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ORIGINAL PAPER

Prim based link quality and thermal aware adaptive routing protocol for IoMT using SigFox network in WBAN

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Abstract
The displacement of a sensor node on the human body to monitor the internal changes of human is an emerging technology. The Internet of Medical Things (IoMT) reduces an individual's fatal problems. Hence, this paper presents the routing protocol for wireless body area network (WBAN) based on thermal and link quality and low-cost transmission. First, the number of paths is discovered based on the link quality and the thermal effect to transmit the sensed data by the IoMT device. All those evolved paths are optimized based on the cost for transmission; the prim's algorithm achieves this. The price for all paths achieved by the prim's algorithm is stored in the prim table, which will reduce the computation complexity and time. This two-stage process makes the proposed routing algorithm adaptive, hence the name Prim Based Link Quality and Thermal Aware Adaptive Routing (PLTAAR) protocol. Due to the focus on link quality, the energy utilized by the biosensor node for the retransmission of data queuing is reduced, and the thermal aware consideration protects the human from radiation effects caused by the IoMT devices. The proposed system model for the medical service is implemented on MATLAB.

Keywords Biosensor · Internet of medical things (IoMT) device · Wireless body area network (WBAN) · Link quality · Thermal effect · Prim's algorithm · Energy utilization

1 Introduction

A wireless sensor network (WSN) can be used in many applications. There is a notable advantage of the WSN on the internet of medical things (IoMT) (Gardašević et al. 2020). The WSN is used in healthcare, surveillance, military, agriculture etc. (Sharma and Bhatt 2018; Mostafaei et al. 2018; Jamal and Butt 2017; Ouyang et al. 2019). One of its most important applications is healthcare monitoring due to its use for humans results in a wireless body area network. WBAN is a subset of WSN (Abidi et al. 2017), where the sensor network is used to sense the health condition of the human body (early diagnosis of disease). In many instances, the biosensor acts like a personal digital assistant (PDA) (Pramanik et al. 2019). The biosensors are low power devices; hence, they are well suited to use in the human body that does not cause any impact on the human. There are three classifications of biosensors: in-body, on-body and off-body biosensors, based on their use in humans or patients for medical support (Ventura et al. 2019). Although WBAN has many advantages, it also has a disadvantage: restricted energy, limited memory, low transmission range, and low processing power. In addition, due to the heterogeneous biosensors (Selem et al. 2019), different quality of service (QoS) levels and the reliability and high data quality could be provided.

Once the biosensor is placed, it is difficult to exchange the sensors every time the energy is exhausted. But, the energy exhaustion problem reduces the robustness of the network. This is the major research gap faced by the researcher in developing an energy-efficient and robust network structure for WBAN. Also, when we go for implantable biosensors for health monitoring, high security and energy treats are found (Hou et al. 2018). Hence, the paper aimed to design

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a routing on WBAN with effective protocols that provide energy management and a robust network structure.

The routing of data from the IoMT devices to the authenticated ones involves a three-tier process: inter-WBAN, intra-WBAN and beyond-WBAN (George and Jacob 2019; Wang et al. 2020). The goal of energy-efficient routing protocol through a three-tier process is to use low energy for each transfer of the monitored medical information, which reduces the sensor network's operational cost. The routing methods for the WBAN mainly concentrate on energy-efficient routing concerning clustering process, cross-layered and postural (Bhanumathi and Sangeetha 2017).

The energy-aware routing based on WBAN is implemented concerning block chain technology for a lightweight and secure communication strategy (Shahbazi and Byun 2020) but suffers from overhead on the network. The critical data routing is done by considering the on-body medical super sensor node (Sagar et al. 2020). The model saves energy usage, but computation complexity has a problem. Fuzzy control based energy-efficient routing protocol (Wang et al. 2021) enhanced the network's reliability, but lack of energy consumption rate. Meanwhile, the robust nature of a network would be achieved by considering link quality, the thermal and radiation effect and energy efficiency. When the IoMT devices operate continuously, then extensive heat is generated that will damage the tissues of humans.

Along with that, the IoMT devices emitting electromagnetic radiation will also affect human health. This will cause biological changes to the human organ. The poor link quality enables retransmission due to channel fading, interference and weak signals. Also, the reduction in the energy level of the biosensor will increase the heat dissipation; thus, the three metrics are related to each other by the energy.

Several kinds of research are made by considering spatial peak specific absorption rate: a thermal aware routing (ATAR) (Ahmed et al. 2021), designed with two threshold levels for signal strength indication. The above method neglected the problem of link breaches; this motivated us to develop an optimal routing scheme by considering above mentioned metrics for energy management without any health impact using IoMT devices.

This paper proposes a safe and efficient health monitoring network by implanting IoMT devices in the human body. The information is collected on the central node, which will transmit to the authorized user concerning the link quality, the thermal and radiation effect and energy efficiency of each biosensor. The data path between the IoMT device and the central node is obtained by considering the path's thermal effect and link quality to reach the destination. For low cost transmission, the path achieved by the above consideration is processed by the Prim's algorithm for selecting a single path to reach the destination. In literature, the Krushal's algorithm is widely used for the path selection, but the path achieved by the exploration phase will be random. The traditional algorithm is not supported for the random link; hence the need is to select an algorithm that can select a path when subjected to any circumstances. Therefore, the prim algorithm is utilized for path selection.

1.1 Contribution

- A WBAN that has mitigated humans' health effects by controlling the heat and radiation dissipated from IoMT devices is made.
- To manage energy in the IoMT devices, a two-step routing process of path discovery and selection is imposed on the SigFox network.
- An adaptive routing scheme is developed by considering humans' health constraints and the biosensor's energy constraints in WBAN.

The paper is structured as follows: Sect. 2 comprises various extant routing protocols used in WBAN. Section 3 is the design of the PLTAAR protocol for the WBAN based IoMT. Section 4 comprises an analysis of the routing protocol, and at last, Sect. 5 is completed by illustrating the overall conclusion of the work.

2 Related work

The section provides the various routing techniques involved in the healthcare monitoring systems.

