

# Minimizing Path Loss in Medical Wireless Sensors in Wireless Body Area Sensor Networks

Rahat Ali Khan<sup>1\*</sup>, Altaf Mazhar Soomro<sup>1,2</sup> and Hima Zafar<sup>3</sup>

<sup>1</sup>Institute of Information and Communication Technology, University of Sindh Pakistan; rahatalikhan@gmail.com

<sup>2</sup>School of Engineering, University of Melbourne, Australia; altaf266@gmail.com

<sup>3</sup>Department of Mechatronics Engineering, Mehran University of Engineering and Technology, Pakistan; himazafar12@gmail.com

## Abstract

**Objectives:** To save the energy consumption of the sensors in transmission so that they may operate for longer time span.

**Methods/Statistical Analysis:** It is suggested to use eight sensors placed on the human body and then transposition has been applied to all of these sensors to reduce the distance of each sensor from the sink. Path loss was calculated after transposition in terms of distance and results were compared with the existing schemes. Euclidean distance technique was applied to calculate the distance values and then observed for their positions. **Findings:** In this investigation, the main parameter is the path loss which needs to be reduced so as to make the transmission better and to make network stable. The findings are unique in the sense that with the help of the proposed values of sensor positions a routing protocols be designed which will have a better network stability and network life time and this will be achieved as the sensors will deplete less energy during transmission. The main idea behind this research is to find the most suitable sensor locations on the body where they can consume less energy during data transmission to sink and have more life to operate.

**Application/Improvements:** The proposed scheme is applicable to body area systems which have limited energy sources due to the size of the sensors. The proposed scheme is compared with two existing schemes and there were improvements in terms of path loss parameter.

**Keywords:** Distance, Energy, Path Loss, Sensors

## 1. Introduction

There has been a huge development in Information and Communication Technology in education, healthcare sector and infrastructure less wireless networking.<sup>1,2</sup> Mobile Ad-Hoc Networks (MANETs) do not require a fixed kind of infrastructure. The communication takes place between sensor nodes used as intermediate nodes to send the data to the destination. This structure has given birth to other networks like Body Area Networks. Wireless Body Area Sensors Networks (WBASNs) consist of small sized sensors including invasive as well as non-invasive sensors which continuously monitor the physiological activities of a human body and transfer information wirelessly in real time.<sup>3</sup> The medical sensors used in WBASNs are the result of demand for the better healthcare solutions and concerns.<sup>4,5</sup>

WBASNs applications are not only towards health sector but also in the monitoring of sports players in the field while playing and soldier monitoring in the battle field.<sup>6</sup> Architecture of WBSANs is shown in Figure 1 where it can be observed that sensors were placed on the human body communicate with a sink or the base station.

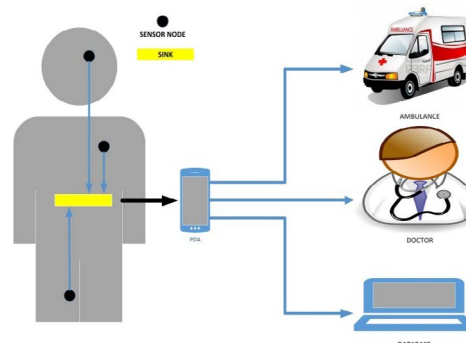


Figure 1. WBASN Architecture.

The sink is a device which collects data from the sensors, computes it and then transfers it towards a mobile device or a fixed PC. Furthermore, collected data will be sent to entities like a medical representative, an ambulance, or to a central medical server for storing this data. In WBASNs the successful transmission of information from a sensor (node) to destination (sink) is of extreme significance because this information is related to a person's health and sometimes this is critical information.<sup>7</sup> Energy efficiency of WBASNs has been widely investigated for the sensors to increase the life of a network. Mostly sensors used in WBASN are battery powered and have constraints such as energy usage and battery life. Sensors used in WBSANs should have extended battery life and energy efficient if operate for long time.<sup>8</sup> wireless body area network (WBAN) The path loss depends on the distance of the transmission between transmitter and receiver nodes.<sup>9</sup> Further the paper is divided into four sections.

