An Energy Efficient Base Stations Optimization Scheme for Mobile Wireless Sensor Networks Enabled IoTs

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Abstract
Internet of Things (IoTs) is one the substantial development that has been observed in computing paradigms in the recent years. Around 30 billion smart devices are connected to IoTs and it will be doubled by 2025. Mobile Wireless Sensor Networks makes the implementation of IoTs easier. They are extensively employed in many real-life applications like monitoring of environmental changes, disasters prediction, health care etc. As the sensor nodes are with limited energy so the efficient consumption of energy is very important for the lifetime of the network. e.g., in military surveillance application, they will be deployed in the areas where it is difficult to recharge the batteries and we need longer lifetime to watch the activities of enemies. Base station (BS) positioning is considered an effective method to improve the performance of MWSNs. The goal of this research is to minimize total energy Consumption and to prolong lifetime of a MWSN by optimizing the position of the base station in different mobility models. Location of BS is optimized by using the average values of nodes location. Our findings suggest that deployment of multiple, mobile base stations increases the network lifetime. MATLAB simulations for different mobility models with different field sizes and number of nodes are performed. The rate of energy consumption with static sensor nodes and mobile sensor nodes is also compared.

Index Terms—*Energy Efficiency, Mobile Wireless Sensor Networks based IoTs*

I. Introduction

In the last decade, a swift evolution has been observed in computing paradigms. Different networks want to interact and use services of each other. Internet of things (IOTs) is a paradigm which acts as flag conveyor between these state-of-the-art technologies [1][2]. One of the easiest implementations of IoTs is wireless sensor networks. Wireless Sensor Network (WSN) is a composition of countless sensor nodes[3]. Having limited processing capabilities, 'mote' is used to gather sensory information and send data to the user. These motes are capable to connect with each other directly or to another fixed node, or a module, called Base Station (BS). Base stations are responsible for the connection between different networks [2] [4]. Base Station (BS) interconnects the sensor nodes to make overall communication possible. They can be used in different scenarios like for disaster management[5], in military[6], landslide monitoring[7], environmental monitoring[8] etc.

WSNs share a common medium for data transferring among themselves. In a sensor network, sensor nodes act like detection stations. These sensor nodes are portable, small, and lightweight. The main responsibilities of sensor nodes are to sense events, gather data from its surroundings and then transfer it to the Base Station**.** To monitor an environment, sensor nodes can either be spread arbitrarily over an area or located in fixed places.

Mobile Wireless Sensor Network (MWSN) is another type of WSN in which sensor nodes are in mobile state and changing their positions from place to place. MWSN can be positioned in any condition and managed with rapid topology changes. In **MWSN**, sensor nodes randomly move around in their target fields to sense data, and then to transmit this information to the BS, normally placed outside

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the field. Meanwhile sensor nodes utilize their energy while transmitting the gathered information to the BS.

Wireless Sensor Networks (WSNs) have extraordinary skills for integrating sensing with computing and communication as well as for distributed sensing, coordination, and control. The mobility in wireless networks significantly increases the application space of both robots and distributed sensor networks. Mobility also helps to decrease multi-hop communication between sensor nodes and BS. Thus, it is helpful to increase network lifetime and to reduce the delay by optimizing the energy required to transmit and receive messages [9]. Architecture of Mobile WSN based IoTs is represented in fig 1.

Mobility models are of different types which show the movement of mobile sensors, and how the mobile sensors change their velocity, location, and acceleration over time. Mobility configurations may act as an important part in defining the protocol performance and follow the movement pattern of targeted real-life applications in a realistic way[10]. When new techniques for communication or navigation are investigated these models are commonly used for simulation purpose [11].

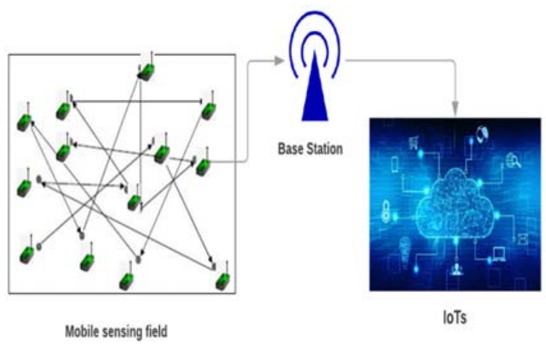

Fig 1 Mobile WSN based IoTs

II. Random way point mobility model

It is proposed by Johnson and Maltz is the variation of Random walk model with spatial dependence [12]. Mobile nodes move arbitrary and free without any restrictions. In this model, a time between change in route and/or speed is defined as pause time. A mobile node (MN) moves randomly in the simulation area, stops in one location over specific pause time and randomly selects an end point (x,y) with constraints such as speed between [0,Vmax], a pause time between [Pmin, Pmax]. At the speed, the MN then moves to the new selected location. After reaching the next location, the mobile node waits over a specific pause time before moving towards the next selected destination. In this model, nodes are in the central location of the network rather than close to the ends[13].

This model cannot store the information about any process among the nodes, so it is memory-less mobility model in which future decisions do not rely on previous status [14]. This means that every decision is independent of any past decision, parameters like the current velocity are independent of their previous records, and the future velocity is also independent of its current velocity.

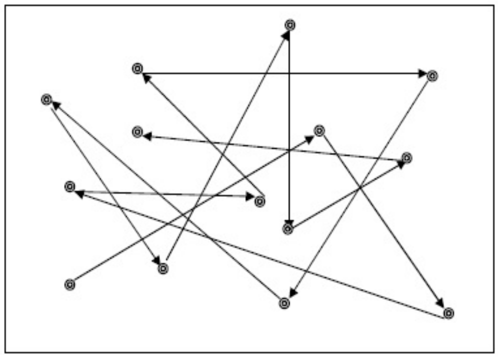

Fig. 1. Movement of Nodes in Random way point mobility model

Manhattan pathway mobility model:

Its Use grid road topology [15]. This model can be used in city areas where streets are in well-ordered way and the mobile nodes can move in horizontal or vertical direction. At every junction of a horizontal and a vertical path, the mobile node can go left, right, straight or backward with a particular probability [16].

