

How to Cite:

Rakesh, K. K., & Kumar, P. S. (2022). Linear optimization model for mobile cluster heads to improve the lifetime of sensor network. *International Journal of Health Sciences*, 6(S5), 2977–2996.
<https://doi.org/10.53730/ijhs.v6nS5.9306>

Linear optimization model for mobile cluster heads to improve the lifetime of sensor network

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Abstract---Mobile elements are used in wireless sensor network to increase the longevity of network by minimizing the overloading of one hop sensors. Mobility has proven very useful in reducing the formation of energy holes by balancing the load among all the sensor nodes. The paper proposes exploiting mobile cluster heads to move along a predetermined trajectory to collect data. As autonomous moving strategies impose heavy overhead and data latency issues, predetermined trajectories have proven successful in improvising the lifespan of network. The contributions of the paper are twofold. First we have proposed a predetermined trajectory model along with a cluster formation procedure for the cluster heads to involve in data collection. The cluster heads stop for a fixed time duration “t” at each rendezvous point for data collection. Second, we have proposed a mathematical formulation to optimize the sojourn time duration of the cluster head based on the one hop residual energy of the sensor nodes.

Keywords---Wireless Sensor Network, Cluster head, clustering, Rendezvous points, Network Lifetime, Data Collector.

1. Introduction

Wireless sensor network refers to the deployment of large number of tiny sensor nodes for the purpose of monitoring certain parameters like temperature, pressure, moisture, movement of a particular location. The individual sensor nodes sense the intended parameter and pass the sensed information as data

packets to the base station. This simple structure is termed as flat network where the sensors will communicate the data packets directly to the base station via single hop or multi hop communication. Sensors which are available near the base station send their data packets through single hop communication.[2] Whereas the sensor nodes which are away from the base station will forward their data through multi hop communication. Multihop communication refers to the concept of sending data packets through intermediate sensor nodes. Since the communication radius of the sensor node is limited, it is not possible for those nodes to directly send the packet rather they send them through their neighboring nodes [1]. This type of flat network is not suitable for real time application as there so many disadvantages associated with a flat network model. The main drawbacks of flat network are as follows.

- The sensor nodes will lose their energy very soon as the data packets has to be sent to the base station which is located farther away.
- Data collection and data dissemination will become a very tedious process.
- Scalability of the network will be very tough.
- Flat networks result in increased communication delay and management complexity [6][7]

In order to avoid the above said drawbacks, the sensor nodes are assembled into groups called clusters where each cluster will be allotted a leader called cluster head. The cluster head will usually be a energy rich node with high communication radius. Clustering of nodes can be done by using an algorithm design technique where the clusters members will form a tree structure to connect to the cluster head. This cluster is viewed in the form of a corona-based structure model by many of the researchers where the sensors which can directly communicate with the base station forms the first corona layer. Sensors which communicate with the cluster head through first corona sensors in two hops falls under second corona, three hops under third corona and so on. In this type of model, it can be observed that sensors in first corona will deplete their battery level soon due to the reason that they act as a bridge between the sensors in other corona and cluster head. All the other corona sensors are able to communicate with the cluster head only with the help of first corona sensors. So as transmitting and receiving packets leads to energy loss and since the first corona sensors forwards and receives a lot of data packets , they deplete their energy level very fast that results in a quick demise. This swift demise of one hop sensors results in a condition termed as “Energy Hole”. Energy hole is formed when all the sensor nodes in first corona drain their battery energy level which makes it not viable for sensors in the other layers to communicate with the cluster head. Thus, the entire cluster became inactive as the cluster head is not able to receive any data from the sensors.

The inactive state of the clusters extremely decline the lifetime of wireless sensor network. So research works which focus on enhancing the lifetime of wireless sensor network concentrates on evading or postponing the formation of energy holes in the network. One of the best solutions is to keep altering the one hop sensor nodes (i.e) a completely dissimilar set of nodes will act as one hop sensors rather than overloading the same set of nodes. The most promising way to achieve this is to change the cluster heads at regular intervals which will also alter the one hop sensors or the cluster head can be moved to a new location which will

also yield better results. So many researchers have concentrated on utilization of mobile cluster head where the cluster head will relocate themselves to an energy rich zone at the end of each round. The corona division of the network along with the cluster head is depicted on the following figure. (Figure 1). The diagram depicts a sensor network which is divided into three corona divisions.

