

Transposition-Based Energy Optimization Technique for Internet of Medical Things

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Abstract:

Internet of Medical Things deals with human physiological parameters to make human life better. It uses internet based devices called sensors which are of small size and have the limitations of having small sized batteries. Once these batteries are drained, they need to get recharged. The recharging if these batteries is not a solution in term of human health care as these sensors are implanted on human body. This is because continuous monitoring is required so that patient treatment be processed. The sensors use this battery energy is all processes but is much more consumed in communication. There needs to be a mechanism to overcome this issue. Routing protocols are designed to make the network better to let the sensors work for more time. In this paper a multi hopping and transposition based technique is proposed for implementing sensors on calculative way. This positioning makes the routing between the sensors to have lesser distance factor which makes the communication energy to be consumed lesser. Euclidean distance formula is used so that the distance of the sensors from the sink is calculated. As the data is transferred consuming energy so to reduce this energy multu hopping is needed. This allows sensors to transfer their recorded data to other sensors in which a sequence that the data reaches successfully to the base station.

Keywords: IoT, IoMT, Energy,

I. INTRODUCTION

Internet of Medical Things (IoMT) is a field of Internet of Things (IoT). This field of research deal with the physiological parameter measurement of humans [1]. It is helpful in many aspects in human health. The human vital signs are measured and this data is stored for further betterment of the humans. IoMT uses tiny sensors to capture the human physiological parameters [2]. As these sensors are based on Nano Electro Mechanical Systems (NEMS) / Micro Electro Mechanical Systems (MEMS) technology so they are small in size making them suitable for daily medical base usages for continuous monitoring [3]. The size although is their advantage in making them suitable and portable but also provide limitations. These limitations are of battery capacity. These sensors are able to sense, process the sensed data and communicate the sensed data. As depicted in Figure 1 it can be observed that the energy is consumed in all aspects of the sensors but it is much more consumed in communication [4].

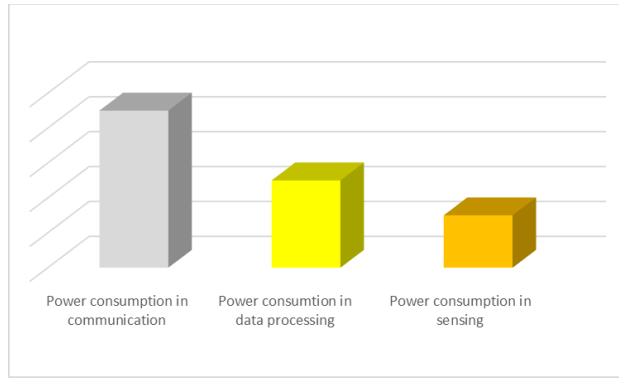


Figure 1: Power consumption comparison of sensor parameters

This communication is between sensor to sensor or between sensors to sink node. Sink node is a type of device that is a central device which gathers data from sensors and is also responsible for transmitting the data towards other entities which require this data [5]. These sensors are differentiated as either wearable sensors or invasive sensors. Table 1 shows the categories of IoMT sensors in detail.

Table 1: Categories of IoMT sensors

Sensor Type	Invasive Sensors	Wearable sensors
Sensors	Retina implants Pacemaker	Electro Myo Graphy (EMG) Electro Encephalo Gram (EEG) Electro Cardio Gram (ECG)

These sensors can be placed on human body as to record the parameters. As per the application of the sensors they are placed on the part of human body. This is depicted in Figure 2

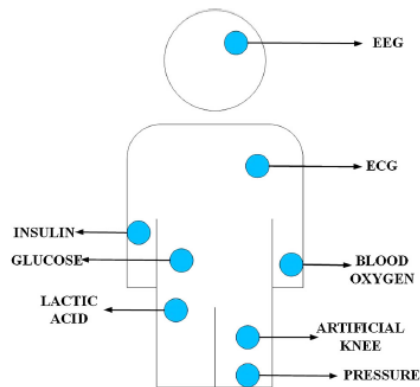


Figure 2: Sensor placement for monitoring

II. ARCHITECTURE OF IOMT

The architecture of IoMT is represented in Figure 3. The architecture is categorized in three tiers. Tier 1 is the human itself as a patient or a person under observation having sensors and sink node in the body as shown. It can be observed that the human has multiple sensors (represented by circular dots) on the body which are used to measure physiological parameters. If the data is needed to be communicated then the sensors send their data to the sink node (represented by rectangular box). This complete process comes under the umbrella of tier 1.