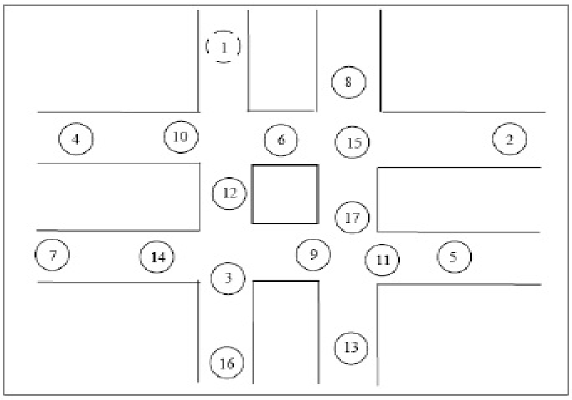

Fig 2 Movement of nodes for Manhattan mobility model

The rest of the paper is organized as follows. Section II explains literature review, III presents the methodology and discusses comparison between different energy efficient method, section IV describes the simulation set-up and results, whereas section V concludes the paper and enlists a few directions for future work.

III. LITERATURE REVIEW

In recent years, a lot of research has been done on selecting optimum position of BS and designing network for energy conservation and extension in network lifetime. In [17], Distributed collaborative beamforming (DCB) in MWSNs is used to enhance the energy of the network. They also improve dominated sorting genetic algorithm-II (INSGA-II) and a distributed parallel INSGA-II (DPINSGAII). The use of DCB based on a virtual node antenna array (VNAA) may contribute to increase the energy consumption but it is considered as a tradeoff between cost and energy.

The approach used in [18] selects the position of BS by choosing *n* nodes. It forms polygon vertices by considering traffic density to locate BS, which lies in one hop distance to nodes. BS is always placed in the middle of the vertices of selected area. Moreover, results show that relocation of BS in this respect decreases the average energy consumption of network and increases its throughput. Whereas the Mechanism given by author does not consider the case where boundaries of polygon may intermingle. In contrast to that in our scheme we consider each potentially important node to contribute to the calculation automatically.

In [19], another technique is introduced. Author uses k-means algorithm, which makes clusters in the network and BS is placed in the mid of each cluster. However, their method to find a center of each cluster does not include any power-aware distance metrics. Thus, for multiple base stations there is a need to create multiple clusters. Percentage of dead sensor nodes in network is used as a key factor to define lifetime. One of the drawbacks of this approach is the prior knowledge about existence of base stations, because it defines the number of clusters to be created. Their solution is centralized, in that a system designer should calculate the BS position. For this purpose, node locations are assumed to be known before the solution phase.

In paper [20], Author describes another method for propagating the position of a mobile BS to the nodes in WSNs. Author used the overhear property of wireless transmission, in which a node can hear the packets in the nearby area that are not intended for itself.

In [21], BS positioning problem is formulated as a maximum flow problem. To implement their BS positioning method, they argue that any maximum flow algorithm (e.g. [22]) can compute the needed calculations. Also, the production of data across the network is considered as the metric to be maximized. A fixed data rate for sensor nodes is assumed in the network model. The authors aim to find optimal positions for multiple BSs such that consumption of energy by the sensor nodes is decreased. They also investigate the effect of the BSs' layout on the data production and flow in the network. In this paper, it is shown that their method for choosing the BS position can significantly improve the data rate and total energy consumption of a WSN.

However, their approach is based on a centralized algorithm where a global knowledge is provided to a single workstation, including every sensor node's location in the network. Furthermore, the number of BSs is assumed to be fixed and known in advance. Also, author has not considered the BS relocation.

IV. METHODOLOGY

In today's world, Mobility in WSN acts as a key role in execution of the application. Generally, sensors in Mobile wireless sensor networks are mobile and can move from one position to another. This can help in collecting data from large areas. The main concern is energy of the network, as the network will die out if energy of sensor nodes gets drained. The main objective is to increase the lifetime of the network by appropriate use of energy of the sensor nodes. Our study is to develop a mechanism in which minimum amount of energy will be required to maximize lifetime of network. The infrastructure which I consider for this research is on the mobility models in wireless sensors networks. The two models which I consider are:

- Random way point mobility model
- Pathway mobility model

To illustrate our mechanisms, nodes in the network field are mobile and BS is stationary in one case and partially mobile in other. Equal energy is distributed to all nodes. Some of the energy is given to the BS which is used to receive data from targeted area. Nodes consume their energy whenever they sense, transmit or receive data from field or from any other node. Nodes gather information and transfer to the BS.

A. Static model

Sensor nodes are scattered randomly in the network field and broadcast their location in the field. The position of nodes will be same in every round.

The ideal position of base station can find by taking the average of nodes location in X and Y coordinates

$$X = \frac{x_1+x_2+x_3+\cdots+x_N}{N} \quad (1)$$

$$Y = \frac{y_1+y_2+y_3+\cdots+y_N}{N} \quad (2)$$

Where x_1, x_2 up to x_N are the position of the nodes in X-axis and y_1, y_2 up to y_N are the positions of nodes in Y-axis and N is entire number of nodes in the network field.

So the average value of nodes location at X-axis is

$$X = \frac{\sum_{i=1}^{N} x_i}{N} \quad (3)$$

And the average value of nodes location at Y-axis is

$$Y = \frac{\sum_{i=1}^{N} y_i}{N} \quad (4)$$

So the ideal location of the base station = (X , Y)

Where, X and Y are the location of BS in x-coordinate and y-coordinate respectively.

Now the possible locations for the base station in the network field can be

$$(X_{bs_1}, Y_{bs_1}), (X_{bs_2}, Y_{bs_2}), (X_{bs_3}, Y_{bs_3}),, (X_{bs_m}, Y_{bs_m}) \quad (5)$$

m is total number of possible base station location.

Distance from ideal location of base station to the possible locations of base station can be find by using formula

$$dist_i = \sqrt{(X - X_{bs_i})^2 + (Y - Y_{bs_i})^2} \quad (6)$$

Where, i = 1, 2, 3, ……, m

To find the minimum distance

$$d_{min} = \min(dist_1, dist_2, dist_3, \ldots\ldots, dist_m) \quad (7)$$

d_{min} = minimum distance from ideal location of BS

So

$$w = index(d_{min}) \quad (8)$$

Where, W is the index of minimum distance

So

$$BS_{location} = (X_{bs_w}, Y_{bs_w}) \quad (9)$$

Where,

X_{bsw}= best location of base station in X-axis

Y_{bsw} = best location of base station in Y-axis

B. Random way point model (non mobile)

Nodes are mobile and change their positions randomly after specified number of rounds and then nodes broadcast their location.

The ideal location of base station can be find by using formula

$$X = \frac{dx}{2} \quad (10)$$

And

$$Y = \frac{dy}{2} \quad (11)$$

dx= size of the field in x-axis

dy= size of the field in y-axis

ideal location = (X,Y)

Now we can find the possible base stations location, d_{min} by using equations (5)(7)(9) from static model.

If we place two Base stations in the network field then the 2nd base station will be placed diagonally to the 1st base station.

