THE ASIAN BULLETIN OF BIG DATA MANAGMENT
Vol. 5. Issue 1 (2025)
https://doi.org/10.62019/abbdm.v5i1.303

ASIAN BULLETIN OF BIG DATA MANAGEMENT
ISSN (Print): 2959-0795
http://abbdm.com/
ISSN (online): 2959-0809

Reliable and Efficient Internet of Medical Things Routing Protocol

Rahat Ali Khan*, Shahzad Memon, Azhar Ali Shah, Xiaodong Liu

Chronicle

Article history
Received: 21st Jan, 2025
Received in the revised format: 12th Feb, 2025
Accepted: 27th Feb, 2025
Available online: 15 March, 2025

Rahat Ali Khan, Shahzad Memon & Azhar Ali Shah are currently affiliated with Faculty of Engineering and Technology, University of Sindh Pakistan.
Email: rahataliikhan@gmail.com
Email:shahzad.memon@usindh.edu.pk
Email: azhar.shah@usindh.edu.pk

Xiaodong Liu is currently affiliated with School of Computing, Edinburgh Napier University, Scotland.
Email: x.liu@napier.ac.uk
Corresponding Author*

Abstract

Internet of Medical Things (IoMT) is an emerging field of technology which is gaining importance because its applications related to health care sector. Sensor are used in this technology that record the physiological data and send them to outside world for further processing. In this paper an efficient routing protocol has been proposed with eight sensor nodes proposed to be used. The proposed protocol is based on multi hopping based technique. The proposed protocol a forwarder node is used. The forwarder node is for the sensor nodes which use multi hopping. The proposed routing protocol has been compared with three routing protocols using MATLAB.

Keywords: MATLAB, (IoMT), physiological, data, technique

INTRODUCTION

Advancement in the field of ICT has paved the way for development of very small scaled devices known as "Micro Electro Mechanical Systems" (MEMS) and also "Nano Electro Mechanical Systems" (NEMS) [1]. These are small sized but powerful devices called sensors or sometimes referred as wireless sensor nodes in a wireless network. These sensors form a network wirelessly called Wireless Sensor Networks (WSNs) [2]. Wireless Sensor Network (WSN) is a spread cluster of sensor nodes, which are connected to each other through wireless communication [3]. A very little or no infrastructure is needed by WSN which comprises of sensor nodes that can range from few tens to thousands and those sensors in the network could work collectively for monitoring [4]. Sensor nodes are devices consuming low power. They contain processor, memory, a power supply, a transceiver, and an actuator [5], [6]. These sensor nodes can be used for sensing continuously, event ID, event detection, location sensing, and control of actuators [6]. The functions that these sensors perform are sensing, processing of data and communication [7]. When observing physical phenomena is needed then WSNs are very affective means. WSN allows users to collect data in those geographic locations which are difficult to reach [8].

IoMT Protocols, Internet of Medical Things (IoMT): There are several diseases from which people are suffering from are fatal. When these diseases are detected it is already too late to be recovered so it is necessary that these diseases may be detected at early stages. It is found that if these diseases are detected then they can be prevented. Therefore there must medical systems for early detection. Its solution lies in wearable system for health care monitoring that is proactive and also affordable which must have capabilities of detecting abnormal conditions. This early detection can lead up to early treatment which results in quality of life. In this scenario heart rate monitoring allows patient to be engaged in their daily routine instead of staying at hospital or any other medical service. This can be achieved through a network which consists of small sized (Micro or Nano), smart and low – power consuming sensors. These sensors can be placed either on body, or be implanted in human body. These sensors providing timely data. Such networks are commonly referred to as Wireless Body Area Networks. Van Dam et al introduced Wireless body area sensor network (WBASN) first time in 2001 [13]. Monitoring of health care is one of the major and important applications of IoMT. Figure 2 illustrates an example scenario of IoMT.

