Spiral Based Sink Mobility Method Aiming Lengthening of Lifetime of Sensor Networks

Priyanka chhillar[1], Kirti Bhatia[2], Rohini sharma[3]

[1]*Student, CSE,Sat Kabir Institute of Technology & Management, Bahadurgarh,India*
[2]*A.P,CSE, Sat Kabir Institute of Technology & Management, Bahadurgarh,India*
[3]*Research Scholar, School of Computer & Systems Sciences, Jawaharlal Nehru UniversityNew Delhi*

***

Abstract - *Wireless sensor networks are gaining substantial consideration owing to their prospective applications in ecological monitoring and other significant purviews. In sensor networks, uneven energy utilization is an inherent issue and it can significantly reduce the network lifetime. Selection of the chain leaders is an efficient way of balanced energy utilization. The sink movement along the network area is another way of improving the network lifetime. We hereby propose multi-chain leader and spiral based sink mobility method to enhance the lifetime of the sensor network. We set an optimal trajectory for the sink movement to make well-adjusted energy utilization in sensors of the network. We have compared our protocol with another chain based and sink mobility based method in terms of network lifetime, throughput and residual energy of the network. The simulation results authorize that our projected method outperforms other protocol in terms of different performance metrics*.

1.INTRODUCTION

Wireless sensor networks are constituted of a huge quantity of randomly dispersed sensor nodes [1]. Sensor nodes have limited battery power and sometimes deployed in a remote area. It is not possible to recharge the battery of sensors in the remote or inaccessible areas. Moreover, an irregular energy utilization is a challenging issue in the field of sensor systems and it can create the energy holes [2-3] problem in the area. Due to the energy holes problem sensors near the sink deplete energy sooner as equated to rest of the nodes of the network and as a result it lessens the network lifetime. Use of mobile sink is an powerful technique to improve the lifetime of the system [4-8]. The sink mobility facilitates the sensors to transfer the data with very low transmission energy consumption. The sink collects he data at various locations called sink sites [4] or sojourn locations [9]. Moreover, it also reduces the delay in data transmission.

There are various ways to improve the lifetime of the sensor networks. The LEACH [10], the SEP [11] and the DEEC [12] protocols are clustered based techniques which improve network lifetime in an efficient way. But the clustering alone is not sufficient to enhance the efficiency of the sensor networks. The LEACH protocol has several drawbacks which cause unbalanced energy utilization in the sensor networks [13]. Node deployment based techniques are quite effective to enhance the lifetime of the network [14].

The efficiency of sink mobility depends upon its trajectory and various sojourn locations. Authors in [15] have introduced the basic idea of sink mobility for proper utilization of sensor's energy. In their proposed method, the sink moves in the entire network and collects data from various sensors through single-hop. But, this methodology may undergo in lengthy latency and it is possible that it does not equalize the power utilization among the sensors effectively. In [5], authors have suggested the movement of the sink in rounds. After the completion of every round, the sink triggers a persistent shift in the direction of the sensor that has the maximum enduring energy. Other than the sink mobility, chain based protocols are also very useful in improving the lifetime of the sensor networks.

The PEGASIS [16] is a famous chain based method in which nodes do not directly transmit to the base station; instead they use a chain leader for data transmission. The protocol forms a chain of sensors and all sensor transmit data to its closest neighbor. However, only the chain leader communicates with the base station. The main drawback of the PEGASIS is the length of chain of sensors. A long chain causes delay in data transmission.

The IEEPB [17] is an improvement over the PEGASIS protocol. It forms small chains of fewer nodes and produces the tolerable delay in data transmission. The multi-chain theory of IEEPB reduces the network overhead because of the lesser number of networks, and reduces the distance between the connected nodes and the base station. Moreover, sink mobility reduces the burden of the nodes that are adjacent to the sink.

We propose Spiral Based Sink Mobility (SBSM) method, which enhances the lifetime of the sensor network by means of exploiting the functionality of the multi - chain method and sink mobility on a spiral path.