C. Random-way point mobility model (mobile base station)

In random-way point model, nodes are movable and arbitrarily change their position after specified number of rounds. In this case, base station can also change its position after certain number of rounds so that it can collect data from the whole field easily. As the base station can move, the energy consumption by all nodes will be equal because there is no particular single node connected to base station for transmitting data. Different nodes can transmit information to the BS in different rounds as base station change its position after certain number of rounds. The postion of the base staion can find same as the static model but repeat the process after specified frequency of rounds.

D. Pathway mobility model (BS non-mobile)

Mobile nodes move along with the specified path which is predefined in the simulation field. The best position of the base station can be found by slicing the path in which nodes can move and take the average of this path.

$$X = \frac{p_{x_1}+p_{x_2}+\ldots+p_{x_O}}{O} \qquad (12)$$

And

$$Y = \frac{p_{y_1}+p_{y_2}+\ldots+p_{y_O}}{O} \qquad (13)$$

Where, $P_{x1}, p_{x2},\ldots,p_{xO}$ = smallest partitions of pathway on x-axis

$P_{y1}, p_{y2},\ldots,p_{xO}$ = smallest partitions of pathway on y-axis

O_x = total number of partitions in x-axis

O_y = total number of partitions in y-axis

So the ideal location of base station in pathway mobility model is

Ideal location = (X ,Y)

Where, X and Y are the ideal points for the location of BS in X-axis and Y-axis respectively.

Now we can find the possible base stations location, d_{min} by using equations (5)(7)(9) from static model.

If we place two Base stations in the network field then the 2nd base station will be placed diagonally to the 1st base station.

E. Pathway mobility model (BS mobile)

In a situation where base station is mobile, position of the base station can find as same as in the static model but repeat the process after specifeid frequancy of round.

V. SIMULATION SET-UP AND RESULTS

The implementation has been done in Mat lab while evaluating the performance of our projected algorithm. The experimental setup consists of sensor nodes and base station. Sensor nodes are randomly positioned in the targeted field. Three different models considered in our research are as following:

A. Static model

In static model, nodes are randomly positioned in the network field and cannot change their positions whereas a single base station is deployed on the best possible location. We consider various simulations with different number of nodes and different field size.

Table 1 Simulations results for static model

Mode	Field Size (meters)	Nodes	Energy	Consumption
1	100x100	50	0.4414	11.72%
2	100x100	50	0.44807	10.39%
3	100x100	50	0.4513	9.74%
4	100x100	50	0.4538	9.24%
1	100x100	25	0.4395	12.10%
2	100x100	25	0.4467	10.66%
3	100x100	25	0.4493	10.14%
4	100x100	25	0.4517	9.66%
1	50x50	50	0.4585	8.30%
2	50x50	50	0.4596	8.08%
3	50x50	50	0.46	8.00%
4	50x50	50	0.4605	7.90%
1	50x50	25	0.4591	8.18%
2	50x50	25	0.4598	8.04%
3	50x50	25	0.4602	7.96%
4	50x50	25	0.4612	7.76%

In this model, we consider 4 modes. In each mode, position of base station will be change. This will show that which mode is best for the less consumption of energy.

In **mode 1**, base station is placed at a point where (x=0, y=0). This mode consumes more energy as compare to other modes because some nodes will be at far distance from the base station in this case. In **mode 2**, position of base station is at a point where (x=0, $y=y_{max}/4$). This mode is better than mode 1 but still consumes more energy than other modes. In **mode 3**, position of base station is at a point where (x=0,y=y_{max}/2). This mode is better than above modes.

In mode 4, we consider the best possible location of the base station. The ideal location of base station can be located by taking the average of nodes location in X and Y coordinates by using equation (4.3) and (4.4). Now the possible locations for the base station in the network field can be find by equation (4.5). Minimum distance from the ideal location to best possible location can be find by using equation (4.6). Best possible location can be found by using equation (4.9). This mode is best in static model because less amount of energy is consumed by the nodes due to position of base station in the network field.

We plotted graphs with different field sizes and different number of nodes to spot the mode best for minimal energy consumption.

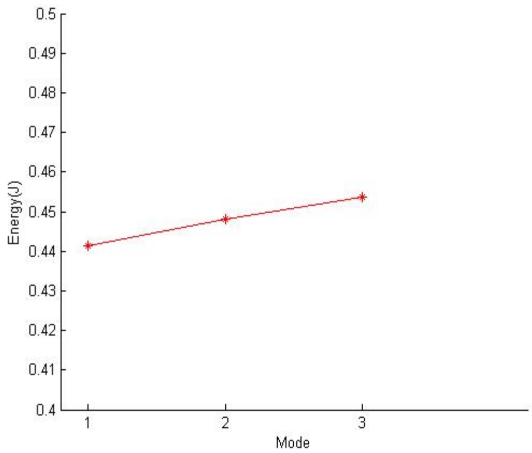

Fig 3 Energy consumption in Static model with field size 100m x 100m and no.of nodes: 50 (1)

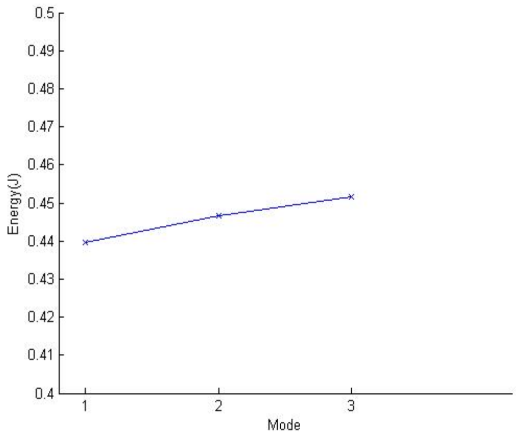

Fig 4 Energy consumption in Static model with field size 100m x 100m and No. of Nodes: 25 (2)

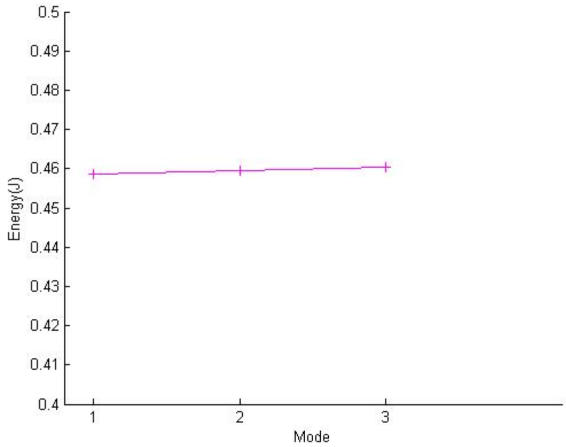

Fig 5 Energy consumption in Static model with Field Size: 50m x 50m and No. of Nodes: 50 (3)

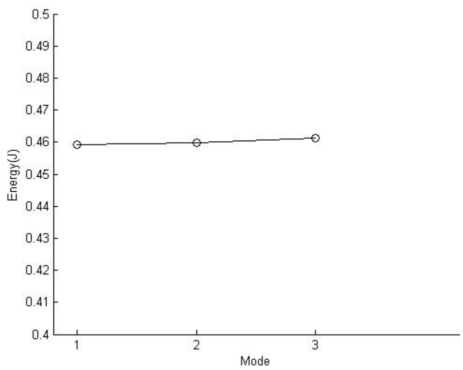

Fig 6 Energy consumption in Static model with Field Size: 50m x 50m and No. of Nodes: 25 (4)

These graphs show energy consumption for different modes with different number of nodes and different field size in static mode.

