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# Transposition Technique for Minimization of Path Loss in Wireless On-Body Medical Sensors

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**Abstract:**Wireless Body Area Sensor Networks (WBASNs) have gained significant attention as they are related to human health. Path loss is the major problem in sensors communication and it produces attenuation which reduces the signal strength. In this paper, a new transposition Sensor Transposition for Energy Efficient Routing (STEER) scheme of wireless medical sensors was introduced to minimize path loss and also achieve maximum battery life of a wireless sensor. A simulation of WBASN designed in Matlab with eight sensors and one sink. Initially, the sensors were placed randomly on different far and close positions to sink to obtain the best placement positions on a human body to achieve minimum path loss. In additions, the sink position has been changed to the different coordinates to check its effect on path loss. Finally, the simulation results of new STEERwere compared with existing transposition schemes available in the literature.

**Keywords:** Wireless medical sensors, Path loss, Sink, Transposition, Energy efficiency

## 1. INTRODUCTION

As the life expectancy has increased the world over so have the healthcare issues as health related problems increase during old age. The number of old age people around the world is predicted to reach 1,198 million by 2025 (Oey, *et. al.*, 2012). In Pakistan, the population of people who are 60 years old or above during 2015 was about 12.13 million which is expected to reach 21.38 million by the year 2030. WBASNs (Wireless Body Area Sensor Networks) are getting more attention due to their medical and non-medical applications. WBASN technology employs implantable, very small sized sensors inside or on the skin of the human body for the purpose of monitoring physiological parameters. These parameters include heart rate (ECG), temperature, blood pressure or blood sugar level to determine the behavior or medical parameters of any patient or a normal person (El-Sayed, *et. al.,* 2008). An access point known as sink or base station is also placed on the human body so that it can collect data from the sensors for further processing (El-Sayed *et al.,* 2008; Ibrahim, and Liu, 2008).These sensors are operated on batteries and are difficult to recharge. It is assumed that the batteries should work at least for a decade (Timmons andScanlon, 2004). The sensor nodes being small in size have limited amount of battery power resulting energy constraints (Oey *et al.,* 2012). If the sensor battery is completely drained, then the sensors will stop functioning. In this regard energy efficient systems areneeded to be developed *et. al.*, 2016). Some of the major challenges faced by WBASN researchers are power consumption, attenuation of signals andenergy harvesting (Nadeem *et al.,* 2015). Power is mostly consumed in communicating data whereas path loss is another major issue with attenuated communication. The increase in communication distance for signal increases path loss.

### 1.1 Path Loss

Energy is one of themost important constraints in wireless medical sensorsbecause they cannot be charged on regular basis.At present, someavailable sensor technologies are re-chargeable; however, they require continuous attention on battery. Life of sensor dependson consumption of energy which is consumed in sensing and in communication (Ibrahim *et al.,* 2008). Losses may distractcommunication,resulting in degradation inthe performance of monitoring (Ahmed *et al.,* 2015).The difference of the transmitting power and receiving power is called path loss and its unit is decibels (dB).Energy which a sensor node consumes in data communication is more than data sensing or data processing as shown in **(Fig. 1)** (Ahmed *et al.,* 2015; (Ibrahim *et al.*, 2008) and is represented mathematically in equation 1 *et. al.*, 2014).

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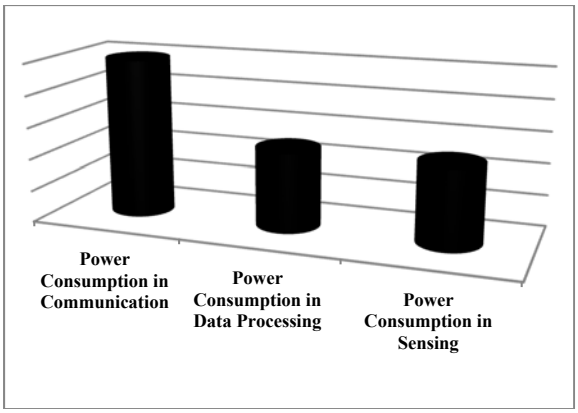



**Fig-1: Power consumption comparison of sensor parameters**
(Ahmed *et al.,* 2015; Ibrahim *et al.,* 2008)

$$\mathbf{E_{node} = E_{tx} + E_{retx} + E_{ack} + E_{acc}} \ldots\ldots\ldots\ldots\ldots \textbf{(Equation 1)}$$

Where E node represents aggregate of all energy parameters that a sensor consumes during transmission, Etx is extent of energy which is consumed during data transmission, Eretx is energy amount needed when data is needed to be retransmitted, Eack is energy consumed by a node to transmit an Acknowledge (ACK) packet and energy amount which is consumed by procedures in channel access is represented by Eacc. From Equation 1 it can be observed that total energy consumed by individual node totally depends on four parameters out of which three are related to transmission.

