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DESIGNING HIGH THROUGHPUT ROUTING PROTOCOL FOR WIRELESS BODY AREA NETWORKS

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***Abstract*—Wireless Body Area Network (WBAN) is new emerging sub-field of WSN. A key application of Wireless Body Area Network is health monitoring. Wireless sensors are placed on the human body or implanted in the body to monitor vital signs like blood pressure, body temperature, heart rate, glucose level etc. Use of Wireless Body Area Network technology to monitor health parameters significantly reduces the expenditures of patient in hospital. Wireless Body Area Sensors are used to monitor human health with limited energy resources. Different energy efficient routing schemes are used to forward data from body sensors to medical server. It is important that sensed data of patient reliably received to medical specialist for further analysis. To minimize energy consumption and to increase the throughput, we aim to propose a scheme that achieves a longer stability period. Nodes stay alive for longer period and consume minimum energy.**

***Index Terms*— BAN, WSN, Health monitoring.**

I. INTRODUCTION

BANs evolved from generic networks referred to as wireless sensor networks (WSNs), which belongs to a big network family known as PAN. BAN however may be described as a set of nodes that can be used to sense, actuate, compute and communicate in a multi-hub wireless channel with each other. BAN's operation around the human body allows it to be used to collect, process and store physiological, activity and environmental parameters from the host's body and it's immediate surroundings. The operation of BAN is not limited to only the outside of the human body. It can be used to implant in order to perform specific tasks.

The development of BAN became necessary since the existing low power and short- range standards such as PAN could not fulfil some of the requirements for medical applications. BAN standards are to support a combination of reliability, QoS, low power, data rate and must be non-interference. The proposed data rate for BAN is up to 10Mbps and it is to use existing industrial scientific medical bands or any frequency band approved by national medical and regulatory authority.

A. BAN Positioning

BAN is described as a short-range, low-powered device that operates around the human body (not limited to humans) providing a variety of applications. These applications may include medical, personal entertainment and consumer electronics. BANs can be described as special WSNs that have lesser nodes and much reliable with special importance placed on QoS as compared to the tradition WSN. BAN in some cases is referred to as BSN.

The positioning of BAN in relation with other wireless networks is shown in figure 1.

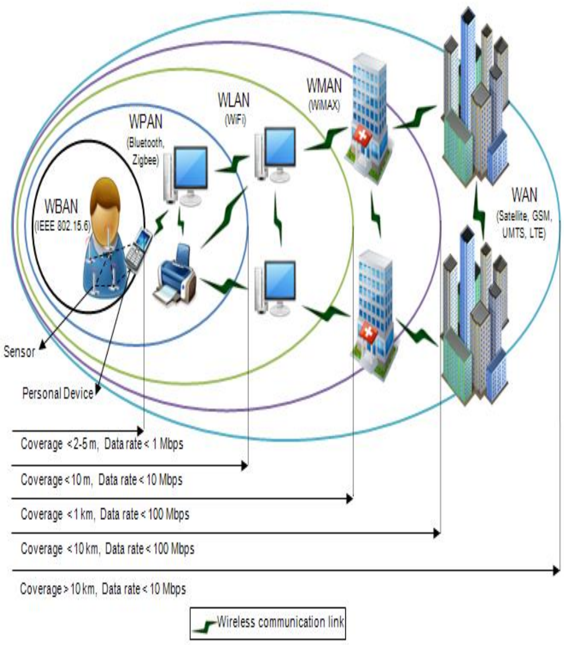


Figure 1: Comparison of BAN with other wireless networks

B. Architecture of BAN

The architectures of BAN can be summarized in the following categories:

- Hardware
- Network topology
- Communication technology
- Software
- Deployment
- Physical environment
- Energy source

1) The Hardware

The IEEE TG6 recommended and approved hardware components for BAN are as follows:

- A general purpose sensor (humidity, temperature and light)
- A medical device (pulse-oximeter)
- A data collector or aggregator (image collector)
- A controller or tuner (infusion-pump) and
- An access point or a gateway (smart phone)

A lot of platforms for sensing and processing specific signals have been developed.