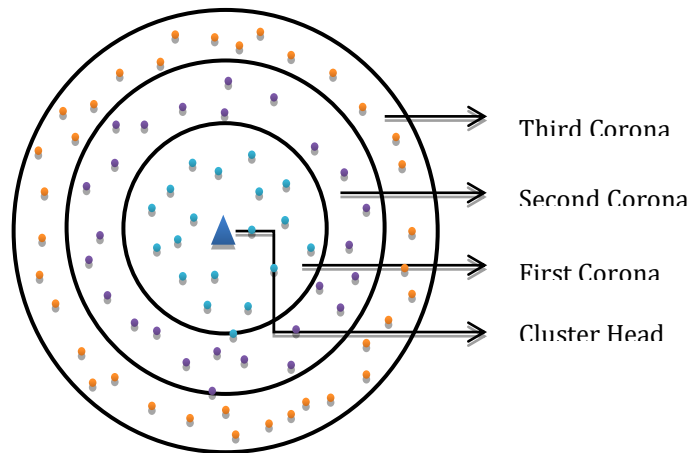


Figure 1 Corona Division of a Sensor Network

2. Related Works

Many researchers have focused in Energy hole issues by implementing various techniques to minimize the formation of the same and thereby increasing the lifetime of nodes. The work of [7] uses the concept of multiple mobile sinks in order to minimize the energy hole formation. The authors has divided the network into hexagonal tiling and proposed a predetermined trajectory for the sinks to move. The sinks stop on multiple spots along the predetermined trajectory for data collection. The paper shows two variations of stopping time. Constant time and variable stopping time based on an LPP model depending on the residual energy in this stopping zone. Experimental results showcased a significant improvement in the life time of the nodes.

In the work of [8], the space for positioning the base station is converted to a finite solution space and an ILP model is exploited to find the best sojourn locations. Various past research works has focused on formulating an Integer linear programming model on a continuous search space whereas this is a novel procedure used by the authors to run the ILP on an finite space.

[3] focuses on a procedure to extract the trajectory for the mobile base station. The mobile base station traverse the network using the trajectory and visits the cluster beads to collect the data packets. The algorithm declares the set of energy rich nodes as cluster heads algorithm and the cluster group is constrained to two hops. At the beginning of a data collection round, the clustering trees are formed and the data packets are collected and buffered by the cluster heads. The

collected data packets are transferred by the cluster heads to the base station when the same comes in close to the cluster heads.

The authors of [10] implemented a new technique for finding the hop count. The shortest path between the source and the destination is used when these nodes are positioned in equal manner. The simulation results show a significant improvement in network performance over the other traditional strategy.

The authors of [5] contributed to another study detailed in [Xing et al, 2008], in which the cluster head is chosen as the base station's rendezvous point. The data gathering algorithm presented in [4] is event-based, with the base station only visiting the cluster head when it creates data. [6] describes how to take advantage of numerous mobile sinks travelling in a specified path. For data gathering, the author partitioned the network into hexagonal tiles and made the sinks move along the hexagonal tiling. For the sinks, the article uses both constant and adaptive stopping time.

In versatile halting, a special Linear Programming Problem is developed to carve out the best halting opportunity. The papers [14,15] portray information gathering utilizing limited bounce counts. Bounded transfer jump versatile information gathering (BRH-MDG) is a new surveying based portable information gathering approach introduced by the creators of [15], which is planned as an enhancement issue. Surveying focuses were delegated pieces of sensor hubs that store privately collected information and send it to the portable base station when it comes adequately close.

The creators moreover guarantee that the sensor associated with the surveying areas will have a productive bundle restricted to a specific number of bounces. In another work [16] Chen et al citing the deficiency of BRH-MDG calculation, that it didn't cautiously break down and improve the energy utilization of the whole organization, proposed one more numerical model with an original calculation called EEBRHM. The trial results show that under the proof of limited hand-off jump, contrasted and BRH-MDG, EEBRHM can expand the organizations lifetime by 730%. Similarly [Pradeepa et al, 2016] examined proposed another Integer Linear Programming (ILP) model for situating various base stations in an organization. The up-and-coming areas for position of base station are gotten through the ILP model. Aside from giving ILP plan to situating different base stations, the creators likewise proposed a heuristic convention to track down the ideal area for binding the base station. Reproduction tests show great improvement concerning network lifetime. Allocating detecting region into subareas is talked about in [15]&[16].

Chen et al proposed a lifetime enhancement calculation restricted by information transmission postponement and jumps (LOA_DH) for versatile sink-based remote sensor organizations. In LOA_DH, hardly any significant imperatives are inspected, and a streamlining model is recommended. The creators have utilized Maximum limit way directing calculation to work out the energy utilization of correspondence and a hereditary calculation which adjusts people to meet all imperatives is utilized to tackle the streamlining model. The proposed calculation recognizes the ideal sink visit general setting which will amplify the sensor network lifetime. The result enhances the lifespan of network, amount of nervy

consumed among the sensor nodes and the quantity of data discarded.. In[16], the model proposed by the author the network area is divided into numerous hexagons in which the RPs are placed at the geometric centre of each hexagonal area.

The limited hand-off join TSP lessen strategy proposed in [12] is named such (BR-CTR). To bring down the quantity of stay detects, the limited transfer join TSP-decrease technique investigates the union area of sensor correspondence ranges. The BR-CTR process is utilized related to a way change component to abbreviate the projected travel way effectively. In contrasted with existing single bounce and multi jump versatile information assortment methods, reenactment results recommend that the proposed calculation performs well.

