# Revised EECBSR for Energy Efficient and Reliable Routing in WBAN

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**ABSTRACT:**
A Wireless Body Area Network (WBAN) is capable of performing autonomous sensing of physiological signals of the human body without interrupting their normal activities. It consists of various intelligent, miniature and low power bio-sensor nodes placed on or in the close proximity of the human body. Routing in WBANs is a major issue as the reliability of a network depends on routing. Complex structure and mobile nature of human body are the main obstacles while designing routing protocols for WBANs. In this work, we have revised the performance of EECBSR (Even Energy Consumption and Back Side Routing) protocol by selecting a forwarder node with minimum cost function. Minimum distance of nodes from sink, residual energies of individual nodes and the total residual energy of the network are used to formulate the cost function in Revised-EECBSR. Sensor nodes are deployed on front side and as well as back side on the human body. Results show that REVISED-EECBSR performs better in terms of throughput, path loss, delay and network's stability than existing EECBSR protocol.

**KEYWORDS:** Energy efficient, Routing, EECBSR, WBAN, Reliability, Path loss, Delay.

## 1. INTRODUCTION

Due to advancement in wireless communication and integrated circuits, micro-electro-mechanical systems gave origin to affordable, scalable and reliable remote health monitoring systems called Wireless Body Area Networks (WBANs) [1]. These are a big boon for old aged and handicapped persons as they don't have to travel far to get their health monitored. A WBAN is a radio frequency based intelligent wireless technology in which various tiny, low powered, heterogeneous and intelligent bio-sensor nodes are strategically placed on or in the close proximity of the human body [1], [2]. Sensing and communication are the two major tasks performed by these bio-sensor nodes. The central hub receives the data from sensor nodes and further transmits to the remote server by using the internet, as depicted in figure 1. It provides the real time feedback to the concerned person. In WBANs in-body sensor nodes perform health monitoring, while on-body sensor nodes find their use in healthcare, gaming and multimedia applications [3]. WBAN is standardized by IEEE 802.15.6, which defines a MAC layer that supports the Ultra-Wideband (UWB), narrowband and Human-body communication [1]. A WBAN is capable of performing low range communications which lead to frequent partitioning of links among nodes [4], [5]. Applications of WBANs span over a wide area from healthcare, military, ambient intelligence and sports to entertainment like music, games etc. [2], [6]. Figure 1 shows the general architecture of a WBAN.

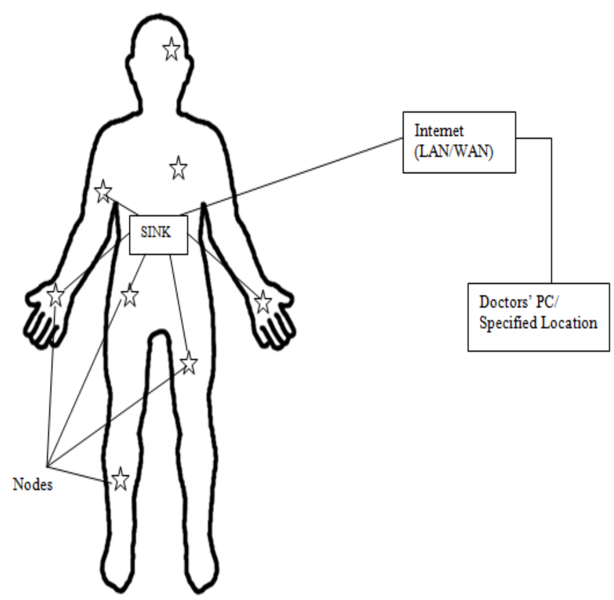



**Fig. 1.** Deployment of nodes on human body.

Due to limited battery power energy efficiency and reliability become the main issues in any WBAN. In this study, reliability of EECBSR (Even Energy Consumption and Back Side Routing) [7] is revised by selecting a forwarder with minimum cost function. Cost function is evaluated using minimum distance of nodes from sink and their residual energies.

