IJRECE VOL. 6 ISSUE 4 (OCTOBER- DECEMBER 2018) ISSN: 2393-9028 (PRINT) | ISSN: 2348-2281 (ONLINE)

Mitigate the travelling time in WSN using Energy Efficient collection point algorithm

Y Venkatlakshmi [1], Karri babu [2]
[1]*Asst.Prof, Department of ECE, Abhinav Hitech College Of Engineering, Chilkur Balaji Temple Rd, Himayat Nagar, Hyderabad, Telengana, India-500075*
[2]*Asst.Prof, Department of CSE, Abhinav Hitech College Of Engineering, Chilkur Balaji Temple Rd, Himayat Nagar, Hyderabad, Telengana, India-500075*

Abstract- The benefits of using the sink mobility have been well recognized in wireless sensor networks (WSNs) to extend network lifetime. All types of obstacles could be there in the sensing field in physical atmospheres. Hence, to discover an obstacle-avoiding shortest route, a research challenge represents how to effectively dispatch the mobile sink. On the basis of cluster-based method, this paper offers an energy-effective routing mechanism for the mobile sink in WSNs with obstacles. The nodes selected as cluster heads collects data from their respective cluster members and send the collected data towards the mobile sink in relation to the cluster-based process. In this paper, from the starting site, the mobile sink starts the data-collecting route from time to time and then collects data directly from these cluster heads in a single-hop range, and finally comes back towards the beginning position. In order to discover the obstacle-avoidance shortest path, here we consider an existing scheme such as heuristic tour planning algorithm for the mobile sink. However, the conventional procedures are more challenging to solve because of the complexity of the planning problem in WSNs with obstacles as well as tour time. We propose an effective data gathering method to solve this problem. In order to discover the path for cluster heads and collect the data from CH's and store it, we propose a collection point process for the mobile sink constructed on the data collection. From the starting site, the mobile sink node starts the data-collecting route from time to time and then collects data directly from these collector points in a single-hop range, and finally comes back towards the beginning position. The effectiveness of our method is verified using Simulation results through NS2 software.

Keywords: WSN, Clustering, Mobile Sink, Cluster Head, Obstacles, Energy efficient routing.

I. INTRODUCTION

In many aspects such as health monitoring, environmental monitoring, military surveillance, and various others as Internet of Thing (IoT), Wireless Sensor Networks (WSNs) have been used [1]-[5]. Energy effectiveness has turned out to be the most significant concern for WSNs. Though, power supplies for sensor nodes are restricted as well as tough to exchange. Moreover, nodes nearby the base station (also named as sink) consume more energy than other nodes, as the nodes transmit the collected data using sensor nodes which is far away from the sink. Therefore, the data gathered by additional sensors cannot be sent to the sink once these sensors fail which are adjacent to the sink. Even though many of the nodes who still have a lot of energy, the overall network gets disconnected. Therefore, the vital challenge for WSNs is to prolong the lifespan of the network and to minimize the energy consumption of sensor nodes. A structure of a huge number of low cost, low power multi-efficient sensor nodes that are broadly spread either in the system or adjacent to it defines a sensor network**.** Sensing, data processing and communicating components are involved in these nodes whose size is very small. The location of these small nodes must not to be complete. However it also means those protocols of sensor networks and its procedures need to hold the self-organizing abilities in inaccessible regions and offers random allocation. Nevertheless energy supply and bandwidth limits the nodes and the low power consumption requirements is one of the most significant limitations on sensor nodes. Several challenges to the design and managing networks have been posed by these constraints which are joined using a specific deployment of large number of nodes. On the entire layers of networking protocol stack, these challenges require energy alertness. For overall sensor application categories, the issues associated with the physical and link layers are usually common. Dynamic voltage scaling, radio communication hardware, low duty cycle issues, system portioning, and energy aware MAC protocols are the areas where the research on System level power awareness has been focused. In order to find various techniques for energy-efficient route setup and reliable relaying of data from the sensor nodes towards the sink is the main intention so that the lifetime of the network is maximized at the network layer. We try to notice manufacturing issues and feature their suggestions in this area since the execution of a routing protocol is firmly recognized using the building model. To extend the lifespan of WSNs, various approaches have been proposed. A cross-layer optimized geographic node-disjoint multipath routing algorithm is proposed in this paper [6]. For reducing the energy expenditure of WSNs to a greater level, we can use a mobile node which is shown in recent efforts. The lifespan of WSNs is extended accordingly. Mobile nodes consume more energy and more powerful capabilities than the static nodes. By moving across the sensing field, Mobile nodes can collect data from entire static nodes that are usually mounted on a mobile vehicle equipped with sufficient energy.