In [12], The proposed algorithm makes a good decision for devising a good routing model for the sink based on the residual energy of the node and considering the distance as well. The load of the network is balanced and residual energy reserve is also increased thereby increasing the lifetime of network. Experimental analysis showcases a good performance of the proposed algorithm and also exhibits a proper performance in terms of enhancing the lifetime of network, transmission overhead and throughput of the network. Also, the proposed algorithm support retransmission of messages in case of delay encountered during transmissions.

The major purpose of the paper [Chang et al, 2016] is to use tree structure and multi jumps to lessen the sensor hubs' information transmission distances. The area of the portable sink, the distances between individual sensor hubs, and the remaining energy of every sensor hub are factors in deciding the steering structure. The organization's lifetime is stretched out through bringing down energy use and adjusting network interest. The recommended plan's capacity to accomplish legitimate execution regarding energy utilization, network lifetime, throughput, and transmission above is exhibited by exploratory discoveries. In Paper [18] deals with the issue of enhancing the lifespan of network by formulating a new clustering procedure which produced set of dynamic clusters. Consumption of energy is fairly distributed among all the cluster heads which enhances the lifetime of wireless sensor network. Erring algorithm based on the study where they deploy alternative direction method to compute the radius of the clusters. The authors have extended their contribution by proposing a clustering algorithm called On-demand, Optimal Clustering (OPTIC). They quote that cluster head election procedure discussed earlier is termed as adaptive. This is because of the dynamism in the occasion of events. The authors propose that the clustering algorithm aims to minimize the message and computation overhead. Simulation analysis exhibit that the proposed clustering model Experimental results demonstrate that improves the balanced energy parameter by more than 18% and lifespan of the network by more than 19% in comparison with the other clustering models.

In[19], The clustering algorithm proposed by the authors in these paper alters the LEACH protocol (steady state phase) in a heterogeneous environment. The authors proposed a new optimization model where three significant parameters like number of cluster heads, compactness and separation are considered in the objective function. Experimental analysis proves that the proposed optimization

model is more efficient in enhancing the lifetime of network in comparison with the existing optimization model. Authors in [20] discuss algorithm that deploy adaptive fuzzy logic, deterministic, probabilistic and Multi-attribute decision making methodologies for the purpose of clustering the network and selection of cluster head. The authors mention that the already existing algorithms enhance the longevity of network and energy efficiency but fall short in offering a better quality of service and security. The authors tries to combine the concepts of computational intelligence and network intelligence to provide a better quality of service. The lifetime of the nework is enhanced toa significant level in both heterogenous and homogenous types of sensor network environment.

This work presented in [21] propose a new algorithm termedSPDAC(shortest path discovery for area coverage) which optimizes the trajectory of the relay node used in the network. These realy nodes helps to resolve the network coverage issues by deploying the sensor nodes using specific strategies. Also, the authors extend their contribution by introducing a new scheme prediction-based clustering protocol for energy consumption (PCP-EC) which minimizes the overhead involved in static node communication. The authors argue that the proposed models will favour in maximizing ghe lifetime of network.Experiments aredone using network simulator tool to showcase the performance of the proposed algorithm in providing a better quality of service.

3. Shortcomings of Autonomous moving strategy and Contributions of the Paper

The drawbacks recognized with the past research works are as follows.

- Every time when the energy at the rendezvous point falls below a threshold, the sink should move to a new location which involves aggregating the energy from the entire set of nodes in the network.
- This involves a significant amount of overhead every time when the sink moves to a new location.
- Also an algorithm should be executed to find the best energy rich point for the sink to sojourn.
- Another drawback noticed in the existing work is the new energy rich sojourn location if found in a far away spot, the time taken by the sink to travel to the sojourn point impose significant amount of shortcomings particularly in event driven sensor networks.

The shortcomings with autonomous moving strategies are eliminated with the concept of predetermined trajectory. The concept of predetermined trajectory does not involve any overhead involved with choosing the next sojourn point for sink. The sojourn spots are predetermined, so when the residual energy level falls below a threshold, the sink moves to the next predefined spot without any further delay and processing. The predetermined trajectory is designed in such a way that it sojourns at the next energy rich spot after each round. The following are the contributions of our paper.

- A protocol for deployment of multiple cluster heads in the network.
- A new form of predetermined trajectory for movement of cluster heads along their destined cluster.

- Algorithm for cluster tree formation for data collection and aggregation for cluster heads.
- A mathematical formulation for optimal time placement of the cluster heads.

4. Network representation and Problem Definition

4.1 Network representation

The following are the assumptions considered with the network model.