## 2. Research Methodology

Researchers in the article proposed multi-hop communication.<sup>10</sup> The nodes which were nearer to the sink were consuming more energy and also there was increased delay. A monitoring system was developed by the article in which a system integrated physiological parameters record in a web based portal.<sup>11</sup> This helps the medical consultants to get informed of the patient's and whenever the patient visit is scheduled then without the wastage of time the medical history is already available. Simulation based architecture was presented in the article to reduce stereotyped disorders of motion especially in kids or patients having Autism Spectrum Disorder.<sup>12</sup> Time Division Multiple Access technique is used for the adjustment of transmission and slots are allocated thus saving energy consumption<sup>8</sup> wireless body area network (WBAN). A work was carried out for path loss reduction technique in the article.<sup>13</sup> A conceptual model has been proposed by the article presented.<sup>14</sup> In this model it was proposed that in an emergency case a real time message be sent to the consultants. The hardware as well as software structural design in a wireless sensor network system for the monitoring of issue related to health are proposed. This paper also outlines state of the art innovations for monitoring systems and proposes future aspects which can help in future health systems.

A telemedicine multi-tier system has been proposed by the researchers in the article.<sup>15</sup> This system is able to get sensed data from sensors and then feedback is provided. Based on the cloud assistance an ambient assisted living framework has been proposed by the article presented.<sup>16</sup> In this work the researchers have proposed that there should be two modes or planes, one for data and second for the control. The MAC has been combined with cloud and was error resilient scheme. Energy efficient routing protocol for hospital has been proposed by the researchers in the article.<sup>17</sup> They investigated and found that if there is a change in topology then that causes the battery sources to drain fast which makes the network unstable and performance goes down. They have proposed energy aware and stable routing. This technique takes benefit from the residual energy and stability of the sensor nodes. Healthcare monitoring system is based on ZigBee which has been proposed by the authors in the article presented.<sup>18</sup> OPNET was used as a simulation tool. They have proposed to use ZigBee in a beacon enable mode. This helped to avoid the energy utilization in the idle mode. In the article a protocol has been proposed which is energy efficient.<sup>19</sup> In this research a technique has been proposed that is to use sensor nodes as intermediate nodes. The responsibility assigned to the intermediate node is gathering the data from other sensor nodes and send this data to the sink after aggregating. This technique is applied on the sensors nodes which have more distance as compared to other sensor nodes. If there happens that any sensor node's has less amount of energy remaining then in this case only the critical data is sent only. Zahoor energy and QoS-aware (ZEQoS) protocol has been proposed by the article presented in which there are three algorithms which have used.<sup>20</sup> These protocols are used for detect the delays at end to end, end to end reliability of all paths for the selection of best possible path and in the end communication cost calculation. Routing table path selector algorithm, constructor algorithm and neighbor table constructor algorithm are the three algorithms that have been used in the proposed work. For the purpose of monitoring multiple patients a protocol has been proposed which is an interference aware protocol. The data transmission is based on the condition of the patients.<sup>21</sup> which results in electromagnetic interference that may impair wireless transmissions between medical devices. On the other hand, reliable and continuous collection via wireless communications of patient vital signs such as

blood pressure and flow, core temperature, ECG, carbon dioxide (CO2) Improvisation of energy efficiency by the help of propagation model has been proposed by the article.<sup>22</sup> In order to avoid hotspots use dedicated relay devices also has been proposed because they will help to increase the life time of the network.

### 3. Energy Analysis

Equation (1) represents the energy consumption of the single hop scheme and Equation 3 represents the multi hop energy analysis equation can be represented as

$$E_{sh} = E_{TX} \quad [1]$$

$E_{TX}$  = Transmission energy. It is computation as can be represented as

$$E_{TX} = (E_{amp} + E_{elec}) * s * d^2 \quad [2]$$

$$E_{mh} = s * n \left[ E_{TX} + (E_{DA} + E_{RX}) * \frac{(n-1)}{n} \right] \quad [3]$$

$E_{DA}$  = energy consumed in data aggregation,  $E_{RX}$  = energy consumed in data reception,  $n$  = number of hops,  $s$  = size of the packet. The equation expressing energy consumption of the radio model can be represented as

$$E_{TX(s,d)} = E_{TX}s + E_{amp}sd^n \quad [4]$$

The entire energy consumed by a WBASN sensor node to transmit data is represented as

$$E_{node} = E_{tx} + E_{retx} + E_{ack} + E_{acc} \quad [5]$$

$E_{node}$ : cumulative amount of energy consumed by a node

$E_{tx}$ : amount of energy used in data transmission,

$E_{retx}$ : Amount of energy utilized when retransmitting

$E_{ack}$ : Energy consumed while transmitting acknowledgement.