B. Random way-point mobility model

In Random way-point mobility model, nodes are randomly deployed in the network field and change their position after specified number of rounds. We will check the results for single base station, two base stations and mobile base station.

We consider various simulations with different number of nodes and different field size.

C. Non- mobile Base station

In random way point model, we consider 3 modes. In each mode position of base station will be changed. This will show that which mode is best for the less consumption of energy.

Table 2 Simulation results for random way model with non-mobile BS

Mode	Field Size (meters)	Nodes	Energy	Consumption
1	100x100	50	0.4432	11.36%
2	100x100	50	0.4496	10.08%
3	100x100	50	0.4486	10.28%
1	100x100	25	0.4405	11.90%
2	100x100	25	0.4468	10.64%
3	100x100	25	0.4486	10.28%
1	50x50	50	0.4588	8.24%
2	50x50	50	0.4597	8.06%
3	50x50	50	0.46	8.00%
1	50x50	25	0.4586	8.28%
2	50x50	25	0.4595	8.10%
3	50x50	25	0.4598	8.04%

In **mode 1**, base station is placed at a point where (x=, y=0). This mode consumes more energy as compare to other modes because some nodes will be at far distance from the base station in this case. In **mode 2**, position of base station is at a point where (x=0, $y=y_{max}/4$). This mode is better than mode 1 but still consumes more energy.

In **mode 3**, we consider the best possible location of the base station from the equations above in random way model Now different graphs are plotted to check the results

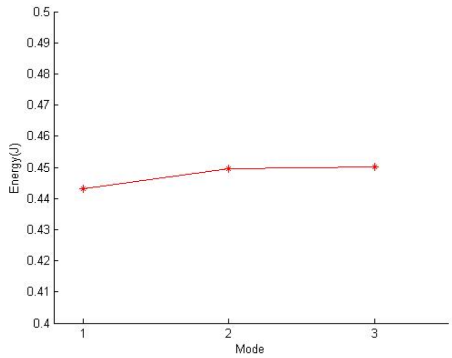

Fig 7 Energy Consumption in Random way model non-mobile BS with Field Size: 100m x 100m and No. of Nodes: 50 (1)

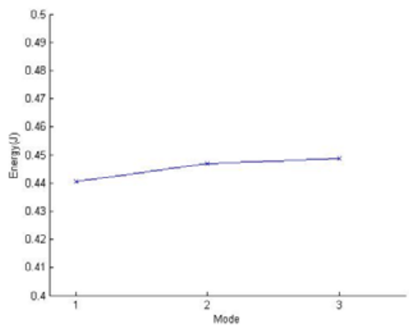

Fig 8 Energy Consumption in Random way model non-mobile BS with Field Size: 100m x 100m and No. of Nodes: 25 (2)

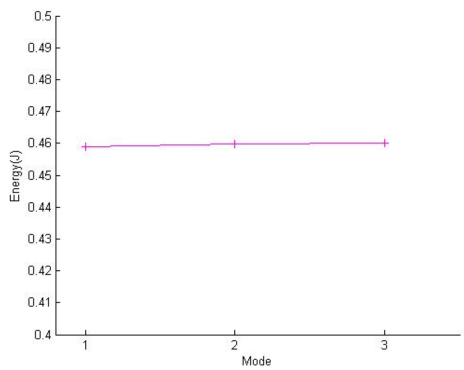

Fig 9 Energy Consumption in Random way model non-mobile BS with Field Size: 50m x 50m and No. of Nodes: 50 (3)

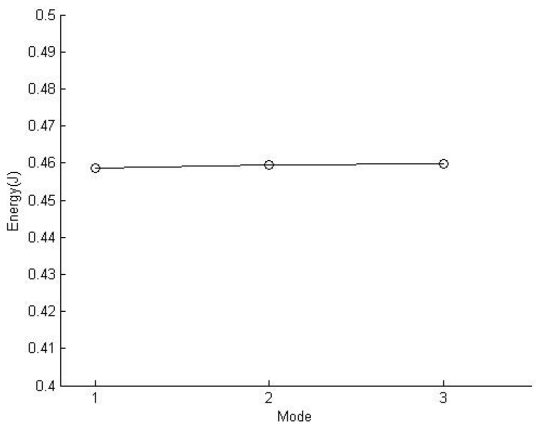

Fig 10 Energy Consumption in Random way model non-mobile BS with Field Size: 50m x 50m and No. of Nodes: 25 (4)

These graphs show energy consumption for different modes with different number of nodes and different field size in Random way point mobility model when BS is non-mobile.

D. Two Base stations:

In this case, we consider two Base stations in the network field so that energy conservation is lesser in this case. Consider this case as mode 4 so that we can campare this mode with the modes of non-mobile Bs.

Table 3 Simulation results for random way model with two BS

Mode	Field Size (meters)	Nodes	Energy	Consumption	No. of Base Stations
4	100x100	50	0.4567	8.66%	2
4	100x100	25	0.4541	9.18%	2
4	50x50	50	0.4611	7.78%	2
4	50x50	25	0.4609	7.82%	2

The 2nd base station will be placed diagonally to the 1st base station.

Now we plot the graphs with mode 1,2,3 of non-mobile Bs case and mode 4 of 2 Bs case to compare the results.