The data gathered by the sink now needs to be transmitted [4]. This is tier 2. As shown in Figure 1, the tier 2 has three components: a Personal Digital Assistant (PDA) or it could be a mobile phone, Personal Computer (PC) and a communication tower. Tier 2 could comprise of any of these three options. The responsibility of tier 2 is to collect data from the sink node which is at tier 2 and then transmit / communicate the data to tier 3. Tier 2 devices should be placed in such a way that the sink node must be able to communicate properly as it is of low ranges [6]. As shown there is a cloud in tier 2 meaning that these all components in tier 2 use cloud internet services in one way or another.

Tier 3 has 4 entities as shown are described as first is the medical representative or doctor to whom data is sent for observation and second is the ambulance if there is a need depending on the condition of patient. Third is database for record keeping and last is to send the information to loved ones if the patient is remotely located. These all entities in tier 3 are not compulsory to exist altogether [7].

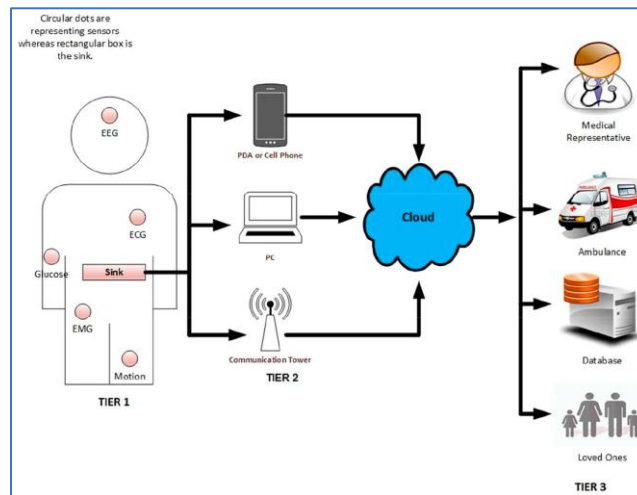


Figure 3: Architecture of IoMT

Now that these sensors have capability to consume much energy in transmission researches are being carried to make the transmission effective. This effectiveness will provide the sensors the facility to save their battery life and do not deplete faster. The research is being carried to make the network for longer time. This research is to make energy efficient routing protocol.

In this paper research is proposed to achieve energy efficiency in IoMT routing by effectively calculating the positioning of the sensors called transposition. This will provide sensors to communicate their data at lower distance. Multi hopping method is used also. This makes the proposed technique operate effectively as the sensors are on the calculated places and for communication data is not transmitted directly to the sink instead the sensor which transmits data will transmit it to its nearest sensor to achieve multi hopping. In this way the energy of the sensors remain intact and they operate for longer span of time. A routing protocol becomes unstable if any of the sensors in the routing protocol depletes its total energy. When all of the sensors lose their energy the network life time is ended. These two parameters are compared of the proposed technique with the existing technique.

III. LITERATURE REVIEW

A protocol named “Sink mobility based Energy Efficient Data dissemination in IoMT” has been proposed by researchers in [8]. They have tried to address Wireless Body Area Network (WBAN) dynamic scenario in order to increase energy efficiency of sensors that are used in the network. They have developed a rectangular shaped network comprising of 4 sensors on body which are Energy Powered (EP) According to their study hot spot problem is caused due to static network. Remora Optimization Algorithm (ROA) has been used so that out of all the sensors used a Cluster Head (CH) is selected. This is done for optimization and energy balancing between sensors.

Light Weight energy – efficient Block Cipher based on Deoxyribo Nucleic Acid (DNA) cryptography (LWBC – DNA) method has been used in [9]. This study proposes to secure data in IoMT environments and on the same time

improve life span of objects by saving energy. It is able to encrypt block which are of 64 bits using a key. This key is of 16 bits and goes through 16 iterations using Exclusive NOR (XNOR), Exclusive OR (XOR) and concatenation so that it can produce a cipher text of 32 – bit.