## 2. ROUTING AND ITS ISSUES IN WBAN

Recent studies on WBANs have focused on MAC layer, security, routing techniques and network layer [6]. Reliability and low power transmission are the two most important factors which are crucial for adopting the WBANs globally [1]. Routing decides the reliability of a network. It is a process to select the transmission path. To perform efficient routing the routing technology of WBANs has to meet various significant requirements such as network lifetime extension, energy efficiency, physical characteristics of the human body etc. Routing protocols in WBANs classified as per the human body requirement are shown in Table 1.

**Table 1.** Classification of Routing Protocols in WBAN [3].

| **Category of Routing** | **Examples** | **Goals & Technique** |
|---|---|---|
| **Cluster based Routing Protocols** | EERDT [8] | Improves QoS using hierarchical routing |
| | ANYBODY [9] | Achieve even energy consumption using back and front side routing |
| | HIT [10] | |
| **QoS Aware Routing Protocols** | ESR (Energy Aware & Stable Routing) [2] | Increase the reliable delivery of critical data using different modules and approaches like centralized and distributed. |
| | QPRR (QoS Aware Peering Routing for Reliability-Sensitive Data) [11] | |
| | DMQoS (Data Centric Multi-Objectives QoS Aware Routing) [12] | Provides Data Centric QoS support |
| **Postural Movement Based Routing Protocols** | PRPLC (Probabilistic Routing in On-body Sensor Networks with Postural Disconnections) [5] | Provide reduced delay and link quality is revised |
| | ETPA (Energy-Efficient Thermal and Power Aware Routing) [13] | Cost function is calculated using temperature of nodes, their energy levels and received power from neighboring nodes. Provides reduced energy and temperature. |
| **Cross-Layer Routing Protocols** | Probabilistic routing [5] | Store & forward packet routing is used and supports mobility |
| | ASRQ [14] | Retransmits only lost frames rather than whole data frames |
| | CICADA [15] | Provided reliability using increased number of retransmissions and scheme randomization |
| **Temperature Aware Routing Protocols** | M-ATTEMPT [16] | Provides energy efficient routing keeping in view the mobility of human body by considering the hand movements and also makes new routes whenever a hotspot is detected. |
| | RTM-RP [17] | It uses linear programming model and detects hot-spot link |
| | HPR [18] | Time synchronization and sub-intervals are used between nodes |

In cluster based routing nodes are arranged in the form of clusters. A Cluster is used to achieve the optimality of networks. Optimal routing refers to the transmission of the data in less time using minimum energy. EERDT (Energy Efficient and Reliable Data Transfer) [8], Anybody [9] and HIT (Hybrid Indirect Transmission) [10] come under this category. EERDT is a reliable and power efficient routing protocol and uses hierarchical routing. In this a CH (cluster head) with maximum cost function is selected to aggregate the data for further analysis. Anybody applies LEACH routing of WSNs in WBANs. HIT chooses one or more cluster heads to transmit the data to the base station.

QoS aware routing protocols deal with the critical data like EEG, ECG etc. [3]. They use different modules to meet the different QoS requirements. ESR (Energy Aware and Stable Routing) [2], QPRR (QoS Aware Peering Routing for Reliability-Sensitive Data) [11], DMQoS (Data Centric Multi-Objectives QoS Aware Routing) [12] are the examples of QoS routing. ESR [2] is a stable, reliable and energy efficient routing protocol, designed for mobile nodes with limited power supply. A stable link is selected to transmit the data by formulating an objective model. QPRR is responsible to secure the patients' information. For this centralized and distributed approaches are used. DMQoS uses four types of data packet and five different modules for different purposes.

Since, mobility is the main cause of partitioning of links among sensor nodes in the human body. Therefore, postural movement routing protocols are used for detecting a change in body posture and solving the link partitioning problem. PRPLC (Probabilistic Routing in On-body Sensor Networks with Postural Disconnections) [5] and ETPA (Energy-Efficient Thermal and Power Aware Routing) [13] are comes under postural routing in WBANs. PRPLC [5] is designed using a stochastic link cost with frequent body postures. In the context of on-body topology, Postural Link Cost Formulation (PLCF) is proposed which automatically adjusts the communication link in case of mobility and provides an end-to-end path with minimum storage delay.

