1. The receiver estimate the PRR value by comparing ć to c if they are not equal. Receiver also checks the time of receiving five packets and if time is expired and ć = 5 then steps 25-28 are repeat for computing the Stability factor (SF). A receiver calculate the FLQE value in Figure 3.8. But the time for five packet is not expired, then reset waiting time and wait for new packet.

Complexity of Algorithm 3.2

In Algorithm 3.2, a function defined to evaluate the value of FLQE. Each statement in the function executes for 1 unit of time. So, time complexity $T(n) = O(1)$.

3.5.3 Estimating Temperature

The temperature of the nodes mounted on the patient body notably affects tissue as result in tissue damage. The thermal dissipation from nodes influences the patient's tissue. Continuous processing rises the thermal dissolution of the nodes and tissues too. However, the smaller temperature ignored. It also raises the issue of network stability and lifetime. In TAHT, the node's temperature measured by defining a threshold. If any node in the network is heated and exceeds from threshold level heated node will be suspended for the upcoming three or more rounds until its temperature reaches the threshold level [72]. Normal human body tissue can tolerate (36°-40°) temperature [48]. In TAHT, temperature thresholds defined into three conditions for a node, as shown in the Algorithm 3.3.

Threshold Temp Condition	
Condition 0	N_{cur}-temp < N-temp
Condition 1	N_{cur}-temp >= N-temp < Thr-temp
Condition 2	N_{cur}-temp >= Thr-temp

Naming unit	
Neighbor node’s temperature	N-temp
Threshold temperature	Thr-temp
Node’s temperature	N_{cur}-temp

Table 3. 3: Temperature Estimation Table

Algorithm 3.3: Temperature estimation

```
If node_id Detect temperature exceed from threshold
If( Ncur-temp<N-temp)
   Packet_deliver
elseif (PDR==low && Ncur-temp>=N-temp< Thr-temp || packet == retransmission)
   Packet_deliver
If ( Ncur-temp >= Thr-temp )
  Do
     NCur-temp ← Suspend                    //  Suspend node
     N-temp ← NCur-temp                     //  Update node status
     i++
     While( i=5 )
endif
```

In the temperature estimation scheme, the temperature of a node is estimated on these three conditions. In condition 0, a node's temperature is compared with neighbor node and a node can receive and forward the data. Node's state changes from condition 0 to condition 1 when the packet delivery ratio (PDR) is low or retransmits. Moreover, if a temperature node is higher than the predefined threshold level this node is called a heated node it is said to be in condition 2. The node generates an alert packet and forwarded it to its neighbors. On receiving the alert packet, at first, it checks the routing table whether it exists or not. If it exists in the routing table of receiver, nodes update its routing table. A node will be suspended for the upcoming three or more rounds until its temperature reaches the threshold level.

3.5.4 Forwarding Data

In TAHT, a data packet has six parts which includes packet type, sender id, previous hop id, next hop id, sequence no, sender remaining energy. That helps to forward the data from source to destination. Shown in figure 3.12.

Data Packet

Packet Type (8 bits)	Sender ID (16 bits)	Previous Hop ID (16 bits)	Next Hop ID (16 bits)	Sequence Number (16 bits)	Sender Remaining Energy (16 bits)

Figure 3.9: Data Packet Format

Packet type describe the type to differentiate between Initial packet, link assuring packet and data packet, source id defines the source, previous hop id defines the beginning, next hop id is for selecting the node from routing table, residual energy of node that remains. Sink's location is known to all the nodes.

Route is calculated on temperature, energy, and link quality towards the first hop neighbor after distributing the data. The cost value is calculated on energy, temperature, and link quality between neighboring nodes by following equation.

$$cost(x) = W_1\left(1 - \frac{e}{e.thr}\right) + W_2\left(1 - \frac{temp}{tenp.thr}\right) + W_3\left(1 - \frac{LQ}{LQ.thr}\right) \quad (3.8)$$

Where the '*e*' is for the current node residual energy, '*temp*' represents the current node temperature and '*LQ*' represents the link quality estimation using FLQE. Weights *W* is assigned *W1, W2, W3* parameters energy, temperature, and link quality respectively, that is *W1>W2>W3* and *W1+W2+W3=1.* Their values are fixed *W1=0.5, W2=0.4, W3=0.2* respectively [72]. The highest weight is given to energy to enhance the network's lifetime ad run smoothly. The second highest weight is given to the temperature to prevent the tissue and also select the neighbors. The least is the link quality, which transmits data without damaging the tissue.