Q – Learning based Quality of Services (QoS) Aware Routing (QQAR) research has been proposed by the researchers in [10] which basically addresses problem of QoS issues in IoMT. They have suggested three steps for their proposed work. In first step they have proposed the usage of two hop bases estimation of reliability. This reliability is towards sink nodes from source nodes. The usage of two hop is to guarantee packet delivery successfully. In second stage they have prioritized packets on the basis of traffic. This is used to ensure that even though network is congested, critical packets should be delivered successfully. Third step is to avoid congestion in their network they have proposed to use multiple sinks load balancing technique by adjusting routing decisions. To select appropriate neighbor sensor node to forward packets they have utilized Q – learning.

A framework has been proposed which is able to perform user authentication to secure IoMT network. The proposed protocol allows user to access Block Chain Networking (BCN) by providing them legal authentication. It does not allow user to store large amount of data in Block Chain (BC). An authorized user only is able to upload data related to health care in BC. They have proposed to use Encrypted K – Means Clustering – based Stellar Consensus Protocol (EKMC –SCP) for data to be communicated securely in BCN. To make the protocol more robust key generation method has been used. Their framework is based on Elliptic Curve Menezes – Qu –Vanstone – based Message Authentication Code (ECMQV – MAC). The data in this system is secured using mechanism of key generation and Deltoid curve – based Pallier Cryptosystem (DC – PC). Method of Dixon’s Method – based Blum – Goldwasser Cryptosystem (DM – BGC) has been used to generate keys [11].

IV. PROPOSED SCHEME

In this section the detailed description of the proposed methodology is described in detail

A. Sensor Selection

In the proposed scheme nRF2401A has been used. It is used because it is a low powered operating sensor. It operates at 2.4 Giga Hertz (GHz) Industrial, Scientific, and Medical (ISM) band. It becomes suitable for IoMT because of its low – power wireless applications operating for short ranges.

B. Sensor Positioning

As the proposed scheme has to be compared with already exiting scheme(s) so for that parameters should remain the same so the number of sensors used in the proposed scheme has been kept to 8. Table 2 gives the positioning of all the sensors in x and y coordinates.

Table 2: Sensor Coordinates

Sensor Node	X / Y Coordinate Value	Sensor Node	X / Y Coordinate Value
Sensor Node 1	37 cm / 10 cm	Sensor Node 5	60 cm / 75 cm
Sensor Node 2	54 cm / 30 cm	Sensor Node 6	22 cm / 90 cm
Sensor Node 3	37 cm / 55 cm	Sensor Node 7	24 cm / 70 cm
Sensor Node 4	53 cm / 55 cm	Sensor Node 8	50 cm / 80 cm

C. Distance Analysis

The data collection is performed and communicated to the sink node by the sensors. Euclidean distance formula [12] is used to calculate distance of the sensor nodes from the sink node as represented in equation 1 given below:

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \quad (1)$$

For IoMT the Euclidean distance formula is given as

- x coordinate value of the sensor node is represented by x_2
- x coordinate value of sink node is represented as x_1
- y coordinate value of the sensor node is given as y_2
- y coordinate value of sink node is given as y_1

The total number of sensors are 8 so there will be 8 distance values which are added up for cumulative distance as given in the equation 2 below:

$$d_t = \sum_{i=1}^8 d_{s_i} = d_{s_1} + d_{s_2} + d_{s_3} + d_{s_4} + d_{s_5} + d_{s_6} + d_{s_7} + d_{s_8} \quad (2)$$

d_{s_1} to d_{s_8} are the distance values of the sensors from 1 to 8

D. Power Consumption Analysis

The power consumed in transmission in the proposed technique is discussed in this section. For single hop mode of communication the sensor node which is transmitting data consumes energy as given in equation 3 below

$$E_{SH} = E_{TX} \quad (3)$$

E_{TX} = Energy consumed in transmission

The mathematical representation of energy being used in multi hop communication is given as

$$E_{MH} = s \times n \times \left[(E_{TX} + E_{RX} + E_{DA}) \times \frac{(n-1)}{n} \right] \quad (4)$$

s = Packet size

n = Hop count

E_{RX} = Receiving Energy

E_{DA} = Data Aggregation Energy

E_{TX} = Transmission Energy and is represented mathematically as

$$E_{TX} = (E_{AMP} + E_{ELEC}) \times s \times d^2 \quad (5)$$

E_{DA} = Energy consumed during data aggregation

E_{ELEC} = Energy consumed BY the components

V. RESULTS

In Figure 4 the simulation results are presented and compared between the proposed scheme (named as IoMT RP) and existing routing protocol (named as EERP1) in terms of stability of the network and life time of the network. As the network starts working the sensors in the network start depleting their energies as time proceeds. As first sensor loses its entire energy this makes the network unstable. The network still operates until and unless all the sensors in a network deplete their energies. As observed in Figure 4 the EERP1 becomes unstable (first sensor node losses its entire energy) at around 2148 nodes and all of its sensor nodes deplete their energy around 7445 nodes. The Figure 4 it can be observed that the proposed method has longer stability period. The proposed method is able to achieve 28.49% and 7% more stability period and network life time respectively.