2) Network Topology

The IEEE 802 TG6 recommended and approved a one-hub network topology with zero to mMaxBANSize of nodes. A simple one-hub network topology is represented in figure 2.

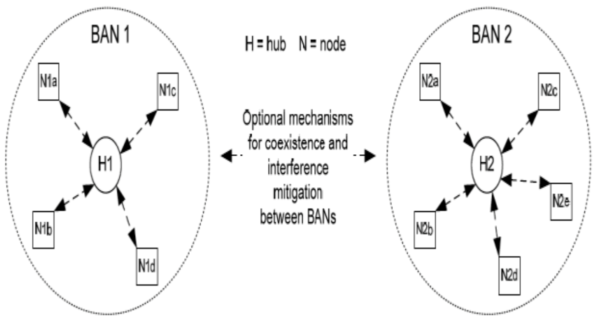
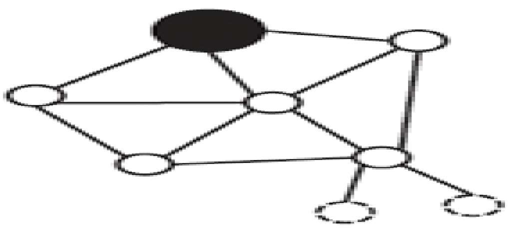
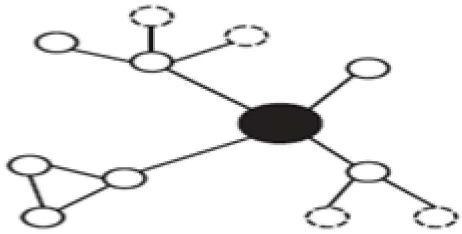


Figure 2. One-hub star network topology

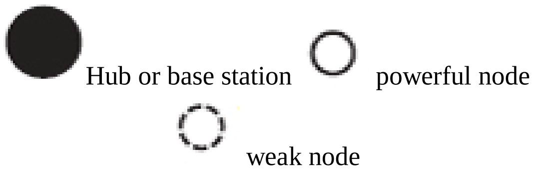
The Task Group also recommended mesh and hybrid network topology as shown figure 3.



(a)



(b)



(b)

Figure 3. Recommended (a) mesh and (b) hybrid network topology for BAN

In BANs nodes and hubs are time synchronized based on packet arrival time. Communication is through a wireless channel with assumable reliability. A node in BAN has neighboring nodes to perform communication through a one-hub wireless link. Figure 4 provides an insight to network topology for BAN.

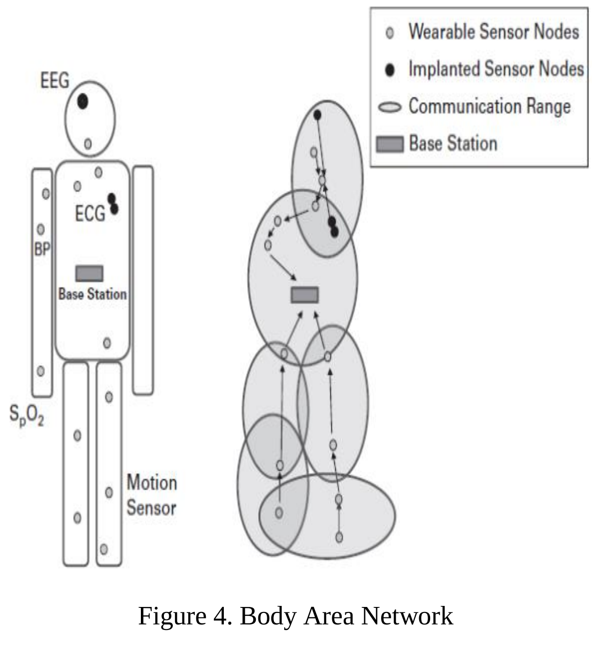


Figure 4. Body Area Network

C. Communication Technology

Researchers have put forward a lot of communication technologies for BAN. These technologies vary in frequency of transmission, range and power consumption. Although BAN operates heavily in PHY and MAC layer, it has five layers in its protocol stack. These layers perform specific tasks to ensure smooth communication between node – node and node – hub.