Algorithm 3.4: Packet Forwarding

```
If (S ∈ N_cur  &&  N_cur ∈ route_tab )    //  in 1st hop
    S ← N_cur   ||   N_cur ← S    // forwarding packet
```

```
    Elseif( S∈N_cur  &&  N_cur∉ Tab )
        N_n ← Call_Cost_Function()  //  Function call
        N_cur ← N_n
      If(N_n ≠ 0 )
       P.e ← N_cur.e       //  update
       P.t ← N_cur.t       //   update
       Repeat 5 to 10
        Else
      Packet_drop
      Endif
    Else
      Ph.count> maxhop
       Packet_drop
    Endif
```

The data forwarding scheme first analysis the node whether it's in the first hop neighbor of the sink or node if it belongs to the first hop neighbor the packet will forward to the neighbor node. However, if it does not belong to the routing table but its first hop neighbor it calls Call_Cost_Function to estimate the cost value as below Algorithm 3.5. Otherwise, it drops the packet if the packet count is larger than the maximum hop.

Algorithm 3.5: Call_Cost_Function

Cost.min=0, W1=0.5, W2=0.4, W3=0.2, E_{max}=100, $temp_{max}$=40°, LQ_{max}=100

$$cost(e, temp, LQ) = W_1\left(1 - \frac{e}{e.max}\right) + W_2\left(1 - \frac{temp}{tenp.max}\right) + W_3\left(1 - \frac{LQ}{LQ.max}\right)$$

If cost.min < cost **then**

Cost.min = cost

next_hop=N_n

Endif

Return to packet forwarding

The cost function estimates the cost value and the least valued node from the routing table are chosen for neighbor hop.

3.5.5 Energy Equilibrium

In this protocol, the energy of node is updating only when that node is in the range of sender. Energy equilibrium in network is an important factor as it contributes in expanding network lifetime.

Algorithm 3.6: Energy Equilibrium

If packet_reply_back **then** //check entry packet and sequence number

  Route table[N_{cur}].drop= 0

  Route table[ID_{ph}].energy = $energy_{ph}$

  Sorting route table // on new energy and temp

En**dif**

In the energy equilibrium scheme, when node B selects neighbor node A and on air the packet. Node A further broadcast the packet to the selected next hop. Since node B is in the range of node A, it will choose the same packet. To verify whether it is the same packet or not, it checks the packet entry in the routing table and packet sequence number as shown in the algorithm. After the confirmation message node updates the energy in the routing table. This process permits entries to use for the next hop that allow remove the decayed entries and improves the network lifetime.

3.6 Summary

This chapter identify problems and how to resolve identified problems. Proposed work has explained in operational framework. Sampling design for proposed work. The proposed work are examine on different parameters for implementation. The proposed work divided into four schemes, Network Initialization, Link Quality Estimation, and Temperature Estimation, and Data Forwarding and Energy Balancing. These schemes also explained in diagram. It also shows the effect of proposed work on the network lifetime, route planning before data forwarding. Moreover, the objectives are forward the cascaded data to the sink for further examination in real time.

CHAPTER 4

PERFORMANCE EVALUATION OF TAHT

4.1 Overview

This chapter discuss and implement our TAHT algorithms discussed in chapter 3. In terms of performance measures, simulate the protocol as well. In this section, a comparative study of approaches has provided.

4.2 Result and Analysis

To evaluate the robustness and the effectiveness of THAT and consider the evaluation metrics Number of dead nodes, Throughput, Temperature Dissipation, Packet Delivery Ratio, and Network lifetime. We calculate the results for these metrics and a comparative analysis performed with TAEO [19] and Energy-Efficient and Reliable Routing Scheme (ERRS) [32] protocols. Results presented in the form of graphs. These results produce from the simulator for each metric.