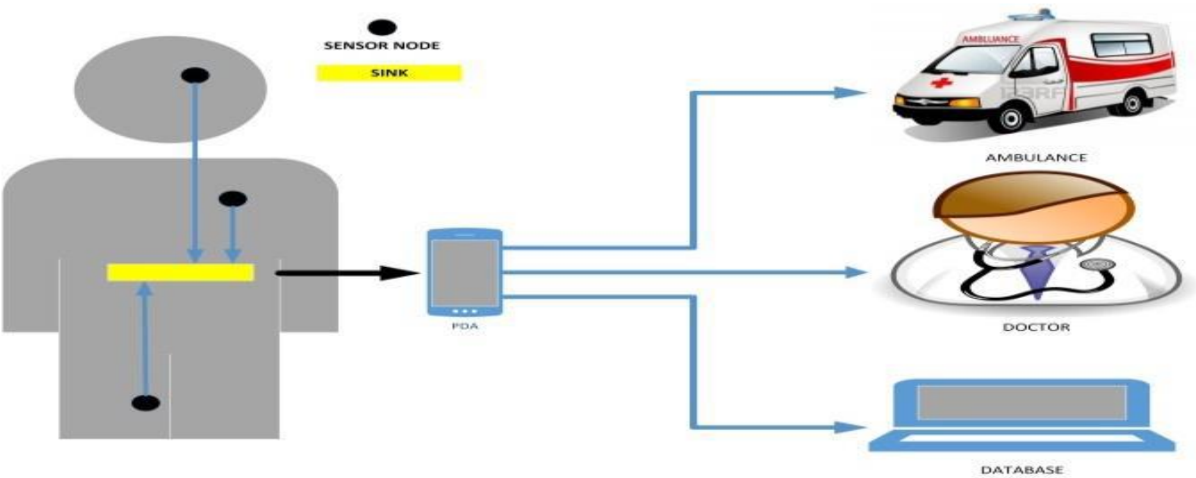

Figure 2.
IoMT Architecture

Categories of Sensors for IoMT

Sensors which are used in IoMT are categorized as either being invasive or non – invasive. Sensor nodes which can be implanted in human body under skin are called invasive sensor nodes. They are also known as in – body sensors. Sensor nodes which can be only be deployed on human skin are called non - invasive sensor nodes. They are also known as on – body sensors [14].

Table 1.
Categories of IoMT Sensors

Invasive / In – Body Sensors	Deep brain stimulator Electronic pill for drug delivery Cochlear implants Wireless capsule endoscope (electronic pill)
	Retina implants Pacemaker Implantable defibrillators Oxygen, pH

Non - invasive / On – Body sensors	Blood pressure Pulse Oximeter Temperature Electroencephalogram (EEG) Electromyography (EMG) Glucose sensor Electrocardiogram (ECG)

The sensors used in IoMT as listed in table1 can be deployed on human body at different parts as shown in figure 3