The residuum of the paper is planned as follows: Part 2 represents related work . Section 3 have the network model and its assumptions. Section 4 gives information about using energy consumption model. Section 5 illustrates a detailed outline of the proposed SBSM protocol. Section 6 analyzes the results of the simulations. Section 7 finally concludes the work and gives some points about future work.

2. RELATED WORK

There are various power efficient protocols available for sensor networks [18]. Authors in [19] have used dual transmission power levels and ACO techniques to improve the system's lifetime. Authors in [14] have used Archimedes' spiral node deployment function to enhance network lifetime. Data compression techniques are also useful in reducing the power consumption of the network [20]. We have compared our proposed protocol SBSM with the MIEEPB protocol [9]. The MIEEPB protocol divides the total number of sensor nodes into four parts and form a separate chain for each set of nodes. Every chain has two leaders, primary and secondary. The primary leader is elected on the basis of enduring energy and distance of a sensor from the sink. After the selection of the primary node, the secondary leader node is selected by measuring its distance from the base station. If the distance of a sensor from the base station is lesser than the distance of node from the primary leader, the sensor node is selected as a secondary leader and it directly transmits to the base station. This method has a fixed trajectory for the movement of the sink. The sink moves from one region to another and collects data from the chain leaders.

3.NETWORK MODEL AND ASSUMPTIONS

- We have considered a 100 × 100 m^2 surveillance area.
- Total 100 nodes are distributed randomly and consistently over the area.
- All sensors are homogeneous (equal initial energy).
- All sensor nodes are stationary after deployment.
- Sensors are aware of their neighbor's location through some GPS device.
- The sink has an unlimited quantity of energy.

1. ENERGY CONSUMPTION MODEL

We have implemented first order radio energy model [19] for energy consumption during the communication of sensor nodes. The **energy consumed in transmission** of *k* bits of data over a distance *d* is given by:

$$E_{tx}(k,d) = \begin{Bmatrix} k * E_{elec} + k * \varepsilon_{friss-amp} * d^2, d < d_0 \\ k * E_{elec} + k * \varepsilon_{two-ray-amp} * d^4, d \geq d_0 \end{Bmatrix} \quad (1)$$

Where E_{elec} is the electrical energy which is used to amplify the electronic circuit and d_0 is a cross-over distance (threshold value). If the distance between the transmitter and receiver is less than the threshold value (d_0) , energy consumed in transmission follows the free space model while the distance is greater than the d_0, energy consumption follows the multichannel model.

Energy disbursed in receiving the *k* bits of information *d* given by:

$$E_{rx}(k) = E_{elec} \times k \quad (2)$$

Energy disbursed by a node in aggregating the data received by the child nodes:

$$E_l(l,k) = l \cdot k \cdot E_{DA} \quad (3)$$

Where l is the number of messages received from l children. Every sensor node compresses the received data bits by the data aggregation factor of 0.5 via distributed compressive sampling technique.

2. SPIRAL BASED SINK MOBILITY METHOD

2.1 MULTI-CHAIN CREATION AND CHAIN LEADER SELECTION

The process of chain formation in our proposed protocol SBSM is similar to the PEGASIS protocol. Our protocol support multi-chain formation in the network as follows:

- The sink node transmits the HELLO packets to all the sensors and receives their location information.
- The sink node selects the farthest node from the group of first 25 nodes, by comparing its distance from all the 25 nodes.
- The farthest node is also known as the end node and it finds the nearest neighbor from itself. Every node finds the nearest node and attaches to it. A chain is formed for the group of first 25 nodes in the network.
- In the chain, a node (p) that receives data from another node (c) is known as the parent of that node (child node).

- The same procedure is repeated for next 25 nodes and so on. There are total four chains are formed in the network (Figure 1).
- A chain leader has been selected in each chain. All node compares its distance from the sink and the node that has least distance from the sink is selected as the chain leader.