Saba et al. (2020) proposed a secure and energy-efficient framework (SEF) for the IoMT based on e-health care. Here the IoMT were interconnected with the unique edges that could be done by assuming a numerical weight for each edge. Then the Kruskal's algorithm was used to extract the most value from the sub-graphs. That will optimize the routing decisions of the IoMT sensor with minimum overhead and the used energy by the sensor nodes. After all these steps, the patients' medical information was kept secured from the malicious nodes using the lightweight cryptographic method. The routing system of the technique involves the sub-graph extraction using a cost function, an arrangement of the edge nodes, adding edges without cycle and end-to-end minimum cost value.

Al-Turjman and Deebak (2020) proposed the privacy-aware energy-efficient (P-AEER) protocol for the secure routing of medical information. The method minimizes cost with improved security and reduced energy consumption against unauthentic access. To have a minimum cost function, the criteria used here were the edges of the sub-graph connected by several vertices without using the cyclic process. The Krushal's algorithm formed the sub-graph. The cipher block algorithm was used between the nodes to verify the encryption chain of the generated data block.

Saleh et al. (2018) proposed the energy-efficient framework to reduce the energy consumed by the sensor nodes. The model uses the quaternary transceiver with the amplitude or phase modulator to increase the transmission bits, which was not achieved in the binary transceiver. The neural network-based static random access memory was used with the cluster-based WSN. That system would reduce the consumed power by the sensor node for the transfer and the cost of storage.

Ahmed et al. (2019) proposed the thermal and energy-aware routing (TEAR) scheme for the medical information routing with the WBAN. The model minimizes cost for the three constraints: energy consumption, heat dissipation, and the link quality between the two communicating nodes. The model aided in minimising the energy emission that would affect patient tissues and enhance the network lifetime. After this procedure, the routing on the system was done. The transmission power was low for that protocol, directly reducing the packet collision.

Geetha and Ganesan (2020) proposed the routing protocol based on cooperative energy-efficient and priority with network coding (CEPRAN). The cuckoo search optimization was used to identify the relay node on the group of sensor nodes mounted on the body. The energy consumed for hop and multi-hops was reduced by incorporating the cooperative approach. The relay node acts as a bridge between the nodes and the sink node; thus, the relay nodes occupy the place of the gateway node.

Qureshi et al. (2020) proposed the hop selective routing scheme based on link quality and energy utilization for WBAN. That energy-aware routing (EAR) will minimize the utilization of energy by the sensor nodes. Then the link quality was determined to have the following hop routing, enhancing the data transmission. Thus the system makes reliable data services. The method adopted the handshake mechanism to overcome the issues of network overloading by a short message scheme. The control messages in the system have information about the residual energy and link quality, the data was efficiently routed from this information.

Table 1 shows the energy consumption, throughput, and other parameters for 100 s of simulation time.

Several routing methods deal with the WBAN, but few researchers have solved the energy consumption problem, thermal effect on humans, and link quality issues. Hence those parameters are considered for the routing of data by IoMT devices.

3 Proposed methodology

This paper performs the routing protocol for the WBAN based IoMT. The medical data is gathered on the IoMT devices, which transmit this data to the central node using the proposed routing technique. The proposed routing protocol is based on link quality and thermal aware adaptive routing. First, the protocol discovers all available paths with high

Table 1 Comparison of state-of-the-art techniques

Authors	Method	Performance evaluation	Cons
Saleh et al. (2018)	Neural network static random access memory	Energy consumption = 33.42 J w.r.t distance	Due to high energy consumption, transmission power would be very high along with the heating ratio
Ahmed et al. (2019)	Thermal and energy-aware routing	PDR = 92.3% Heating ratio = 0.925 for 40Kbps of data rate	The poor lifetime and the model were not robust
Saba et al. (2020)	Secure and energy-efficient framework	Throughput = 90% Energy consumption = 0.023 J PDR = 88% Link breaches = 7.26%	If the nodes were mobile, many link breaches might occur
Al-Turjman and Deebak (2020)	Privacy-aware energy-efficient routing	Throughput = 80.34% Link breaches = 12.3%	A complex security system had performed
Geetha and Ganesan (2020)	Cooperative energy-efficient and priority-based reliable routing protocol	Throughput = 92% Energy consumption = 0.58 J PDR = 93%	Applicable only for the static network. Also, link breaches were high
Qureshi et al. (2020)	Energy-aware routing	Throughput = 1247 Mbps Energy consumption = 0.053 J PDR = 88%	Quality of link was poor for mobile nodes
Ahmed et al. (2021)	A thermal aware routing protocol	Energy consumption = 14.15 mJ Heating ratio = 0.92 for 40 Kbps of data rate	The quality of the data transmission link was affected by the increased data rate

quality and low thermal effects. By exploring these paths to reach the destination, the prim's algorithm makes the cost analysis. Then the routable path is selected based on the low cost link for transmission, the prim's algorithm achieves this step. To reduce the computational time and complexity, the cost for all discovered path is calculated and stored on the table named prim table. The stored data is used without the computation process if any cost for the same path is needed. This two-step process makes the protocol an adaptive technique. Thus the developed protocol reduces the problem of poor packet delivery ratio, high energy consumption, and high cost transmission.

3.1 Wireless body area network-based IoMT

In WBAN, the sensor nodes (IoMT devices) are placed beneath the skin or on the body to examine the features named as temperature, blood pump ECG, muscle pressure, EEG, pressure sensor at the leg, etc. The sensors used for this type are called biosensors and are used in the IoMT field. When the sensor network is used in the IoT, the setup will be classified as inter-WBAN, intra-WBAN and beyond-WBAN. The inter and intra-WBAN can be studied by the routing protocol used in the article, whereas the SigFox network can do the beyond-WBAN, but its security issues are focused on future work. In intra-WBAN, the data is routed from the IoMT devices to the base station. In inter-WBAN, the communication between the biosensor nodes. In some cases, the gateway node transmits the data with a high energy level. The energy consumption of the biosensor node depends on the processing, data aggregation and sensor properties of the biosensors.

Here the data sensed by the biosensors are transmitted to the gateway node (personal server). It is received by the SigFox base station, where the SigFox cloud will direct the data to the authenticated users, as shown in Fig. 1. In WBAN, the routing protocol is designed with reduced routing overhead on the network by considering the thermal effect and energy consumption. The dynamic power levels are set to the IoMT devices based on the distance for the communication, which is a key point for the designed routing system.