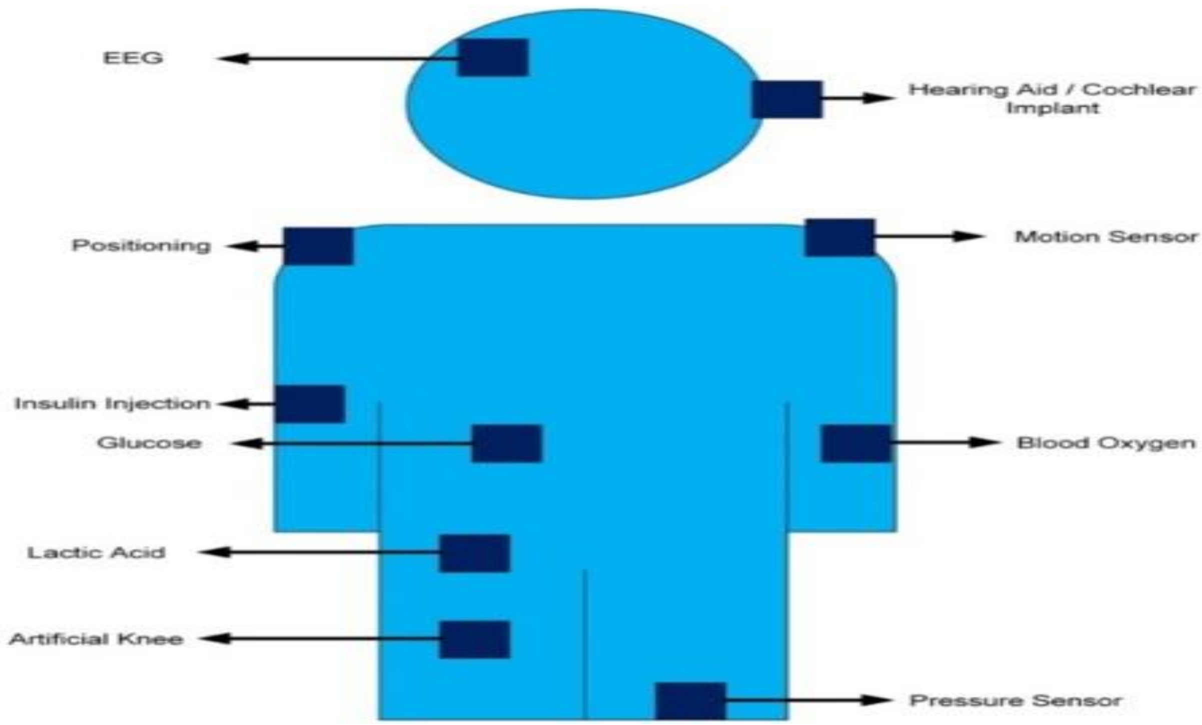

Figure 2.
Sesnor Deployment

As these sensors are small in size so they contain small batteries in them. The sensor nodes used in IoMT are related to human health so continous monitoring in needed. If the sensor nodes dies that is if the battery of any sensor nodes ends then it needs to be charged again. This is not a practical way to remove them from human skin and charge the batteries on regular basis.

LITERATURE REVIEW

In [15] simulation of WBAN is presented having different network configurations. These are based on random or fixed positions of nodes. They have considered to select lower values Specific Absorption Rate (SAR) in order to have less impact on human tissue. In terms of path loss, energy consumption and network lifetime their generated results show that that incremental approach performs better than direct approach. In paper [16] researchers have proposed Lightweight Authentication and Key Agreement (LAKA) protocol which is secure, key agreement and light weight authentication protocol. As per their results the proposed protocol has 15%lesser cost of storage and 57% lesser communication overhead. So the proposed protocol has better efficiency in terms of computational time, execution cost and power consumption. Researchers in [17] have investigated energy efficiency and spectral for smart health care applications based wireless body area sensor networks. Their focus is on improvement of spectrum utilization by sharing of spectrum resources intelligently. For this they have used Cognitive Radio (CR) technology which allows sensor nodes in the network to co-exist without any compromise on their quality – of – service (QoS). They have used Power Splitting Cooperation (PSC) and Time Switching Cooperation (TSC).

These are two Energy Harvesting (EH) protocols which are engaged to assist primary network with secondary node cooperation in return for spectrum access. Researchers in [18] have proposed energy efficient algorithm which is based on clustering and uses ANT Colony optimization. They have developed this algorithm to finding shortest path for next hop. They have modified ANT colony algorithm. Their proposed system monitors data of patient continuously and sends to base station (BS) via. Cluster Heads (CH), means through Medical Device Coordinators (MDCs) during emergency situations. Monitoring of patients has also been done and Objective Modular Network Testbed in C++ (OMNeT++) has been used to validate results and they proved that their results were better than that of the conventional methods. They compared parameters like energy, network life time and throughput. The proposed algorithm maximizes network lifetime by the use of modified cluster head rotation process during route construction. In [19] the authors have proposed an architecture for the purpose of improving Quality of Service (QoS) and energy management system of Wireless Body Area Networks (WBANs) using one sink node.

The proposed algorithm categorizes the data which is sensed into three categories (i) High Normal, (ii) Normal and (iii) Critical. They also have developed Weighted Energy and QoS (WEQ) algorithm. This algorithm is developed for the selection of optimal path for high normal and normal data. They have considered parameters like distance, link stability, residual energy and delay for computing weight value. The route on which data will be transmitted is the one that has high value of weight. In [20] researchers have designed optimization model which is energy efficient. They have developed the model for Institute of Electrical and Electronics Engineers (IEEE) standard 802.15.6 based wireless body area network. They have introduced payload strength and code rate adaptation algorithm.