- The PHY layer; deals with radio hardware and antenna specifications.

- MAC layer; handles channel access and contention management.
- Network layer; provides a structure reliable data transfer and routing management.
- Application-support sub layer; deals with applications that secure the communication infrastructure.
- Application framework; provides abstraction functionalities of the radio to the application

Several factors influence the choice of technology for communication, however standards provide basic requirements. Available technologies that work along side BAN are; Zibee, 6lowPAN and Bluetooth low power.

D. Software

BANs are made up of the sensor type of devices and the base station devices that require different software to function. Sensors or nodes use event-driven software in order to optimize power usage. Computation is event-driven which is based on occurrence of an-event. The most commonly used OS is TinyOS, however there are other OS such as LiteOS, Contiki, RIOT and ERIKA Enterprise. The base stations are normally smart phones with OS such as Android, iOS, and Windows Silverlight.

E. Deployment

Deployment of sensors in BAN depends on the application and the desired function it has to perform. Sensors could be worn or implanted within the human body for specific applications. For example, medical sensors could be deployed to monitor or deliver medications to patients. BAN has also been networked with car sensors (CAN) to enhanced safety of the driver by providing feedbacks of fatigue. Researchers are exploring a lot of areas where BAN can be deployed to enhance the quality of life and increase safety.

F. Physical Environment

The human body is mainly the physical environment, although BAN is not limited to only humans.

The environmental influences on the sensor nodes are crucial and the same way deployment can cause side effects on the environment.

G. Energy Source

To ensure mobility without any obstruction of movement, BAN devices have to be connected wirelessly. Thus the communication between sensing nodes and hubs should basically be wireless. For this purpose to be achieved, nodes and hubs energy sources should be independent. Batteries are the most primary source of energy for BAN and these could be re-chargeable or un-rechargeable. Depending of the BAN application one of the energy source above or both can be selected.

II. Literature Review

In WBAN technology, large numbers of routing schemes are proposed. In this section, we present some proposed routing protocols. Latre et al. proposed A Secure Low-Delay Protocol for Multi-hop Wireless Body Area Networks (CICADA) routing protocol which consists of a spanning tree structure [1]. CI - CADA used Time Division Multiple Access (TDMA) protocol to schedule transmission of nodes. The nodes near the root act as forwarder nodes or parent nodes, these nodes collect data from their associated children nodes and relay to sink. Due to extra traffic load of children nodes on parent nodes causes parent nodes to deplete their energy fast. In Quwaider et al. presented a routing protocol which tolerates to changes in network. They used store and forward mechanism to increase the likelihood of a data packet to reac h successfully to sink node. Each sensor node has the capability to store a data packet. In source to destination route, each node stores data packet and transmits to next node. Storing a data packet and then retransmitting causes more energy to consum e and longer end to end delay.

Ehyaie et al. proposed a solution to minimize energy consumption. They deploy some non-sensing, dedicated nodes with additional energy source. This technique minimizes energy consumption of nodes and enhances the network lifetime, however, additional hardware required for relay nodes increase the cost of the network. A clustering based protocol A Self-Organization Protocol for Body Area Networks (ANYBODY) is proposed in [4]. The objective of this protocol is to restrict the sensor nodes to transmit data direct to sink. It improves the efficiency of network by changing the selection criteria of CHs. In [5] Nabi et al. proposed a protocol similar to store and forward mechanism. They integrate this store and forward scheme with Transmit Power Adaption (TPA). To control transmission power consumption, all nodes know their neighbours. Nodes transmit data with minimum power and with a stable link quality. A similar method was proposed by Guo et al. in [6]. They also used Transmission Power Control (TPC) scheme as Nabi et al. proposed. When link quality of a node decreased, an Automatic Repeat Request (ARR) is transmitted and retransmit the drop packet. Retransmission of lost packet increases the throughput of the network with the expense of energy consumption. Tsouri et al. in [7], [8] used creeping waves to relay data packet. They proposed this protocol to minimize energy consumption of nodes while keeping the reliable on body link.