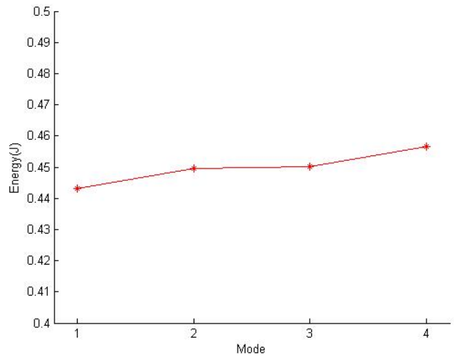

Fig 11 Energy Consumption in Random way model two Base Stations Mode with Field Size: 100m x 100m and No. of Nodes: 50 (1)

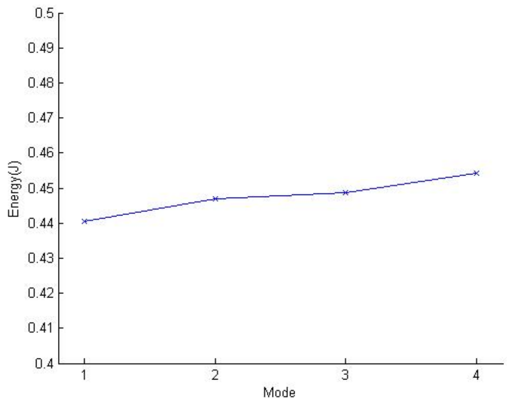

Fig 12 Energy Consumption in Random way model two Base Stations Mode with Field Size: 100m x 100m and No. of Nodes: 25 (2)

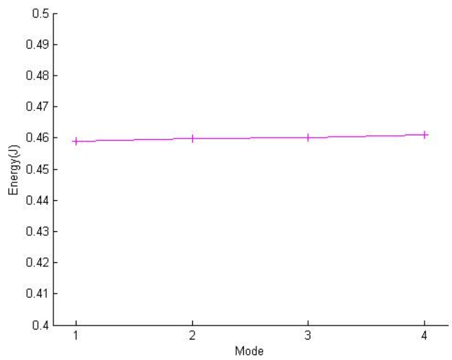

Fig 13 Energy Consumption in Random way model two Base Stations Mode with Field Size: 50m x 50m and No. of Nodes: 50 (3)

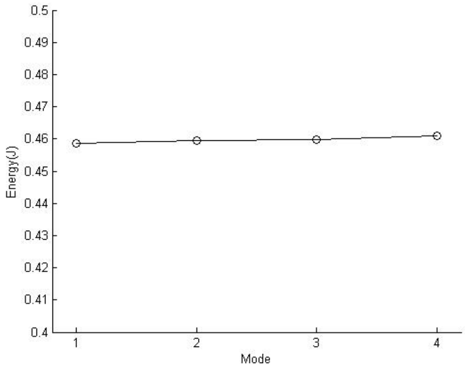

Fig 14 Energy Consumption in Random way model two Base Stations Mode with Field Size: 50m x 50m and No. of Nodes: 25 (4)

Aforementioned graph shows that by putting two base station (non-mobile) in the network field, the latter consumes less energy as compared to the network with single base station (non-mobile). The two base station covers the whole network so that some nodes send their data to one base station and remaining nodes to the other base station.

E. Mobile Base station:

In this case, base station can also change its position after certain number of rounds so that it can collect data from the whole field easily. Consider this case as mode 4 so that we can campare this mode with the modes of non-mobile Bs

Table 4 Simulations results for Random way model with mobile BS

Mode	Field Size (meters)	Nodes	Energy	Consumption
4	100x100	50	0.4524	9.52%
4	100x100	25	0.4502	9.96%
4	50x50	50	0.4602	7.96%
4	50x50	25	0.4601	7.98%

The postion of the base staion can be found same as the static model by equations in chapter 4. but repeat the process after specified frequency of rounds.

Now we plot the graphs with mode 1,2,3 of non-mobile BS case and mode 4 of mobile BS case to compare the results.

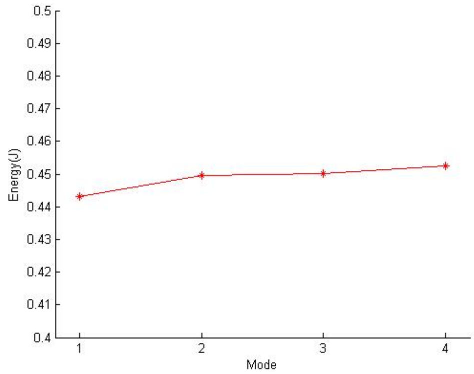

Fig 15 Energy Consumption in Random way model Mobile BS Mode with Field Size: 100m x 100m and No. of Nodes: 50 (1)

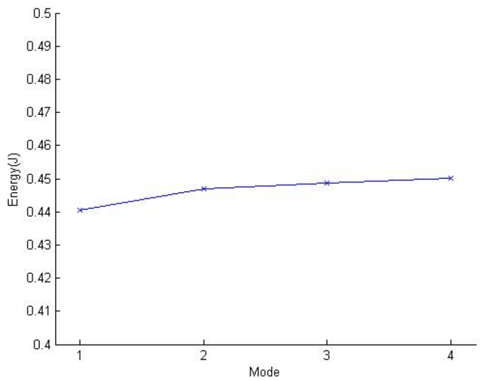

Fig 16 Energy Consumption in Random way model Mobile BS Mode With Field Size: 100m x 100m and No. of Nodes: 25 (2)

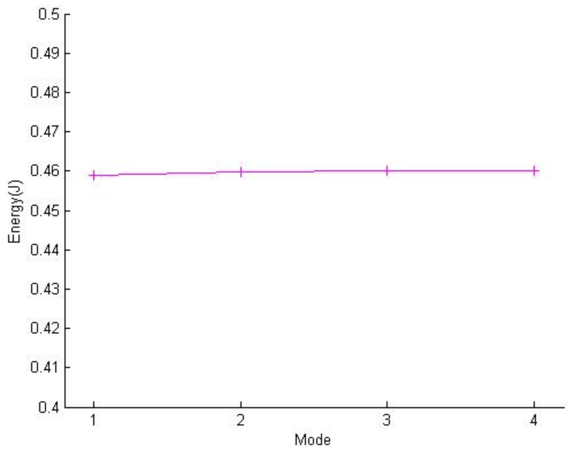

Fig 17 Energy Consumption in Random way model Mobile BS Mode with Field Size: 50m x 50m and No. of Nodes: 50 (3)

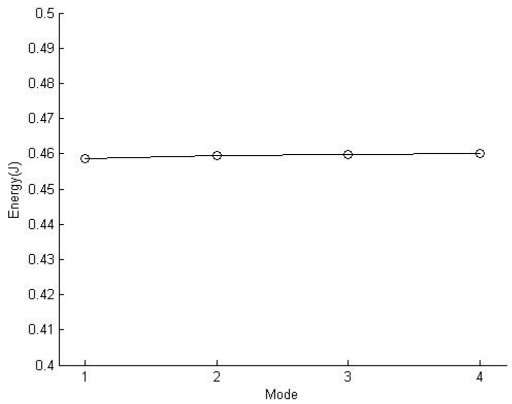

Fig 18 Energy Consumption in Random way model Mobile BS Mode with Field Size: 50m x 50m and No. of Nodes: 25 (4)

In these graphs, mode 4 shows the mobile base station which consume very less energy as compared to other modes because in this mode, BS station change its position after specific rounds. So that it covers the entire network field.