$E_{acc}$ : Energy utilized by the channel access procedures

The transmission consumes additional energy whenever compared to the other parameters of sensors like sensing and data processing. The sensors communicate their data to the sink and this information may be critical and the major factor affecting the signal in the way that it may not reach the destination in the correct manner is the path loss. Path loss depends on upon the frequency and the distance between the transmitter and the receiver. The transmission can be made effective by reducing the path loss because in wireless communication path loss is probable to occur.

### 4. Parameters used for Simulation

**Path Loss** – The Path loss represents signal weakening. WBASN transmission is significantly affected by path loss. The path loss occurs due to different body channel impairments. The transmitting antenna transfers power in outward direction and is there is any obstacle that will attenuate the transmitted signal.

The path loss can be demonstrated by the following equation is represented as

$$PL(f, D) = PLo + 10n \log_{10} \frac{D}{d_0} + S \quad [6]$$

$PL$  = Path loss measured in dB,  $D$  = Distance from transmitting end to receiving end,  $d_0$  = Reference distance,  $n$  = coefficient of path loss,  $S$  = Scattering term and  $PLo$  = Path loss at reference distance and can be represented as

$$PLo = 10 \log_{10} \left[ \frac{4\pi D f}{c} \right]^2 \quad [7]$$

Then

$$PL(f, D) = 10 \log_{10} \left[ \frac{4\pi D f}{c} \right]^2 + 10n \log_{10} \frac{D}{d_0} + S \quad [8]$$

In WBASN, different human postures also affect the transmitted signal.

### 5. Simulation

The proposed scheme is termed as RK scheme. For the analysis of the proposed RK scheme's transposition method for sensors, this section is further divided into three sections.

#### 5.1 The Coordinate Values of Sensor Positions

The values of the proposed transposition schemes are defined in terms of distance in centimeters. The Y coordinate is the height of the human body and x coordinate is the width. Total numbers of deployed sensors in this scheme are 8. These sensors are at distance from the sink. This distance is the communication distance as a sensor is the transmitter and the sink is the receiver. These sensors are to be transposed in order make the distance of each node from the sink decrease when compared to the coordinates being suggested in Co-LAEEBA Scheme and SIMPLE scheme.<sup>23,9</sup> The quantity of energy used is

dependent on the distance of transmitter and receiver node. The proposed coordinates of the sensor nodes deployed are given in Table 1.

**Table 1.** Coordinates of sensor nodes on human body

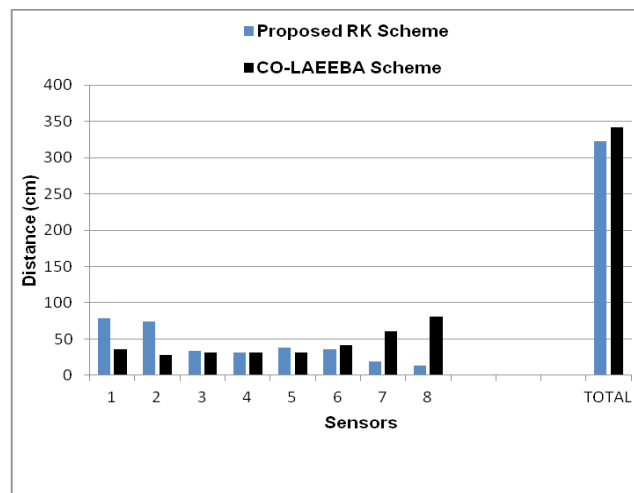
| Sensor Node   | X Coordinate<br>(m) | Y Coordinate<br>(m) |
|---------------|---------------------|---------------------|
| Sensor Node1  | 0.37                | 0.1                 |
| Sensor Node 2 | 0.55                | 0.15                |
| Sensor Node 3 | 0.37                | 0.55                |
| Sensor Node 4 | 0.55                | 0.6                 |
| Sensor Node 5 | 0.65                | 0.6                 |
| Sensor Node 6 | 0.17                | 0.6                 |
| Sensor Node 7 | 0.34                | 0.7                 |
| Sensor Node 8 | 0.5                 | 0.8                 |

