



Reducing the Impact of Path Loss in Internet of Health Things Based on Residual Energy Calculation

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Abstract

Internet of Health Things is a sub field of Internet of Things that deals with the human physiological monitoring. It is a specialized field comprising on small state of the art devices that are used to record human vital signs and changes that occur. The recorded data transmission is wireless in nature so there are factors like path loss that come along to make wireless transmission ineffective. Energy efficiency and reliable communication are most critical challenges in Internet of Health Things. Path loss is a critical parameter which directly impacts on reliability as well as on energy consumption of wireless communication systems, influencing quality of communication between sensor nodes and sink. This study analyzes the evolution of path loss over network rounds to evaluate the stability and energy performance of an adaptive routing scheme. This research proposed in this paper investigates variations in path loss across occurred in multiple transmission rounds in an Internet of Health Things environment also focusing on achieving the efficiency in terms of energy in a routing protocol.

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INTRODUCTION

It is observed that in recent years there has been a vast development on the field of Information and Communication Technology. This has led to wireless communication which has reduced the complexity of using wires for communication. Data now be transmitted using wireless system which has enabled relaxation of mobility. Nano technology has been developing a lot making small scaled devices called Nano Electro Mechanical System (NEMS) [1]. These small scaled NEMS are devices that are capable of recording the parameters they are designed for and communicate the recorded data using wireless communication. The data is being transmitted using internet as its backbone. Using multiple NEMS devices a network is designed which rarely uses any sort of infrastructure. One device connects with other and in this data is reached at its destination. This is called Internet of Things (IoT). Figure 1 represents its applications and can be observed that how wide it is that it can be helpful in health care sector, smart cities, industries and environment. Having no infrastructure is the biggest advantage of IoT as it can be implemented where there is no chance of deployment of infrastructure [2]. The field of IoT which deals specifically with human health care sector is called Internet of Health Things (IoHT) and sometimes Internet of Medical Things (IoMT). In IoHT the NEMS devices are called Sensor Nodes (SNs) or sensors. Sensors measure the physiological vital signs of humans for which they are capable of. As illustrated in figure 2 it can be observed that there are various places on human body where the sensors can be placed to record the parameters and changes. The figure 2 presents illustration of a human body – centric Internet of Health

Things (IoHT) showing the location of the biomedical sensors on different parts of human body for continuous health monitoring. An electroencephalogram (EEG) Sensor is placed on head to measure neurological analysis, cochlear implant is also placed near the ear for enhancing auditory perception. Lactic acid sensor placed at leg as well as on lower torso is included to assess muscle fatigue activity. For adaptive movement control artificial knee is placed on another leg.

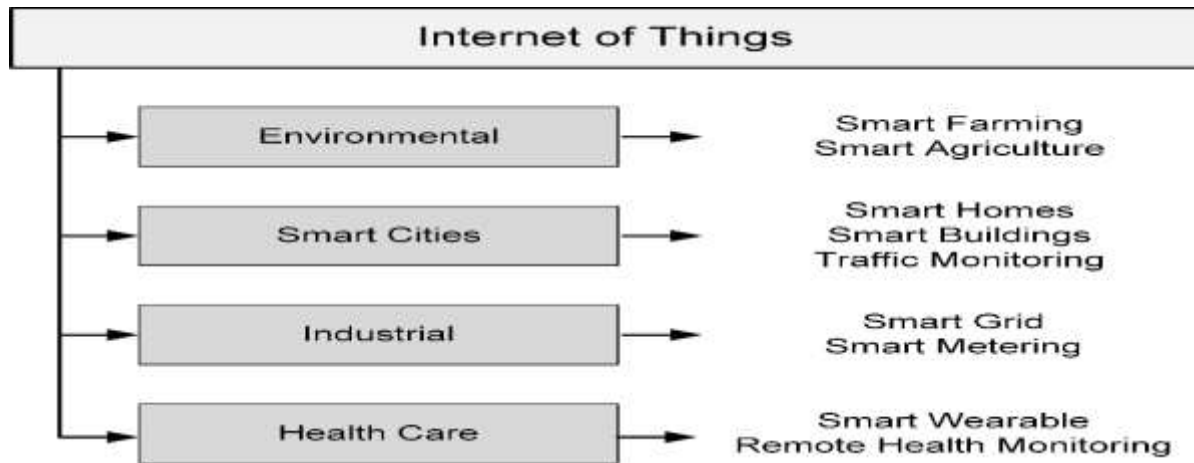


Figure 1. IoT Applications

Pressure sensor is shown placed on foot, which measures pressure distribution which is useful for detecting gait abnormalities. A glucose sensor for blood glucose monitoring is placed on abdominal area. Insulin injection device is for insulin delivery system is also there. To track body posture, a positioning sensor is placed on upper torso and shoulder area. On upper body motion sensor is positioned to detect physical activity. Blood oxygen (SpO₂) sensor is placed on chest region to monitor oxygen saturation levels.