During communication a transmitting antenna transmits power and any obstacle in between will cause the destruction of transmitted signal. In WBASN other factors which affect transmission are the signal body movement, postures address. In WBASNs, there are two types of transmissions first when the physiological data collected by sensors is sent to sink node and second from sink to medical stations (Pantelopoulos and Bourbakis, 2010).

During transmission, if the signal is not received at the destination or received in attenuated condition then the received signal is difficult to process. These signals may possess the information necessary for processing on urgent basis. If these signals with important information are received in attenuated form then sensor node has to resend this information carrying signals. This resending of signals consumes the amount of energy needed which in turn creates the network to be less capable and therefore the lifetime of the node becomes less (El-Sayed *et al.,* 2008). Path loss is affected by two parameters i.e. distance and frequency. Path loss related to frequency and distance is given in Equation 2 (Khan *et al.,* 2012).

$$\boldsymbol{PL = PLo + 10nlog_{10}\frac{d}{do} + X\sigma} \ldots\ldots\ldots\ldots\ldots \textbf{(Equation 2)}$$

Where *PL* is the aggregate path loss and its unit is dB, *d* is the distance between transmitter and receiver measured in centimeters, $d_o$ is reference distance, *n* is coefficient of path loss, $X\sigma$is the termfor scattering. $PL_o$ is the path loss at a reference distance given in Equation 3:

$$\boldsymbol{PLo = 10log_{10}\frac{(4\pi df)^2}{c}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots \textbf{(Equation 3)}$$

Where *c* is the speed of light and*f* is the frequency. In this paper a transposition schemes of sensors and sink are proposed and the effects of path loss variation are observed by relocating sink on different parts of the human body.The proposed repositioning of sink has produced encouraging results by reducing path loss resulting in increased lifetime of WBASNs so the battery life is increased providing extended network life.

## 2. RELATED WORK

WBASNs have constraints in terms of energy so various studies have been carried out to provide longer battery life and energy efficiency. In this section, the research that has been done so far regarding energy efficiency in WBSN is being discussed.

A Minimum Power Cooperative Routing (MPCR) algorithm is presented in (Ibrahim *et al.,* 2008), selecting a route on the basis of minimum power. The cost function was introduced in (Ahmed *et al.,* 2014) which selects the suitable route from the sensor towards the sink and the distance and residual energy of other sensors are kept updated so that sensor having high residual energy may be utilized. An energy efficient routing protocol (Sahndhu, 2015) is proposed in which intermediate nodes have been used.These intermediate nodes collect and aggregate data from other sensors,which are far from the sink. In a case of nodes having limited energy then only critical data is transmitted also that energy can be saved. Thermal-aware routing protocol is proposed in (Monowar and Hassan, 2014) which detects the hotspots and selects the shortest route from the sensor node to the destination. A protocol has been proposed by (Sandhu *et al.,* 2014) where the sensor nodes are directed to send their data to the forwarder node. This forwarder node is responsible for forwarding data to sink. Among all of the sensor nodes the forwarder node is selected; possessing higher energy as compared to other sensor nodes. This minimizes the distance of the transmission such as between sensor node and the sink to conserve energy.

## 3. PROPOSED SCHEME

The proposed scheme is named as Sensor Transposition for Energy Efficient Routing (STEER) scheme. Following sections present the analysis of the sensor transposition and deployment of STEER along with simulation results of sensor transposition. A subsequent section is dedicated for sink transposition and deployment along with simulation results. STEER is compared with existing scheme RE-ATTEMPT (Ahmad *et al.,* 2014) where STEER showed better results by reducingthe path loss to save battery power and energy.