F. Pathway mobility model:

In pathway mobility model, nodes are deployed in specified pathway in the network field and change their position after specified number of rounds. We will check the results for single base station, two base stations and with mobile base station.

We consider various simulations with different number of nodes and different field size.

G. Non-mobile Base station

In pathway model, we consider 4 modes. In each mode position of base station will be changed. This will show which mode is best for the less consumption of energy.

Table 5 Simulations results for Pathway model with Non-mobile BS

Mode	Field Size (meters)	Nodes	Energy	Consumption
1	100x100	50	0.446	10.80%
2	100x100	50	0.4506	9.88%
3	100x100	50	0.4509	9.82%
4	100x100	50	0.4547	9.06%
1	100x100	25	0.4442	11.16%
2	100x100	25	0.4486	10.28%
3	100x100	25	0.449	10.20%
4	100x100	25	0.4529	9.42%
1	50x50	50	0.4592	8.16%
2	50x50	50	0.4598	8.04%
3	50x50	50	0.4598	8.04%
4	50x50	50	0.4607	7.86%
1	50x50	25	0.4592	8.16%
2	50x50	25	0.4594	8.12%
3	50x50	25	0.4596	8.08%
4	50x50	25	0.4607	7.86%

In **mode 1**, base station is placed at a point where (x=0, y=0). This mode consumes more energy as compared to other modes because some nodes will be at far distance from the base station in this case. In **mode 2**, position of base station is at a point where ($x=0,y=y_{max}/4$) This mode is better than mode 1 but ideally consumes more energy. In **mode 3**, position of base station is at a point where ($x=0,y=y_{max}/2$). This mode is better than above modes.

In **mode 4**, we consider the best possible location of the base station from above calculated equations

Different graphs are plotted to check the results

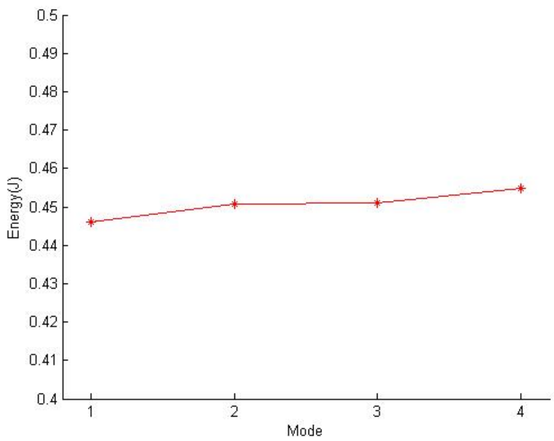

Fig 19 Energy Consumption in Pathway Non Mobile Mode with Field Size: 100m x 100m and No. of Nodes: 50 (1)

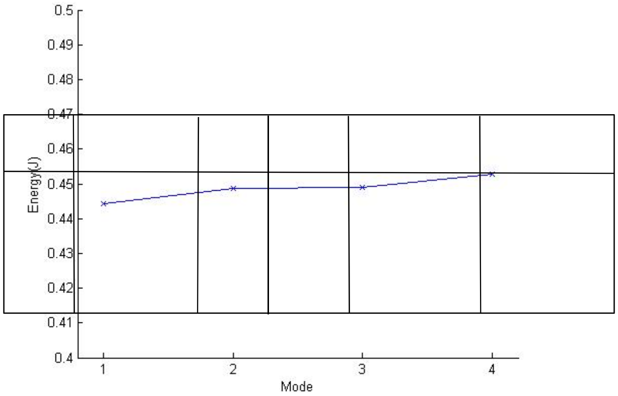

Fig 20 Energy Consumption in Pathway Non Mobile Mode with Field Size: 100m x 100m and No. of Nodes: 25 (2)

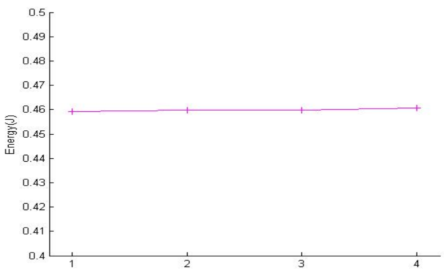

Fig 21 Energy Consumption in Pathway Non Mobile Mode with Field Size: 50m x 50m and No. of Nodes: 50 (3)

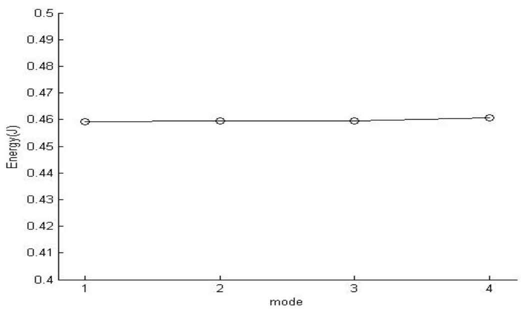

Fig 22 Energy Consumption in Pathway Non Mobile Mode with Field Size: 50m x 50m and No. of Nodes: 25 (4)

These graphs show energy consumption for different modes with different number of nodes and different field size in non-mobile Base Station Case.

H. Two Base stations:

In this case, we consider two Base stations in the network field so that energy conservation is lesser in this case. Consider this case as mode 5 so that we can campare this mode with the modes of non-mobile BS.

Table 6 Simulation results for pathway model with two BS

Mode	Field Size(meters)	Nodes	Energy	Consumption	No.of Base Statione
5	100x100	50	0.457	8.60%	2
5	100x100	25	0.4551	8.98%	2
5	50x50	50	0.4612	7.76%	2
5	50x50	25	0.4609	7.82%	2

The 2nd base station will be placed diagonally to the 1st base station. Now we plot the graphs with mode 1,2,3,4 of non-mobile BS case and mode 5 of two Bs case to compare the results.