Mobile nodes in one-hop or multi-hop way can collect the data from static nodes. Several different methods have been proposed by the papers [7]-[10]. In this paper, mobile nodes are employed as the mobile sink for data collection that moves across the sensing field. The mobile sink decreases the communication overhead for sensor nodes adjacent to the base station or the sink that leads to the uniform energy consumption in one way. In another way, we can process the disconnected and sparse network well with the movement of the sink. Thus, by the optimum control of the route of the mobile sink, the network lifespan can be expressively prolonged. The sensing field might include several difficulties in physical atmospheres. Therefore, an investigation challenge is proposed that helps to find an obstacle-avoiding shortest route for the mobile sink to extend the network lifespan.

In this paper, in order to discover an obstacle-avoiding shortest path, the mobile sink will move across the network with obstacles. When moving across the sensing field, the mobile sink must consider the energy consumption balance among the nodes at similar period. We use the cluster-based technique to dispatch the mobile sink effectively which is presented in [11] and [12]. Entire sensor nodes in the sensing field are distributed into two groups in relation to the cluster-based method: cluster heads and cluster members. Cluster heads performs data collection from resultant cluster members and then passes data to the mobile sink, whereas the cluster members collect environment information. As the mobile sink collects all sensing data from cluster heads, we consider that up to some extent of delay WSNs can endure. From starting position, the mobile sink initiates its periodical movement and returns finally. The sensing data from cluster heads is collected by the mobile sink during its movement. The mobile sink can move near the cluster heads by consuming less energy when its moving path is scheduled. Therefore, the lifetime of the network can be significantly extended. In this paper, the lifetime of the network is defined as the time interval where the sensor nodes start working from the initial stage until the expiry of entire static sensors. Nevertheless, in physical atmospheres, the scheduling for the mobile sink is made more complex by the sensing field that contains several obstacles. At this point, except to the site of obstacles, the mobile sink can move to any site. Thus, to find an obstacle-avoiding shortest route in the presence of obstacles, a research challenge is projected which shows the way to dispatch the mobile sink efficiently.

In order to make the problem of dispatching more simple in WSNs with obstacles, we consume certain steps to solve the scheduling for the mobile sink. We offer a grid-based method through which the sensing region is divided into the same size grid cells when the problem complexity is given. The size of the grid cells is closely related to communication radius of static sensors and they are considered to be the basic unit. There exist some obstacles in the grid cells as the two-dimensional plane is divided into grid cells which are of similar size. The obstacles may occupy some part of grid cells, since the grid cells are intersected by the edges of obstacles. We assume that the grid cell is considered as obstacles, when a part of one grid cell is occupied by the obstacles. Hence, to make the scheduling for the mobile sink more easily, we consider regularization shape of obstacles. In terms of the regularization shape of obstacles, we can then construct a spanning graph. The scheduling for the mobile sink will become more efficient with the search space of the mobile sink from all grid cells towards the spanning graph obtaining grid cells. Therefore, for the mobile sink, we could finally find an obstacle-avoiding shortest route.

II. RELATED WORK

The advantage of using the mobility of nodes has been well recognized in the recent studies. We can reduce the traffic burden and improve energy efficiency by using the mobility of nodes in WSNs. Therefore, the lifetime of the network is extended significantly. Several different approaches have been proposed in many papers. In the literature, the related works of the mobility of nodes is studied.

In order to minimize the communication cost the authors present a scheme named VGDRA for the mobile sink in [13]. The sensor field is divided into cells named as virtual grid which are of same size and the nodes adjacent to the center are selected as the cell-header nodes. Additionally, a virtual backbone structure is constructed which consists of the cell header nodes. By communicating with the border cell header nodes, the mobile sink collects the sensing data in moving across the sensor field. The reconstruction process of routes comprises only a subset of cell-header nodes in order to reduce the cost of overall communication. To ease the suboptimal energy dissipation, a mixed integer programming framework for base station is proposed by the authors in [14]. The base station mobility is introduced to WSNs with the intention of reversing the suboptimal energy dissipation trends. By using mobility patterns for base station, the lifetime of the network is finally prolonged. To build a convex optimization model, the paper [15] uses the technique of support vector regression through which the optimal trajectory of the mobile sink can be determined. A trajectory (called COT) affects the lifetime of the network. To collect the captured data of events, the mobile sink in the event-driven is used which maximizes the lifetime of the network.