## 5.2 Data Analysis: Comparison of the Variations in Node Distances

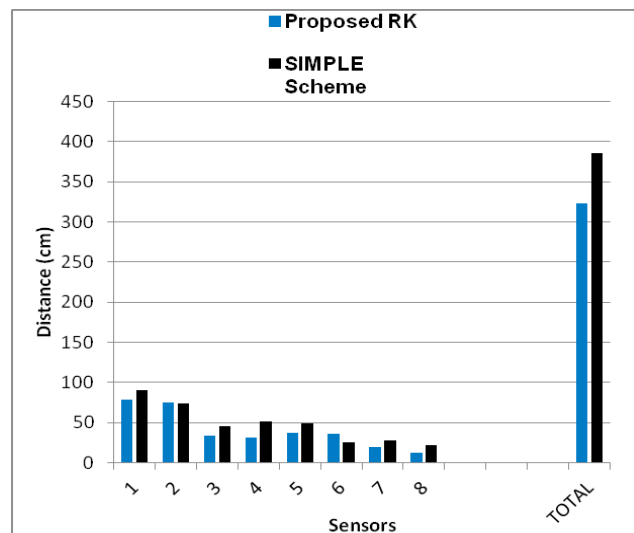
In this section the comparison has to be performed in terms of node distance from sink of the proposed RK scheme with the two schemes that are Co-LAEEBA and SIMPLE schemes proposed in the article and respectively.<sup>9,23</sup> These both schemes have eight sensor nodes deployed at different positions. With the help of the coordinates of the proposed RK scheme the distances are computed and compared with Co-LAEEBA and SIMPLE schemes.<sup>9,23</sup>

In Figure 2 distance analysis of Co-LAEEBA scheme<sup>23</sup> and proposed RK scheme is illustrated. It may be observed that the distance of nodes 1, 2, 3, 4 and 5 in the proposed RK scheme are higher as compared to Co-LAEEBA scheme.<sup>23</sup> Distances of nodes 6, 7 and 8 in the proposed RK scheme are smaller than the Co-LAEEBA scheme.<sup>23</sup> It can clearly be observed that the proposed RK scheme has total distance of 323.0346 cm and Co-LAEEBA scheme has 341.8894 cm total distance.<sup>23</sup> So the proposed RK scheme achieves as compared to the Co-LAEEBA scheme.<sup>23</sup>

In Figure 3 distance analysis of SIMPLE Scheme and proposed RK scheme is illustrated.<sup>9</sup> It may be observed that the distance of nodes 2 and in the proposed RK scheme are higher as compared to SIMPLE Scheme.<sup>9</sup> Distances of nodes 1, 3, 4, 5, 7 and 8 in the proposed RK scheme are smaller than the SIMPLE Scheme.<sup>9</sup> It can clearly be observed that the proposed RK scheme has total distance of 323.0346 cm and SIMPLE Scheme has 385.56 cm total distance.<sup>9</sup> So the proposed RK scheme achieves as compared to the SIMPLE Scheme.<sup>9</sup>



**Figure 2.** Distance of proposed scheme with Co-LAEEBA Scheme.



**Figure 3.** Distance of proposed scheme with SIMPLE Scheme.

## 6. Results

Figure 4 shows the path loss calculation in dB with respect to the distance in centimeters of entire sensor nodes of SIMPLE Scheme.<sup>9</sup> Path loss of node 1 is represented by red, path loss of node 2 is denoted 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. In Figure 5 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 8 having the least value of the path loss due to having the less distance as compared to all other sensor nodes.