In THAT, sensor nodes used ZigBee for communication to exchange data packets with each other. In the simulation, sensor nodes have a threshold limit of temperature when their value exceeds the corresponding sensor node will be suspended until it reaches the threshold or less. Each node transfers the data through a predefined route to ignore traffic collisions. The statistical data has been calculated and examined through performance metrics.

4.3 Performance Comparison with Protocols

The proposed TAHT scheme is compared with benchmark schemes such as TAEO and ERRS. Following are the comparison that have compared with Benchmark method.

4.3.1 Throughput Effect on Data Transmission

In performance metrics throughput is the important metric in routing protocols. Figure 4.1 shows that the number of packet received by sink called throughput that depends upon the number of active nodes. The optimal energy usage and temperature voidance keep the nodes alive that results in better throughput with respect to TAEO and ERRS, in propose protocol as it initially estimate the link quality and each node know its neighbor nodes for the optimal route selection that effect on the performance of data transmission to sink. The proposed protocol performs better in terms of link quality estimation and route selection. Initially it performs as same as ERRS and gradually increase the packet transmission, on 8000 rounds and onwards the packet transmission is consistently increase as temperature and link estimated before.

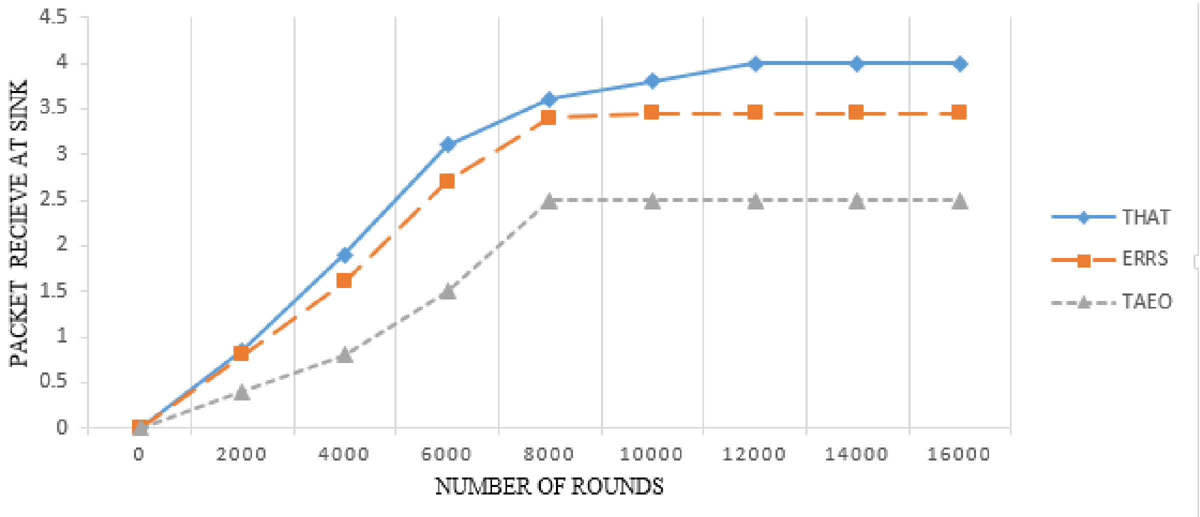


Figure 4.1: Throughput

4.3.2 Packet Delivery Ratio

It is an important performance metrics where packet transmission is measured of routing protocol in TAHT. Packet delivery ratio is number of packets received at the destination to the number of packets sent from the source. In Figure 4.2, shows a comparision between two protocols.The PDR increases because of route planning, and the all the possible routes are measured for data transmission based on link quality. Below results shows that TAHT performs 20% better from other protocol ERRS where it only use forwarder selection and its rotation are done on the basis of energy status while TAHT selects the node on the basis of function cost that is calculated by temperature, energy status, link quality.