### 3.1 Sensor Transpositions and Deployment

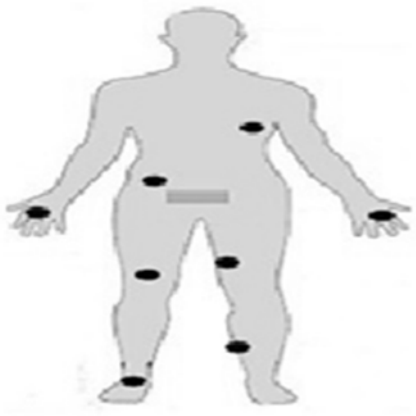
The values of the proposed transposition scheme are defined in terms of the distance measured in centimeters. The X coordinate is the width and Y coordinate is the height of the human body.Atotal number of deployed sensors are eight, placing sink at the waist. These sensors are transposed in order to decrease the distance of each node from the sink and proposed positions are compared with coordinates suggested by the authors in (Ahmad *et al.,* 2014). The energy consumption is directly proportional to the distance of transmitting node to receiver node. If path loss is required to be reduced then this distance must be reduced.

The transposition is based on distance by keeping into account that sensor functions are not disturbed. Changing the position may affect the operation of the sensors, so the new positions are to be selected carefully. **(Table-1)** presents the x and y coordinates values of the proposed STEER entire eight nodes.

**Table-1: Sensor Coordinates of the** STEER

| Sensor No. | X coordinate | Y coordinate |
|---|---|---|
| Sensor 1 | 27 cm | 10 cm |
| Sensor 2 | 45 cm | 15 cm |
| Sensor 3 | 27 cm | 55 cm |
| Sensor 4 | 45 cm | 60 cm |
| Sensor 5 | 65 cm | 60 cm |
| Sensor 6 | 7 cm | 60 cm |
| Sensor 7 | 24 cm | 70 cm |
| Sensor 8 | 40 cm | 80 cm |

**Fig.2** depicts the positions of sensors and sink of STEER and RE-ATTEMPT (Ahmad *et al.,* 2014). The sensor coordinate values of STEER in **(Table-1)**are deployed on human body as shown in **(Fig.2a)** in which the rectangular box represents the sink and**(Fig.2b)** is the node deployment of RE-ATTEMPT (Ahmad *et al.,* 2014).



(a)

**Fig-2: Node deployment (a)** STEER**(b**

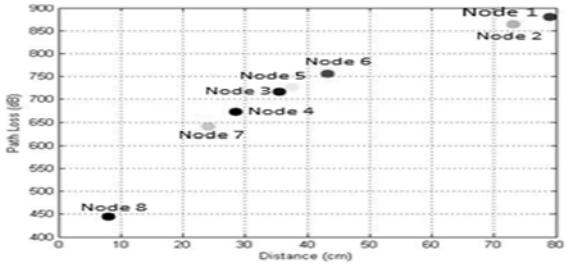
## 4. DISTANCE ANALYSIS

For the purpose of data analysis, the distances of all the sensors with respect to sink are computed by Euclidean distance method (Ahmad *et al.,* 2014). The number of sensors deployed in RE-ATTEMPT (Ahmad *et al.,* 2014), is eight but the sink is deployed at the 40 cm in x and90 cm in y coordinate. Distances are computed based on the sensors and sink position proposed in **(Table-2)** shows the values of all distances of RE-ATTEMPT (Ahmad *et al.,* 2014) in which d1 is the distance of sensor node 1, d2 is the distance of sensor node 2 up to sensor 8. The total distance is the sum of all individual distances. Distances of the STEER are also shown in Table 2 in which it is compared to the existing scheme RE-ATTEMPT (Ahmad *et al.,* 2014). **(Table-2)** compares all distances of the proposed STEER with RE-ATTEMPT (Ahmad *et al.,* 2014). In **(Table-2)** it can be observed that at distances d1, d2, d3 andd6; RE-ATTEMPT (Ahmad *et al.,* 2014)has lesser distance as compared to STEER.At distances d4, d5, d7 andd8 STEER achieved lesser distance when compared to RE-ATTEMPT (Ahmad *et al.,* 2014). The fewer distance values are written in bold letters for indication. The aggregate of the distance of STEERis 12.8334 cm which is less than that of the RE-ATTEMPT (Ahmad *et al.,* 2014). In WBASNs every centimeter is important because when the sensors have minimum distance then they will consume less energy because they will have less distance to send data.