Cross layer routing resolves the issues related to network layer and MAC layer [6]. Temperature aware routing protocols are intended to protect the human body from electromagnetic radiations. It detects the hot-spot link and avoids them from being selected on the path from source node to sink [3], [17]. Routing protocols such as M-ATTEMPT (Mobility- Supporting Adaptive Threshold based Thermal aware Energy-efficient Multi-hop Protocol) [16], RTM-RP (Relay based Thermal Aware and Mobility Support routing protocol) [17] and HPR (Hot Spot Preventing) [18] and RAIN (Routing Algorithm for Network of Homogeneous and ID-Less Bio-Medical Sensor Nodes) [19] come under this category. M-ATTEMPT supports heterogeneity of sensor nodes in which nodes with high data rate are deployed on less mobile places on the human body. Single hop and multihop transmissions are used to send the critical and normal data of the patients to the central hub respectively. Apart from this, linear programming model is used to retrieve the maximum information and minimum energy consumption of nodes. RTM-RP routing tackles the high energy consumption and rise in temperature of sensor nodes in the body. To overcome the disconnection problem, a specific condition is defined between transmitter and receiver. This routing is more flexible in terms of input parameters and it can be adjusted depending upon the application type.

From the recent research trends, it can been seen that there exist routing protocols which cannot be classified into any single abovementioned group. Author has proposed a routing protocol for effective data transmission in [7] named as Even Energy Consumption and Back Side Routing (EECBSR). It uses the properties of cluster based routing as well as QoS aware routing. A forwarder node is chosen with minimum cost function. Standard deviation function is considered for calculating the cost function. Even Energy Consumption and path loss calculation help in achieving the QoS of WBANs.

### 2.1. Research Gap

Nodes in WBANs are continuously engaged in sensing, processing and transmitting data to sink node. All aforementioned routing protocols in literature review are intended to satisfy only certain requirements. Network lifetime, security and electromagnetic radiations are the major issues, which have to be solved. In this work, we have revised the work of EECBSR in which nodes are placed on front as well as back of the human body. It has issues which are as follows: First, it consumes a lot of energy. Second, data transfer from sensor nodes to sink node is less as compared to REVISED-EECBSR. It takes a lot of time to calculate the cost function as the standard deviation formula is used to calculate the cost function.

### 2.2. Motivation

WBANs have to deal with critical data of the patients. Reliable communication is the most major concern in WBANs. Lack of reliability can lead to loss of significant data of the concerned person. Different energy efficient routing protocols are proposed by different authors to select a forwarder node. Most of the previous work is related to nodes placed on the front side of the human body and very less work has been done on routing that involves nodes placed on the back of the human body**.** The main objectives behind our work are:

(1) To achieve maximum throughput as well as stability period of the network. Throughput

determines the successful data transmission of concerned person.

(2) REVISED-EECBSR is intended to reduce energy consumption of nodes, path loss and delay. Lower is the delay, faster the data is sent from nodes to sink node.

## 3. DISCUSSION ON REVISED-EECBSR AND EECBSR

In proposed work, sensor nodes are deployed on front side and as well as back side of the human body in a three dimensional manner**.** Total twelve sensor nodes are deployed with equal initial energy, i.e. 0.5 J. Out of which eight nodes are placed on the front side of the body, as shown in figure 2 (a). Four nodes are on the back side of the human body as depicted in figure 2 (b). Nodes in the form of star depict the normal nodes whereas two nodes with diamond shape depict the critical nodes which carry the crucial data as shown in figure 2 (b). Hence, these two nodes directly transmit the data to the sink node and the remaining sensor nodes communicate the data through multihop routing using a forwarder (cluster head). The sink node (central hub) is placed at front side of the human body. A three-dimensional area, (0.5m* 0.9 m* 0.5 m) is considered for simulation of this work.