- The type of network is considered to be heterogeneous type of network with static sensor nodes and mobile cluster heads.
- The network area is divided into grid areas each of size $CR/2$ where CR represents the communication radius of cluster heads.
- There will be roughly $N/(CR/2)$ number of cluster heads that should be deployed in the network.
- The radius of each grid circles is assumed to be $CR/2$ in order to enable the cluster head in each grid to communicate with the all of its adjacent grid cluster heads.
- The cluster heads are considered to be possessing movement capacities and they move along a predetermined trajectory.
- Data collection and aggregation is done periodically.
- Data link between sensor nodes is considered to be bidirectional and error free sort of communication.
- A good medium access layer where there is no possibility of data packet collisions and retransmissions
- Cluster heads are assumed to high in communication radius and with high energy backup,
- Cluster heads can move from one rendezvous point to another without any hindrance.

4.2 Problem Definition

The problem of data collection is defined as follows.

- Assumed a Wireless sensor network where the nodes are arbitrarily deployed to monitor and $CR/2$ number of cluster heads.
- Formulate a model to deploy the cluster heads and move them on a predetermined trajectory for data collection across the network.
- Design a new procedure for formation of clustering tree at the rendezvous point of the cluster head.
- Create a mathematical formulation for optimizing the sojourn time of the cluster head at the rendezvous point.

5. Proposed Predetermined Trajectory Model

The trajectory is modeled in such a way that the mobile cluster head tries to cover the entire network area. The trajectory is designed in such a way that it swipes back and forth in its own cluster area so that the energy level in any sojourn point will not fall below a specific threshold. The predetermined trajectory is designed based on the concept of corona division of sensor network. Usually the

network area to be sensed is divided into various coronas as depicted in Figure 1. The cluster head/sink being at the centre, first corona comprises of sensors which can directly communicate with the cluster head in one hop. Second corona comprises of sensor nodes who cannot communicate directly with the cluster head rather communicate by using one node as intermediate node.(i.e via two hops). /similarly the entire network can be divided in to many coronas based on the hop count of the individual sensor nodes.

The predetermined trajectory is designed in a manner that the cluster head starts its collection from the centre point of the corona division. Then after a data collection period of time T , the cluster heads follows the trajectory to move to the next sojourn point. The trajectory chooses the next sojourn location at a random point in the second corona. This is to make a completely a different set of sensors to act as the first corona sensors in order to minimize the formation of hotspot. The trajectory sojourn location clearly indicates that every time the cluster heads sojourns at a point, a different set of sensor nodes will act as the first corona sensor nodes. This will distribute the energy consumption in a fair manner among all the sensor nodes rather than overloading a specific set of nodes. The trajectory is depicted in Figure 2.

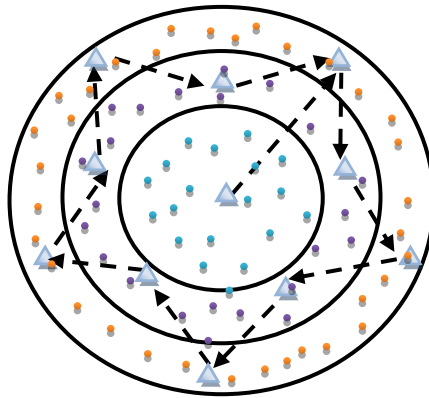


Figure 2 Cluster head Trajectory for Data Collection

5.1 Method for Data Collection

- The network area is divided into various grids and each cluster head is initially placed at the centre of each grid.
- Corona division is assumed at each grid considering the cluster head as the data collecting node.
- The cluster head form a clustering tree in its grid by calling the procedure for cluster initialization()
- The cluster head sojourns at the sojourn point for a time period " t " and a data collection process is initiated using the clustering tree formed during the cluster initialization process.
- The location of the cluster head should be synchronous with the location of other cluster heads in their grid. So the trajectory path is also considered to be synchronous.

- At the expiry of time period “t”, the cluster heads follows the trajectory path and moves to the next sojourn position.
- The data collection clustering tree and collection process is continued for the time period “t”.
- The above sets of steps are repeated for the sojourn points along the trajectory.

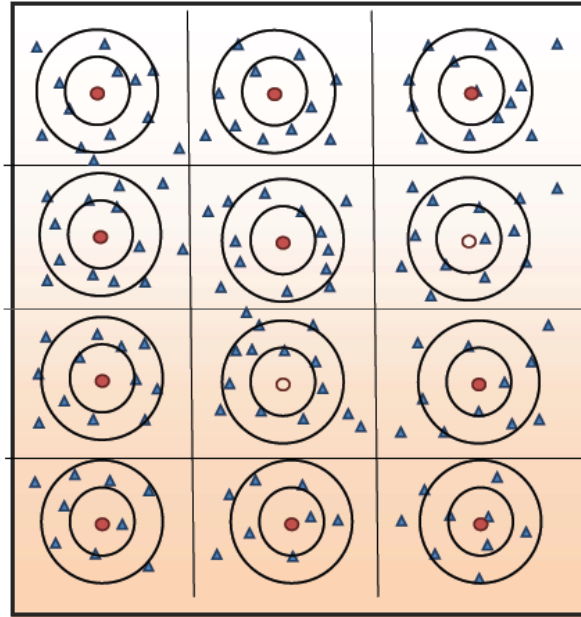


Figure 3 Corona Divisions with Multiple Grids

Procedure Data Collection**Begin**

If (First round)

Begin

Position Cluster Heads at the centre of each cluster

Call Cluster Initialization Procedure.