They have focused on using Medium Access Control (MAC) and physical (PHY) in using cross layer. For hospitals the proposed model allows combined packet length optimization and code rate in Additive White Gaussian Noise (AWGN) channel when it uses model for path loss. Researchers in [21] have used Automated Validation of Internet Security Protocols and Applications (AVISPA) and ProVerif tools. They have developed a protocol for distributing and generating cryptography keys in Wireless Body Area Networks. This system is based on security based on biometrics using Electro Cardio Gram (ECG) for the generation and the distribution of cryptographic keys in Wireless Body Area Networks. They have used ECG for security validation. In order to make ECG signals available to all of the sensors used in the algorithm time synchronization has been used. Three techniques have been used (i) creation of key based on biometrics, (ii) morphing function and (iii) error correcting code. This system allows to generate and to distribute symmetric cryptographic keys which are reliable and secure. These keys are used for the purpose of security. Wake Up Receiver (WUR) perspectives with event driven transfer of data is given in [22]. In this paper they have compared their proposed WUR based medium access control protocol with duty cycled protocol for energy consumption.

Their research suggests that for WBAN in which sensor nodes are near to each other, then in this scenario detection should be based on Radio Frequency (RF) envelope. This is because it consumes low power. In this paper modification has been done enabling WUR to obtain control instructions. Their system achieves energy improvement and do not need to have complex modifications. Quwaider and Biswas in [23] have designed a protocol in which they have proposed to use single hopping communication method in order to send data from sensors node to base station. The proposed method is very successful in terms of delay that it has least amount of delay. This protocol has the disadvantage for the senor nodes placed at a distance that the deplete energy faster as compared to near ones because they need more energy to send data. Seo et al in [24] have proposed an experimental adaptive routing protocol in which they have used multiple hopping. The multi hopping is between the base station and the sensor nodes. They have developed mathematical model for it to maintain balance in power consumption with certain Quality of Service (QoS).

Their algorithm is targeting critical data in emergency situations. In their simulations there was less than 3 percent of maximum loss of packets. Tauqir et al in [25] have proposed "Distance Aware Relaying Energy-efficient (DARE)" protocol. This protocol uses a hospital ward scenario which consists of eight patients. Each patient is supposed to have seven sensor nodes on the human for measurement of physiological monitoring like (i) motion, (ii) Electrocardiogram (ECG), (iii) temperature level, (iv) pulse rate, (v) toxins level, (vi) heart rate and (vii) glucose level. On body relay is proposed to be used in order to minimize the energy consumption. This relay is used by sensor nodes to base station. In this protocol they have allowed some of the sensors used to perform their monitoring consecutively and others monitor when a given value of threshold is achieved. In order to save human body tissues o get affected they have defined very less parameters for energy. Human tissues get affected when there is heat dissipation.

Simulation Parameters

In this section the parameters used for simulation are described like the transceiver used, sensor node positioning and mathematical models.

Transceiver

In the proposed routing protocol nRF2401A transceiver has been used. It works on 2.4 Giga Hertz (GHz) frequency. It is a transceiver which is a low power consumption device and this is the reason it is preferred to be used in the proposed IoMT RP. Table 2 shows parameters of nRF2401A used in simulation. The reason of selection of this transceiver

Table 2.
Transceiver

Parameter	nRF2401A	CC2420	Unit

DC current (Transmission)	**10.5**	17.4	mA
DC current (Receiving)	**18**	19.7	mA
Minimum supply voltage	**1.9**	2.1	V
Transmission Energy	**16.7**	96.9	nJ/bit
Receiving Energy	**36.1**	172.8	nJ/bit
Amplification Energy	**1.97**	271	nJ/bit

Table 2.
nRF2401A Transceiver Parameters

Parameter	Value
Transmission Power	16.7 ηJ/bit
Transmission DC current	10.5 mA
Receiving Power	36.1 ηJ/bit
Receiving DC current	18 mA
Minimum voltage supply	1.9 v
Frequency	2.4 GHz

Sensor Node Positioning

In the proposed routing protocol the number of sensor nodes used is eight which have been assigned x and y coordinates describing their positions where they are plotted. Table 3 shows the coordinates of the sensor nodes positioned.