### 3.1. Algorithm of Revised EECBSR is as follows:

1. Initially all sensor nodes are deployed on front side as well as back side of the body with equal initial energy. Nodes in diamond shape situated on the back side of the body send the critical data.
2. After that, a forwarder node is selected with minimum cost function, given as follows:

$$CostFunction\_Ieecbsr(j) = (D\min) * \left( \frac{Sum\_R.E. - R.E)j}{Eo - R.Ej} \right) \quad (1)$$

   where, j is the particular node for which cost function is to be calculated.
   R.E is the residual energy of node
   $D_{min}$ is the minimum distance of all nodes from sink.
   Eo is initial energy of a node
   Sum_R.E. is the sum of residual energies of all alive nodes in the network.
3. Once the forwarder has been selected, remaining nodes find their distance from the forwarder (DNF) and sink node (DNS) using (2) and (3) and transmit the sensed data to the respective forwarder or sink node. After that energy consumed by sensor nodes is calculated using (4).

$$D_{NF}(j) = \sqrt{(S(j).x - S(n).x)^2 + (S(j).y - S(n).y)^2 + (S(j).z - S(n).z)^2} \quad (2)$$

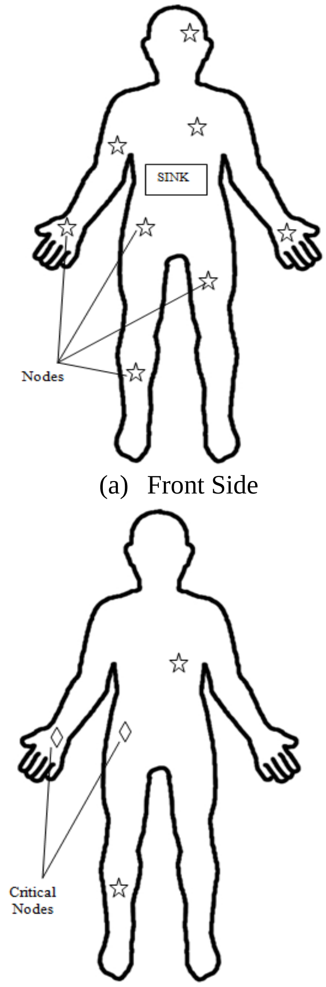
$$D_{NS}(j) = \sqrt{(S(j).x - sk.x)^2 + (S(j).y - sk.y)^2 + (S(j).z - sk.z)^2} \quad (3)$$

$$ECons(i) = Tra * (z) + Amp * z * (Min\_D_{NF\_NS})^2 \quad (4)$$

   where, n= Node number of the node selected as forwarder
   j is the particular node for which distance from forwarder or sink is to be calculated.
   i is the particular node for which energy consumption is to be calculated.
   $E_{Cons}$= Energy Consumed by a particular node
   Tra= Energy consumed by transmitter to transmit the data.
   Amp= Energy consumed by amplifier to amplify the data.
   z= Size of data in bits, need to be transferred.
   Min_$D_{NF_NS}$= Minimum distance from node to forwarder or sink node.
4. In next phase, forwarder takes data from all nodes, aggregates it and further transmits it to the base station. After that forwarder node calculates its energy using (5):

$$E_{ConsF}(i) = (Tra + Rcv + Dagg) * z + Amp * z * (D_{FS}2) \quad (5)$$

   where, $E_{ConsF}$= Energy Consumed by forwarder node
   i is the forwarder node
   Tra= Energy consumed by transmitter to transmit the data.
   Rcv= Energy consumed by receiver to receive the data.
   Dagg= Energy consumed to aggregate the data.
   Amp= Energy consumed by amplifier to amplify the data.
   z= Size of data in bits, need to be transfer.
   $D_{FS}$ = Distance from forwarder to sink node.
5. In next round, forwarder is chosen on the basis of cost function using (1). After that sensor nodes transmit the data to the sink node or forwarder and calculate their consumed energy using (5).
6. Step 2-5 will be repeated until all nodes deplete their energy or number of rounds has been finished.




(a) Front Side

(b) Back Side

**Fig. 2.** Nodes deployment on front side and back side of human body.

### 3.2. Algorithm of EECBSR [7] is as follows:

Network parameters will be same as Revised EECBSR, apart from cost function and equations of energy consumed by forwarder node and other sensor nodes. Routing procedure of EECBSR [7] is also same as Revised EECBSR. In EECBSR [7], forwarder node is selected with minimum standard deviation function (SDF). SDV is calculated as follows.