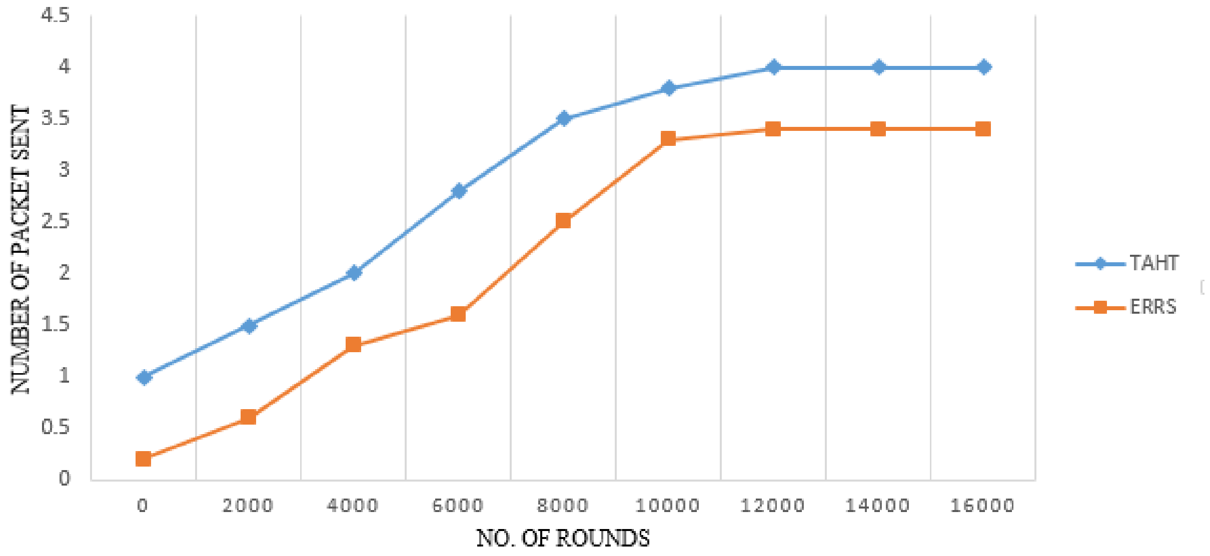


Figure 4.2: Packet Delivery Ratio

4.3.3 Temperature Dissipation

The temperature of a node rise when a node is constantly use in data transmission. Figure 4.3 shows the comparison between TAEO and TAHT, in which TAHT has 25% heated nodes and 75% unheated nodes while the TAEO has 30% of heated nodes and 70% of unheated nodes. This comparison shows an improvement in proposed protocol. These results in better data transmission, less suspension of nodes increase the performance.

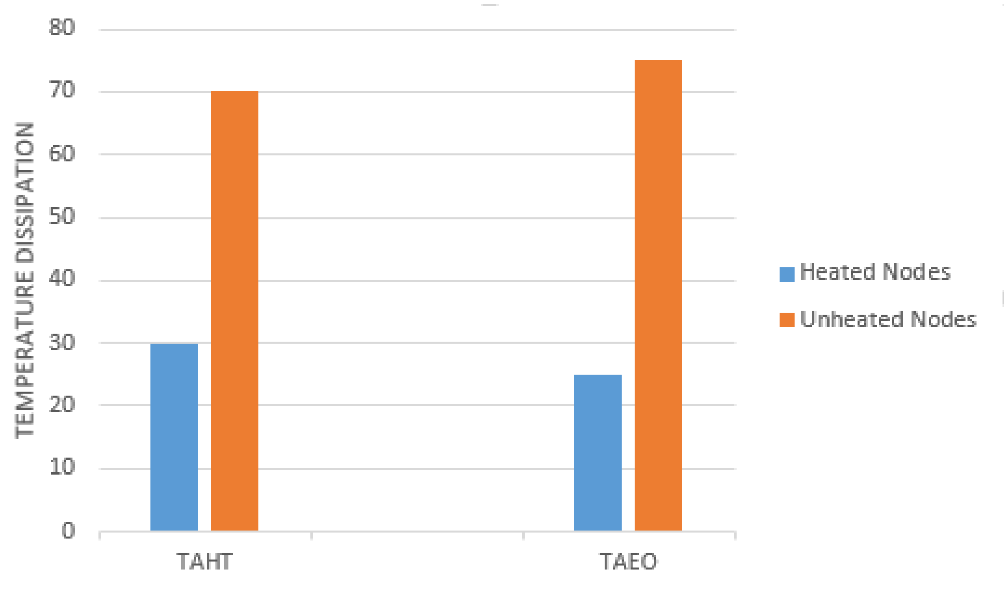


Figure 4.3: Temperature

4.3.4 Number of Dead Nodes (Stability)

Number of dead nodes shows the stability of network and the stability could affected by the suspension of nodes or dead nodes. TAHT estimate the balance the energy continuously in a routing table that help in selecting the nearest neighbor to control the temperature, packet load and data collusions. Figure 4.4 presents the stability where TAHT lost its all 11 nodes at 14000 rounds whereas ERRS lost its all nodes at 8000 rounds and TAEO lost its all 6 nodes between 6000 to 8000 rounds. The proposed network is stable as compare to other network.