Table 3.
Sensor Nodes' Coordinates

Sensor Node	X Coordinate Value	Y Coordinate Value
Sensor Node 1	0.37 m	0.1 m
Sensor Node 2	0.54 m	0.3 m
Sensor Node 3	0.37 m	0.55 m
Sensor Node 4	0.53 m	0.55 m
Sensor Node 5	0.6 m	0.75 m
Sensor Node 6	0.22 m	0.9 m
Sensor Node 7	0.24 m	0.7 m
Sensor Node 8	0.5 m	0.8 m

These sensors send their recorded data to sink node which also needs to be located. Sink node is placed at 0.25 m and 0.9 m on x - coordinate and y – coordinate respectively.

Distance Analysis

The sensor nodes after being positioned start recording data. They have certain distance from the sink node which needs to be calculated. This is an important parameter because of the fact that if there is more distance then sensor nodes need to transmit data at longer distances which need more energy. Energy is a parameter which is very crucial and needs to be saved. Distance calculaton formula is given in equation 1

$$\mathrm{distanceA(i)} = \sqrt{\mathrm{SA(i).xd} - (\mathrm{sink1.x})^2 + \mathrm{SA(i).yd} - (\mathrm{sink1.y})^2} \quad \text{Equation 1}$$

Selection of Forwarder Node

After successful completion of a single round of simulation the cost function comes in action which perform testing using distance and energy level of every sensor node.

Based on this calculation a forwarder node is selected. All the sensor nodes are tested in cost function. Cost function is calculated from equation 2.

$$\text{Cost function (i)} = {}^{\text{distance (i)}}\!/_{\text{S(i). E}} \quad \text{Equation 1}$$

From equation 1 it can be observed that any of the sensor node which has least value of cost function will be selected as forwarder node. It means a forwarder node will be the one having higher energy level than other sensor nodes.

Path loss Analysis

When wireless transmission take place then there exists path loss. It is of a very significant importance that cannot be ignored. Path loss calculation is performed using equation 4

$$PL(node_{num}) = 10 * \log {}^{(4\pi Df}\!/_{c})^2 + \log\left({}^{\text{distance}}\!/_{d_o}\right) + S \quad \text{Equation 4}$$

From equation 4 it can be observed that path loss is related to distance and frequency. After computing distance of every sensor node then path loss of entire sensors is computed.

RESULTS AND DISCUSSION

In this section simulation results performed in MATLAB 2020a are presented. The proposed routing scheme is named as Internet of Medical Things Routing Protocol (IoMT RP) and the existing schemes with which it is compared are named as EERP 1 [26], EERP 2 [7] and EERP 3 [27] for clarification. Figure 4 represents comparison of the proposed IoMT RP routing protocol in terms of dead nodes. The proposed IoMT RP is compared with EERP 1 [26] in figure 4a, with EERP 2 [7] in figure 4b, and EERP 3 [27] in figure 4c. Figure 4: Dead Nodes Comparison (a) Proposed IoMT RP with EERP 1 (b) Proposed IoMT RP with EERP 2 (c) Proposed IoMT RP with EERP 3. The details of figure 4 are given in table 4.

The network become unstable when any one of its sensor nodes losses its energy fully. In table 4 it can be observed that EERP 1 losses its first sensor node in round 2148, EERP 2 losses its first sensor node in round 2161, EERP 3 losses its first sensor node in round 2156 while proposed IOMT RP losses its first sensor node in round 4221. So from table 1 it is clear that EERP 1, EERP 2 and EERP 3 become unstable just after 2148, 2161 and 2156 rounds respectively while the proposed IoMT RP becomes unstable after 4221 rounds. This shows that the proposed IoMT RP is much stable than all of the existing routing protocols. As the simulation progresses the sensor nodes lose their energies. When all the sensor nodes die the network life time is calculated that how much round a network protocol was able to complete. EERP 1 has a network life time of 7445 rounds, life time of EERP 2 is of 7486 rounds, and EERP 3 has life time of 7485 round. The proposed IoMT RP has a life time of 7630 rounds. The life time life of proposed IoMT RP is far more than the routing protocols with which it was compared.