$$SDV(j) = \sqrt{\left(\left(\frac{(R.E.)_j{}^2}{node}\right) - Avg\_R.E.^2\right)} \quad (6)$$

where, j is the particular node for which cost function is to be calculated.
R.E is the residual energy of node.
Avg_R.E. is the average of the residual energy of nodes
node is total number of nodes in the network

$$E_{Cons}(i) = Trans*(z) + Ampl*3.38*z*(Min\_D_{NF\_NS})^{3.38} \quad (7)$$

where, $E_{Cons}$= Energy Consumed by a particular node
Trans= Energy consumed by transmitter to transmit the data.
Ampl= Energy consumed by amplifier to amplify the data.
z= Size of data in bits, need to be transfer.
Min_$D_{NF_NS}$= Distance from node to forwarder or sink node.

$$E_{ConsF}(i) = (Trans + Rcvr + Dtagg)*z + Ampl*3.38*z*(D_{FS}3.38) \quad (8)$$

where, $E_{ConsF}$= Energy Consumed by forwarder node
Trans= Energy consumed by transmitter to transmit the data.
Rcvr= Energy consumed by receiver to receive the data.
Dtagg= Energy consumed to aggregate the data.
Ampl= Energy consumed by amplifier to amplify the data.
z= Required no. of data bits need to be transferred.
$D_{FS}$ = Distance from forwarder to sink node.

Generally, two types of radio models Nordic (nRF2401A) and Chipcon (CC2420) are used by different authors. Parameters of both radio models are given in Table 2. In this work we have used first order radio model as it consumes less energy and performs better as compared to other. Network parameters like number of nodes, sink's position, and size of data are given in Table 3.

**Table 2.** Radio Models used in [13].

| Radio Model | nRF 2401A | CC 2420 |
|---|---|---|
| Trans | 16.7nJ/bit | 96.9 nJ/bit |
| Rcvr | 36.1nJ/bit | 172.8 nJ/bit |
| Ampl | 1.97nJ/b | 2.71e$^{-7}$J/b |

**Table 3.** Network Parameters.

| Parameter | Value |
|---|---|
| Initial Energy of nodes, Eo | 0.5 J |
| Amplifying energy (Ampl) | 1.97nJ/b |
| Energy consumed in transmission (Trans) | 16.7nJ/bit |
| Energy consumed in receiving (Rcvr) | 36.1nJ/bit |
| Energy consumed in data aggregation (Dtagg) | 5nJ/ bit |
| Size of data (z) | 4000 bits |
| Total No. of nodes | 12 |
| No. of nodes on front side | 8 |
| No. of nodes on back side | 4 |
| Tool used for implementation | MATLAB R2013a |

## 4. PERFORMANCE EVALUATION

Network's performance is evaluated on the basis of different criteria. These are discussed as below:

*Residual energy*: It is the remaining energy of sensor nodes after performing their task like sensing, transmitting and processing.

*Throughput:* Maximum information of concerned person is sent to the base station in form of packets. Number of packets transmitted gives the throughput of the network.

*No. of dead nodes:* When sensor node losses all its energy after some round, the node dies.

*First and all nodes dead:* It is very important parameter because death of first node decides the stability period of network and last node dead decides the network lifetime.

*Path Loss:* It refers to the decrease in power density of a signal as it travels through space. Path Loss equation used is the one described in [20]. It is calculated as follows:

$$PLoss(freq, d1) = PLo + 10p\log 10(d1/do) + X\sigma \quad (9)$$

Where, PLoss is path loss in dB, d1 is distance between transmitter and receiver, do is reference distance (taken as 10 cm), p is path loss coefficient. Value of p for WBANs is 3.38, X is Gaussian random variable and $\sigma$ is standard deviation. Freq is the transmission frequency (2.4 GHz). PLo is path loss at reference distance do and is expressed as:

$$PLo = 10\log_{10}\left(\frac{4*\Pi*d1*freq^2}{s}\right) \quad (10)$$

Where, s is speed of light.

*Delay:* It represents the time difference between a signal sent by the transmitter and received by the receiver at the other end.

Simulated results of comparison between Revised-EECBSR and EECBSR [7] are discussed as follows:

Energy consumed by the deployed sensor nodes on the human body per round is shown in figure 3. Here, X-axis and Y-axis represent the residual energy of nodes and the number of rounds respectively. Since the sensor nodes deployed on the body have limited battery power in WBANs. It exposed that REVISED-EECBSR consume less energy as compared to EECBSR.