III. Proposed Method

In order to introduce our model, we presume that the sink is placed in the centre of the human body. Since Wireless Body Area Sensor Networks are heterogeneous networks, and positions of nodes on human body is an issue. We resolve this concern by placing nodes in descending order of their data rate with respect to sink. Thus, the nodes with high data rate send data directly to the sink node, and can effortlessly forward the arriving data from low data rate sensors. Inconvenience analyzed in previous section is set in following manner:

1) Single- hop communication is utilized for emergency services and on-demand data,

2) For usual data delivery multi- hop communication is utilized,

3) To prolong life-time of network by selecting the path with less hop-counts.

Fig. 5 portrays the stages of proposed routing protocol with above mentioned characteristics. There are four stages in our in proposed routing protocol. These are initialization stage, routing stage, scheduling stage and steady state or data transmission stage. Initialization stage of the proposed routing algorithm is discussed in next subsection.

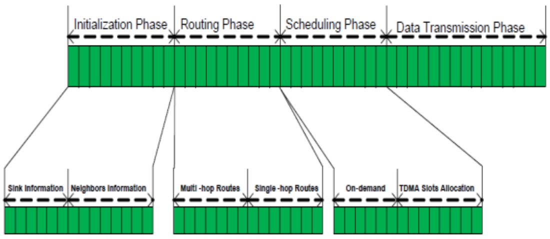


Fig. 5. Sequence of stages in each round

A. Initialization Stage

In initialization stage, all nodes broadcast HI messages. These HI message contains neighbours information and distance of sink nodes in form of hope- counts. In this manner, all nodes are updated with their neighbours, sink node position and available routes to the sink node.

B. Routing Stage

In this stage, routes with fewer hopes to sink node are selected from available routes. We presume nodes have information of all nodes and position of the sink nodes. So, selected routes are steadfast and consume fewer energy. Emergency services are also defined in proposed routing protocol. In crucial scenarios, all processes are lagged until successful reception of critical data at the sink node. In case of emergency, all the implanted nodes on the body can communicate directly to the base station. Moreover, all sensor nodes can communicate directly to the sink node when demand is arrived from sink node. In direct communication, delay is much less as compared to multi-hop communication. Because in multi-hop communication, each intermediate node receives, processes and then sends data to next node. The reception, processing and then transmitting the received data on each intermediate node which causes delay. And some time congestion also increased this delay. In critical scenario, delay is not acceptable. This delay is diminished by sending data through single-hop communication. We compute energy consumed in single-hop communication ESHOP as:

ES−HOP = Etransmit (1)

And transmission energy Etransmit is calculated as:

Etransmit = Eelec + Eamp (2)

where, Eelec is the energy consumed for processing data and Eamp is energy consumed by transmit amplifier. We suppose a linear network in which all nodes are implanted at equal distance from each other. To transmit b bits up to n hops, the transmission energy is given as:

Etransmit= = n(b * Eelec + b * Eamp) *d2 (3)

here d2 is the energy loss due to the transmission.

Etransmit = n *b(Eelec + Eamp) *d2 (4)

In our single-hop/multi-hop traffic control algorithm 1, if a node sensed emergency or on-demand data, then it uses single-hop communication. In single-hop communication, the sensor node uses full power of battery to sends its data. Conversely, for normal data is received, the multi-hop communication is used to send data to sink node. Thus, collectively less power is consumed without effecting reliability in term of delay. As the distance enhances more energy is consumed to transmit data. Thus, in multi-hop communication, energy consumption is very less.