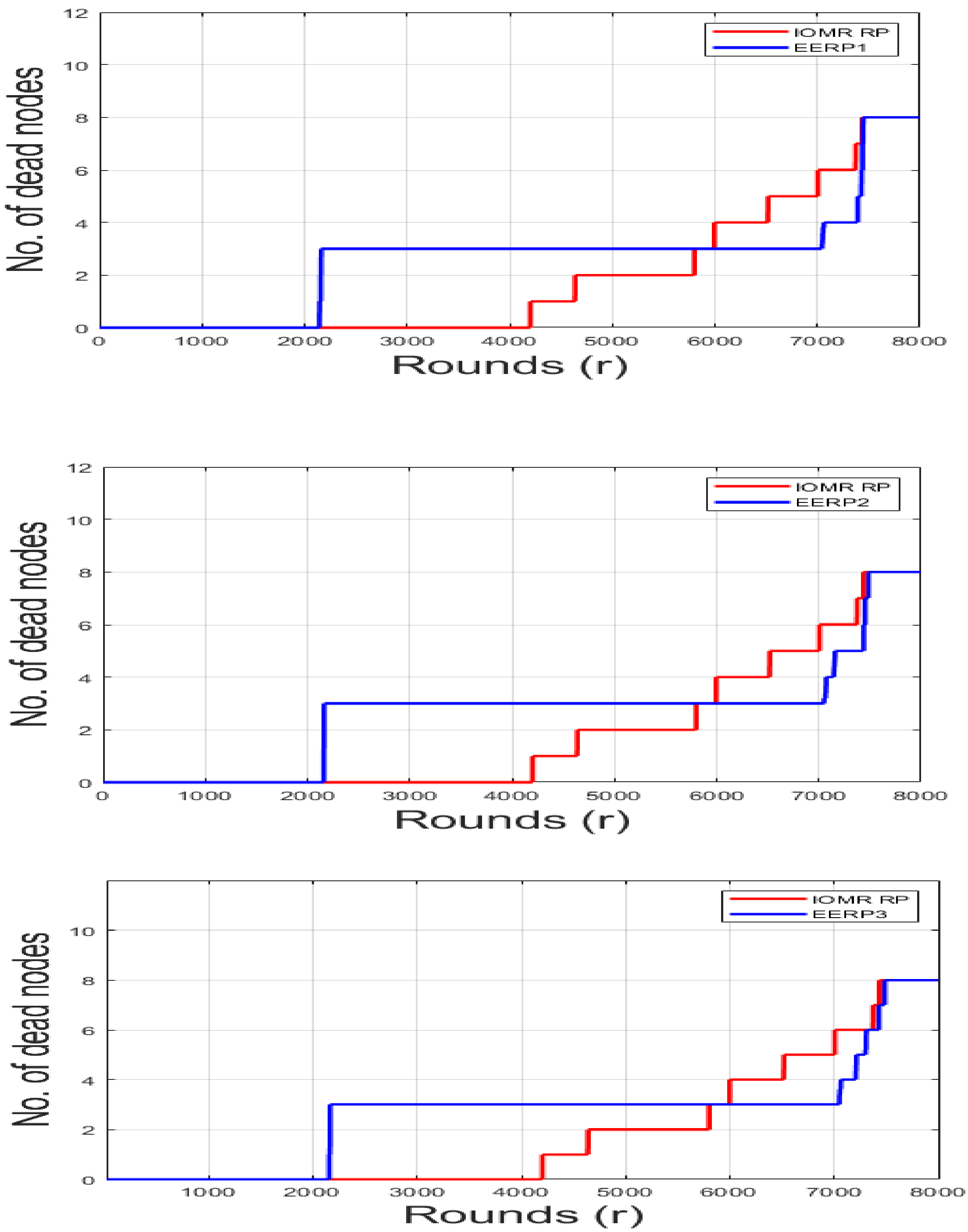

Figure 3.
a.b,c

Table 4.
Dead Nodes Comparison

	Number of Rounds							
Sensor Node	**Node 1**	**Node 2**	**Node 3**	**Node 4**	**Node 5**	**Node 6**	**Node 7**	**Node 8**
EERP 1 [26]	2148	2160	2162	7059	7427	7430	7444	7445
EERP 2 [7]	2161	2162	2163	7066	7157	7439	7484	7486

