Enhancement of Transmission Efficiency in Wireless On-Body Medical Sensors

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Abstract: Growing developments in technology now is focused to provide better facilities towards human health. Advancement in electronics and wireless communications has led to the reality of biosensors which are small in size and are easily implanted to or are wearable by humans. Wireless Body Area Sensor Network (WBASN) is a technological field in which sensors are placed on human body to measure physiological parameters. The sensors are very small in size and have the capabilities to observe the physiological parameters and the changes occurring and after observing transmit them for further process. One of the main limitations for the sensors which are being used in WBASN is power. The sensors have a battery used to provide power. Energy is consumed mostly when transmission takes place. During transmission, path loss is generated which results in an attenuated output signal. This transmission path loss is dependent on two factors that are distance and frequency. The distance is from transmitting sensor node to the base station or sink. In this paper a technique based on transposition for on body medical sensors is proposed for the reduction of the path loss. The proposed scheme is transposition of the sensors on the human body. This transposition is based on the lesser distance of the sensors from sink or the base station.

Keywords: *Path loss, Sensors, Energy, Distance, Transpose.*

1. Introduction

Development in technology has led to the existence of Micro-Electro-Mechanical-Systems (MEMS). MEMS based components are small sized which have the capabilities is sensing, transmitting and receiving [1]. Wireless Body Area Sensors Networks * (WBASNs) is a subfield of Wireless Sensor Networks (WSN). Wireless Body Area Sensor Networks (WBASNs) have gained significant attention as they are related to human health [2]. WBASNs consist of MEMS sensors which can either be invasive or non-invasive. WBASN sensors which monitor the physiological parameters of humans and if required they may also transmit the recorded observation [3]. WBASN are the result of the requirement of better healthcare requirements. Its applications are not only towards medical sector but also towards the monitoring of players while in field or may be any animal is being monitored [4]. Table 1 shows various applications of WBASNs. WBASN network consists of sensors which observe the physiological parameters and store them for further processing. Sink is device which is used in these types of networks to gather data from the respective sensors[5]–[7].

The sink is also responsible to gather data. The architecture of WBASN is illustrated in Fig.1 in which it may be observed that sensors as well as sink are placed on the body. Sensors keep recording the physiological parameters and at an instance send this data to the sink. The sink further processes this data and whenever needed transmits to the personal digital assistant (PDA) which can be a smart phone or laptop[8]. The PDA sends this data to the entities like an ambulance system, doctor or to a medical server / database. The sensors used in WBASN have transceiver, processing unit and a battery. As sensors are small in size and this is the reason they have some limitations [9]. They need power or energy to operate. Once they are implanted on the human body it is difficult for the sensors to get charged again and again. These devices may be made energy efficient so that they may operate for longer span of time. In WBASN the communication has much significance as compared to other parameter because this information is related to human health and at some time interval it may also be possible that the information is critical and needs to reach at the destination without any delay. The delay is majorly caused by path loss [10].

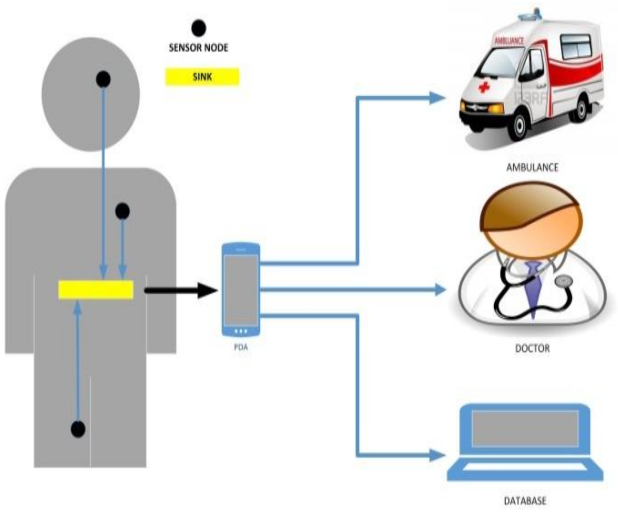

Figure. 1. Wireless Body Area Sensor Network Architecture

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Table 1: Applications of Wireless Body Area Sensor Networks

Applications' Categories		
Medical		**Non-Medical**
Wearable WBASN	**Implant WBASN**	Real Time Streaming Entertainment Applications Emergency (non-medical)
Assessing Soldier Fatigue and Battle Readiness Aiding Professional and Armature Sport Training Sleep Staging Wearable Health Monitoring	Cardiovascular Diseases Cancer Detection	

In this paper a new scheme has been provided to overcome this issue of path loss so that the WBANS networks communication may become efficient and comparison of the results with path loss of existing scheme. The rest of the paper is organized as. Section 2 discussed relative work, section 3 describes in detail the Power consumption analysis of WBASN, in section 4 the Mathematical models used for Simulation are given, in section 5 the proposed scheme is discussed and section 6 is the result and conclusion.