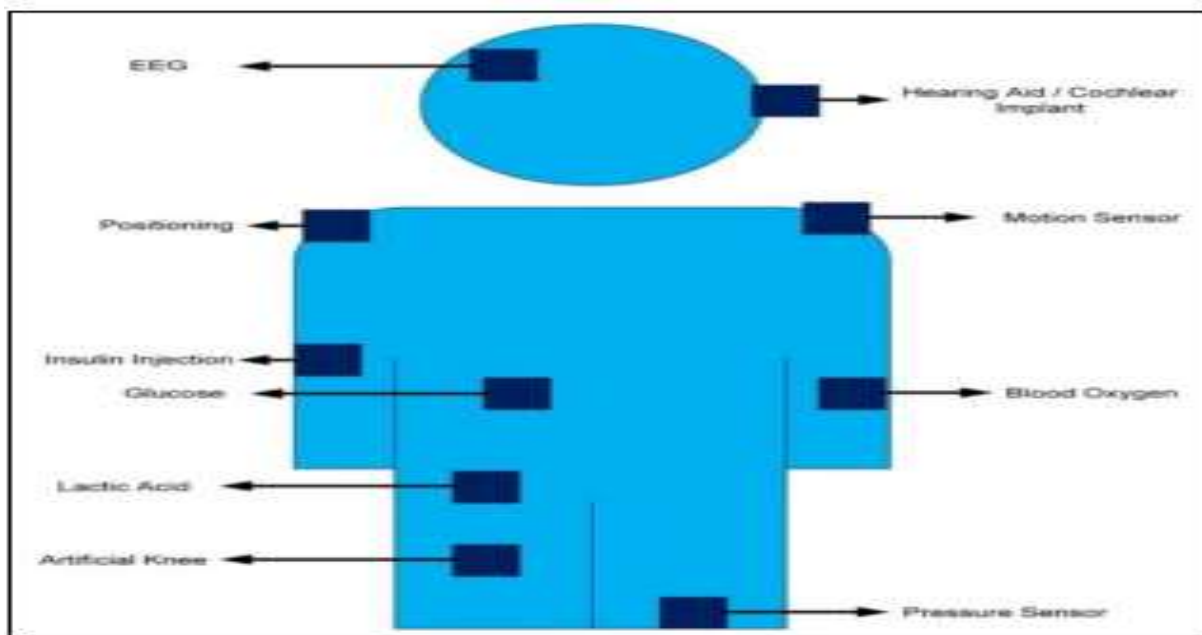


Figure 2. IoHT Sensor Positioning

The sensors illustrated in figure 2 are categorized as either loHT In Body Sensors (I – IBS) or loHT On Body Sensors (I – OBS). Table 1 categorizes and lists various loHT sensors. I – IBS are biomedical sensing devices inserted inside the human body. This insertion could be either partial or complete and is done to assist medical treatments, detect abnormalities and monitoring physiological parameters. I – OBS biomedical sensing devices capable of monitoring physiological signals without the need of penetration in the skin or entering the body. They operate either being attached to skin surface or used at a short distance [3].

Table 1.
loHT Sensor Categorization

I – IBS	I – OBS
Glucose sensors	Electro Cardio Gram (ECG)
Pacemakers	Pulse oximeters
Cochlear implants	Thermal sensors
Wireless capsule endoscope	Blood pressure monitors
Neural implants such as Electro Encephalo Gram (EEG)	

The architectural working of Internet of Health Things is illustrated in figure 3. In figure 3 there can be observed that there are three levels or stages of Internet of Health Thing working.