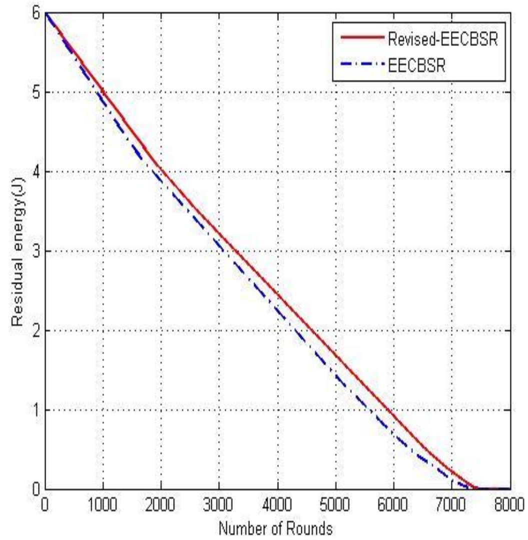



**Fig. 3.** Residual Energy of nodes in Revised-EECBSR & EECBSR.

Reliability of network is improved as REVISED-EECBSR protocol transfers more data packets to the base station as compared to EECBSR as shown in figure 4. Stability period is given by time from the start of network communication till first node in the network dies.

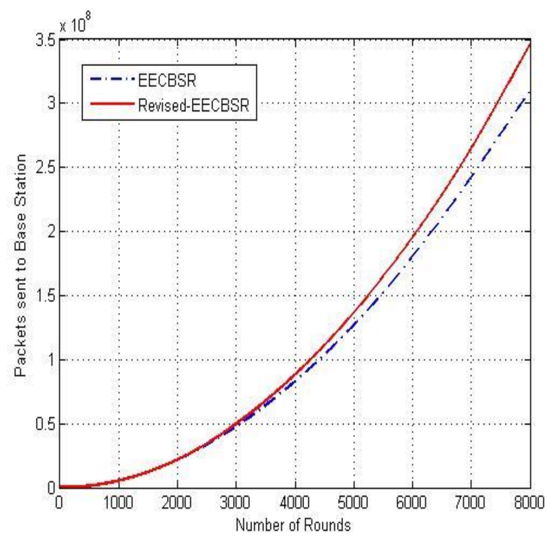



**Fig.4.** Throughput of Revised - EECBSR & EECBSR.

In figure 5 most of the nodes die almost around the same time thus energy is consumed evenly by the sensors. Even energy consumption is achieved by using an efficient cost function, which is used to choose a forwarder node. Most sensor nodes of REVISED-EECBSR are dead at the same time.

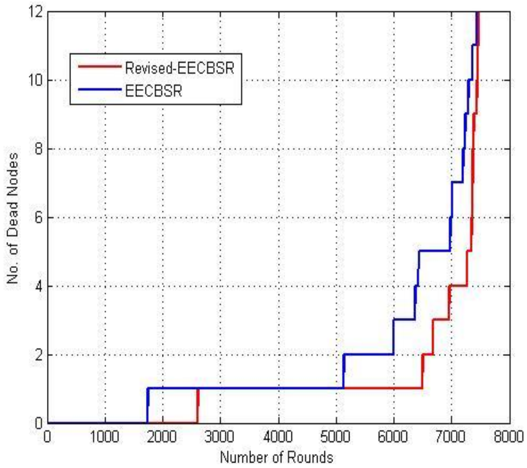



**Fig. 5.** Number of dead nodes in Revised-EECBSR & EECBSR.

Stability Period of network is shown in figure 6. REVISED-EECBSR survives for more number of rounds as compared to EECBSR. In REVISED-EECBSR first node dies around 2509, while in EECBSR first node dies earlier at 1747th round. Figure 6 also shows the lifetime of network of REVISED-EECBSR and EECBSR. All nodes died at round 7430 in EECBSR and at round 7464 in REVISED-EECSR protocol.