2. Literature Review

The authors in [11] have proposed a protocol which is based on Time Division Multiple Access (TDMA) used for the purpose of adjusting transmission and its duration. The allocation of the slots has been optimized by minimization in the energy consumption. Transposed based minimization scheme proposed by [10]. The work presented in [12] proposes a routing protocol which utilizes intermediate nodes. These intermediate nodes gather the data of other node after aggregating it route it to the sink. In this scheme the when the sensors' energy becomes less than that of threshold value then only the critical data is sent to the sink. The nodes which are closer to the sink will send their data direct to the sink and when the energy of these sensors become less than the threshold then only the critical data is sent. Also a cost function is proposed for the selection of relay nodes. For the purpose of uniform load distribution the relay nodes are to be rotated in all rounds based on the cost function. The authors in [13], [14] developed monitoring system which integrates the physiological and their record into a web portal so that real time remote monitoring is allowed. This system allows the facility from the point if disaster so that the data is sent to the portal so that the consultant doctors be informed and the medical center is ready for the patients. The work in [15] present simulation as well as measured data for frequency of 402-405 MHz radio propagation path loss in a room for MICS band. For the purpose of indoor room measurement furnished room as well as unfurnished room is studied and results were evaluated. The scheme provided by authors in [10] have proposed a technique in which they used single hop communication model and placed sink on the center of the human body and then simulated for the results in terms of path loss. The scheme in [16] presented situation based architecture for the purpose of reducing stereotyped disorders of motion in kids who have sickness of Autism Spectrum Disorder. In this model abnormal activities are identified. The impact of different values for ε_r (relative permittivity) and σ (conductivity) of tissues in a human body at a frequency of 2.45 GHz has been calculated based on 3D model by [17]. The proposed model is valid up to 8 cm for dipole antennas. The comparison of path losses of heterogeneous and homogenous human tissues is also performed. A multi-tier telemedicine system is introduced by [18] and proposed a prototype WBAN network for computer-assisted rehabilitation. This system analyses the data from the sensors and then gives feedback. If the data is critical then the warnings are also generated so that any necessary action is taken and simultaneously the data is being sent to the medical servers. In [19] proposed framework for Ambient Assisted Living based on cloud assisted protocols. In this work the authors have proposed two planes of operation for data as well as for control. It is an error resilient scheme based MAC having cloud capabilities. Also they investigated the options network management to cloud keeping data storage at local plane.

In [20] two components have been investigated that are absorption and path loss for in-to-out body for wireless link based on radio frequency. This link generated using 3D electromagnetic solver was between a receiver which was placed outside the body and an endoscopy capsule. The band used is Medical Implant Communication Service (MICS) operating at frequency of 402 MHz. In [21] a path loss model has been proposed for on-body WBASN network based on ultra-wide band (UWB). In this work the researchers used dipole UWB antenna and double loop UWB antenna. The frequency range selected was 2 to 8 GHz. The results show that in terms of attenuation the loop antenna gave better results as compared to dipole antenna. Loop antenna had greater path loss comparing to dipole. A new method of delivering power wirelessly to devices which are micro in size and are located remotely within a WBASN is presented in [22]. They presented a coupled mechanical oscillator which is driven by acoustic waves or through ultrasound. In this system the power is delivered through ultrasonic power. No electrical form is required for actuation in this system.

These devices are able to be used in diagnosis basis to therapeutic levels. Latre et al. [23] proposed activity scheduling which aimed towards improvement in terms of reliability in communication and energy efficiency. In their proposed work they built a static routing tree with time slot allocated. Sensors have been assigned time slots as per routing tree. The sensors are allowed to send their data in their time slots. To make sure that signal interference and idle listening does not occur, this system works in distributed manner. The authors in [24] have focused on energy efficiency in terms of communication in sensing networks which are small-scale and are undergoing high path loss. They derived radio and propagation for communication based along the body. In this comparison was also performed between single and multi-hop networking models. It was found that communication based on single-hop was inefficient for far nodes and multi-hop performs better but for nodes closer to sink come into account then hotspots come into existence.