2.2 SPIRAL BASED SINK MOBILITY

The sink movement is used to lengthen the lifetime of the sensor network. The sink follows the spiral based trajectory along the sensor network. It moves from one spiral curve to the next spiral curve in clockwise direction and waits for a constant time at the pre specified locations (sojourn location) as follows:

- The sink starts its movement from the center position.
- First it stays at 90° position from the starting point of the movement in anti-clockwise direction.
- Next it stays at the 180° position from the beginning point in anti-clockwise direction.
- Next it stays at the 270° position from the beginning point in anti-clockwise direction.
- Finally, it stays at the 360° position from the beginning point in anti-clockwise direction and next curve of spiral path starts from here.
- Again, the sink stays at 90° position from the center position and the process continues for the next curve of the spiral path.
- When the sink completes its movement on the entire spiral path, one round is complete.
- During one round, sink stays at 17 locations to gather data from the sensors.
- The network lifetime can be increased by increasing the total sojourn time as follows:
- $S_T = \sum_{i=1}^{17} T_i$

(4)

2.3 DATA COLLECTION AND COMPRESSION

- When the sink stays at sojourn locations, it gathers data from the chain leader of every chain.
- The chain leader collects data from the end nodes by transmitting a token to the end nodes. When a node receives a token, it transmits its data to the next node in the chain. The receiving node is called the parent node and transmitting node is called the child node.
- Each parent node compresses the data and transmits to the next node of chain in the direction of chain leader.
- Chain leader of each chain transmits data to the sink node.
- **In our proposed method SBSM, role of chain leader changes with the movement of the sink node.**
- A node close to the sink will be selected as the chain leader from each chain.
- When the sink moves from one curve to the next curve of the spiral path, chain leader of each chain change simultaneously.
- When the sink stays on the first and last curve of the spiral path, chain leader of the chain transmits token only in one direction, but when the sink stays at the middle curves of the spiral path chain leader transmits tokens in both directions and collects data from the nodes of its chain.
- If a node has more than one child node, it uses TDMA mechanism for data communication.

- This spiral based movement of sink reduces the distance among the chain leader and the sink. Moreover, the alternate selection of chain leaders balances the power consumption in sensor nodes of the network.

4. SIMULATION AND RESULTS ANALYSIS

This division explains the simulation results of the proposed SBSM protocol. We have designed a 100 sensor nodes scenario using the MATLAB. The parameters for simulations have been given in the TABLE1.

Table: Simulation Parameters and their Values

Parameters	**Values**
Area	100 m × 100 m
Number of sensors	100
Initial energy of sensors	0.5 j
Packet Size	2000 bits
Initial Position of the sink	(50m,50m)
E_{elec}	50 nJ/Bit

$E_{friss-amp}$	10 pJ/bits m^2
$E_{two-ray-amp}$	0.0013 pJ/bit/m^4
E_{DA}	50 nJ/Bit

We have performed extensive simulations and analyzed the results accordingly. We have distributed the 100 sensor nodes in a 100 m^2 area. Nodes are divided into four groups. Every group of 25 nodes forms a chain and as a result there four chains in the network. Every chain has one chain leader at a time and it change with the movement of sink on the spiral path. Figure 1 shows the formation of chains in a 100 m × 100 m field. Every chain is represented by a different color. The sink is at the center position of the area.