3.2 Prim based link quality and thermal aware adaptive routing protocol (PLTAAR)

The IoMT devices will route the sensed data using the adaptive routing protocol. The designed protocol is adaptive by utilizing the prim's algorithm and storing the generated cost function in the prim table for future use. The data transmission among the biosensor node (IoMT devices) will form the inter-WBAN, and the data transmission among the IoMT device with the personal server is intra-layer. The routing technique focuses on the link quality and the thermal effect on the IoMT devices. For this, the link quality and the thermal effect are framed as shown below:

3.2.1 Thermal effect computation

The change in the thermal effect of human tissue is provided by SAR as,

$$S_R = \frac{\theta|E|^2}{\mu} \tag{1}$$

where, E is the electric field and θ indicates the electrical conductivity of human tissue. The temperature of the tissue depends on its density and is represented as μ. The change in thermal effect of the node a is expressed as,

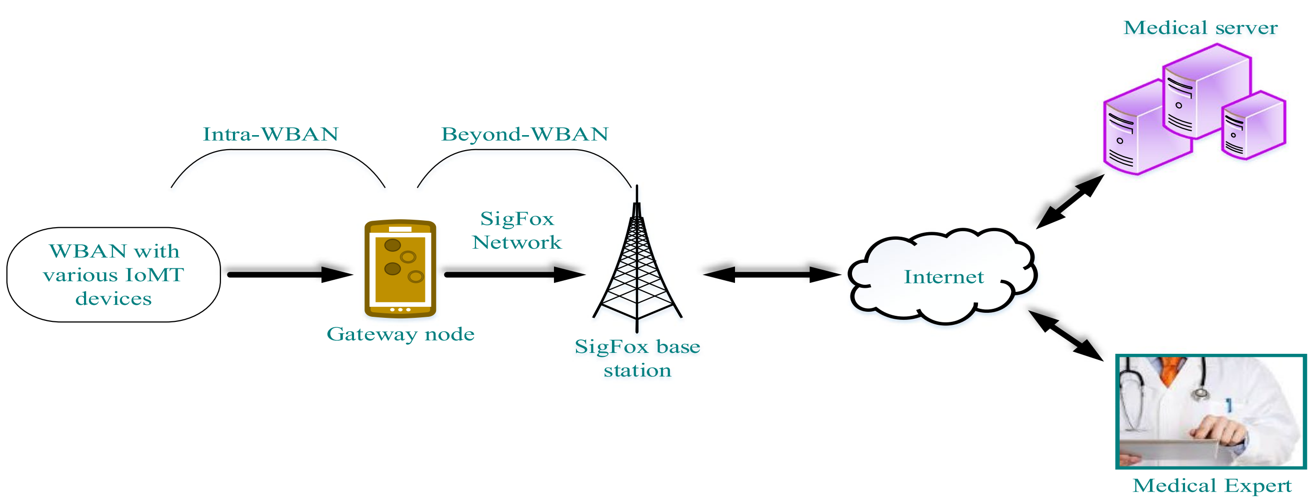


Fig. 1 WBAN structure based on IoMT

$$\Delta T = \frac{S_R^{current}}{S_R^{initial}} \quad (2)$$

where, $S_R^{initial}$ is the initial heat in the human tissue and $S_R^{current}$ is the heat on the tissue after several transmissions. This is calculated in every biosensor node to initiate the routing procedure.

3.2.2 Link quality

The link quality to receive the signal with high strength is given by L_{a-b}, a is transmitting node and b is receiving node. The link quality is measured at the receiving end; mathematically, it is given by,

$$L_{a-b} = \frac{P_a}{P_b} \quad (3)$$

From the above equation, it is noted that the link quality depends on the transmitting power of the biosensor and receiving power of biosensor, and is denoted as P_a and P_b respectively. The link with the least cost is used for transmission.

The routing technique uses two steps as path diversity: the number of path with link quality and thermal effect is taken. The next step is routable path selection, where the prim algorithm selects the best path using the minimal cost function.

3.2.3 Path diversity

The medical information is gathered on the biosensor, and the sensed information are routed to the IoMT devices. The node on the 3D space searches a routable path to direct the medical information to the destination of the human body. The biosensor will sense the data and transmit the data to the destination by considering the axis's thermal effect and link quality. The path to reach the IoMT devices is explored based on thermal and link quality in the 3D search space.

The biosensor sense the medical information, if the perceived information is deviated from what the sensor is set, then the ALERT information is sent along with the perceived changes. When the transmission is initiated, the route to the destination devices is checked for thermal change. If any temperature change is perceived, the following workflow of Fig. 2 is performed.

When the biosensor node initiates the data transfer, the thermal change on the path close to the source node is checked. If there is a large thermal change, the data transfer