3. Energy Analysis

The sensors that are used in WBASNs are very small in size. This is the reason they have small sized battery. These sensors have energy constraints. The sensors perform three tasks namely sensing, data communication and data processing[25], [26]. In figure 2 it can be observed that out of three parameters the transmission id consuming more energy.

In WBASNs the mathematical representation of transmitting energy is represented in equation 1.

$$\mathrm{E_{TX}} = \left(\mathrm{E_{amp}} + \mathrm{E_{elec}}\right) * \mathrm{s} * \mathrm{d}^2 \tag{1}$$

In equation 1 the parameter d represents the distance. Increase in distance will increase the transmission energy making sensor to consume more energy. The amount of energy which is consumed by a sensor node in WBASN for transmitting data is given by equation 2.

$$\mathrm{E_{node}} = \mathrm{E_{tx}} + \mathrm{E_{retx}} + \mathrm{E_{ack}} + \mathrm{E_{acc}} \tag{2}$$

E_{node} : Total energy

E_{tx} : Transmission energy

E_{retx} : retransmit energy

E_{ack} : Energy consumed while transmitting acknowledge (ACK) packet.

E_{acc} : Energy used up by the channel access procedures

From Fig. 2 it is clear that the communication consumes much amount of energy and from in equation 2 total energy that a node consumes consists of three transmission parameters out of four. Path loss will be higher if the distance is increased. Keeping all the observation the correct and exact positioning of the sensor nodes is required so that there may be an effective communication. In this way that the sensor nodes may consume lesser amount of energy and making sure that the transmission takes place once instead of resending. This retransmission again will consume energy that is why WBASN network may be designed so efficient that the communication is successful in a single attempt. Path loss affects the signal to that it may not be able to reach at its required place or destination or if the signal reaches its destination it well not be in its correct form (attenuated). In the next section path loss is defined with its mathematical models.

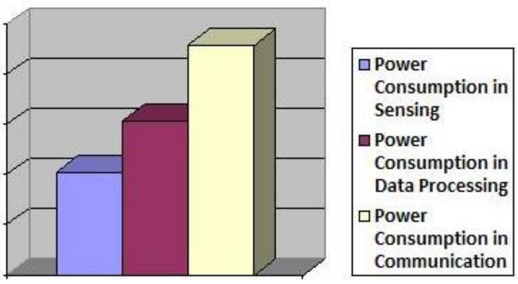

Figure 2. Power consumption analysis [7]

4. Mathematical Models used for Simulation

Path loss is dependent upon two factors, frequency and the distance. If the communication needs to be effective and efficient then path loss needs to be reduced. Path loss represents attenuation in the strength of signal. It is basically is the change between the transmitted power and the received power. The transmission of WBASN is hugely affected by the path loss. If there happens to be any obstacle in between the communication path then the signal gets damaged. Human body is made of water creating the signal to distort. All these factors create path loss. Path loss ids represented mathematically as:

$$\mathrm{PL(f, D)} = \mathrm{PLo} + 10\mathrm{nLog_{10}} \frac{\mathrm{D}}{\mathrm{do}} + \mathrm{S} \tag{3}$$

D_o: Reference distance

PL: Path loss (dB)

D: Distance from sensor node (transmitter) to sink (Receiver) distance

n: Coefficient of Path loss

S: Scattering term

PL_o: Path loss at reference distance and it is computed as:

$$\mathrm{PLo} = 10\mathrm{Log_{10}} \left[\frac{4\pi \mathrm{Df}}{\mathrm{c}}\right]^2 \tag{4}$$

Then

$$\mathrm{PL(f, D)} = 10\mathrm{Log_{10}} \left[\frac{4\pi \mathrm{Df}}{\mathrm{c}}\right]^2 + 10\mathrm{nLog_{10}} \frac{\mathrm{D}}{\mathrm{do}} + \mathrm{S} \tag{5}$$

5. Proposed Scheme and Simulation

In this section the proposed scheme is defined and then the simulation is performed on Matlab 2015a. This section is further divided in two sub sections.