EERP 3 [27]	2156	2162	2163	7065	7214	7308	7430	7485
IOMT RP	4221	4664	5788	5997	6525	7006	7452	7630

Second parameter which has been taken into account is the number of successful packets received at the destination. If there are more number of packets received at the destination then the routing protocol is called efficient and reliable. Figure 5 represents comparison of the proposed IoMT RP routing protocol in terms of dead nodes. The proposed IoMT RP is compared with EERP 1 [26] in figure 5a, with EERP 2 [7] in figure 5b, and EERP 3 [27] in figure 5c.
a,b,c

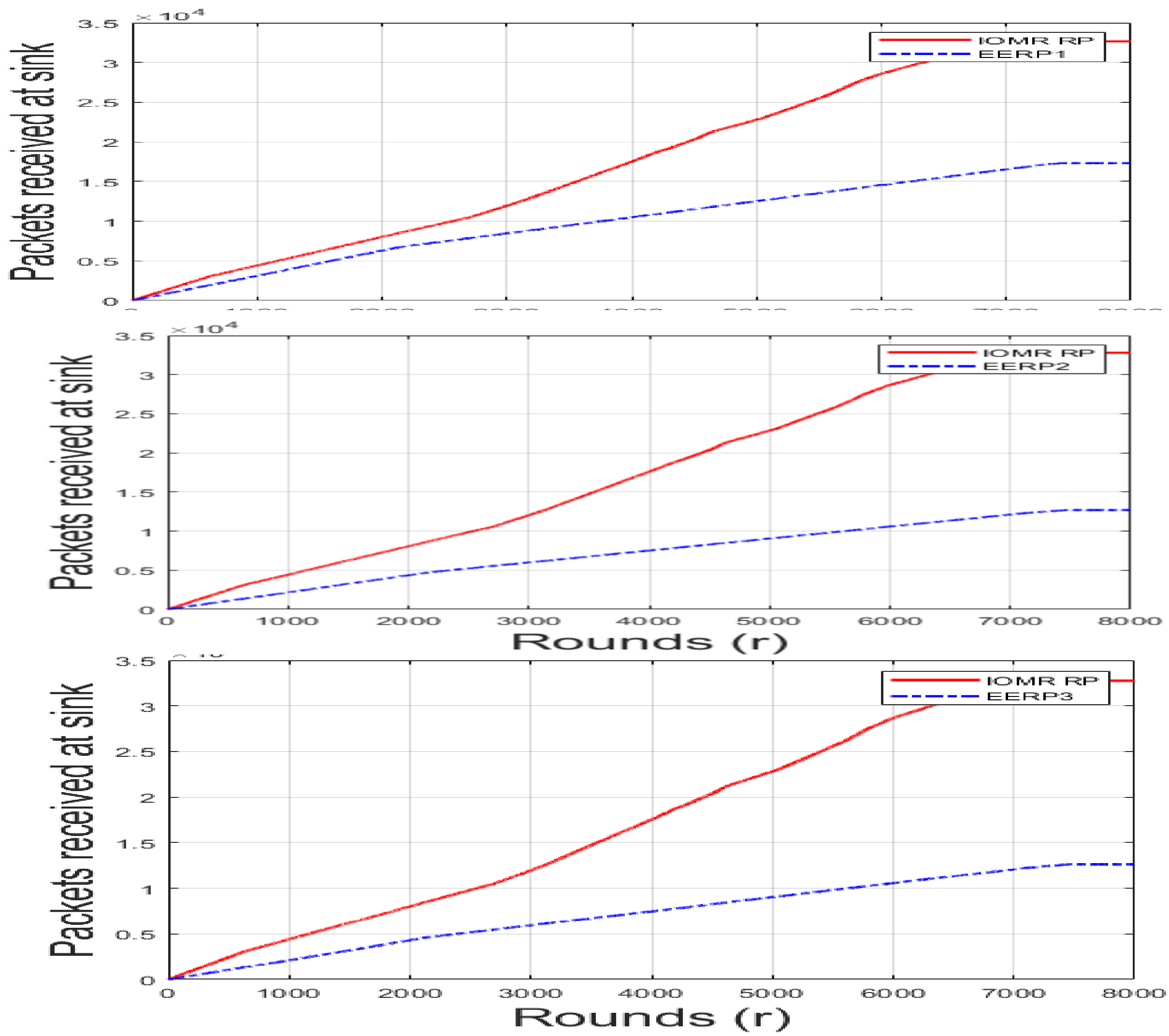

Figure 4.
Received Packets Comparison (a) Proposed IoMT RP with EERP 1 (b) Proposed IoMT RP with EERP 2 (c) Proposed IoMT RP with EERP 3

The details of figure 5 are given in table 5. From table 5 it can be observed that number of successful packet delivered to the destination in EERP 1 [26] are 17380, packets which got delivered in EERP 2 [7] are 12690 and 12710 packet received successfully in EERP 3 [27]. The proposed IoMT RP delivered 32740 packets. Number of packets delivered in proposed IoMT RP are much higher than the other three routing protocols.

Table 4.
Received Packets Comparison

Routing Protocol	Packets Received
EERP 1 [26]	17380
EERP 2 [7]	12690
EERP 3 [27]	12710
IOMT RP	32740

CONCLUSION

In this paper an efficient routing protocol has been proposed with eight sensor nodes proposed to be used. These sensor nodes are used for physiological parameter testing and processing the data to the sink node. These sensor nodes and sink node are used on human body. Forwarder node is proposed to be selected after every single round based on having least value of cost function. This value is dependent on the distance and residual energy of sensor node. The forwarder node is for the sensor nodes which use multi hopping. The proposed routing protocol has been compared with three routing protocols and it performed well and outclassed all of the existing routing protocols.