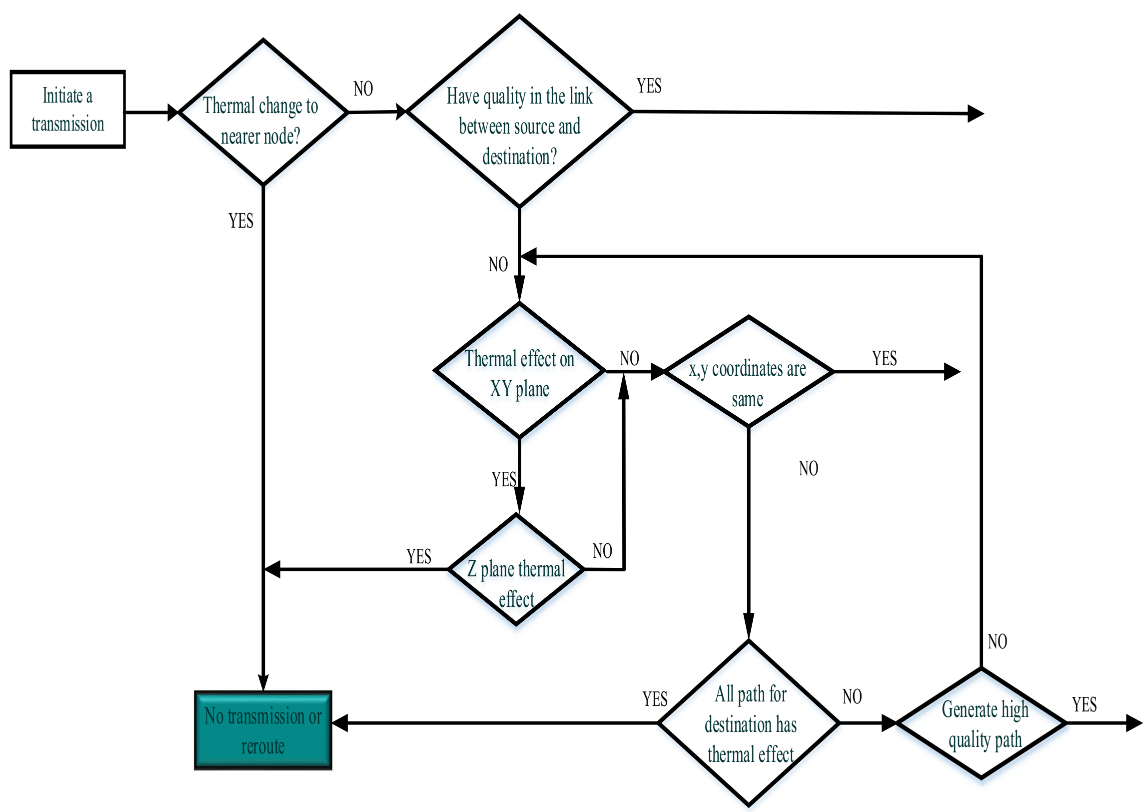


Fig. 2 Path diversity process based on link quality and thermal effect

is terminated, which saves a lot of energy that is unnecessarily drained from the biosensor node at first. If no thermal change occurs, the connection quality between the source and the intermediate node is checked. If better quality is perceived, then the data will be transmitted successfully. During the low quality between the two nodes, then the thermal effect on the XY plane is noted. For the negligible thermal effect on the plane, the coordinates are then checked to see whether both coordinates are similar, if so, the path is selected. While the coordinates do not match, the entire path to the target is examined for the thermal effect. When the examined condition is true, the transmission is disrupted. The link quality for all the available paths is noticed for the transmission.

For the thermal effect on the XY plane, the Z plane is checked for temperature change. At this stage, the transmission is ignored for the high heat dissipation on the available path. Else the transmission is checked at the x, y coordinates. At this phase, a number of paths are available for transmission; those paths are optimized for low transmission cost by the minimum spanning tree algorithm named prim's algorithm.

3.2.4 Path selection

The Prim's algorithm is used to find the low cost transmission path on the WBAN network. It has the advantage of cost-efficient transmission. Prim's algorithm works on all available path that is achieved during the path diversity phase. The selection for this kind of sub-graph flow is due to the undirected flow of the subject. The prim's algorithm gives the interconnection of the biosensor nodes. The prim's algorithm randomly plots the edges between the biosensor nodes by disjoint sets. To find the minimum cost function for the path to communicate the IoMT devices on the prim's algorithm is used. Here, the minimal distance path is not taken for transmission. The distance is not considered here. Only the cost for the transmission is considered. The prim's algorithm is used to setup the node on the patient by having the minimum cost function.

Prim's algorithm is a Greedy algorithm that maintains two sets of vertices (Iqbal et al. 2017). The edges will connect the two sets at every step and pick only the minimum weighted edge. Once the edges are selected, the endpoint will move to the edge specified with the minimum spanning tree. The interconnection of the biosensor to form a complete graph is represented by S having the unique edges of U, which is located between the IoMT devices. The number of edges that connect the two vertices is referred to as cut-in-graph.

At every step, a cut is formed, where the minimum cost edge is found, including the vertices set. Figure 4 is shown an example to show the working of the Prim's algorithm for a minimal cost function based on the weight. For the considered example, there are 18 edges located between the vertex that biosensors. The overall routing procedure is shown in Figs. 3, 4. Initially, the set is empty, and the cost (weight) for each path (edge) is assigned to the vertices. For the considered example, the step by step process of the minimum cost function is shown below:

Algorithm

Step 1: The initial node for transmitting the data is represented as D, included in the minimum spanning tree set.

Step 2: When the node is selected, the cost value for the adjacent vertices is updated.