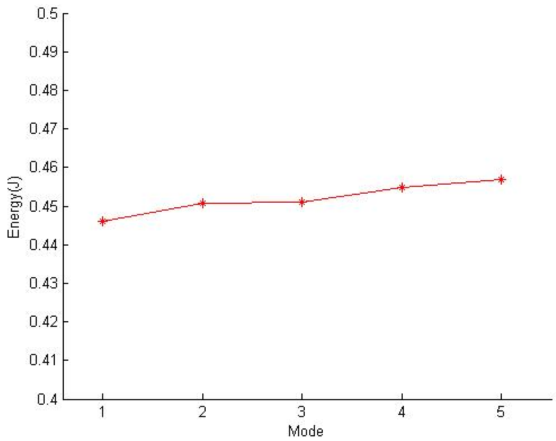

Fig 23 Energy Consumption in Pathway 2 Base stations Mode with Field Size: 100m x 100m and No. of Nodes: 50 (1)

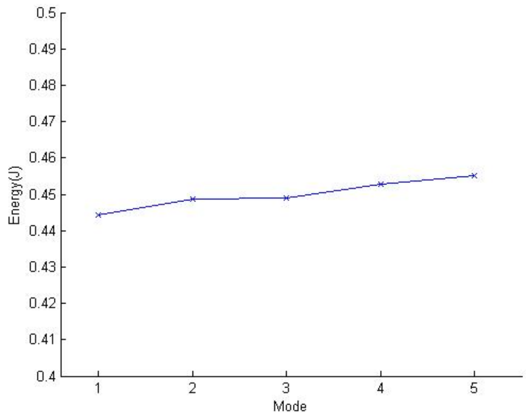

Fig 24 Energy Consumption in Pathway 2 Base stations Mode with Field Size: 100m x 100m and No. of Nodes: 25 (2)

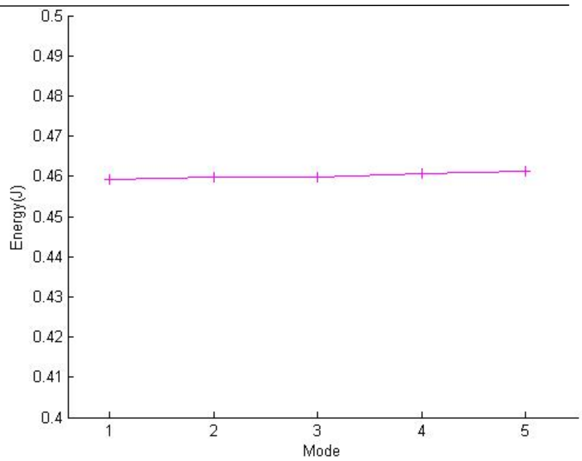

Fig 25 Energy Consumption in Pathway 2 Base stations Mode with Field Size: 50m x 50m and No. of Nodes: 50 (3)

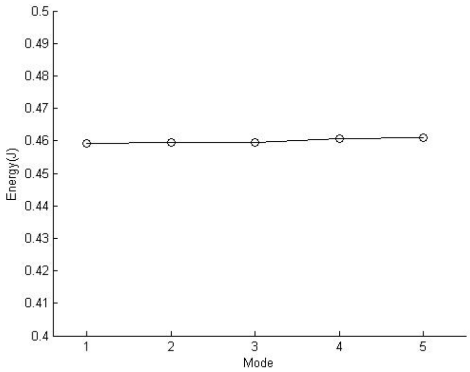

Fig 26 Energy Consumption in Pathway 2 Base stations Mode with Field Size: 50m x 50m and No. of Nodes: 25 (4)

So these graphs show that if we place two base station in the network field, the network consumes less energy as compared to the network with single base station. The two base station covers the whole network so that some nodes send their data to one base station and remaining nodes to the other base station.

I. Mobile Base station

In this case, base station can also change its position after certain number of rounds so that it can collect data from the whole field easily. Consider this case as mode 5 so that we can campare this mode with the modes of non-mobile Bs.

Table 7 Simulations Results for pathway model with Mobile BS

Mode	Field Size(meters)	Nodes	Energy	Consumption
5	100x100	50	0.4539	9.22%
5	100x100	25	0.4522	9.56%
5	50x50	50	0.4605	7.90%
5	50x50	25	0.4605	7.90%

The postion of the base staion can find same as the static modelbut repeat the process after specified frequency of rounds. Now we plot the graphs with mode 1,2,3,4 of non-mobile BS case and mode 5 of mobile BS case to compare the results.

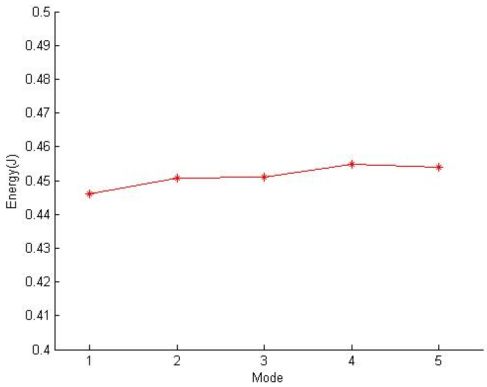

Fig 27 Energy Consumption in Pathway mobile BS Mode with Field Size: 100m x 100m and No. of Nodes: 50 (1)

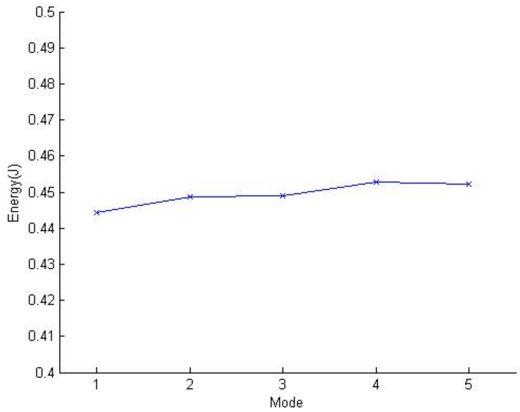

Fig 28 Energy Consumption in Pathway mobile BS Mode with Field Size: 100m x 100m and No. of Nodes: 25 (2)

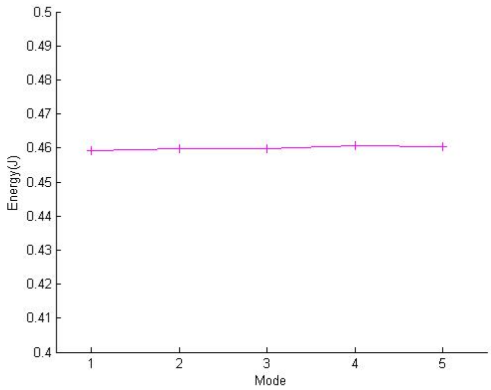

Fig 29 Energy Consumption in Pathway mobile BS Mode with Field Size: 50m x 50m and No. of Nodes: 50 (3)

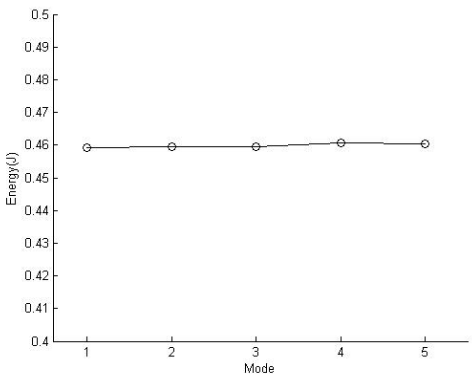

Fig 30 Energy Consumption in Pathway mobile BS Mode with Field Size: 50m x 50m and No. of Nodes: 25 (4)

These graphs show energy consumption for different modes with different number of nodes and different field size in static model.