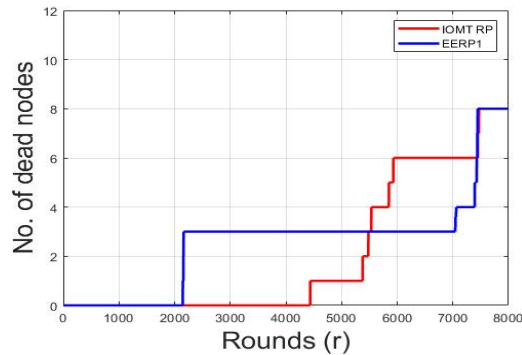


Figure 4: Proposed IoMT RP with EERP1 Comparison

The complete description of Figure 4 in terms stability of the network and life time of the network node by node is given in Table 3.

Table 3: Node by Node Comparison

Protocols	Number of Rounds							
	Node 1	Node 2	Node 3	Node 4	Node 5	Node 6	Node 7	Node 8
EERP 1 [13]	2148	2160	2162	7059	7427	7430	7444	7445
IoMT RP	4221	4664	5788	5997	6525	7006	7452	7630

The proposed IoMT RP shows better stability until 4700 rounds whereas EERP1 has dead nodes starting as early as 2100 rounds representing that the proposed IoMT RP has a longer stable network period. This indicates better energy balancing and efficient load distribution and improved quality of service (QoS). The proposed routing protocol selects routing paths based on residual energy levels and node proximity. It also avoids low energy sensor nodes which prevents premature node failures. This reduces link breakage and maintains consistent communication paths.

The novelty of transposition and multi hop communication in the proposed IoMT RP lies in the unique integration of transposition logic with dynamic energy aware routing decisions, specifically personalized for resource constrained IoMT environments. Transposition is used as a mechanism to reorder sensor nodes based on residual energy and Euclidean proximity to the sink. This ensures that sensors nodes with higher energy and optimal location are favored in the routing path, balancing load distribution and minimizing premature node failures.

The proposed algorithm's lightweight computational design makes it highly suitable for deployment on constrained microcontroller platforms commonly used in IoMT devices (e.g., ARM Cortex-M series, ESP32, or nRF52, nRF24L01+). Mean values with standard deviation for key performance metrics (e.g., network lifetime, energy consumption, and packet delivery ratio), averaged over multiple independent simulation runs. Confidence intervals (at 95%) plotted in performance graphs, where applicable, to visually represent the stability and variation in the results across scenarios. The transposition operation, which reorders nodes based on residual energy and Euclidean distance. The multi hop route selection mechanism evaluates neighbors based on a composite metric is selected on the basis of distance and residual energy. The transposition and routing decisions are not performed every cycle, but periodically based on energy thresholds, reducing overhead.

VI. IMPACT OF DEAD NODES ON THE NETWORK

There is a loss of real time monitoring because dead nodes result in loss of real time physiological data. This weakens reliability of monitoring system and causes delay in monitoring. Data has to be rerouted through the remaining sensor nodes. The data received will have missing data because of one or more dead nodes. This can lead to incorrect analysis. Table 4 shows the comparison of the number of rounds for both schemes in terms of network stability and lifetime.

Table 4: Network Stability and Network Lifetime Comparison

Protocols	Network Stability	Network Lifetime
EERP 1 [13]	2148	7445
IoMT RP	4221	7630

Conclusion

In this paper a transposition based routing scheme which is energy efficient with multi hopping technique has been proposed to be used. The total number of sensors used is 8 with a sink on body to gather data. As the distance plays a vital role in successful transmission in IoMT so Euclidean distance method has been used to calculate distance so that

the distance is minimum between the sensors. The lesser the distance the communication is effective. The parameters for which the proposed scheme is compared for is network stability and life time. As per the results the proposed scheme outperforms the scheme with which it is compared.

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