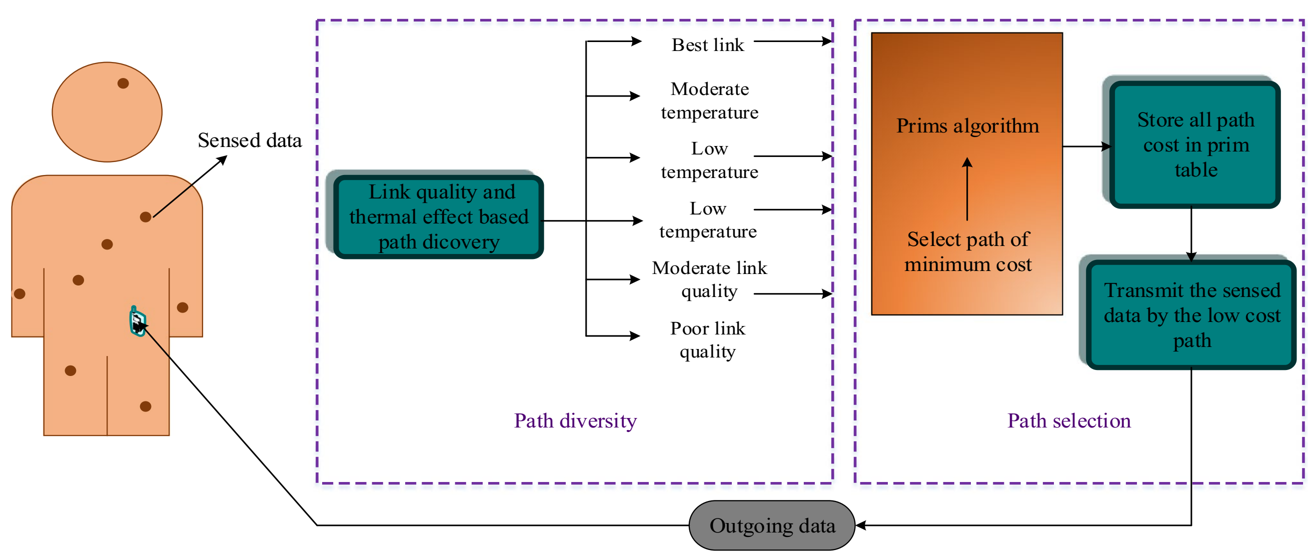


Fig. 3 Routing of the proposed technique

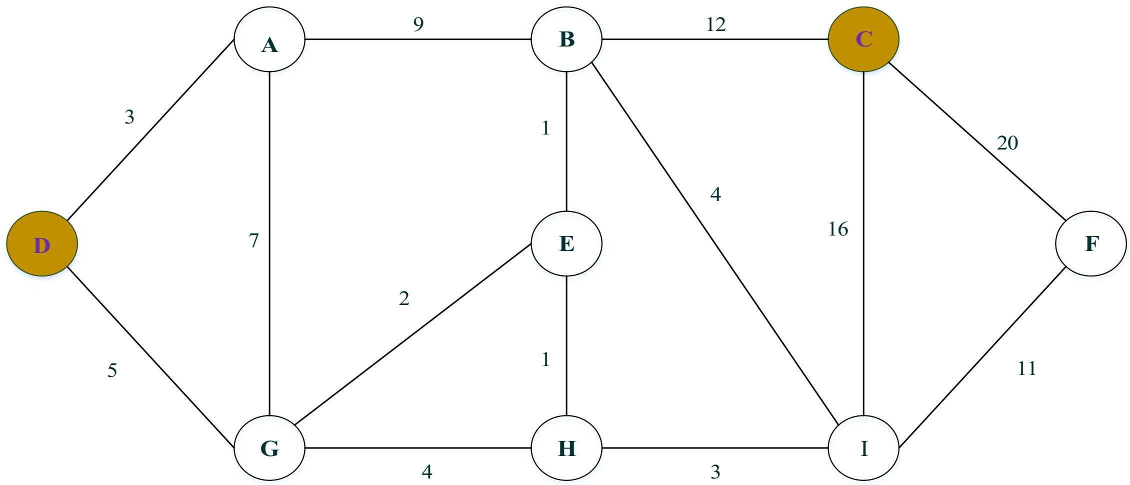


Fig. 4 Example model to illustrate prim's algorithm

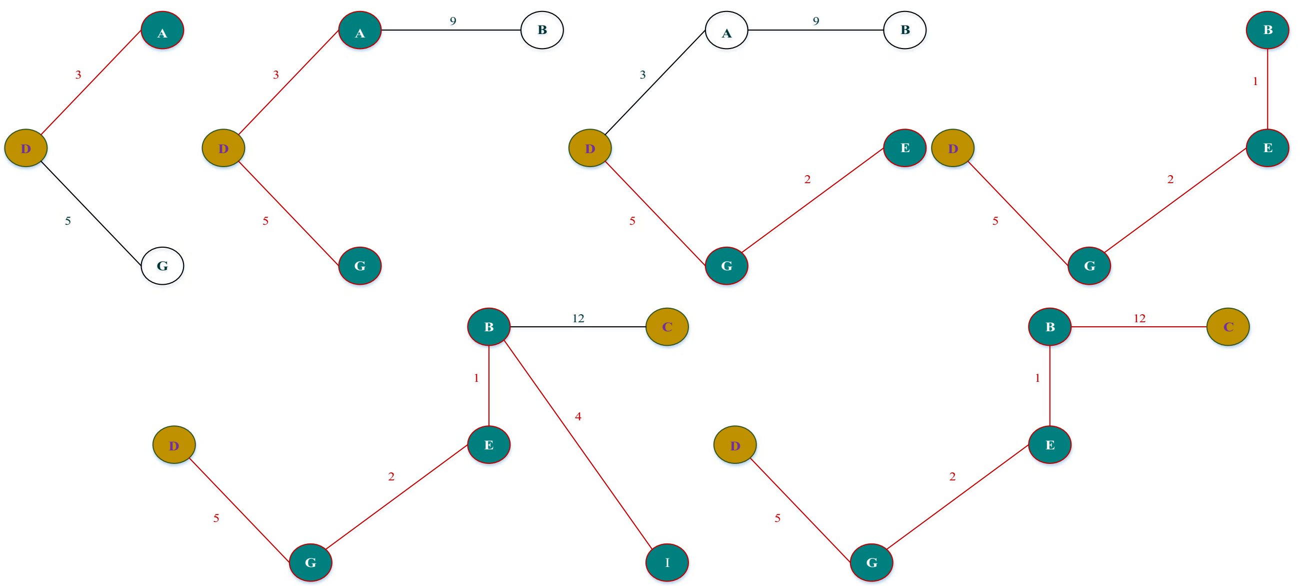


Fig. 5 Sub-graph flow of Prim's algorithm to search for minimal cost path

Step 3: The adjacent vertices of D are A and G having the cost values of 3 and 5, respectively.

Step 4: The sub-graph formed by selecting the minimum cost value is shown in Fig. 5.

Step 5: Then, the path to the next vertex of A is generated. If the cost value for that path is less than the already generated vertex, then the current path is chosen. Else the other path is considered. Here the cost value for the B vertex is 9, so it is ignored, and vertex G is chosen to route.

Step 6: Again, the adjacent vertex of the G node is explored as E and H, and its cost value is 2 and 4, respectively.

Step 7: The minimal cost value is checked, here the node E has the minimal cost value as 2, and then this route is taken to route the data.

Step 8: At this point, the adjacent vertex of E is B and H, where B and H have the least cost value. But the path to reach C is adequate with the B since node H involves the cost at H-I and I-C, which is huger than the other model.

The path to travel data on the WBAN is updated by the prim's algorithm. The cost of the available path in the stage is stored in the prim table for later use without calculation. The data observed by the IoMT devices is transmitted to the SigFox base station (intra-WBAN), where the information is transferred to the authenticated user using the internet.

