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COST FUNCTION BASED FORWARD NODE SELECTION TOWARDS ENERGY OPTIMIZATION FOR INTERNET OF MEDICAL THINGS

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Abstract
Internet of Medical Things is an important field of research which focusses towards the betterment of human health. It comprises of tiny sized sensors that can record changes in human physiological parameters. These sensors have limited source of battery power due to their size. As the transmission is wireless in nature so there is reduction in the strength of transmitted signal due to attenuation. This attenuation is due to path loss. In this paper a cost function based technique is proposed to be used in order to minimize the signal attenuations.

INTRODUCTION

5.56 billion people are reported to be internet users round the globe making it a total of 67.9% of the population of the world [1]. This has led to develop gadgets and devices that are based on internet and are pervasive in nature. Internet of Things (IoT) paradigm that is a field which is rapidly gaining interest. IoT supports connecting devices, like computers, tablets as well as mobile phones. These devices sense parameters and transfer recorded data [2]. It involves small devices that are called sensors. These sensors are based on technologies like Nano / Micro Electro Mechanical Systems (NEMS / MEMS). Internet of Medical Things (IoMT) is a sub field of IoT [3]. IoMT deals with parameters related to medical sciences [4]. With approximately more than 30 billion medical devices connected, the market for IoMT will grow from $41 billion in the year 2020 to $158 billion by the year 2027, with over 30 billion connected medical devices predicted by 2025 [5]. 300 billion United States Dollars (USD) can be saved if the health care sector relies on IoMT specially in cases of tele – health monitoring and chronic diseases [5]. The devices used in IoMT are connected to the internet so that the observed / recorded data is communicated with other devices in order to exchange data information. This information is also sent to healthcare providers, patient's database, and other entities. These devices used are called sensors. The sensors are of different categories which are represented in table 1

Table 1: Categories of IoMT sensors

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

Invasive sensors are those which can be implanted in the human body to record the parameters. One of the examples is the pacemaker which is a very well – known device used. EEG, EMG and ECG sensors are the ones which come in the category of wearable sensors and they measure brain, motion and heart parameters respectively. They are categorized as wearable because they are used on the human body [6].

Architecture of the IoMT

The architecture of IoMT is represented in figure 1. In figure 1 a human body is shown having some round black point and a rectangular box. The round points are assumed to be s sensors and the rectangular box is the sink node. The sensors can be used on various places on human body depending on their application. The sink is a device that captures data from all the sensors. When the data is gathered by the sink then this data can be transferred to outside world for further processing. This further processing could be sending the data to doctor for observation, saving the data for record keeping and to request an ambulance if in need [6].

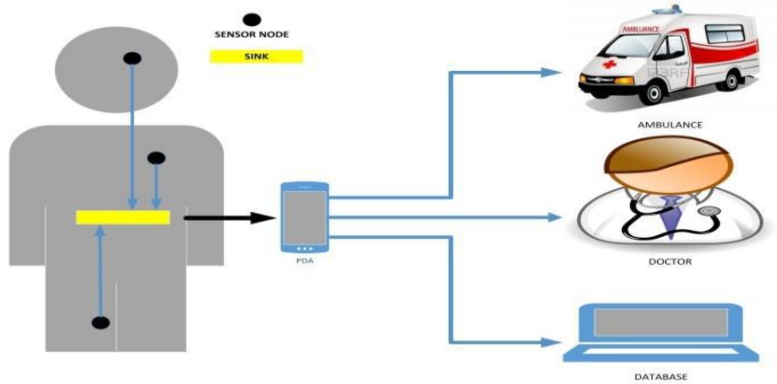

Figure 1: IoMT Architecture

The sensors used in IoMT are for human physiological parameter recording so they should be enough capable of doing so with the fact that they should also provide ease of carrying them on the body. The sensors can be placed on human body on various places as shown in figure 2