For various sensor networks, a mobile data-gathering tour is proposed by the authors in [16]. To collect sensing data from static sensors, an M-collector is introduced which is similar to a mobile base station. From the base station, the MDC begins its periodical movement and finally returns towards the base station for data transferring. The authors take a divide-and-conquer strategy and use multiple M-collectors for some applications in large-scale networks, where each of them moves over a shorter data-gathering tour. In order to charge sensor nodes the authors adopt a wireless energy transfer technology in [17]. To charge some sensor nodes wirelessly, the Wireless Charging Vehicle (WCV) begins a periodical tour from the service station moves across the network and finally returns. A near-optimal solution for the optimization problem is designed by the authors in relation to the novel Reformulation-Linearization Technique (RLT). By means of a multi-round and multi-attribute sensor dispatch problem, the authors consider the of mobile sensors dispatch in [18] and [19]. Environment information is monitored and collected by Static sensors in a hybrid WSN. Only one attribute of events is sensed by each static sensor when events occur. The multiple attributes of events is evaluated by a mobile sensor compared to static sensors. For more detailed analysis, mobile sensors move towards corresponding hot locations in relation to the sensing data from static sensors. To dispatch mobile sensor for hot locations, a two-phase heuristic algorithm is presented by the authors in order to reduce the energy consumption. By using one-to-one approach in the first phase, the authors dispatch MAM sensors towards hot locations. A spanning-tree construction algorithm is presented by the authors for the displacement of MAM sensors according to unassigned hot locations in the second phase. A research challenge is presented which explains the way to dispatch mobile sensors to these hot locations because of similar capabilities of sensors. Nevertheless, the authors didn't consider that the sensing field might contain various obstacles in [13]-[19]. Indeed, the complexity of the route for mobile nodes in sensing field with obstacles is more compared to the sensing field without obstacles.

III. HEURISTIC OBSTACLE AVOIDING ALGORITHM

To find an obstacle-avoiding shortest route for the mobile sink, a heuristic algorithm is presented in this section. In order to construct the spanning graph of the network model, we use an algorithm for solving the dispatch problem of the mobile sink efficiently. All obstacle-avoiding paths can be obtained according to the spanning graph. Moreover, from these obstacle-avoiding routes, the obstacle-avoiding shortest route for the mobile sink can be obtained. Specific steps of the heuristic obstacle-avoiding algorithm are introduced below.

A. Spanning graph algorithm

The obstacle-avoiding shortest route problem is comparable to the Traveling Salesman Problem (TSP) which is a classical problem fundamentally. To solve the TSP, the minimum spanning tree can be utilized. Therefore, an obstacle-avoiding shortest route for the mobile sink can also be found in relation to the minimum spanning tree. A spanning graph which is an undirected graph contains entire minimum spanning trees in this paper. The construction the spanning graph is discussed in this paper. The spanning graph construction has been addressed by several investigations [20], [21]. For constructing the spanning graph, sweep line algorithm is utilized [20]. By making connections in-between the terminals and obstacle corners, the obstacle-avoiding spanning graph which is the set of edges can be formed. Into a finite set of sites, the infinite possible sites for the mobile sink movement will be reduced after the construction of a spanning graph. Hence, for the mobile sink scheduling, the algorithm built on the spanning graph makes it more effective.