Do Data Collection for a time period T.

End**Else****Begin**

Move to the next location following the Trajectory

Call Cluster Initialization Procedure

Do Data Collection for a time period T.

End

Call Data Collection Procedure.

End**Procedure Cluster Initialization****Begin**

For each sensor node "N" in the network

BeginN.Cluster_ID = NullN.Hop_Count = ∞ **End**

For each Cluster Head "CH" in the network

Broadcast (CH.ID, CH.Hop_Count = 1)

For each Sensor "N" receiving the broadcast Message

Begin

If (CH.Hop_Count < N.Hop_Count)

BeginN.Cluster_ID = CH.IDN.Hop_Count = CH.Hop_CountN.Next_Hop_Sensor = ID of the

Cluster Head /Sensor node from

which the message was received.

Increment the CH.Hop_Count by 1

Broadcast(CH.ID, CH.Hop_Count)**End****Else**

Discard the Broadcast Message

Received

End**End**

heads. Here the rendezvous time of the cluster head is fixed for a time period “t”. The next The grid division of network is depicted in figure 3. The diagram indicates the cluster heads of each grid placed in centre of the grid. The cluster heads sojourns for a time period “t” at the centre and at the expiry of time period moves to the next sojourn point as indicated by the trajectory in Figure 2. This movement to next sojourn point is synchronous and all cluster heads move at the same time. Also the outermost corona radius is set to CR/2 where CR is the communication radius of the cluster head. This enables a particular cluster head to communicate with its entire adjacent cluster heads. This inter cluster coordination of the cluster heads will help in aggregation of data packet and decision making among the cluster

section deals with optimized and variable stopping time based on the residual energy of the one hop sensors.

6. Optimize Sojourn Duration – Mathematical Formulation

The contribution of the work is extended further to propose a mathematical formulation where we focus on providing an optimized stopping time for the cluster head. The stopping time period “t” discussed in the previous section does not consider the residual energy of the rendezvous zone. Rather it stops for a fixed time irrespective of the residual energy available at the particular sojourn spot. In this section we try to make the rendezvous time of the cluster head as variable in consideration with the balance energy available at the sojourn spot. A linear programming model is proposed which tries to optimize the sojourn duration of the cluster head based on the residual energy of the one hop sensors. The mathematical formulation requires the list one hop sensors of each cluster head to instigate the optimization process. This is collected by the cluster head by exploiting the clustering initialization algorithm proposed. The clustering algorithm creates cluster groups where the individual sensor nodes initialize their parameter called N.Hopcount. This parameter can be utilized to finalize the one hop sensors. The cluster head maintains the list of sensors whose hop count is one. This list of sensors represents the first corona sensors of the cluster head. This list of sensors is utilized in the mathematical formulation. The mathematical model exploits the energy model proposed by Li and Mohanpatra et al.,2005. The model calculates the energy required for basic sensor functions like sensing, transmuting and receiving as follows.

$$e_r = \delta_1 b.$$

$$e_{\text{sense}} = \alpha_1 b.$$

$$e_t = (\beta_1 + \beta_2 r^n) b.$$

The parametric values are also calculated similar to the one proposed in the same paper.

$$\delta_1 = 135 \times 10^{-9} \text{ J/bit}$$

$$\alpha_1 = 60 \times 10^{-9} \text{ J/bit}$$

$$\beta_1 = 45 \times 10^{-9} \text{ J/bit}$$

$$\beta_2 = 0.001 \times 10^{-12} \text{ J/bit/m}^4$$

The ability of the proposed straight programming plan is augmenting the lifetime of sensor network subject to different imperatives. The imperatives of the proposed direct programming plan center around the lingering energy of the one bounce sensor hubs at the sink visit spots. The enhancement model characterizes the lifetime of sensor network as the amount of visit season of the bunch heads at

different meeting point until the one jump remaining energy of any of the meeting point falls beneath the base energy prerequisite.

6.1 Parametric Variables for the Mathematical Formulation

This parameters used in the linear programming mathematical formulation are as follows.

NL	Network Lifetime
Agg_energy_i	Aggregate energy of the one hop sensor nodes at a particular sojourn location
NOL	Number of locations for the cluster head to sojourn
Soj_time_i	Sojourn time of the cluster head at a particular rendezvous point i
Min_Energy	Minimum residual energy needed at a particular rendezvous point.