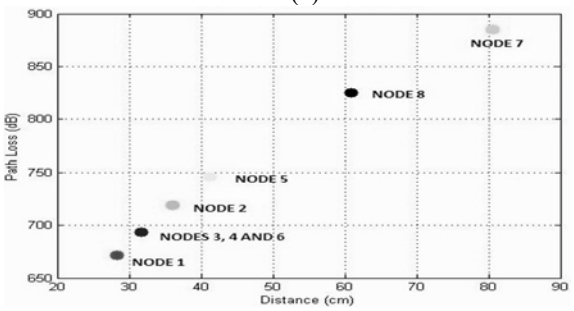
## 5. SIMULATION RESULTS OF SENSOR TRANSPOSITION

For the simulation purpose, MATLAB 2015b has been used and these simulation results are of STEERas shown in **(Fig-3a)**. It may be observed that sensor node 1 possess the value of path loss as this node is having the larger distance as compared to other sensor nodes and the sensor node 8 possess the least value of the path loss because it has less distance as compared to all other

sensor nodes. Simulation results of RE-ATTEMPT (Ahmad *et al.,* 2014)are shown in **(Fig.3b)**. The colors assigned in **(Fig.4)** have been used for understanding purpose; the path loss of node 1 is represented by red point, path loss of node 2 with green, path losses of nodes 3, 4 and6 are equal and represented as a single blue point, path loss of node 5 is represented by yellow point, path loss of node 7 is represented by cyan point and path loss of node 8 is represented by black point in the graph. In **(Fig.3b)** it can be observed that sensor at node 7 resulted in the highest value of path loss as this node is having the larger distance as compared to other sensor nodes and the sensor node 1 having the least value of the path loss due to the less distance as compared to all other sensor nodes.




(a)




(b)

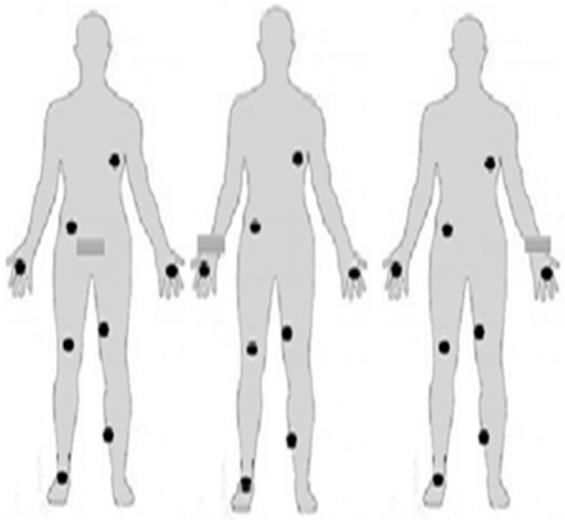
**Fig.3: Simulation results (a) STEER (b) RE-ATTEMPT**

The values of simulation results of both schemes are presented in **(Table-3)**. From Table 3 it may be observed that at sensor node 1 the value of path loss is 880.5534 dB in STEERbut the value obtained in RE-ATTEMPT (Ahmad *et al.,* 2014) is 671.7083 dB. At sensor node number 2 the value of path loss obtained by STEER is 864.0506 dB while RE-ATTEMPT (Ahmad *et al.,* 2014)obtained the lesser value of 719.114 dB. RE-ATTEMPT (Ahmad *et al.,* 2014) has a path loss value of 693.35 dB and 715.8702 dB path loss achieved by STEERat sensor node 3. Path loss values at sensor node 4 obtained by RE-ATTEMPT (Ahmad *et al.,* 2014) and STEER are 693.35 dB and 672.7874 dB respectively. This is the first time that STEERhas achieved lesser path loss. At sensor node 5 the value of path loss is 727.0897 dB in STEERbut the value obtained in RE-ATTEMPT (Ahmad *et al.,* 2014) is 745.8133 dB. At sensor node number 6 the value of path loss obtained by STEER is 755.5471 dB while RE-ATTEMPT (Ahmad *et al.,* 2014)obtained the lesser value of 693.35dB. RE-ATTEMPT (Ahmad *et al.,* 2014) has a path loss value of 884.6912 dB and 640.9573 dB path loss achieved by STEER at sensor node 7. Path loss values at sensor node 8 obtained by RE-ATTEMPT (Ahmad *et al.,* 2014) and the STEER are 825.2487 dB and 444.1063 dB respectively. The cumulative path loss of RE-ATTEMPT (Ahmad *et al.,* 2014) is 5926 dB and STEER is 5701 dB. STEERh as 225 dB lesser path loss as compared to RE-ATTEMPT (Ahmad *et al.,* 2014).This is accomplished due to proper and accurate transposition of the sensors. Lesser path loss value at every sensor is marked bold for indication.