Figure 3.
Architecture of loHT

Sensing devices that are used and implemented in Internet of Health Things are working continuously consuming battery power. They have small scale batteries built in because of their size. In figure 4, comparison of energy consumption during different processes performed by the sensors used in Internet of Health Things is given. From figure 4 it is clearly observed that power is spent in transmission of as compared to other two processes is greater [4].

Figure 4 illustrates the comparative distribution of power consumption which across the three primary operations in loHT sensor node: one is communication, second data processing and last is sensing. Communication is exhibiting highest power consumption which indicates that wireless data transmission consumes most energy. Data processing consumes moderate amount of power consumption that reflects data analysis and handling. Sensing requires least power, as physiological data comprises of low energy sensor nodes. This comparison highlights that optimizing

communication protocols can considerably improve overall energy efficiency and helps in prolonging network lifetime in IoHT systems

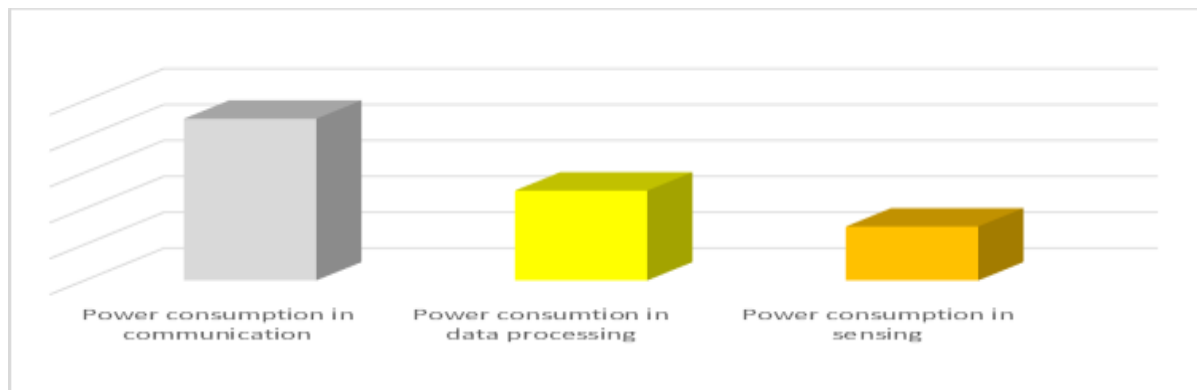


Figure 4.
Battery Power Consumption

This data needs to be transmitted towards the destination successfully and most important correctly. If data is not successfully reached at the destination then it has to be resent. Resending is possible but it takes the energy again. So resending of transmission drains the energy more quickly. This is an issue which has to be worked on. Internet of Health Things uses sensors which are small in size. This size is helpful in a way that patients can carry them on their body easily as a portable device. On the other hand there is a disadvantage that small sized equipment has to be used especially small sized batteries. As every single operation that has to be performed need battery power so smaller sized battery will drain out quickly. If the device losses its battery power then it is useless for the time being until it is recharged or battery replacement process is performed. These options are not viable solutions. This will become complicated. To overcome this issue there needs to be a system that makes these devices operate for a time larger than their conventional time.

LITERATURE REVIEW

Researchers in have proposed a communication protocol naming it as Whale based Routing Protocol for Low – power (RPL) and lossy network. The proposed routing protocol first select Cluster Head (CH) and then by taking help of RPL a communication path is selected [5]. Using the combination of Lagrange technique and convolutional neural network which is one dimensional a framework for intelligent communication has been proposed by [6]. The combination has been done for improving transmission speed and energy efficiency. Signal to Interference plus Noise Ratio and other parameters like distance between device of patient and ambulance, and transmission power have been taken into account. The proposed technique is able to enhance reliability in communication, lesser energy consumption, and data rate. Trusted Secure Routing Protocol has been presented in [7].

This is a type of framework which is extendable due to its adaptability so that it can provide its support to IoT platforms like Industrial Internet of Things, Smart Cities and Smart Homes. It focusses on reduction of cyber security threats like denial of service, unauthorized data and tampering. It secures routing path selection criteria. It consists of phases like data transmission, formation of routing table and network design. An Energy aware control of traffic congestion has been proposed to be used. The controller is centralized and is capable of performing selection of cluster and on the same time performs node clustering. Particle Swarm Optimization (PSO) algorithm has

been integrated in this proposed work to integrate for network performance optimization and selecting cluster head. This selection is based on parameters that are evaluated and the parameters are level of congestion, residual energy, closeness to the base station and distance of cluster. The proposed work shows efficiency in balancing energy efficiency and controlling of congestion in the Wireless Body Area Network in combination of Software Defined Network (SDN) [8].