A. Sensor Positions

In this section the position of the sensors is discussed in detail. The total number of sensors used in the proposed scheme is eight (08). The placement of the sensors is very important because path loss exist on human body because it consists of 70% water. These sensors need to be placed in such an effective location with respect to the sink so that they have lesser distance. Sensors are transmitters and the sink is the receiver. The amount of energy is dependent on the distance between the sensors and the sink. The proposed transposed values for the entire sensors are given in table 2. All these values are in x and y coordinates in meters. Y coordinate represents height and x coordinate represents the width of human body.

Table. 2. Sensor Coordinates

Sensor	X Coordinate (m)	Y Coordinate (m)
Sensor 1	0.37	0.1
Sensor 2	0.55	0.15
Sensor 3	0.37	0.55
Sensor 4	0.55	0.6
Sensor 5	0.65	0.6
Sensor 6	0.17	0.6
Sensor 7	0.34	0.7
Sensor 8	0.5	0.8

B. Comparison of distances

With the proposed values of the coordinates of sensors from Table. 2, the distances of each sensor is computed and then compared to the IM-SIMPLE [11]. The distance factor is computed with Euclidean distance formula in Matlab2015a.

In Fig. 3 (a) the node by node analysis of IM-SIMPLE [11] and proposed scheme is defined. It can be observed that the distance of sensor nodes 1, 2, 4, 5 and 6 in the proposed scheme is higher as compared to IM-SIMPLE [11] whereas the distances of sensor nodes 3, 7 and 8 in the proposed scheme are lesser as compared to the IM-SIMPLE [11]. Figure. 3 (b) depicts the cumulative distance comparison of entire sensors of both the proposed schemes as well as of the IM-SIMPLE [11]. The total distance acquired by the proposed scheme is 307.4 cm and cumulative distance of IM-SIMPLE [11] is 316.4 cm. There is a difference of 9 cm so in terms of distance the proposed scheme outperforms IM-SIMPLE [11].

6. Results

The simulation results of both schemes are shown in figure 4. The graphs are between distance (measured in cm) and path loss (measured in decibels). The round dots represent the individual path loss points of each sensor. Figure 4 is the graph of the IM-SIMPLE [11] and figure 5 is the graph of the proposed scheme.

Figure 4 shows the simulation results of IM-SIMPLE [11]. The path loss of node 1 is represented by red colored dot, path loss of node 2 is represented by green point, path loss of node 3 is given by blue point, path loss of node 4 is shown by black point, path loss of node 5 is denoted by yellow point, path loss of node 6 is represented by magenta point, path loss of node 7 is shown by cyan point and path loss of node 8 is illustrated by red point at bottom left in the graph.

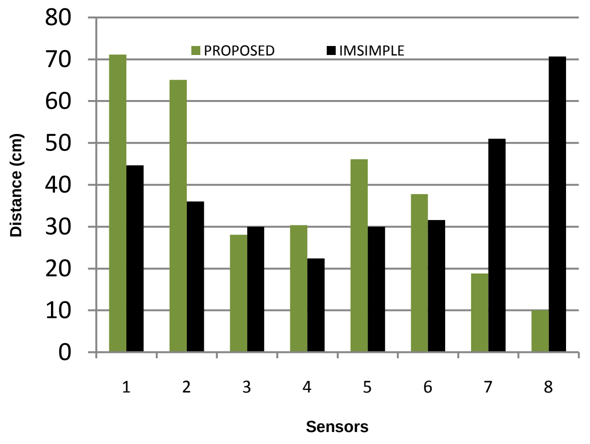

Figure.3. Distance Comparison of both schemes (a): Node by node distance

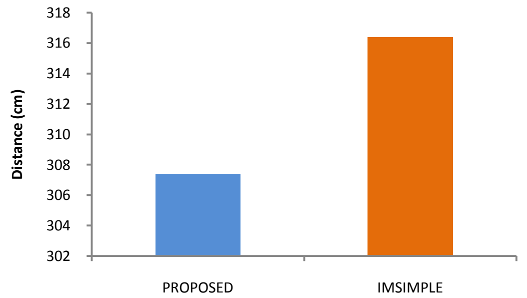

Figure.3. Distance Comparison of both schemes (b): Total distance

It may be observed that sensor node 1 having the highest value of path loss as this node is having the larger distance as compared to other sensor nodes and the sensor node 4 having the least value of the path loss due to having the less distance as compared to all other sensor nodes.