The objective function maximizes the lifetime of sensor network which is defined as the aggregate of the rendezvous time of the cluster head at each location. The constraints focus on the following.

- The first constraint checks whether the aggregate energy of the one hop sensors at each rendezvous point is greater than the minimum energy requirement.
- The second constraint declares the stopping time should always be greater than 0.

$\text{Max NL} = \sum_{i \in \text{NOL}} \text{Soj_time}_i$
Subject to
$\text{Agg_energy}_i > \text{Min_Energy} \quad (1)$
$\text{Soj_time}_i \geq 0 \quad (2)$

This formulation optimizes the sojourn time of the cluster head. The advantages of this mathematical formulation over fixed stopping time are as follows.

- The sojourn duration is optimal which maximizes the network lifetime to a higher extent
- The cluster head sojourn duration depends on the one hop residual energy of the rendezvous point rather than stopping for a fixed duration.
- The sojourn time will vary at different sojourn spots depending on the residual energy at that spot. So this will improve the network longevity to a great extent.

7. Simulation Results

Simulation experiments are conducted using network simulator tool to showcase the performance of the proposed algorithm. Both the cases where the cluster heads are sojourning for fixed duration and optimized sojourn duration as proposed by the linear programming formulation is experimented. The simulation set up is as follows.

- Sensor nodes are deployed randomly in the sensing area
- Network size is 200 nodes.
- First order radio model is considered for simulation
- For transmitting a k-bit message for a distance d the first order radio model considers the following parametric values.

$$E_{Tr}(d, k) = k \times (e_{elec} + e_{amp} \times d^\alpha)$$

$$E_{Rc}(k) = k \times e_{elec}$$

- α and e_{amp} represents the path-loss exponent and energy consumed for transmitting one bit respectively.
- The parametric value set in the simulation experiment. ($d=1$, $e_{elec} = 50$ nJ/bit, $e_{amp} = 0.1$ nJ/bit/m², packet size = 512 bits, uniform data generation rate and $\alpha = 2$)

The simulation is initiated by randomly deploying 200 sensor nodes sensors along with cluster heads. The cluster head is initially allotted to collect data for a fixed sojourn time as discussed in the first contribution of our paper. The proposed trajectory is considered for the movement of cluster head. Data collection is done for a specific number of rounds. The lifetime of the network in terms of number of rounds is studied. The network lifetime here is defined in two ways.

- One is the number of rounds the cluster head is able to hold until the one hop residual energy of any one sojourn location falls below the minimum energy requirement.
- Second, the number of rounds the cluster head is able to hold until the one hop residual energy of “x” number of sojourns spots falls below the minimum energy requirement.

Simulation experiments are done for both the proposed trajectory model and the mathematical formulation model. Number of rounds the cluster head is able to stand until the residual energy of one sojourn location falls below the minimum energy is studied. The results are showcased in Figure 4. Five different strategies are studied over here.

1. Static cluster head where the cluster head is placed in the geometric centre of the network

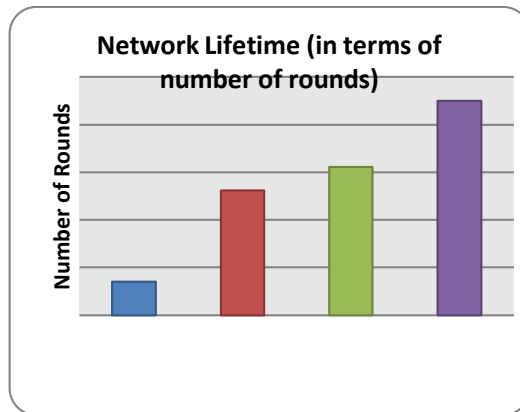


Figure 4 Network Lifetime (Residual energy of one sojourn location falls below the threshold)

2. Mobile CH placed at the periphery of the network
3. Mobile CH placed at random energy rich spots
4. Mobile CH according to the proposed predetermined trajectory,
5. Mobile CH according to the proposed Linear programming model.

Proposed predetermined trajectory shows a significant improvement in terms of number of rounds.

Similarly the lifetime of network the cluster head is able to withstand until the residual energy of three sojourn locations falls below the minimum energy requirement is studied. The result is shown in Figure 5. Here also the proposed trajectory shows good improvement over other methods.