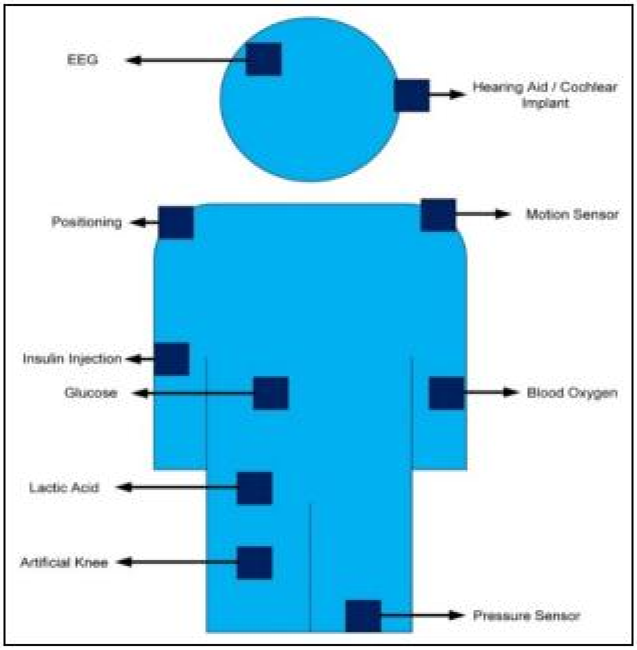

Figure 2: IoMT Sensors' Positioning

The communication of the sensors sending data to sink node is wireless in nature which provides a better solution to humans as compared to wired system which is a bit complicated. The sensors in IoMT are small in size so that the humans may easily carry them on their body which is an advantage but on the same time there occurs a disadvantage that due to their size the battery size also has to be small in size. As the sensors are recording data continuously and sending data towards the sink node to battery is consumed. Once the battery is drained it needs to be recharged. This recharging is not a very convenient method as it takes time and effort and becomes a hectic issue. So the researches are being carried out to make IoMT work for longer span of time so that this charging of the sensors be prolonged. This technique is called optimization of the routing protocol of IoMT or energy efficiency.

Literature Review

In [7], they have proposed to use scheduling strategy which is combination of data freshness and data urgency. Node Scheduling Selection (NSS) and Sink Channel Allocation (SCA) are the two components to overcome issue of real tome transmission of data. They have improved efficiency of scheduling by integrating Deep Reinforcement Learning (DRL).

The researchers have designed an algorithm naming it as Fuzzy Logic – Based Energy – Aware Routing (FL – EAR in [8] which enhances performance of Wireless Body Area Networks (WBANs) by optimizing consumption of energy. Packet Delivery Ratio (PDR) is improved by their designed algorithm. This is achieved by reducing energy consumption.

In [9] authors have addressed issues like permission control, limited scalability and centralization by their proposed algorithm. Their designed algorithm uses a combination of Role Based Access Control (RBAC) and Attribute Based Access Control (ABAC). These both are based on blockchain. Their proposed algorithm works as: For the management of operations of users, User Management Contract (UMC) contract is used; for the handling of data, Medical Data Management Contract (MDMC) contract is used; for the management of rights Policy Contract (PC) is used and to facilitate sharing of data Access Control Contract (ACC) contract is used.

Researchers in [10] propose to compete with the accuracy of already existing algorithm and have named their proposed algorithm as improved Rahat Khan (iRK). They have proposed to use architecture using two sink nodes. The intention of using two nodes is for the purpose of improving reliability. The sink nodes used in the proposed scenario are well placed on back side and front side of the body. As sink node gathers data from sensor nodes so using two sink nodes makes sure that data communication is continuous and uninterrupted. This also helps in energy efficiency as sensor nodes have the option to send data towards nearest sink.

Simulation Parameters

In this section the parameters are discusses which are used to make a routing protocol and how its efficiency is increased.

Cost Function

Cost Function (CF) is proposed and to be as a technique to overcome problem of energy efficiency. It is a mathematical formula. It is basically used for cost estimation in terms of energy. As the sensors and sink node communicate wirelessly so the distance is the factor which counts the most. More the distance will cause more energy of the sensors to be consumed. The cost function of any sensor is be calculated by the formula:

$$Cost\ Function_i = \frac{distance_i}{S(i).E}$$

$S(i).E =$ Energy of the i^{th} node

$distance_i =$ Distance from the sink node to the i^{th} node

Forward Node

CF is used mainly for selecting and making a Forward Node (FN). As there are multiple sensors used in a routing protocol and all the sensors need to communicate to sink node to forward their data. To achieve efficiency in terms of their battery energy is to reduce their energy consumption. If a sensor is at far distance from the sink node then it will generate more energy to send its data towards the sink node hence it will deplete its energy much more faster as compared to other sensors. So a forward node concept is taken into account making a routing protocol into multi – hop communication system. Multi – hop means that the sensor which is far will send its data towards the sensor which is near to it so that its lesser energy gets consumed. The sensor which has its data is called the forward node which passes the data to the sink node. The forward node will have lesser distance from the sink node which takes less amount of energy to be consumed.

nRF2401A Transceiver

In the proposed technique it is proposed that nRF2401A transceiver be used. The energy consumption of this transceiver is much more less which makes it suitable for using it in IoMT routing protocols. In table 2 the energy consumption details of nRF2401A are given

Table 2: nRF2401A Parameters

Feature	nRF2401A
Frequency Range	2.4 Giga Hertz (GHz) Industrial, Scientific and Medical (ISM) Band
Receiving Current Consumption	19 milli Amperes (mA)
Transmission Current Consumption	10.5 mA at 0 decibel – milliwatts (dB)
Voltage Range	1.9 volts (V) to 3.6V