## 6. SINK TRANSPOSITION ANDDEPLOYMENT

The accurate placement of sink is also important to reduce path loss in order to increase network life time by saving the battery of the sensors. The sink collects data from the sensors, computes and sends the data to other entities. Previously the sensors were transposed for the purpose of reducing path loss. The sink placement is relocated and tested for path loss. It is not compulsory that the sink is placed at the center of the body. The transposition of the sink is performed in order to test path loss and to find suitable sink position.

The first scenario in STEER with same sensors' and sink positions is shown in **(Fig.2a)** and is again presented in 5 (a). In the second scenario the sink is transposed to right wrist having x coordinates at 7cm and coordinates at 88 cm shown in **(Fig.4b)**. In the third scenario, the sink is transposed to left wrist having 65 cm in x coordinate and88 cm in y coordinate as shown in **(Fig.4c)**.

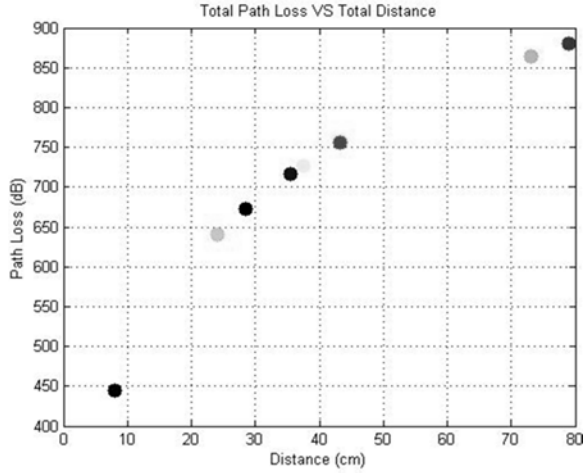


**(a) (b) (c)**

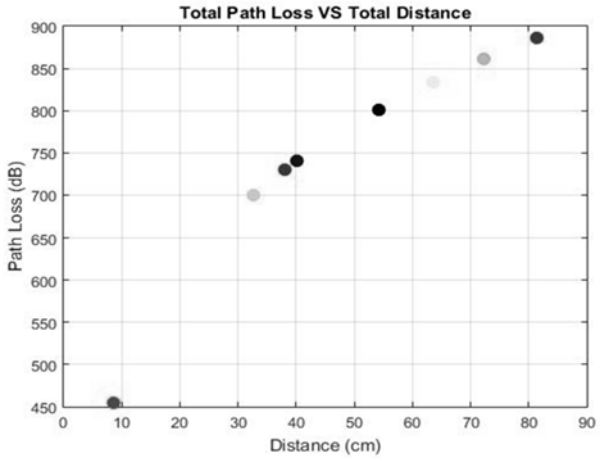
**Fig-4: Sink deployment in STEER(a) with sink at center of body (b) sink at right wrist (c) with sink at left wrist**

## 7. SIMULATION RESULTS FOR SINK TRANSPOSITION

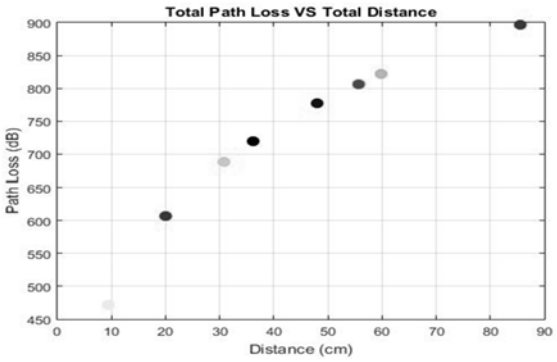
The results shown in **(Fig.5)** are the simulation result of STEER. **(Fig.5b)** represents the simulation results of STEERwhen sink is transposed to right wrist and**( Fig.5c)** is the result of STEERwhen sink is transposed to left wrist.