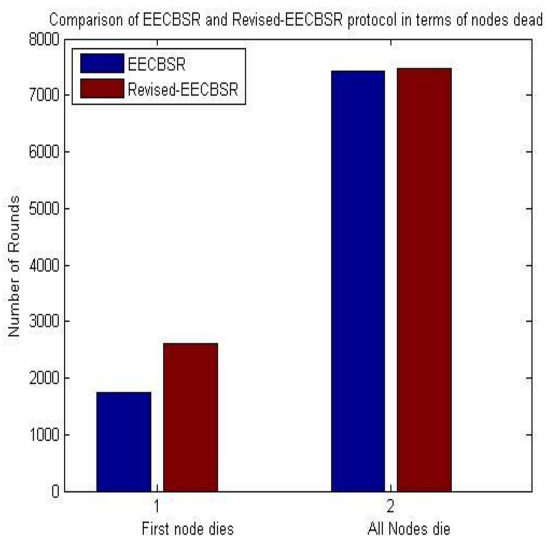



**Fig. 6.** Network's Stability Period of Revised-EECBSR & EECBSR.

Figure 7 and Figure 8 show that initial path loss and delay are less in REVISED_EECBSR. Here path loss and delay are calculated as sum of path loss and delay of individual alive nodes in the network.

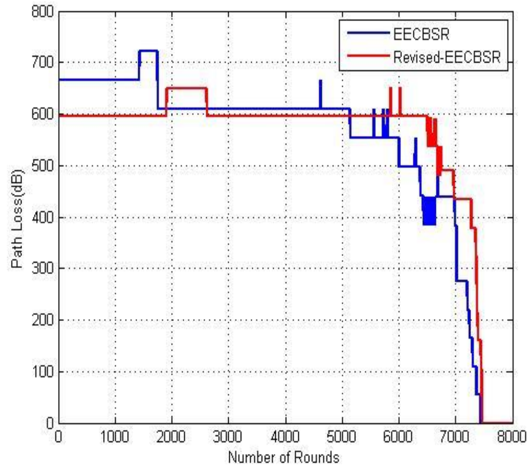



**Fig. 7.** Cumulative Path Loss for Revised-EECBSR & EECBSR.

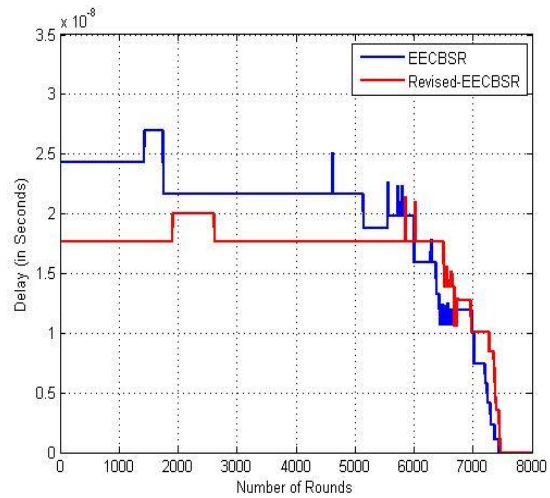



**Fig. 8.** Cumulative Delay for Revised-EECBSR & EECBSR.

Delay and path loss increase after 6000 rounds in REVISED_EECBSR. This is due to the reason that more number of nodes are alive in case of REVISED_EECBSR as compared to EECBSR where nodes die out early. This causes increase in cumulative path loss and delay. Overall, REVISED-EECBSR has better performance in terms of stability period, throughput, network lifetime, energy consumption, path loss and delay.

## 5. CONCLUSION

In this work, we have revised the work of EECBSR by using the cost efficient function. A forwarder node is selected with minimum cost function in REVISED-EECBSR using minimum distance of nodes from sink, their residual energies and the total residual energy of the network. REVISED-EECBSR is simulated in three dimensional area and compared with EECBSR. REVISED-EECBSR showed better performance than EECBSR in terms of delay and path loss. Throughput of network is also increased as REVISED-EECBSR transferred more data packets to the base station. So, the reliability of network is increased. REVISED-EECBSR survives more number of rounds as compared to EECBSR causing an overall increase in network lifetime. Proposed protocol proves better in terms of energy consumption. Parameters like path loss, delay, energy efficiency, stability period and throughput have been taken into consideration in our present work but still areas like security and effect of radiation on human body are still a major concern.

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