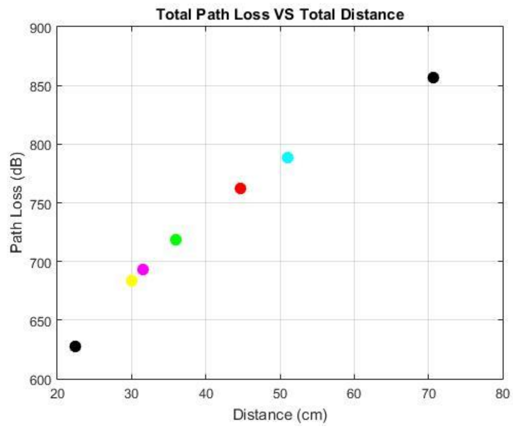

Figure. 4. Simulation results of IM-SIMPLE

Fig.5 represents the simulation result of the proposed scheme. The path loss of node 1 is represented by red point, path loss of node 2 is shown by green point, path loss of node 3 is represented by blue point, path loss of node 4 is denoted by black point, path loss of node 5 is denoted by yellow point, path loss of node 6 is shown by magenta point, path loss of node 7 is given by cyan point and path loss of node 8 is represented by black point at bottom left in the graph. It can be observed that sensor node 8 having the highest value of path loss as this node is having the larger distance as compared to other sensor nodes and the sensor node 4 having the least value of the path loss due to having the less distance as compared to all other sensor nodes. Table 3 summarizes the comparison in chart form. In the table the efficiency of the proposed scheme may be observed. Both schemes are compared in terms of path losses of each sensor and then the cumulative path loss. PL1 is the path loss of sensor node 1, PL2 the path loss of sensor node 2 and so on.

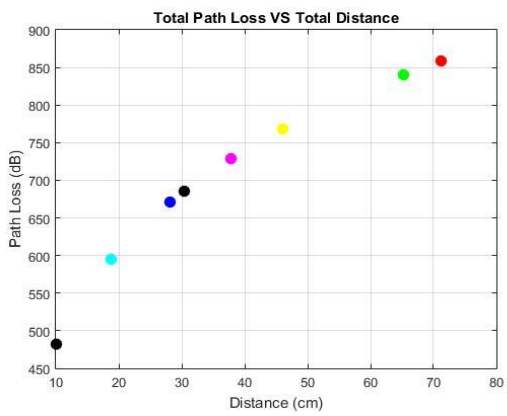

Figure.5. Simulation results of the Proposed Scheme

The simulation results show that values of PL1, PL2, PL4, PL5 and PL6 of the proposed scheme are higher as compared to IM-SIMPLE [11] whereas the values of PL3, PL7 and PL8 are lesser of the proposed scheme as that of the IM-SIMPLE [11].The cumulative path loss IM-SIMPLE [11] is 5.81e+03 dB and the total path loss of the proposed scheme is 5.63e+03 dB. The proposed scheme achieved 1.84e+02 dB lesser path loss.

7. Conclusion

In this paper an efficient scheme for on body wireless medical sensors is proposed. In this scheme transposition is introduced. For sensors used in wireless body area sensor networks the energy is most important parameter on which they depend. The network life time and network stability depends on the life of sensors so sensors may either have huge resources and may be able to utilize their energy in an efficient manner. The sensors being small in size need to operate their battery resources for longer span of time. In this work the transposition is performed based on the Euclidean algorithm. With the help of this technique the distances of all the sensors are calculated. This is based on single hop or direct communication from sensor nodes to the sink. While adjusting the transposition it was taken in account that their functionality is not affected.

The proposed scheme is compared with the IM-SIMPLE scheme. The IM-SIMPLE scheme is multi-hop based and uses the same number of sensors as the proposed scheme. The sink is assumed to be placed at the center of the human body. All the sensors are transposed in terms of sink distance. From the calculation it was observed that at some sensor nodes the distance of the proposed sensor scheme has higher distance values as compared to the IM-SIMPLE scheme and some having lesser values. The total or cumulative distance of the proposed scheme is significantly lesser as compared to that of the IM-SIMPLE scheme. This is a major benefit achieved by the proposed scheme because path loss is directly proportional to the transmission distance. Then the simulation has been carried out on Matlab in terms of path loss. The proposed scheme achieved lesser path loss when compared to the IM-SIMPLE scheme.

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