B. Obstacle avoiding spanning graph construction

The sensing field might contain obstacles with different shapes and sizes in physical environments. On the basis of the spanning graph algorithm above, the obstacle-avoiding spanning graph for the mobile sink scheduling cannot be directly constructed because of the irregular shape of obstacles. Hence, in order to find an obstacle-avoiding shortest route for the mobile sink, a research challenge is presented which explains the technique of utilizing the spanning graph algorithm. To analyze and to solve the problems in WSNs, grid-based techniques are used in papers [22]-[26]. Here, to solve the problem of scheduling the mobile sink is solved using the grid-based techniques. By the usage grid-based techniques, the sensing region is divided into cells which are of the same size grid. Edges of obstacles intersect grid cells as well as obstacles may occupy part of some grid cells obviously. We assume that the grid cell is considered as obstacles whenever the obstacles occupy part of one grid cell.

```
Algorithm: Cluster Head Selection – CHS
Input:
• Deployment Area WSN = s*s,
• Set of sensor nodes $S = \{s_0, s_{1..} \dots s_n\}$ where $s_i$ represents ($x_i$, $y_i$), the
    coordinate of $i^{th}$ Sensor
• Transmission range $T_r$
Output:
• CLH–set of cluster heads
Start:
$(C, R) \leftarrow Welzl's\,(n, SNS)$ // Determine centre C and radius R of
    Welzl's circle that covers all SNS
$CLH \leftarrow \{\emptyset\}$
Partition WSN Area into square grids $G_i$ of side $2 * T_r$, with C as the
    Centre, to the extent possible.
Determine the grid centre points $cen_i$ for each $G_i$ from a set of grid
    centre points
$GP \leftarrow \{G_0 \dots G_m\}$
for $i = 0$ to $m$ where m is number of grids
begin //Identify CHs in welz_circle
    Identify $s_j$ closest to each $G_i$ in welzl_circle
    $CLH \leftarrow CLH \cup s_j$      //append $s_j$ to list of CHs
    $S \leftarrow S - s_j$             //remove $s_j$ from SNS
end for
End
```

IV. PROPOSED SYSTEM

This section describes about the proposed scheme in detail that includes the maintenance of new routes and construction of clusters to the recent location of mobile sink. Involving of clusters with unequal sizes, the entire sensing field is divided into equal regions in this method. The cluster members can communicate with CH in single hop as the Cluster head is placed at the center of every region. For cluster formation and CH selection, LEACH algorithm is invoked in each region. For keeping the track of sink's recent position and moreover relieving the load of cluster members from taking part in route adjustment, CHs are accountable. To sense the event and to report it to cluster head and the establishment of inter cluster communication through gateways is the main task of cluster members.

A. Network Model

For constructing a network model, the following characteristics of the network are taken into account.

- All nodes are assumed to be static and are deployed randomly throughout the sensing field.
- All the sensor nodes within the sensing field will have the same energy level (0.5 J), bandwidth initially and are homogeneous in nature.
- Based on the distance to reach their destination nodes, Sensor nodes use their transmission power.
- The two mobile sinks do not have any resource constraints and are highly powered.
- For every half of the round, both of the mobile sinks are allowed to move in counter clockwise direction to reduce the time taken for completing one round along the periphery of sensing field and to collect the data from CHs and to reduce the number of hops between the source and sink.
- To the limited number of cluster head nodes for readjusting the routes, latest location of sink and Time of Arrival (TOA) will be communicated based on the Time of Arrival (TOA) of sink.

B. Cluster Formation Phase

By dividing the sensing field into 'n' equal sized region, a cluster is constructed by the proposed scheme. For collecting the data from the cluster head of each cluster, unequal sized clustering varying time slots could be used. Out of 'N' number of nodes only 5% of nodes could act as cluster heads based on the LEACH protocol.

Where 'N' is number of nodes (N = 100, 200 to 400 and 500 to 600) and 'K' is number of equal sized region using equation no.(1) as well as a squared number. For each region, cluster heads will be chosen after partitioning the network. A node at the center point of each region will be elected as a cluster head at the beginning. A node closer to the center point and with high residual energy will be elected again as a cluster head after each round of data collection. A cluster head has to notify the status to its member within the region after the election of cluster head and the nodes which are slightly beyond the cluster boundary. With the primary cluster head the information about the secondary cluster head must be shared and the nodes receiving notification message from more than one cluster must associate themselves with the nearest cluster head. Every cluster head will form adjacencies with neighboring cluster heads using gateway nodes in this way.

C. Route adjustment

Nodes must setup their data delivery route in order to adjust with dynamic network topology caused by sink mobility regarding the latest location of the mobile sink. Throughout the network, flooding of location information is avoided in this approach and becomes energy consuming one. For the maintenance of new routes to the latest location of mobile sink only one set of cluster headers are accountable in this scheme.