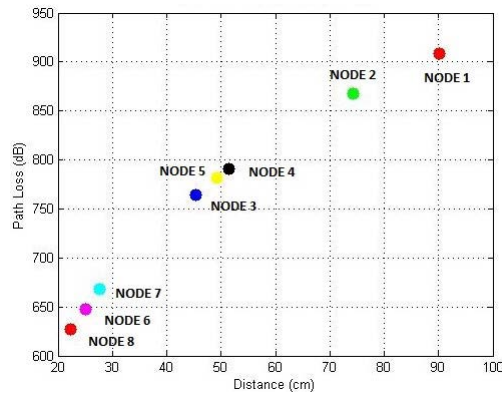


Figure 4. Path loss of SIMPLE Scheme.

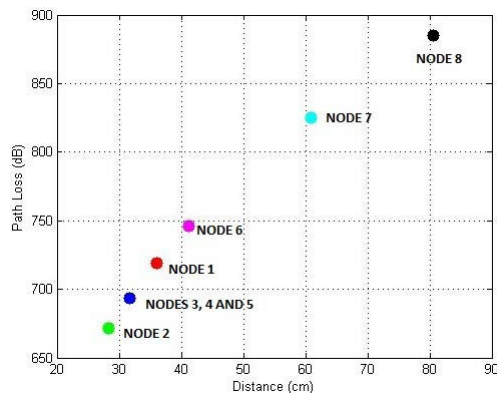


Figure 5. Path loss of CO-LAEEBA Scheme.

Figure 5 illustrates the path loss calculation in dB with respect to the distance in centimeters of all the 8 sensor nodes of Co-LAEEBA Scheme.<sup>23</sup> The simulation result in Figure 5 are as path loss of node 1 is represented by red point, path loss of node 2 is illustrated by green point, path losses of nodes 3, 4 and 5 are equal and denoted as a single blue 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 in the graph.

Table 2. Path Loss Comparison

| SCHEME             | PATH LOSS VALUES |                 |               |               |               |                 |                 |                 |                         |
|--------------------|------------------|-----------------|---------------|---------------|---------------|-----------------|-----------------|-----------------|-------------------------|
|                    | PL1<br>(dB)      | PL2<br>(dB)     | PL3<br>(dB)   | PL4<br>(dB)   | PL5<br>(dB)   | PL6<br>(dB)     | PL7<br>(dB)     | PL8<br>(dB)     | TOTAL PATH<br>LOSS (dB) |
| SIMPLE Scheme      | 908.6702         | 867.3835        | 764.6588      | 790.7863      | 781.7188      | <b>648.0565</b> | 667.9013        | 626.9392        | 6.06e+03                |
| CO-LAEEBA Scheme   | <b>719.114</b>   | <b>671.7083</b> | <b>693.35</b> | <b>693.35</b> | <b>693.35</b> | 745.8133        | 825.2487        | 884.6912        | 5.93e+03                |
| Proposed RK Scheme | 877.7891         | 867.939         | 702.4913      | 694.2242      | 727.0897      | <b>720.0979</b> | <b>596.3041</b> | <b>525.1735</b> | <b>5.71e+03</b>         |

In Figure 6 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 2 having the least value of the path loss due to having the less distance as compared to all other sensor nodes.

Figure 6 illustrates the path loss calculation in dB with respect to the distance in centimeters of entire sensor nodes of proposed scheme. 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 as represented in Figure 6. It can 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 8 having the least value of the path loss due to having the less distance as compared to all other sensor nodes

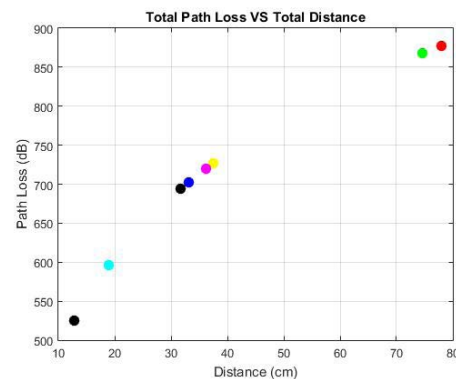


Figure 6. Path loss of proposed RK scheme.

Table 2 summarizes the comparison in chart form. In the table the efficiency of transposition in RK scheme can be observed. Both existing schemes have been compared in terms of path loss.