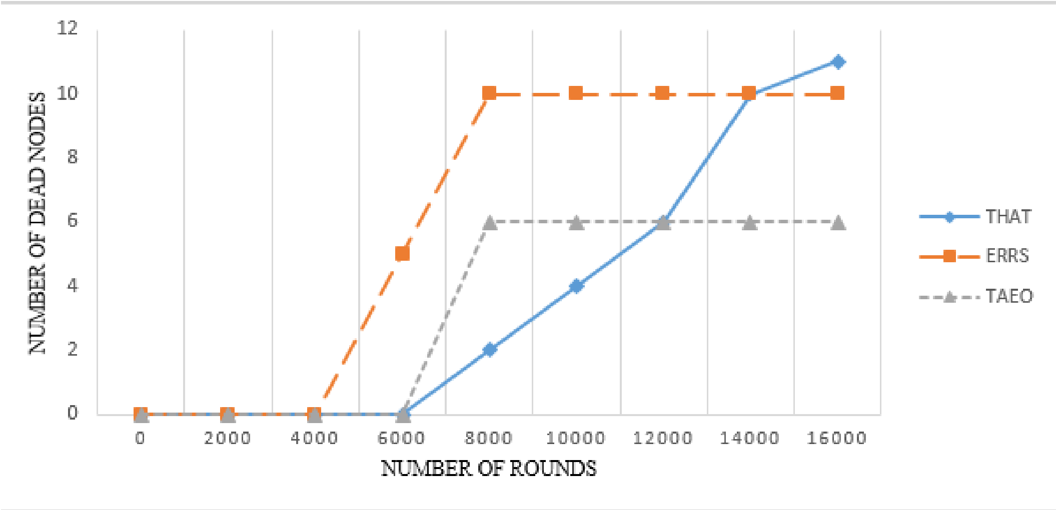


Figure 4.4: Number of Dead Nodes

4.3.5 Network Lifetime

As sensor nodes has limited battery lifetime in WBAN. In network development, battery is an important factor. Network lifetime is depends on each sensor node's energy consumption to enhance the stability of network. TAHT organize an algorithm to enhance PDR for this link quality is measured and control each node’s energy consumption by energy updating continuously and make an equilibrium between node’s energy to enhance the stability of network as compare to TAEO and ERRS. As Figure shows 4.5 there is an improvement in utilizing the energy. TAEO depletes all its energy at 8000 rounds while TAHT drains its half of energy.