Abbreviations

ICT	Information and Communication Technology
NEMS	Nano Electro Mechanical Systems
MEMS	Micro Electro Mechanical Systems
WSN	Wireless Sensor Networks
IoMT	Internet of Medical Things
WBASN	Wireless Body Area Sensor Network
EEG	Electroencephalogram
EMG	Electromyography
ECG	Electrocardiogram
SAR	Specific Absorption Rate
LAKA	Lightweight Authentication and Key Agreement
CR	Cognitive Radio
QoS	Quality – of – Service
PSC	Power Splitting Cooperation
TSC	Time Switching Cooperation
EH	Energy Harvesting
BS	Base Station

CH	Cluster Heads
MDC	Medical Device Coordinators
OMNeT++	Objective Modular Network Testbed in C++
WBANs	Wireless Body Area Networks
WEQ	Weighted Energy and QoS
IEEE	Institute of Electrical and Electronics Engineers
MAC	Medium Access Control
PHY	PHYsical
AWGN	Additive White Gaussian Noise
AVISPA	Automated Validation of Internet Security Protocols and Applications.
WUR	Wake Up Receiver
RF	Radio Frequency
DARE	Distance Aware Relaying Energy-efficient
mA	milli Amperes
GHz	Giga Hertz
ηJ	nano joules
m	meter
IoMT RP	Internet of Medical Things Routing Protocol
EERP	Energy Efficient Routing Protocol

DECLARATIONS

Acknowledgement: We appreciate the generous support from all the supervisors and their different affiliations.
Funding: No funding body in the public, private, or nonprofit sectors provided a particular grant for this research.
Availability of data and material: In the approach, the data sources for the variables are stated.
Authors' contributions: Each author participated equally to the creation of this work.
Conflicts of Interests: The authors declare no conflict of interest.
Consent to Participate: Yes
Consent for publication and Ethical approval: Because this study does not include human or animal data, ethical approval is not required for publication. All authors have given their consent.

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