## 7. Conclusion

In this paper, RK scheme of transposition of medical sensors was proposed for WBASNs. The proposed schemes based on the positions of the physiological sensors which are placed on the human body. The physiological sensors are very small in size and have to perform tasks like recording parameters, processing and transmitting. The transmission is the parameter which consumes more energy as compared to others. So needed was to reduce this path loss in WBASNs and that is why this selection is performed to reduce the path loss. The path loss occurs mostly in wireless communication. The path loss is dependent on frequency as well as the distance of the transmitter to the receiver side. Human body is made of water and water creates the losses in the signals. This is due to path loss that the signals get distorted and when they reach the destination they are not on position to be interpreted. This paper aims towards the minimization of the path loss. Sensors were adjusted on the position and their distance factor was computed by Euclidean distance Formula and was computed on Mat lab. Sink was kept at the center of the body and then all distances were computed. The sensor fitted at their best position with no compromise to the performance of their recording if they are moved. Once the distances are computed the simulation for the path losses were carried out. From Figure 2 and 3 it can be observed that the proposed RK scheme is having lesser distance Ehen compared to the existing two schemes which are SIMPLE and CO-LAEEBA respectively. The simulation results of SIMPLE show that at sensor nodes 1, 2, 3, 4, 5, 7 and 8 the path loss was greater than the proposed RK scheme and just at sensor node 6 it had lesser path loss compared to the proposed RK Scheme. The simulation results of CO-LAEEBA show that at sensor nodes 1, 2, 3, 4 and 5 the path loss is lesser than that of the proposed RK scheme and at sensor nodes 6, 7 and 8 the path loss is greater than that of the proposed RK scheme. The cumulative results that SIMPLE scheme has  $6.06 \times 10^3$  path loss and CO-LAEEBA has  $5.93 \times 10^3$  path loss while the cumulative path loss results of the proposed RK scheme has  $5.71 \times 10^3$  path loss which is less than both of the existing schemes. With RK scheme, the WBASNs can achieve efficiency in term of signal transmission between sensors and sink by reducing the path loss. In the simulation, it was observed that the distance was reduced in comparison to two existing schemes CO-LAEEBA and SIMPLE. This was

achieved because of adjusted positions of sensors. This reduced distance in turn reduces the path loss which provides stability to the network.

## 8. References

1. Jaffri I, Soomro S, Khan RA. ICT in Distance Education : Improving Literacy in The province of Sindh Pakistan. *Sindh University Journal of Education*. 2011, 40(2011), pp. 37-48.
2. Khan RA, Memon S, Awan JH, Zafar H, Mohammadni K. Enhancement of Transmission Efficiency in Wireless On-Body Medical Sensors. *Engineering Science and Technology International Research Journal*. 2017, 1(2), pp. 16-21.
3. Negra R, Jemili I, Belghith A. Wireless Body Area Networks : Applications and technologies. *Procedia Computer Science*. 2016, 83, pp. 1274-1281.
4. Ghamari M, Janko B, Sherratt RS, Harwin W, Piechockic R, Soltanpur C. A Survey on Wireless Body Area Networks for eHealthcare Systems in Residential Environments. *Sensors*. 2016, 16(6), pp. 1-33.
5. Khan NA, Hai M, Sawand MA, Khuzema A, Tariq Mehak. Real Time Monitoring of Human Body Vital Signs using Bluetooth and WLAN. *International Journal of Advanced Computer Science and Applications*. 2016, 7(10), pp. 210-6.
6. Wang JC, Leach M, Wang Z, Lim EG, Man KL, Huang Y. Wireless Body Area Network and its Applications. *International SoC Design Conference (ISOC)*. In proceeding of the IEEE. Gyungju. 2015, pp. 169-70.
7. Movassaghi S, Member S, Majidi A. Enabling Interference-Aware and Energy-Efficient Coexistence of Multiple Wireless Body Area Networks With Unknown Dynamics. *IEEE Access*. 2016, 4, pp. 2935-2951.
8. Liu B, Yan Z, Chen CW. Medium Access Control for Wireless Body Area Networks with QoS Provisioning and Energy Efficient Design. *IEEE Transactions on Mobile Computing*. 2017, 16(2), pp. 422-34.
9. Nadeem Q, Javaid N, Mohammad SN, Khan MY, Sarfraz S, Gull M. SIMPLE: Stable Increased-Throughput Multi-hop Protocol for Link Efficiency in Wireless Body Area Networks. *Eighth International Conference on Broadband and Wireless Computing, Communication and Applications (BWCCA)*. In proceedings IEEE Compiègne. 2013, pp. 221-6
10. Seo S, Gopalan SA, Chun S, Seok K, Nah J, Park J. An energy-efficient configuration management for multi-hop wireless body area networks. *3rd IEEE International Conference on Broadband Network and Multimedia Technology (IC-BNMT)*. In proceedings of IEEE, Beijing. 2010, pp. 1235-9.
11. Gao T, Greenspan D, Welsh M, Juang RR, Alm A. Vital Signs Monitoring and Patient Tracking Over a Wireless Network. *27th Annual Conference In proceeding of the IEEE Engineering in Medicine and Biology*. Shanghai. 2005. pp. 102-5.