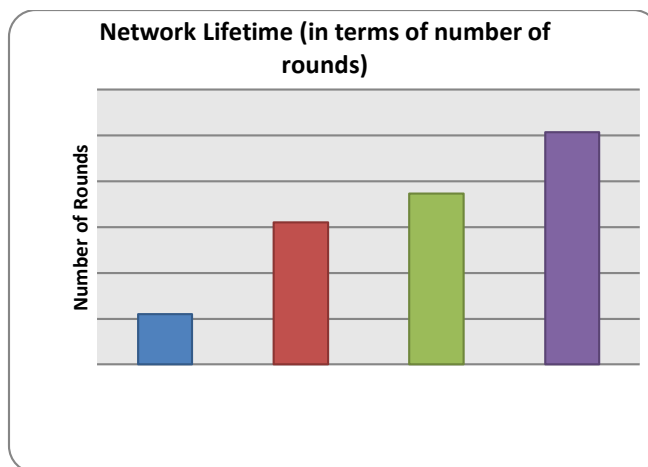


Figure 5 Network Lifetime (Residual energy of three sojourn locations falls below the threshold)

Likewise the average energy consumption of the one hop sensors after a specific number of data collection round is studied which is depicted in Figure 6. The proposed trajectory shows minimal energy consumption in compared to all the

other models. This clearly indicates the possibility of enhanced network lifetime for the proposed trajectory model.

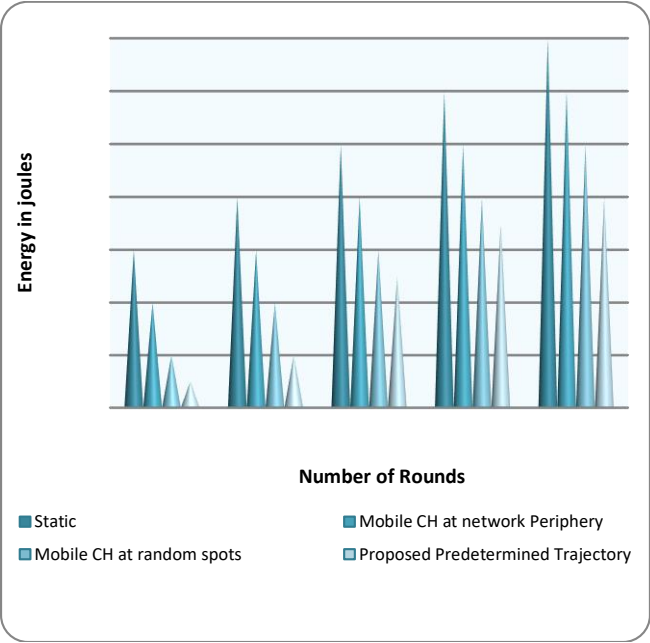


Figure 6 Average Energy Consumption

Similarly the average number of alive nodes in the network after a number of data collection rounds is studies for all the four strategies. The proposed models have more number of alive nodes which will have a direct impact on network longevity in comparison with the other schemes.

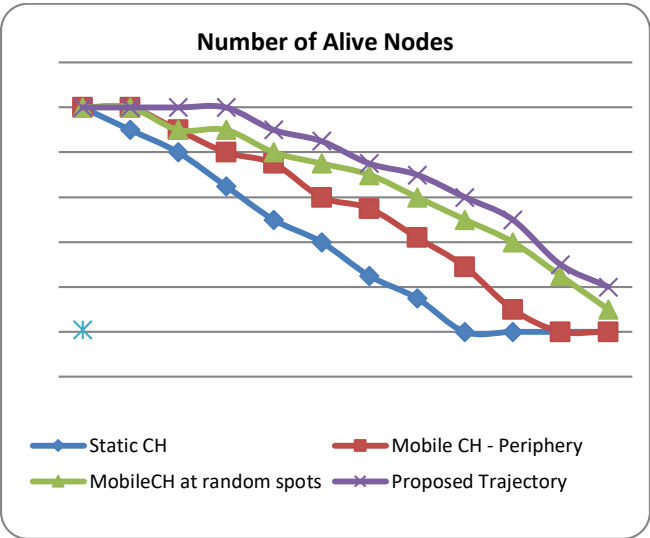


Figure 7 Number of alive nodes after specific number of rounds

The other three models have minimal number of alive nodes which is a indication for decreased network lifetime.(Figure 7) In the same way number of dead nodes is also noted where the proposed trajectory model has minimum number of dead nodes in comparison with the other models. The results are illustrated in Figure 8