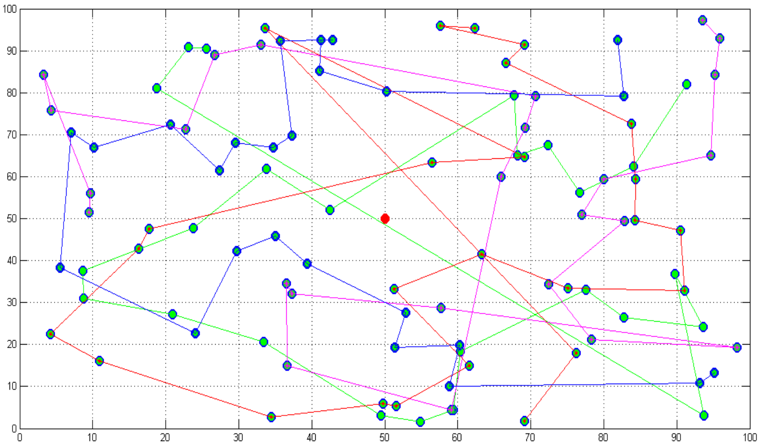
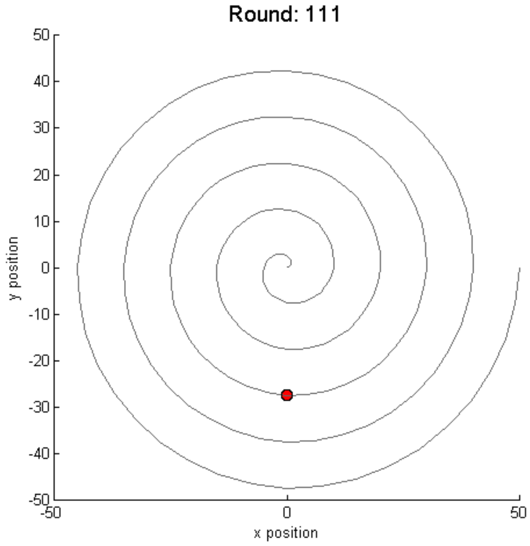


Figure 1: Formation of four chains in a sensor network area by the SBSM protocol.

Figure 2 (a & b), Figure 3(a & b) and Figure 4 (a & b) show the different position of sink movement and its stay at different sojourn locations on the spiral path in the wireless sensor network at different rounds. Figure 2 (a) shows that sink is at 90° from the starting point of the sink positing and Figure 2 (b) shows that now sink is at 180° from the starting point of the sink positing. Figure 3 (a) shows that sink is at 270° from the starting point of the sink positing and Figure 3 (b) shows that now sink is at 360° from the starting point of the sink positing. Figure 4 (a) shows that sink is again at 90° from the starting point of the sink positing, but on different spiral curve and Figure 4 (b) shows that now sink is near the end of spiral trajectory path of the sink movement.

The sink node collects data from chain leaders of each chain at the sojourn locations as described above. We have compared our protocol with the MIEEPB protocol [9] in a homogeneous (nodes with equal initial energy) sensor environment.