4 Result and analysis

In this paper, the novel method for routing in the IoMT device is provided with the consideration of link quality, temperature and also the cost for the transmission. The routing concept focused on the protection of the patient as well as the low cost, high delivery rate transmission. Here the number of paths is selected by considering the link quality and thermal effect on the IoMT devices, which reduce the number of retransmission and queuing of the data. This concept reduces the amount of energy consumed by the biosensors. Then these generated multipath paths are checked for the low-cost path through the Prim's algorithm. The cost for all generated paths is stored in the prim table to later use the same path for a different node. This will reduce the complexity and computational time for the processing. This structure is implemented in the MATLAB platform for the analysis and has studied how the data transmission occurs in the WBAN using the simulation parameters listed in Table 2.

For the analysis, 14 biosensors are used on the WBAN. Those biosensors are considered to implement on the human body to monitor the data. The data such as, EEG, EMG, leg

Table 2 Simulation parameters

Simulation parameter	Ranges	
Number of nodes	14	
Initial energy	1 J	
Traffic type	CBR	
Packet size	22 bytes	
Simulation time	200 s	
Transmission rate	250kbps	
Transmission distance	Urban area	10 km
	Rural area	40 km
Frequency	Urban area	868 MHz
	Rural area	902 MHz

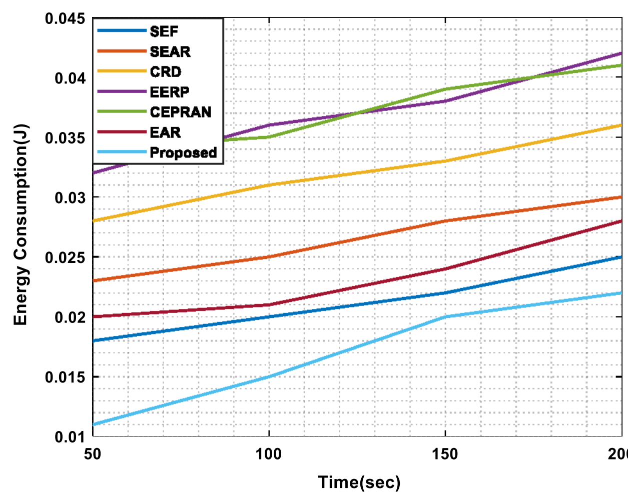
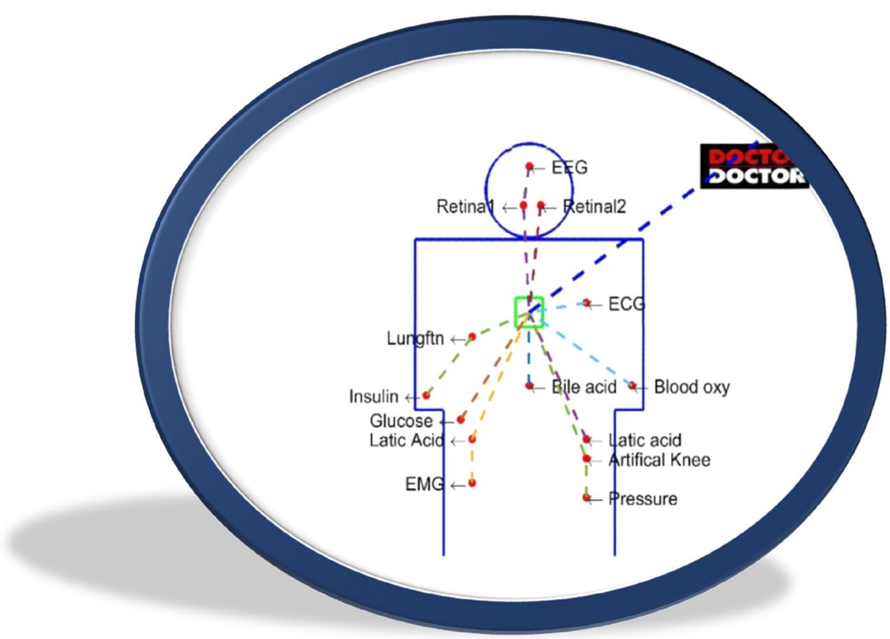


Fig. 7 Energy consumption

Fig. 6 Network structure when implemented in the MATLAB



pressure, ECG, bile acid, lung function, right and left retinal function, glucose level, insulin, blood oxygen, lactic acid content, the orientation of artificial knee. When any IoMT device acquires the abnormal data, it will check the acquired data with the normal range of the particular element. If there are any changes in the data reading, then the IoMT devices will send the acquired data to the authorized user to the doctor, the ambulance, or maybe the server. The data routed by the left retinal IoMT devices is shown in Fig. 6.

The amount of energy consumed by the IoMT devices for the data transmission from the initial energy of 1 J is given in Fig. 7. By analyzing the link quality, the routing protocol decides whether to transmit the data or not. This reduces the number of retransmissions and also reduces the failure of data transmission after crossing multiple paths, which directly saves the energy used by the IoMT devices for each transmission. Thus, the parameters inhibit characteristics of network lifetime. The proposed method is compared with SEF (Saba et al. 2020), S-EAR (Al-Turjman and Deebak 2020), CRD (Sagar et al. 2020), E-ERP (Al-Turjman and Deebak 2020), EAR (Qureshi et al. 2020) and CEPRAN (Geetha and Ganesan 2020). The energy consumption level will be raised when the packet delivery rate increases. For instance, if the packet delivery rate is 96.7%, 0.015 J of energy is consumed from the initial energy content; the proposed method's energy consumption is 0.02 J of energy utilized by the node when the packet delivery rate is 96.1%. This increased energy consumption and reduced delivery rate are due to the active states of a node. On the other hand, the existing methods like SEF, EAR, S-EAR, CRD, E-ERP and CEPRAN show an energy consumption of 0.022 J, 0.24 J, 0.27 J, 0.33 J, 0.38 J and 0.39 J. The delivery rate shows 87.5%, 76.2%, 82.3%, 76.8%, 71.4% and 62.4% for the existing methods, respectively.