**(a)**




**(b)**




**(c)**

**Fig-5: Simulation Resultsof STEER(a) with sink at center of body (b) with sink at right wrist (c) with sink at left wrist**

The path loss valuesof entire eight sensor nodes and cumulative path losses of all these three scenarios are given in **(Table-4)**. From Table 4 it is observed that at the sensor node 1 the value of path loss is 880.5534 dB when the sink is at center, 884.4277 dB when sink placed at right wrist and900.4412 dB when a sink is placed on the left wrist. Placing the sink at the center of the body is better in achieving lesser distance at sensor nodes 2, 3, 4, 7 and8. Whereas at sensor node 5 the path loss was lesser at sink placed at left wrist andat sensor node 6 sink placement at right wrist achieved lesser path loss. The cumulative path loss of STEERwith sink placement at the center of the body is 5701 dB where the sink at right wrist has 6139 dB andsink at left hand has 6194 dB.

The path loss values are written in bold letters as in **(Table-4)** indicating that the value is lowest in all scenarios. When a sink is placed at center, it produced least path loss at 6 out of 8 positions. The center scenario has also produced least aggregate path loss. This means that if the sink is placed at the center of the body then all sensors will have equal distance towards it. This will help sensors to save energy when sending the data to sink. This will help in acquiring energy efficiency in WBASNs.

**Table 2: Distance comparison of** STEER **and RE-ATTEMPT**

| Scheme | Distance | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **d1 (cm)** | **d2 (cm)** | **d3 (cm)** | **d4 (cm)** | **d5 (cm)** | **d6 (cm)** | **d7 (cm)** | **d8 (cm)** | **Total (cm)** |
| STEER | 79.0759 | 73.171 | 35.4683 | 28.4429 | 37.5366 | 43.2782 | 24.0832 | 8 | 329.0561 |
| **RE-ATTEMPT** | 28.2843 | 36.0555 | 31.6228 | 31.6228 | 41.2311 | 31.6228 | 80.6226 | 60.8276 | 341.8895 |

**Table 3: Path loss comparison of STEER and RE-ATTEMPT**

| Scheme | Path Losses | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | PL1 (dB) | PL2 (dB) | PL3 (dB) | PL4 (dB) | PL5 (dB) | PL6 (dB) | PL7 (dB) | PL8 (dB) | Total Path Loss (dB) |
| RE-ATTEMPT ) | 671.7083 | 719.114 | 693.35 | 693.35 | 745.8133 | 693.35 | 884.6912 | 825.2487 | 5926 |
| STEER | 880.5534 | 864.0506 | 715.8702 | 672.7874 | 727.0897 | 755.5471 | 640.9573 | 444.1063 | 5701 |

**Table 4: Path loss comparison of STEERwith sink at three different positions**

| | | PATH LOSS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Sink Position | | PL1 (dB) | PL2 (dB) | PL3 (dB) | PL4 (dB) | PL5 (dB) | PL6 (dB) | PL7 (dB) | PL8 (dB) | Total Path Loss (dB) |
| | Center | 880.5534 | 864.0506 | 715.8702 | 672.7874 | 727.0897 | 755.5471 | 640.9573 | 444.1063 | 5701 |
| | Right Wrist | 884.4277 | 889.0936 | 732.5788 | 773.0969 | 837.1776 | 669.7613 | 646.2120 | 707.2877 | 6139 |
| | Left Wrist | 900.4412 | 871.2334 | 786.1668 | 709.8963 | 669.7613 | 837.1776 | 762.4153 | 657.3607 | 6194 |

## 8. CONCLUSION

In this paper, STEERis proposed for WBASNs. With the help of STEER, the WBASNs can achieve efficiency in term of signal transfer between sensors and sink by reducing the path loss. In the simulation, it was observed that the distance was reduced when newly calculated positions of sensors were adjusted which in turn reduce the path loss and providing stability to the network.After varying sink positions, the results suggest that instead of placing the sink on left or attached to wrist, it is better to place sink in the center of the body. This is because the sink will be closer to all the sensor nodes being at the center of the body and will minimize the path loss in communication. In another case, if sink placed on the left or right wrist of a human the transmitted data from the sensors placed on opposite direction cover more distance and became a reason of an increase in the path loss.

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