Energy conservation is a primary consideration in Wireless Body Area Sensor Networks, as the deployed sensor nodes have restricted energy sources. So, deployed nodes require reasonable use of battery for extended life-time of the network. Implanted sensor nodes on human body have some heating effects.

```
Algorithm 1 Single-hop/Multi-hop traffic control algorithm
1: for i=1:1:n do
2:    Initialization Stage
3:    Tr ← Transmission range of node i
4:    if (Nodei <= Tr ) then
5:    Direct communication with Sink Node
6:    else
7:    if (Critical Data ==1 | On-demand==1) then
8:    Send data to Sink Node
9:    if ( Li,j > CT ) then
10:   Send data to other route
11:   end if
12:   end if
13:   end if
14: end for
```

When we are dealing with wireless communication around the human body, effects of these sensors on human body can also be taken in to consideration. The most significant factor consider for this purpose is Specific Absorption Rate (SAR) and heating effects of the implanted sensor nodes on human body. As nodes implanted closer to sink node are forwarding data of their follower nodes. Whenever these nodes reach their temperature threshold, these nodes break their link to their neighbour nodes for few rounds. As their temperature become normal these sensor nodes set up their previous routes. However, if a sensor node receives a data packet and reaches its temperature threshold then it returns packet to previous node. And previous node mark this link as Hot-spot as shown in Fig. 6 When we are dealing with customary data the Delay Tolerant Network (DTN) is supportive.

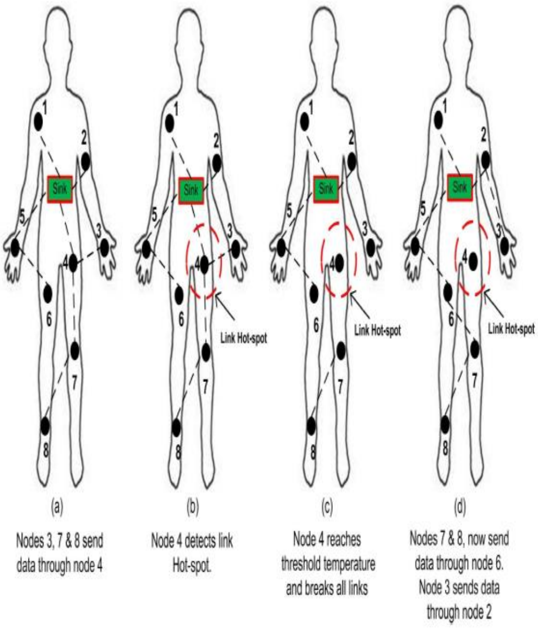


Fig. 6. Link Hot-spot detection

To compute the energy utilization during a multi-hop communication we presume a linear network in which all nodes are deployed at equal distance from each other. The loss of energy during multi-hop communication can be computed using the following equations.

$$E_{M-HOP} = E_{transmit} + E_{received} \quad (5)$$

where, Ereceived is the energy loss for receiving data. If we are transmitting b-bits to a distance of n-hops then the transmission energy will be $n*b*E_{transmit}$ and receiving energy will be $(n-1)*b*E_{received}$. Since the first node transmit only and intermediate nodes first receive n-bits and then transmit these received bits. Therefore, the energy consumed for multi-hop is:

$$E_{M-HOP} = n*b*E_{transmit} + (n-1)*b*E_{received} \quad (6)$$

From equation (2), equation (6) becomes:

$$E_{M-HOP} = n*b*(E_{elec} + E_{amp} * d^2) + (n-1)b* E_{elec} \quad (7)$$

$$= n*b*E_{elec} + n*b*E_{amp}*d^2 + n*b*E_{elec} - b*E_{elec} \quad (8)$$

$$= [2*n*b*E_{elec} + n*b*E_{amp}*d^2 - b*E_{elec}] \quad (9)$$

The proposed routing is discussed in Algorithm 2. If two routes are available the less hop-count route is selected. If two route have same hop-count, than route selected which have less energy consumption to the sink node. Single hop and multi-hop communication of root node with sink is shown in Fig. 7