Path Loss and its analysis

In loHT, as medical sensors are deployed on, in, or around the human body to monitor physiological parameters so reliable wireless communication is critical. Human body propagation causes severe attenuation in signal, making path loss analysis essential for Energy – efficient routing and Network lifetime optimization. It is amount of reduction in signal power as it propagates from the transmitter to the receiver. As the mode of communication in Internet of Health Things is wireless in nature so the signal that travels reduces its strength as it travels from transmitter end to receiver end [9]. This reduction in signal strength is referred to as path loss. It is an important factor which affects performance of wireless networks. Path loss calculation is performed using

$$PL(\text{node}_{num}) = 10 * \log \left(\frac{4\pi Df}{c} \right)^2 + \log \left(\frac{\text{distance}}{d_o} \right) + S$$

- Reference distance (usually 1 meter) is denoted by d_o
- Shadowing effect (random variable which represents environmental effects like body tissues, obstacles, etc.)
- Distance between the transmitter sensor and receiver sensors
- Frequency of the transmitted signal
- Speed of light in free space

Residual Energy

Residual energy [10] plays crucial role in the performance and reliability of loHT. The sensors are continuously monitoring vital physiological parameters. As discussed in previous section these sensing devices are typically powered by small sized batteries with limited options of replacement possibilities, especially in the case of implantable medical devices. Efficient utilization of residual energy directly has effect on network lifetime, and quality of medical data transmission [11]. It is the energy that is remaining in a sensor node. It is the parameter that plays a vital role in designing of routing protocol because it is used to calculate forward node. In sensor network forward node is an important because it is the one which is nearest to sink node [12].

Suppose there are two sensors that have the same distance from the sink then residual energy parameter is checked. The sensor having high value of residual energy will be selected as forward node. So this signifies its importance. In loHT systems, sensor nodes having low residual energy are more prone to failure. This can result in delayed medical responses, data loss and communication interruptions. Awareness enables in residual energy helps in intelligent routing decisions. This decision making is done by prioritizing those sensor nodes that have higher amount of remaining energy for data forwarding. This is helpful in preventing overuse of some nodes and balanced consumption of energy across the network is ensured [13].

nRF24L01A+ Transceiver

nRF24L01+ transceiver [14] has been proposed to be implemented in the proposed work. The total number of sensors are based on this transceiver. It is designed for ultra – low power wireless applications. It is single – chip operated on 2.4 Giga Hertz (GHz) Industrial, Scientific and Medical (ISM) band wireless communication. It has been proposed to be used as it plays an important role in enabling reliable and energy – efficient communication in IoHT. Its features are compact size, low power consumption and robust data transmission capabilities. These features make it well suited for IoHT. Ultra – low power operation is the key operation of nRF24L01A+. This is helpful because heart – rate monitors, temperature sensors and motion trackers are some of the sensors which are battery – constrained devices [15].

It has operating voltage value lying between 1.9 volts to 3.9 volts. Table 2.

Table 2.
nRF24L01+ Technical Details

S. No	Parameter	Value
1.	Frequency Range	2.4 Giga Hertz
2.	Maximum Data Rate	2 Megabits per second
3.	Voltage required for operating	1.9 volts to 3.6 volts
4.	Maximum Current consumption while Operating	13.5 milli Ampere
5.	Minimum Current consumption in Standby Mode	26 micro Ampere
6.	Range of Line of Sight Communication	100 meters

Simulation Setup

In the proposed routing scheme for IoHT the total number of sensor nodes used are 8 and 1 sink node is proposed to be used.

Simulation Result

The graph representing simulation result compares Path Loss (measured in decibels dB) and time of simulation (described as Rounds r) for the proposed IoHT RP (represented in red line) and Energy Efficient Routing Protocol (EERP) (represented in red line). At initial stages of simulation the proposed IoHT RP gets started with 375 dB approximately while EERP has 410 to 420 dB. This means that the proposed IoHT RP has lesser transmission power consumption with better quality of signal at the start of the simulation. When the simulation goes on the proposed IoHT RP has gradual and stepped sort of degradation in path loss. Which means it is adaptive routing. The existing EERP remains flat. This means that the proposed IoHT RP is much more fault tolerant and robust. The proposed IoHT RP lasts for approximately 7800 rounds whereas the existing EERP ends its time just after 7000 rounds. This complete description gives an idea that the proposed IoHT RP is stable and has life span greater than that of the existing EERP.