By the results, mode 5 shows the mobile base station which consumes very less energy as compared to other modes because in this mode, BS station change its position after specific rounds. So that it covers the entire network field.

6. Conclusion

The aim of this research is to optimize the location of base station so that minimal energy is consumed. We have proposed an energy efficient usage of multiple, mobile base stations to increase the lifetime of wireless sensor networks. Our approach uses a scheme in which average minimum distance of nodes from BS is considered to determine the locations of the base stations. We infer from experiments that by using this approach, coupled with multiple and mobile BS, significant increase in network lifetime can be achieved.

We examined the performance of network for different mobility models in which nodes are mobile. We also considered different field size of the network and different number of nodes to conclude the results. Simulation results show that optimal position of BS and relocation technique reduce the usage of energy of the network. In addition, we also determined that BS relocation based on our method and multiple or mobile BS can extend network lifetime with respect to a static model with random location of base station.

References

[1] N. Sana, A. Muhammad, and S. Hwang, "Energy Efficient Routing in WSNs using Near and Far Field Communication," in *International Conference on Green and Human Information Technology*, 2019, pp. 297–300.

[2] I. Yaqoob *et al.*, "Internet of Things Architecture: Recent Advances, Taxonomy, Requirements, and Open Challenges," *IEEE Wirel. Commun.*, vol. 24, no. 3, pp. 10–16, 2017, doi: 10.1109/MWC.2017.1600421.

[3] M. M. Warrier and A. Kumar, "Energy efficient routing in Wireless Sensor Networks: A survey," *Proc. 2016 IEEE Int. Conf. Wirel. Commun. Signal Process. Networking, WiSPNET 2016*, pp. 1987–1992, 2016, doi: 10.1109/WiSPNET.2016.7566490.

[4] P. Rawat, K. D. Singh, H. Chaouchi, and J. M. Bonnin, "Wireless sensor networks: A survey on recent developments and potential synergies," *J. Supercomput.*, vol. 68, no. 1, pp. 1–48, 2014, doi: 10.1007/s11227-013-1021-9.

[5] D. Chen, Z. Liu, L. Wang, M. Dou, J. Chen, and H. Li, "Natural disaster monitoring with wireless sensor networks: A case study of data-intensive applications upon low-cost scalable systems," *Mob. Networks Appl.*, vol. 18, no. 5, pp. 651–663, 2013, doi: 10.1007/s11036-013-0456-9.

[6] E. Felemban, "Advanced Border Intrusion Detection and Surveillance Using Wireless Sensor Network Technology," *Int. J. Commun. Netw. Syst. Sci.*, vol. 06, no. 05, pp. 251–259, 2013, doi: 10.4236/ijcns.2013.65028.

[7] P. Giri, K. Ng, and W. Phillips, "Wireless Sensor Network System for Landslide Monitoring and Warning," *IEEE Trans. Instrum. Meas.*, vol. 68, no. 4, pp. 1210–1220, 2019, doi:

10.1109/TIM.2018.2861999.

[8] J. Yang, C. Zhang, X. Li, Y. Huang, S. Fu, and M. F. Acevedo, "Integration of wireless sensor networks in environmental monitoring cyber infrastructure," *Wirel. Networks*, vol. 16, no. 4, pp. 1091–1108, 2010, doi: 10.1007/s11276-009-0190-1.

[9] O. In, "Mobility-Based Communication in," no. July, pp. 56–62, 2006.

[10] R. A. Pushpa, A. Vallimayil, and V. R. S. Dhulipala, "Impact of mobility models on mobile sensor networks," *ICECT 2011 - 2011 3rd Int. Conf. Electron. Comput. Technol.*, vol. 4, pp. 102–106, 2011, doi: 10.1109/ICECTECH.2011.5941866.

[11] C. Schindelhauer, "Mobility in wireless networks," *Lect. Notes Comput. Sci. (including Subser. Lect. Notes Artif. Intell. Lect. Notes Bioinformatics)*, vol. 3831 LNCS, no. January, pp. 100–116, 2006, doi: 10.1007/11611257_9.

[12] F. Bai and A. Helmy, "Chapter 1 in Wireless Adhoc Networks," pp. 1–30.

[13] B. Divecha, A. Abraham, C. Grosan, and S. Sanyal, "Impact of Node Mobility on MANET Routing Protocols Models," vol. 5, no. 1, pp. 19–24, 2007.

[14] J. Yoon, M. Liu, and B. Noble, "Random Waypoint Considered Harmful," vol. 00, no. C, 2003.

[15] S. Buruhanudeen, M. Othman, M. Othman, and B. M. Ali, "Mobility Models , Broadcasting Methods and Factors Contributing Towards the Efficiency of the MANET Routing Protocols : Overview," pp. 1–5.

[16] J. Tian, J. Hähner, C. Becker, I. Stepanov, and K. Rothermel, "Graph-Based Mobility Model for Mobile Ad Hoc Network Simulation."

[17] G. Sun, X. Zhao, G. Shen, Y. Liu, and A. Wang, "Improving performance of distributed collaborative beamforming in mobile wireless sensor networks : a multi-objective optimization method," vol. 4662, no. c, pp. 1–16, 2020, doi: 10.1109/JIOT.2020.2983519.

[18] K. Akkaya, M. Younis, and M. Bangad, "Sink Repositioning For Enhanced Performance in Wireless Sensor Networks," pp. 1–22.

[19] E. I. Oyman and C. Ersoy, "Multiple Sink Network Design Problem in Large Scale Wireless Sensor Networks."

[20] F. Yu, E. Lee, S. Park, and S. Kim, "A Simple Location Propagation Scheme for Mobile Sink in Wireless Sensor Networks," vol. 14, no. 4, pp. 321–323, 2010.

[21] A. Bogdanov, E. Maneva, and S. Riesenfeld, "Power-aware Base Station Positioning for Sensor Networks," no. May 2014, 2004, doi: 10.1109/INFCOM.2004.1354529.

[22] M. F. Problem, "Algorithmica On Implementing the Push – Relabel Method for the," pp. 390–410, 1997.