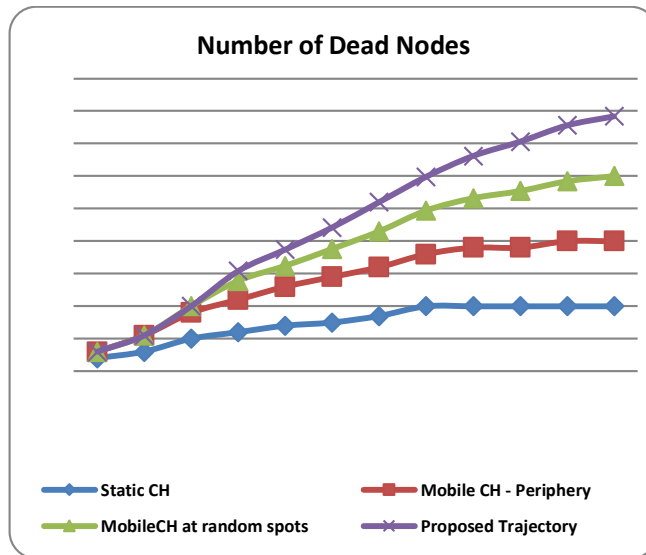


Figure 8 Number of dead nodes after specific number of rounds

The linear programming formulated is executed using LINDO. According to the results for the optimization of time duration, the cluster head is allowed to move along the trajectory and stopped for an optimal time period. Lifetimes of the network for the linear programming model in comparison with the other models are studied. The linear programming model shows a significant improvement in lifetime in terms of number of rounds in comparison with the other models. Even with the proposed predetermined trajectory model the mathematical model shows 15% more improvement in terms of network lifetime. Likewise the network lifetime in terms of number of rounds until three locations falls below the threshold category, the proposed Linear programming model shows 20% higher lifetime. The results are studied and depicted in the following figures. Figure 9 and Figure 10.

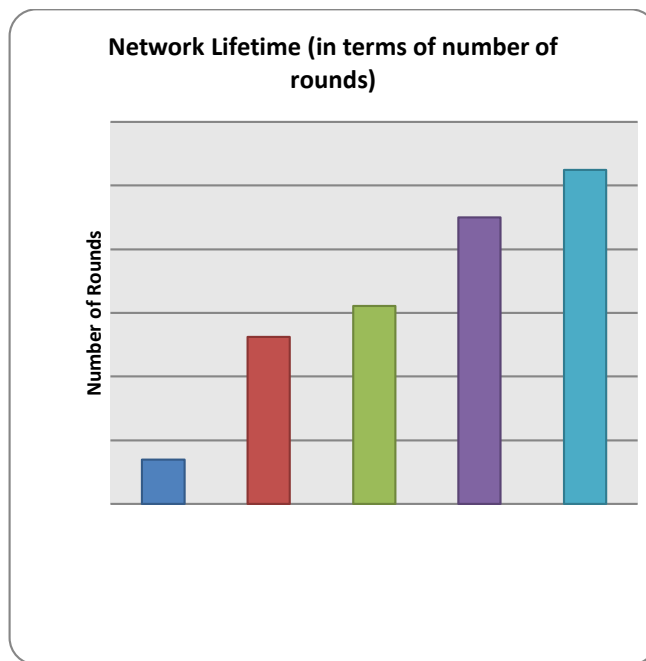


Figure 9 Network Lifetime LPP Model (Residual energy of one sojourn location falls below the threshold)

8. Conclusions and Future Work

The proposed research exploits the concept of moving the cluster head along a predetermined trajectory for the purpose of data collection. In the first method the cluster heads stops for a fixed time duration " t " and initiates a data gathering phase whereas, in the second category a linear programming formulation is created to optimize the sojourn duration of the cluster head. This model optimizes the lifetime of network. The proposed linear programming models shows a

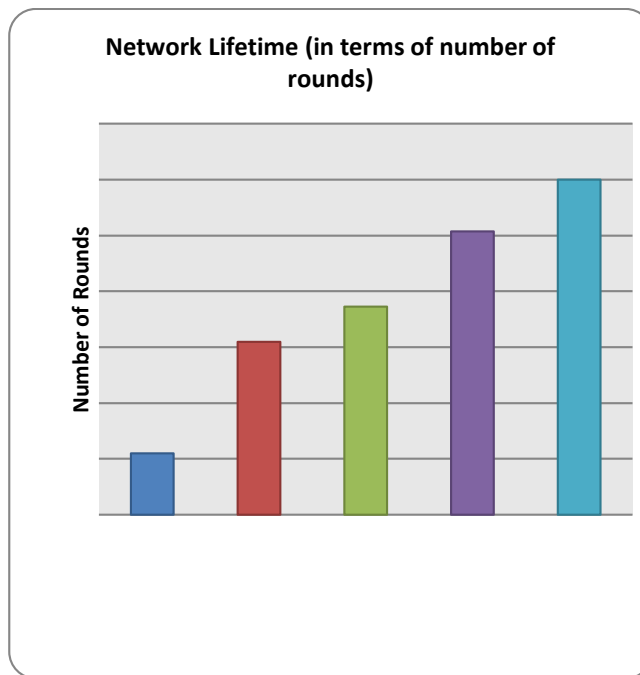


Figure 10 Network Lifetime LPP Model (Residual energy of three sojourn locations falls below the threshold)

Good improvement in terms of network lifetime, number of alive nodes, number of dead node and average energy consumption parameters. Our future work involves proposing a autonomous moving strategy for cluster heads by giving due consideration for the over heads and data latency involved with that. The proposed predetermined trajectory model and linear programming model showcases a better performance in comparison with the other models where the cluster heads are placed at periphery and at random spots.

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