Path Loss

Path loss (PL) is an important and critical factor in the Internet of Medical Things as it directly puts impact on the efficiency, reliability as well as the performance in terms of communication that is performed wirelessly. Reduction in signal strength of transmitted data is referred to as PL. More the PL the wireless transmission gets effected. Its unit is decibels (dB) and is mathematically expressed as

$$PL_{(f,d)} = PL_o + \left(10 \times n \times log_{10} \times \frac{d}{d_o}\right) + s$$

$PL_{(f,d)} =$ Path loss at frequency f and distance d

$PL_o =$ Reference Path loss at reference distance d_o

$n =$ Path loss exponent which totally depends on surrounding environment (open air or a room)

d = Distance from transmitter side to receiver side

$d_o =$ Reference distance which typically has range of 1 meter (m)

$s =$ It represents any attenuation or any Shadowing factor existing that has been caused some environmental problem or obstacles

In IoMT, PL gets influenced by obstacles such as human body posture, interference in wireless communication, walls and also by surrounding equipment.

Sensor Node Energy Consumption

The energy consumption of a sensor that is used in IoMT network is represented by equation given below

$$S(i).E = S(i).E - \Delta E$$

i is representing the sensor number.

ΔE is the change in energy level after a single round

Change in energy level is calculated at the end of every single round because sensor lose its energy performing its tasks.

Results

The results of the proposed routing technique is compared with already Energy Efficient Routing Protocol (EERP) proposed in [11]. Figure 3 shows a comparison of path loss versus rounds graph. In the figure X – Axis is representing the number of rounds (also called as iterations). Y –Axis is representing the signal attenuation in decibels (dB) that is the path loss.

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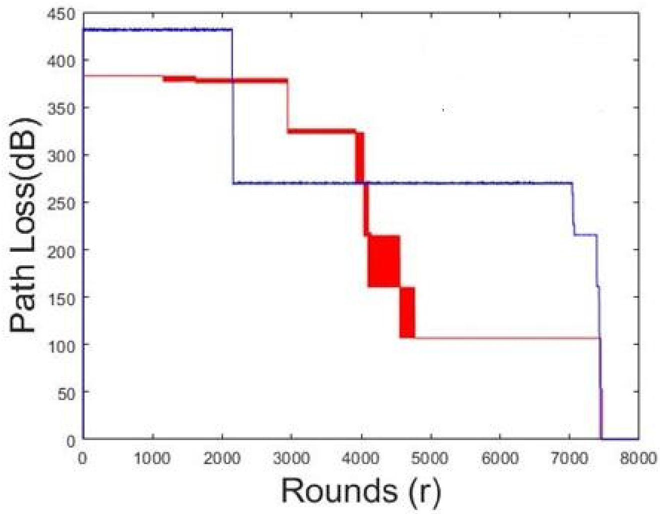

Figure 3: Comparison

Red Line is representing the proposed technique and blue line is representing EERP. The red line path loss gradually decreases with significant drops between rounds 3000 – 5000 rounds. The path loss of blue colored line remains higher for a longer duration and drops sharply after 6000 rounds. Nearly around 2000 rounds the path loss for EERP reduces significantly which shows that the number of sensors used in that network have lost their energy completely making the network unstable. This makes the proposed technique better as compared to EERP.

Conclusion

In this paper a cost function base energy optimization technique has been proposed to be used for Internet of Medical Things Routing Protocol. Cost function calculates the value and determines which sensor will act as a forward node. The selection of forward node is useful in multi – hop communication making sensor save their energy consumption. The proposed scheme achieves much better performance as compared to the existing energy efficient protocol in terms of minimizing path loss which in turn makes it energy stable.

List of Abbreviations

ABAC	Attribute Based Access Control
ACC	Access Control Contract
CF	Cost Function
dBm	decibel – milliwatts
DRL	Deep Reinforcement Learning
ECG	Electro Cardio Gram
EEG	Electro Encephalo Gram
EERP	Energy Efficient Routing Protocol
EMG	Electro Myo Graphy
FL – EAR	Fuzzy Logic Based Energy – Aware Routing
FN	Forward Node
GHz	Giga Hertz
IoMT	Internet of Medical Things
IoT	Internet of Things
iRK	improved Rahat Khan
ISM	Industrial, Scientific, and Medical
mA	milli Ampere
MDMC	Medical Data Management Contract
MEMS	Micro Electro Mechanical Systems
NEMS	Nano Electro Mechanical Systems
NSS	Node Scheduling Selection
PC	Policy Contract
PDR	Packet Delivery Ratio
PL	Path Loss
RBAC	Role Based Access Control
SCA	Sink Channel Allocation
UMC	User Management Contract
USD	United States Dollar
V	Volt
WBAN	Wireless Body Area Network.

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