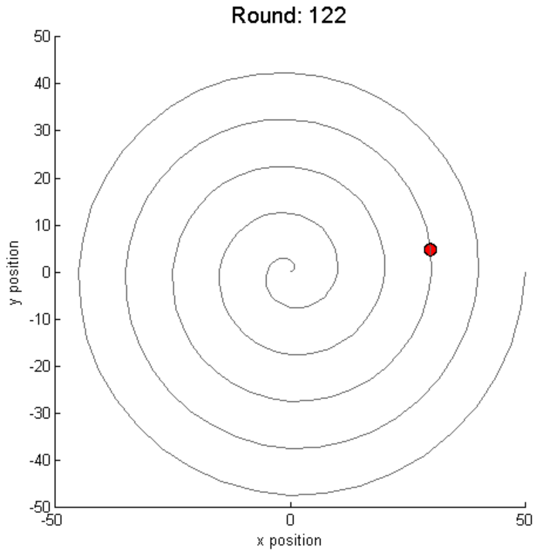


Figure 2: (a) Sink at 90° from the center point (b) Sink at 180° position

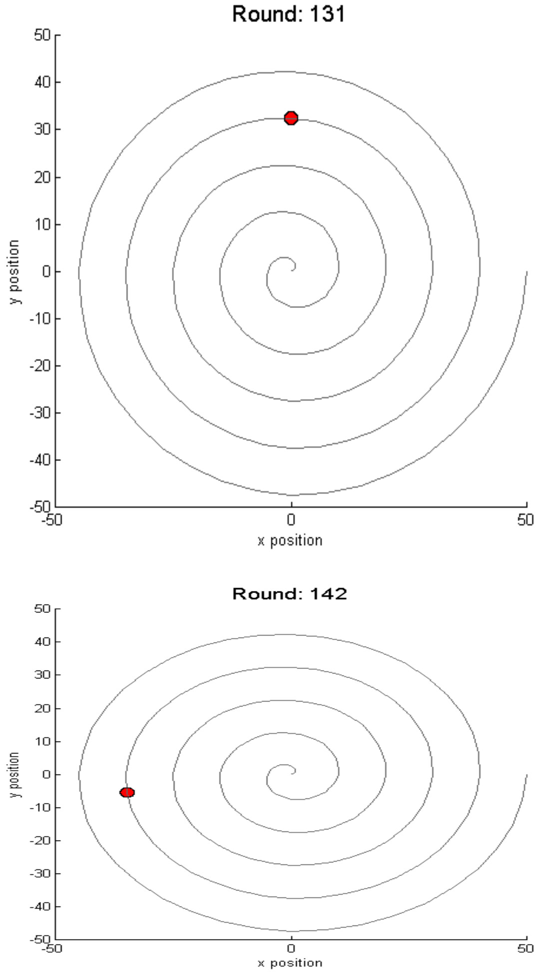


Figure 3: (a) Sink at 270° from the center point
(b) Sink at 360° position

We have run simulations more than 25 times and have taken average of their values. We have analyzed our protocol for network lifetime, stability period, residual energy and throughput of the network.

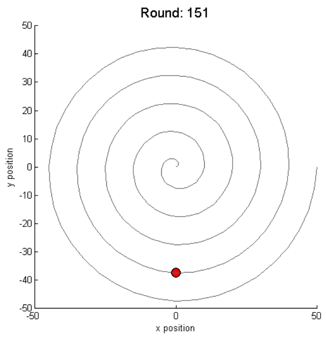


Figure 4: (a) Sink at 90° on next spiral curve (b) Sink movement near the end of spiral path

Network lifetime and the stability period:

Network lifetime is the final number of round, as soon as all the nodes in the system become dead. It is represented by the total number of alive nodes per round in the system. Figure 5 shows the evaluation of number of alive nodes in the system for the SBSM and the MIEEPB protocol.

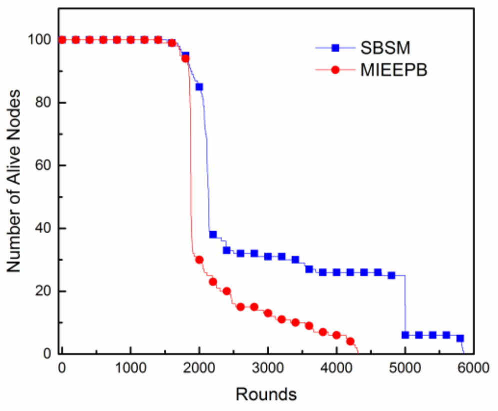


Figure 5: Number of alive nodes per round for SBSM and MIEEPB protocols.

Figure 5 shows that network lifetime of the SBSM protocol is superior than the MIEEPB protocol. The SBSM protocol runs up to round number 5850 while the MIEEPB protocol runs up to 4310 rounds. The main reason; sink changes its position more frequently in the SBSM protocol as compared to the MIEEPB protocol. In the MIEEPB protocol, sink stays at four sojourn locations, while in the SBSM protocol, the sink stays at seventeen locations. Moreover, the role of chain leader also changes in the SBSM protocol while there are two chain leaders (fixed) in the MIEEEPB protocol. It shows that the SBSM protocol has 35.73 % improvement over the MIEEPB protocol in relations of the network lifetime.

The stability period of a network is the period as soon as the first node of the network dies. Figure 6 shows the stability period of the SBSM and the MIEEPB protocols in terms of number of dead nodes per round in the network.

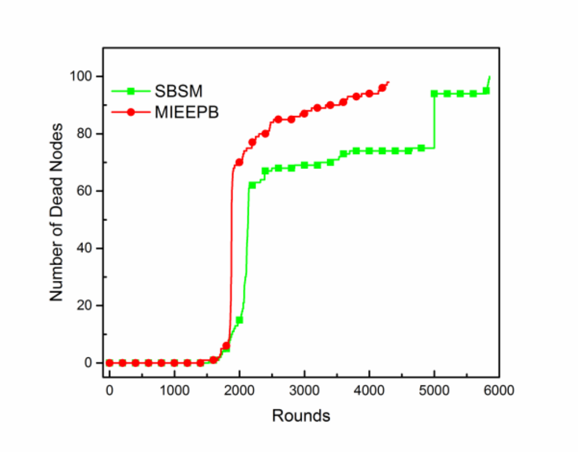


Figure 6 : Number of dead nodes per round in the network.