The packet delivery rate of the proposed routing protocol is compared with the other routing protocols like EAR, SEF, E-ERP, CRD, S-EAR and CEPRAN, is shown in Fig. 8. The packet delivery rate of the proposed method is maintained to the level of 95–98% during the simulation process. The CEPRAN has a very poor packet delivery rate, proving to be an unstable network operation. At the end of the simulation, the proposed method has achieved 95% of assured delivery whereas, the other methods have achieved only 84.5% by SEF, 78.5% of delivery rate by S-EAR, 75% by EAR, 73% of delivery rate by CRD, 68.5% of delivery rate by E-ERP and 62% of assured packet delivery by CEPRAN. The figure shows that in the 160 s, the EAR had tried to achieve a higher delivery rate than the CRD method. But it has not reached the delivery rate of the PLTAAR protocol, which outperforms other methods.

The residual energy is plotted against time in Fig. 9. Residual energy is the amount of energy left over to operate in the network. Due to the reduced number of dead nodes, the residual energy in the device is high. The residual energy is compared with the extant techniques like SEF, S-EAR, CRD, E-ERP, CEPRAN and EAR. At the end of the simulation, the average residual energy available in the node is 0.95 J, 0.953 J, 0.958 J, 0.964 J, 0.97 J and 0.975 J for EAR, CEPRAN, E-ERP, CRD, S-EAR and SEF respectively, whereas for the proposed protocol 0.979 J of energy is available. The proposed method saves smaller residual energy than the other extant methods.

H-Ratio is nothing but the heating ratio on the node. The H-Ratio of the proposed protocol considered the thermal effect, and the parameter is compared with the TEAR and ATAR protocols. That protocol also deals with the same scenario by considering the heating effect on the biosensors. The heating ratio is measured against the amount of data rate used for transmission. When the data rate is 40Kbps,

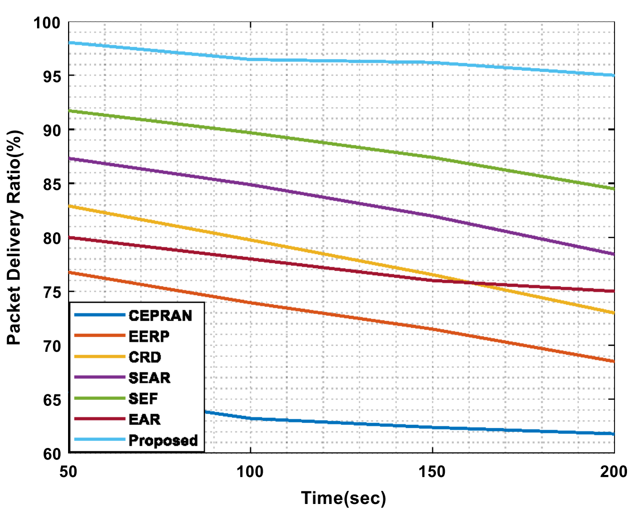


Fig. 8 Packet delivery ratio

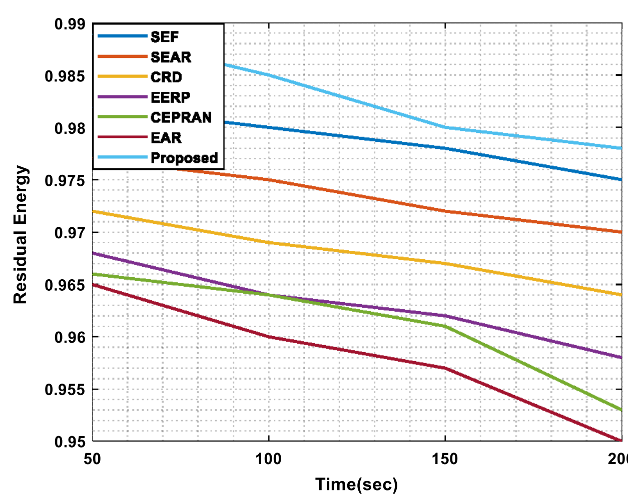


Fig. 9 Residual energy

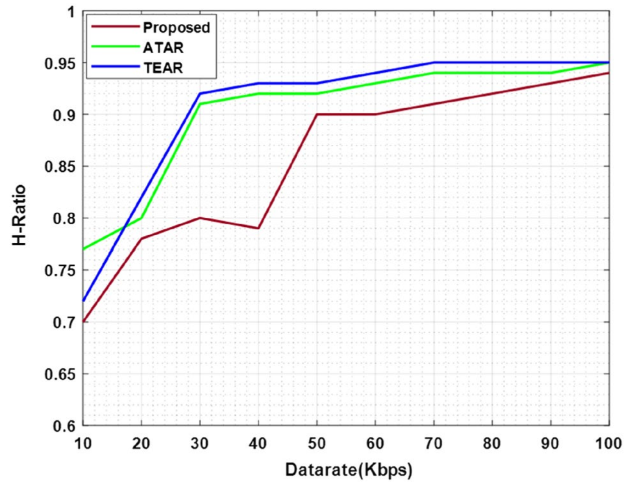


Fig. 10 H-Ratio

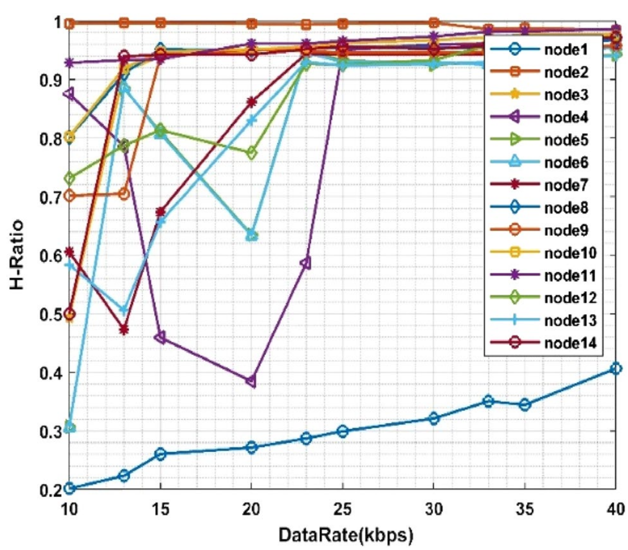


Fig. 11 H-Ratio for 14 biosensors

the proposed method has yielded a 14% improvement over TEAR (Ahmed et al. (2019)) and 12% over ATAR (Ahmed et al. 2021). This indicates that the proposed protocol is well-suited and provides better throughput when the data rate is maintained at 40Kbps, the nominal data rate supported by the protocol. When the data rate is increased to 100Kbps, the TEAR and ATAR encounter the same heating point, and the PLTAAR achieves a 13% improvement over the others. This implies that when the data rate increases, the heating of the node also increases. Here, the thermal constraint routing protocols show a higher temperature on the whole network than the proposed model, as shown in Fig. 10.