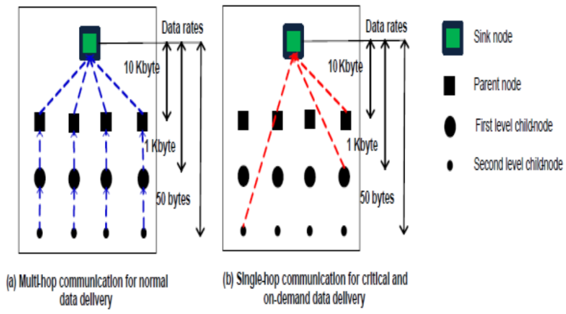


Fig. 7. Energy management for single-hop and multi-hop communication

Algorithm 2 : Proposed Routing approach

Routing Stage
if (route 1 $\leq$ route 2) **then**
    route 1 = selected route
else
    route 2 = selected route
    if (route 1 = route 2) **then**
    $E_{hop-count} \leftarrow$ Energy consumption for a route
        if ($E_{hop-count-1} < E_{hop-count-2}$) **then**
            route 1 = selected route
        else
            route 2 = selected route
        end if
    end if
end if

IV. EXPERIMENTAL EVALUATION

To evaluate proposed protocol, we have conducted an extensive set of experiments using MATLAB R2009a. We studied the performance of the proposed protocol by comparisons with the existing multihop protocol. We take network size of 5m x 5m in which 10 nodes are randomly distributed and sink node is placed in the center of the network. We take 8000rounds for these simulations. For mobility support we change positions of first level child-nodes and second level child nodes after 5 rounds. All parameters taken for these simulations are given in Table 4.1.

Table. 4.1 Simulation parameters

Parameters	Value
Size of Network	5 m x 5m
Number of Nodes	10
Deployment	Random
Sink Location	(2.5, 2.5)
Initial Energy	0.5 J
Number of Rounds	5000
Application type	Periodic-base/ Threshold-base
Packet Size	<= 64 Byte
Traffic Type	CBR
Radio Range	<= 10m

A. Network life time

Fig 8 clearly depicts that the proposed protocol has longer stability period. This is expected, due to the appropriate selection of new forwarder in each round. Hence, each node consumes almost equal energy in each round and all the nodes die almost at the same time. In existing protocol, as temperature of forwarder nodes increases, nodes select alternate longer path which consumes more energy. Hence, these nodes die early. Our proposed protocol achieves 31% more stability period and 0.4% longer network lifetime.

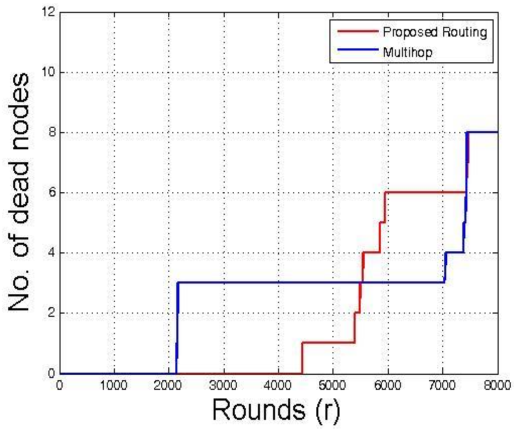


Fig. 8: Analysis of network lifetime

B. Throughput

Our proposed protocol achieves high throughput than existing protocol, as shown in fig 9. Number of packets send to sink depends on the number of alive nodes. More alive nodes send more packets to sink which increases the throughput of network. The stability period of existing protocol is shorter than our proposed protocol which means number of packets sent to sink decreased. Hence, throughput of existing protocol decreased. On the hand, our proposed protocol achieves high throughput due to longer stability period.