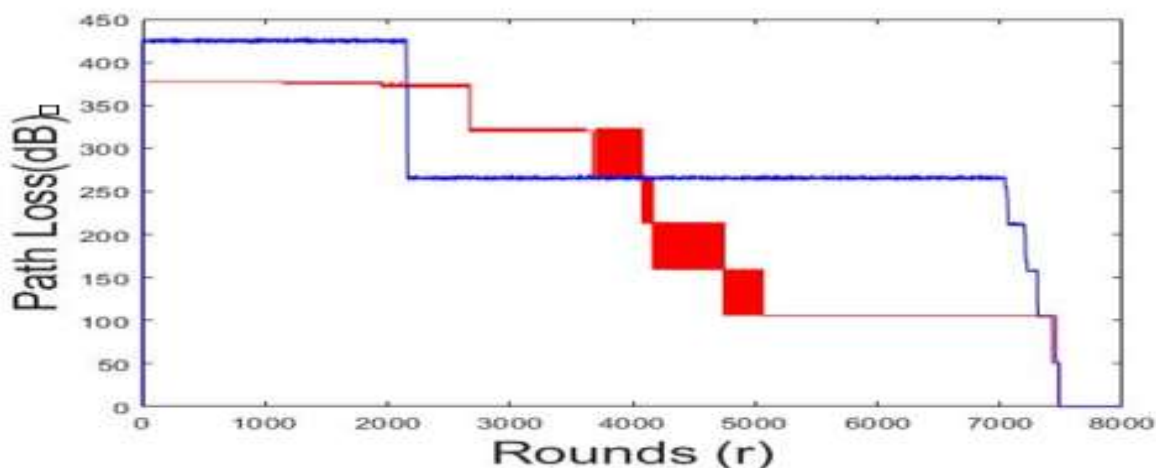


Figure 5. Simulation Table 3

Metric	EERP	Proposed Routing Protocol
Initial Path Loss	Approximately 425 dB	Approximately 380 dB
Final Path Loss	Approximately 0 dB	Approximately 110 dB
Reduction Pattern	Abrupt drops	Controlled step-wise
Energy Efficiency Indicator	Lower	Higher

The proposed routing protocol demonstrates controlled, step – wise path loss reduction which basically indicates routing is adaptive routing, energy – aware transmission and greater link quality. EERP curve has sudden node deaths, poor load balancing as well as higher retransmissions and energy drain.

CONCLUSION

The proposed study reveals a progressive decline in path loss values as the network evolves, highlighting the protocol's ability to optimize transmission paths dynamically. Initially, the network exhibits high path loss levels of approximately 400 dB, indicating significant attenuation due to longer communication distances and unstable link conditions. However, as the protocol adapts through subsequent rounds, it strategically selects optimal forwarder nodes based on residual energy, distance, and link quality factors, resulting in a steady reduction in path loss. The observed trend demonstrates a robust correlation between efficient route selection and communication stability. Moreover, the graph illustrates that as the routing process stabilizes, the overall signal strength improves, ensuring energy conservation and minimizing retransmissions. This adaptive mechanism enhances the overall performance of loHT networks, especially in medical monitoring scenarios where data accuracy and energy efficiency are paramount. The proposed approach thus contributes to improved network lifetime, reduced communication overhead, and reliable medical data transmission, validating its significance for real-time healthcare monitoring systems.

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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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Table 4
Abbreviations

Abbreviation	Full Form
CH	Cluster Head
dB	Decibel
ECG	Electrocardiogram
EEG	Electro Encephalo Gram
EERP	Energy Efficient Routing Protocol
GHz	Giga Hertz
I – OBS	IoHT In Body Sensors
I – OBS	IoHT On Body Sensors
IoHT	Internet of Health Things
IoMT	Internet of Medical Things
IoT	Internet of Things
ISM	Industrial, Scientific and Medical
NEMS	Nano Electro Mechanical System
PSO	Particle Swarm Optimization
RP	Routing Protocol
RPL	Routing Protocol for Low power
SDN	Software Defined Network
SN	Sensor Node