The heating ratio of the 14 considered biosensor node readings is plotted in Fig. 11. The figure shows how the node heats as the data transfer rate increases. Node 2 has a complete H-ratio, which indicates that the number of transmissions through that node is high while the transmission at node 1 is very small; hence the thermal effect is comparatively low. Node 4 has sudden changes or oscillation in its thermal effect, which indicate that the transmission through that node is suddenly reduced, and it has got huge time to settle from its initial value. Similarly, the other nodes 5–7, 9 and 12–14 also face the same scenario by reducing data rate and transmission from the initial heat.

On the other hand, nodes 3, 8, 10 and 11 have encountered high and approximately stable H-ratio concerning the increment in data rate. This implies that the heating of the node varies by data rate, transmission requests and time. The H-ratios depend on the data rate of the recorded data since there is no compromise for reduced data rate of information in the medical field.

The link breach shows the breakage of the link after several time by violating the laws for the data transmission. If any links get throttled for the considered number of times, a violation occurs on the link that leads to the link breaches. For the average simulation time the link breach reduction obtained by the PLTAAR is 1.7% from SEF, 1.1% from P-AEEF, 8.59% from CRD, 9.9% from S-EAR and 12.2% from the E-ERP methods. Overall compared with the state-of-the-art techniques, the model has reduced the link breaches in the network to 6.7%. The link breaches are reduced for the proposed routing method, as shown in Fig. 12. This is due to the generation of multiple path for the data transmission. Creating the link quality-based path accessing will reduce the breach in the link.

The network throughput is shown in Fig. 13. Throughput also gives the amount of data transmission at a given time; it is a parameter that proves the robustness of a model.

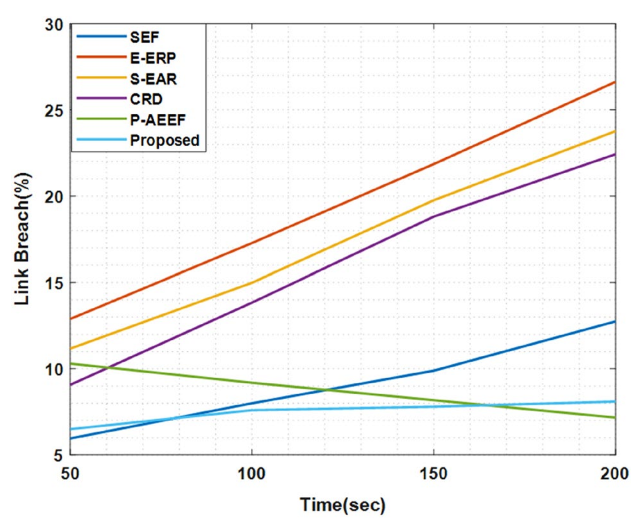


Fig. 12 Link breaches

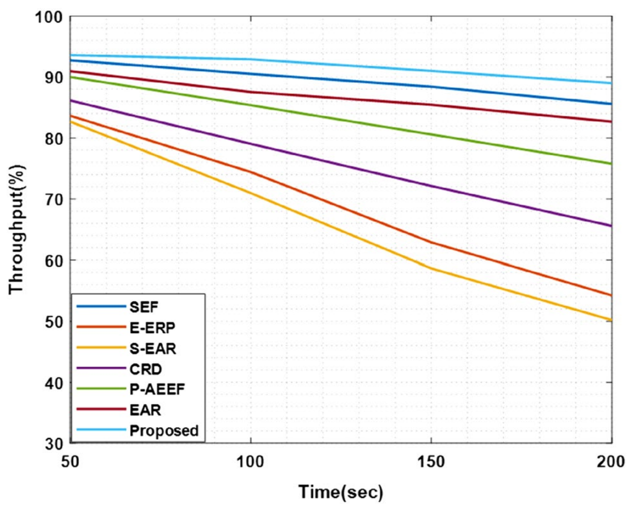


Fig. 13 Throughput

The throughput is compared with the SEF, P-AEEF, E-ERP, EAR, S-EAR and CRD. Initially, the throughput of all the comparative methods will be better, and it was based on injected energy level for the corresponding network. For the simulation time of 200 s, the throughput achieved for S-EAR is 50%, for CRD the throughput is 66.7%, 54% of throughput is obtained for E-ERP, 75.8% for P-AEEF, 82.5% for EAR and 86.7% is achieved for SEF. At the same time, the proposed method has achieved the highest throughput of approximately 89.3%. The average improvement achieved by the proposed method in contrast to the above mentioned extant models is 13.61%. At present, the link breach has maintained a trade-off between SEF and PLTAAR for simulation of 100 s; hence when the mobility is injected SEF may outperform the proposed one. When the time increases, the transmission rate on the network will be low due to traffic. Hence the term will indirectly indicate the network traffic issue.

5 Conclusion

This paper presents the routing protocol for the IoMT devices in intra-WBAN. The paper aimed to make a human organ protection based node utility routing protocol for the patients. The presented two-step routing model has considered thermal effect, link quality and the transmission cost for the safe data transmission in healthcare applications. The proposed PLTAAR protocol reduces the number of retransmission on the network by exploring multiple paths for the transmission. The proposed protocol was outperformed by achieving 13% improvement in H-ratio, 6.7% in reduced link breaches and 13.61% improved throughput from the extant protocols, thereby satisfying the robust condition of energy-efficient protocol in IoMT technology. When the mobility of the node is high, then a high level of link breaches may attempt to happen on PLTAAR.

This work concentrated on the safe acquisition of data from humans. Our future goal is to provide the secure transmission of the collected data to the end-user. That is the increase of the security level beyond-WBAN.

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Declarations

Conflict of interest Authors declare that they have no conflict of interest.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

Consent to participate All the authors involved have agreed to participate in this submitted article.

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