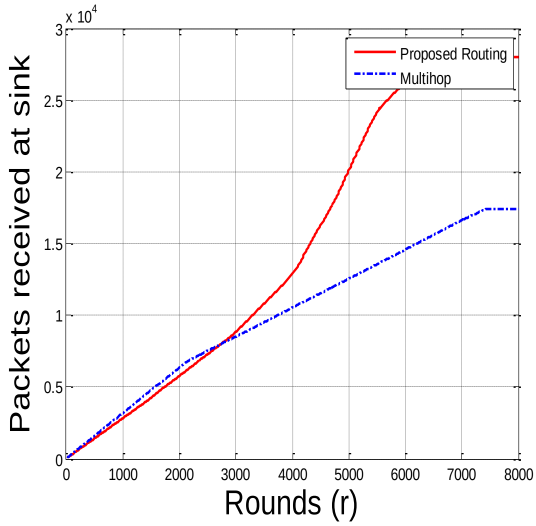


Fig. 9: Analysis of Throughput

C. Residual energy

Simulation results show that proposed protocol consumes minimum energy till 70% of simulation time. It means, in stability period, more nodes have enough energy and they transmit more data packet to sink. It also improves the throughput of the network. On the other hand, in existing protocol, some nodes exhaust early due to heavy traffic load.

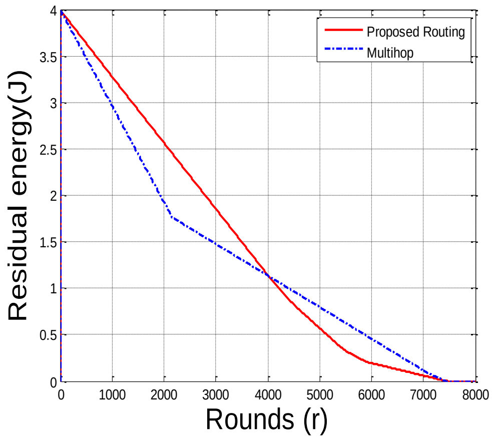


Fig. 10: Analysis of remaining energy

D. Path Loss

Path loss shown in figure 11 is function of distance. It is calculated from its distance to sink with constant frequency 2.4GHz. We use path loss coefficient 3.38 and 4.1 for standard deviation σ. Proposed multi hop topology reduces the path loss as shown in figure 11. It is due to the fact that multi hop transmission reduces the distance, which leads to minimum path loss. Fig 11 represents the results of both topologies. Initially proposed protocol performs well. However, after 2000 rounds, path loss of existing protocol dramatically decreased because some nodes of existing topology die. Minimum number of alive nodes has minimum cumulative path loss. As our proposed protocol has longer stability period and more alive nodes has more cumulative path loss.

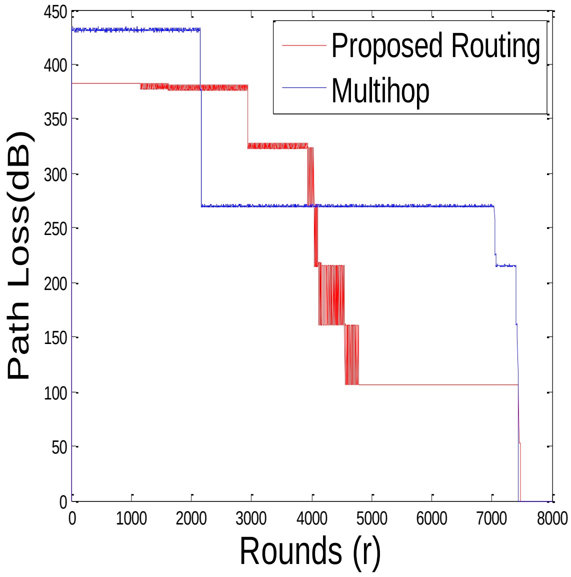


Fig. 11: network path loss

V. Conclusion

In this work, we present an energy efficient routing algorithm for heterogeneous WBASNs. For real-time and on-demand data traffic root node directly communicate with sink node and multi-hop communication is used for normal data delivery. Our proposed routing protocol supports mobility of human body with energy management. Sensor node increase and decrease their transmission range for single-hop and multi-hop communication to save energy. The proposed routing algorithm is thermal- aware which senses the link Hot-spot and routes the data away from these links. After selection of routes sink node creates TDMA schedule for communication between sink node and root nodes for normal data delivery. MATLAB simulations of proposed routing algorithm are performed for lifetime and reliability in comparison with multi- hop communication. Topology and placement of nodes is described with single-hop and multi-hop communication scenario. The results show that the proposed routing algorithm has less energy consumption and more reliable as compared to multi-hop communication.

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