Figure 6 explains that for the SBSM protocol first node dies at round number 1529 while for the MIEEPB protocol the first node dies at round number 1403. There is a sudden increase in the number of dead nodes in the MIEEPB protocol after the round 2000. Next, the instability period is the time duration between the death of first alive node and the last alive node. Our protocol has a longer instability period than the other protocol because the energy consumption is more balanced in our protocol than the MIEEPB protocol. In the SBSM protocol, transmission energy consumption is much less than the MIEEPB protocol and as a result the amount of the residual energy is much more in SBSM based network than the MIEEPB based network (Figure 7).

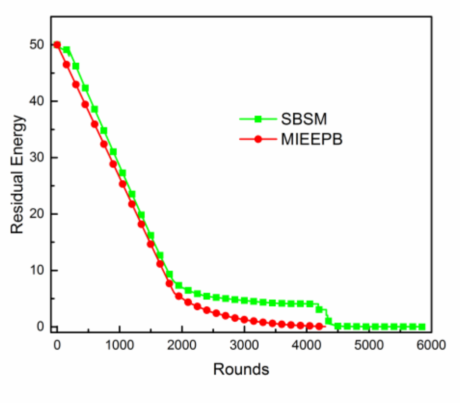


Figure 7: Comparison of residual energy in network for SBSM and MIEEPB protocols.

The amount of residual energy in multi-chain based protocol is sufficient, as the consumption of transmission energy is very less. The region of chain formation is fixed in the MIEEEPB protocol, while in our protocol; a chain can be in any part of the network. Moreover, in the MIEEEPB, the sink moves through the centers of the regions, while in our protocol, it follows a spiral trajectory which covers the entire network in one round. Every node has an access to the sink. There will be very low load on the chain leader. Although, the residual energy decreases progressively for both the protocols, but there is more balanced energy consumption in our protocol.

As the network lifetime is high, total alive nodes remains present in the network for a long duration. If the nodes are present in the network, these will transmit data to the sink and as a result network throughput will also increase. Figure 8 shows the total throughput of the network for the SBSM and the MIEEPB protocols.

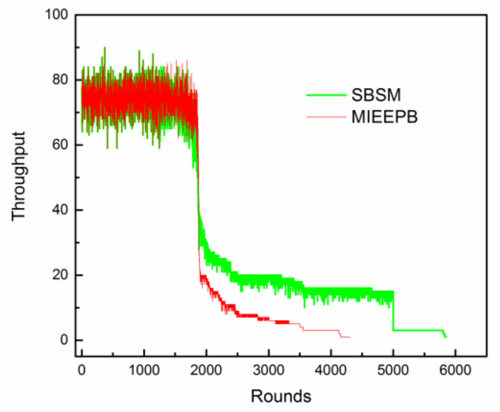


Figure 8: Throughput of the network for the SBSM and the MIEEPB protocols.

Although, the number of alive nodes reduces in the network in the last rounds and connectivity of the network reduces, but the sink collects data from the alive nodes by following the spiral trajectory. Hence the throughput of the network for the SBSM remains higher than the MIEEPB protocol.

5.CONCLUSION AND FUTURE EFFORT

In this work, we endorse a multi-chain model of the PEGASIS along with orientation of sink mobility through a spiral path trajectory to lengthen the lifetime of the network. Our deliberations are helpful in improving the lifetime, stability period and throughput of the network. The SBSM protocol reduces the distance between the nodes by forming smaller chains. Sink mobility further reduces the distance between the chain leader and the sink. It reduces the load on the chain leaders and it collects data in a sparse network in the later rounds. In future work, we will analyze our method for heterogeneous environment and some swarm intelligence based optimization method. Our proposed protocol SBSM has 35.73 % improvement in lifetime over the MIEEPB protocol.