12. Coronato A, De Pietro G, Paragliola G. A monitoring system enhanced by means of situation-awareness for cognitive impaired people. In *Proceedings of the 8th International Conference on Body Area Networks*. Boston, Massachusetts. 2013, pp. 124-7.
13. Khan RA, Memon SA, Zardari S, Dhomeja L Das, Usman M. Transposition Technique for Minimization of Path Loss in Wireless On-Body Medical Sensor. *Sindh University Research Journal*. 2016, 48(4), pp. 747-54.
14. Awan JH, Memon SA, Memon NA, Shah R, Bhutto Z, Khan RA. Conceptual Model for WWBAN (Wearable Wireless Body Area Network). *International Journal of Advanced Computer Science and Applications*. 2017, 8(1), pp. 377-81.
15. Jovanov E, Milenkovic A, Otto C, Groen D, PC. A wireless body area network of intelligent motion sensors for computer assisted physical rehabilitation. *Journal of Neuro Engineering and rehabilitation*. 2005, 2(1), pp. 1-6.
16. Kartsakli E, Antonopoulos A, Lalos A, Tennina S, Di Renzo M, Alonso L, Verikoukis C. Reliable MAC design for ambient assisted living: Moving the coordination to the cloud. *IEEE Communications Magazine*. 2015, 53 (1), pp. 78-86.
17. Smail O, Kerrar A, Zetili Y, Cousin B. ESR: Energy aware and Stable Routing protocol for WBAN networks. In *proceeding of the International Wireless Communications and Mobile Computing Conference (IWCMC)*. Paphos. 2016, pp. 452-7.
18. Huynh D, Chen M. An Energy Efficiency Solution for WBAN in Healthcare Monitoring System. *3rd International Conference on Systems and Informatics (ICSAI)* IEEE. Shanghai. 2016, pp. 685-90.
19. Sahndhu MM, Javaid N, Imran M, Guizani M, Khan ZA, Qasim U. BEC: A Novel Routing Protocol for Balanced Energy Consumption in Wireless Body Area Networks. In *proceeding of the 2015 International Wireless Communications and Mobile Computing Conference (IWCMC)*, Dubrovnik. 2015, pp. 653-8.
20. Khan ZA, Sivakumar S, Phillips W, Robertson B. ZEQoS: A New Energy and QoS-Aware Routing Protocol for Communication of Sensor Devices in Healthcare System. *International Journal of Distributed Sensor Networks*; 2014.
21. Chen B, Varkey JP, Pompili D, Li JKJ, Marsic I. Patient vital signs monitoring using Wireless Body Area Networks. In *proceeding of the 2010 IEEE 36th Annual Northeast Bio-engineering Conference (NEBEC)*, New York, NY. 2010, pp. 1-2.
22. Braem B. The Need for Cooperation and Relaying in Short-Range High Path Loss Sensor Networks. In *proceeding of the International Conference on Sensor Technologies and Applications (SENSORCOMM 07)* Valencia. 2007, pp. 566-71.
23. Ahmed S, Javaid N, Yousaf S. Co-LAEEBA: Cooperative link aware and energy efficient protocol for wireless body area networks. *Computers in Human Behavior*. 2015, 51, pp. 1205-15.