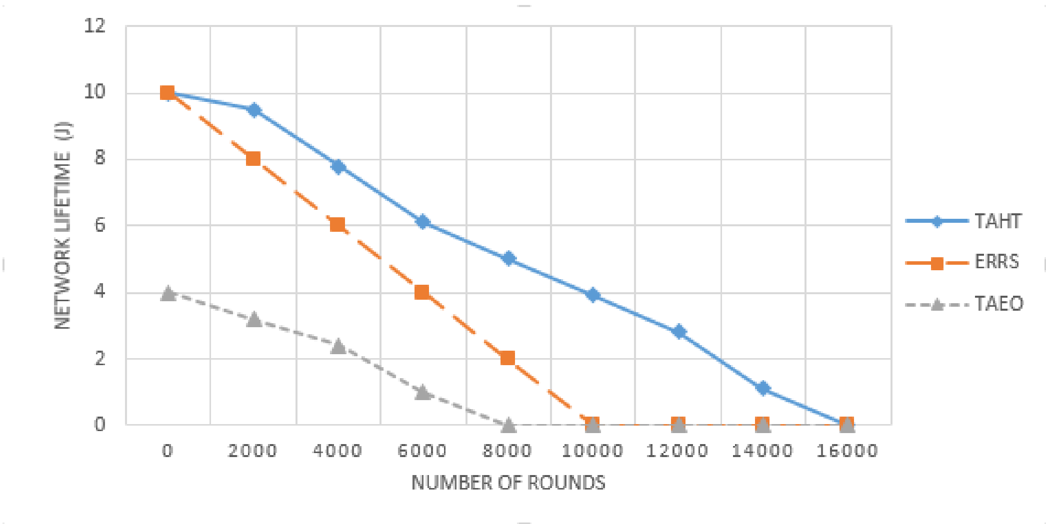


Figure 4.5: Network Lifetime

4.4 Summary

A protocol TAHT has proposed to enhance the PDR and heated nodes that control transmission of data. The objective is to increase PDR and reduce delay and energy consumption. The performance calculated through NS-2 simulator. Moreover, THAT is compared with ERRS and TAEO through different performance metrics, so it is concluded that TAHT is able to enhance data transmission by controlling heated nodes and unnecessary data transmission.

CHAPTER 5

CONCLUSION AND FUTURE WORK OF TAHT

5.1 Overview

This research develop to identify the problem of data packet transmission in uninviting environment and provide a solution that is thermal aware high throughput routing protocol known as TAHT. The performance evaluated by simulation tool known as NS-2 with performance metrics such as number of dead nodes, Throughput, temperature rise, and network lifetime. TAHT protocol out performs protocol ERRS and TAEO in data transmission, link quality, and temperature control. This chapter proposes the section such as section 5.2 explains the conclusion of this research and section 5.3 presents the future work.

5.2 Conclusion

THAT enhances the TAEO protocol, the proposed protocol TAHT identify different problems such as route planning, data forward, exceed in temperature from the given threshold and link quality. In existing protocol TAEO, this only selects the node with temperature controlled and less energy consumption for data transmission that could disturb the traffic or drop the important data from other node this situation can drop the important data packet such as route planning, data forward. Even though, different schemes have proposed on WBAN with different parameter such as energy consumption, and data transmission. TAHT improves throughput and prevents data collisions in the network by managing information transmission through optimal route planning. Initially, it distributes a hello packet from the sink node to its predefined distance neighbor nodes, and through this, estimate link quality.

The graph in Figure 4.1, shows the 20% improvement in TAHT while TAEO achieves 10% throughput from ERRS. TAHT estimates the Packet Delivery Ratio (PDR), indicating the number of packets transmitted from source and the number of packets received at destination node. TAHT processes the simultaneous reception and transmission of five packets at once. In graph of Figure 4.2, TAHT performs 20% better from ERRS protocol based on route planning. TAHT monitor temperature to control the data transmission for smooth transmission. If any of the node's temperature exceed from predefined threshold than that node has suspended for a while until its temperature is normal. At the time of suspension, each neighbor node knows about the suspension. It prevents from damage the tissue of patient's body. In graph of Figure 4.3 shows TAHT performs 5% better than the TAEO as the 75% unheated nodes improves in transmission. Stability is the period of network process, which begins from starting of the network until first node dies. The suspension of nodes impact negatively on network's data transmission because of network reduction. TAEO only focus on the temperature and energy consumption and ERRS focused on the reliability and stability of the network which impact on energy depletion early. TAHT initially estimates the link quality through different metrics and inform to its first hop nodes to find a well-suited next node. This scheme reduce energy consumption for packet transmission and reduce number of dead nodes. In Figure 4.4, TAHT's stability increase as its first node dead after 6000 rounds while ERRS first node died after near 4000 rounds and TAEO died after 6000 rounds. As TAHT has wireless network communication with limited battery lifetime. It use energy balancing scheme to avoid null communication. In this scheme, energy has updated continuously. In graph of Figure 4.5, shows the improvement 40% improvement from TAEO and 20% from ERRS and 90% improvement in energy saving.

5.3 Future Work

In the future, as the proposed protocol have based on hop-by-hop routing communication and single sink environment. Although, hop-by-hop communication distributes the packet transmission efficiently but single sink can increase the effect of burden on few nodes. Therefore, we can add more than one sink nodes to reduce the burden of transmission and for more enhancement in proposed protocol; we can use clustered based routing for communication.

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