D. Rotation of Cluster head

The threshold residual energy will be compared with residual energy of each cluster head after each round. The cluster head selection will be carried out only for that particular cluster whose residual energy falls below the minimum threshold residual energy. The cluster head which is closer to the center of the region and having higher residual energy will be selected as a new cluster head. Frequent re clustering is not needed in each round since we have unequal sized cluster in each region. Also energy consumption is reduced by avoiding cluster head election process or frequent re clustering. The load on the each cluster head as well as number of hops to reach the sink is reduced by the introduction of two mobile sinks. Therefore, when compared to the already existing method, it is proved that the proposed approach performs well.

```
Algorithm: Collection Point Selection
Input:
Set of $n$ sensor nodes S,
Set of cluster heads $CHS \leftarrow \{c□_0, c□_1 .. c□_m\}$
Transmission range $T_r$
Output
CLP- Set of collection points
Start:
for $i = 0$ to $m$
    $CL_i \leftarrow \{\emptyset\}$
    $S' \leftarrow S - CLH$ // remove cluster heads from $S$
    for $j = 0$ to $m$
    begin
        for $i = 0$ to $n$
        begin
            if $dist(s_i, c□_j) \leq T_r$
                $CL_j \leftarrow CL_j \cup s_i$    // add node $s_i$ to the cluster $cl_j$
        End for
        $S' \leftarrow S' - cl_j$   // remove nodes joined in $cl_j$ from $S'$
    End for
$L \leftarrow S'$
$CLP \leftarrow CLH \cup L$    //final set of collection points
$CLP \leftarrow Lin - Kernig□an(CLP)$//determine shortest path
End
Algorithm: dist ($P_1, P_2$)
Input
Two points $P_1$ and $P_2$ | $P_i \leftarrow (x_i, y_i)$
Output
Distance d between points $P_1$ and $P_2$
Start:
$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$
Return (d)
End
```

The distance in-between the nodes inside each cluster is reduced when the k-mean algorithm tries to partition the network graph into K number of clusters. K number of nodes is chosen at random first as the initial center nodes of the clusters. At that point, every node is allocated to its nearest cluster in every single iteration., the center node for each cluster is recalculated When all nodes have been thus assigned, and the process is repeated from the beginning based on the identity of the new center nodes. The clustering step stops when the obtained Centre nodes still the same in two consecutive iterations.

V. EXPERIMENTAL RESULTS

Over a 1000x500m^2 field where four obstacles exist along with 25 sensor nodes which are randomly distributed is assumed in this paper. In this paper, the situation where no hole in the sensing field exists is assumed and static sensors remain the same in their abilities. In the meantime, we assume that the mobile agent is located initially in the top-left corner of the two-dimensional territory and its coordinates are (50 m, 50 m). The mobile agent initiates its obstacle-avoiding periodical movement from beginning point and running towards to cluster heads and finally returns. Table1 presents the system parameters utilized in our simulations. In this paper, to simplify scheduling for the mobile agent, we accept that the information gathered by sensor nodes remains the deferral tolerant information, i.e., they can wait for the mobile agent to arrive and lift them up.

PARAMETER	VALUE
Application Traffic	CBR
Transmission rate	512bytes/ 0.5ms
Radio range	250m
Packet size	512 bytes
Maximum speed	25m/s
Simulation time	8000ms
Number of nodes	21
Area	1000x500
Grid size	10m

Table1: System parameters

- **Evaluation results**

To conduct numerous experiments in the sensing field with obstacles the energy efficient collection point algorithm is utilized in this section. The experimental results of the assumed algorithm in relation to the network lifetime and the path movement of mobile sink are presented below.

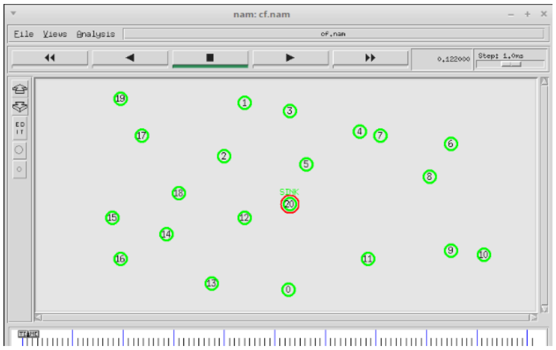

Figure 1: Network Deployment

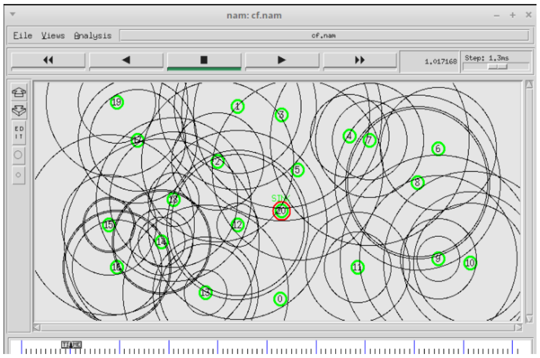

Figure 2: Broadcasting in Network

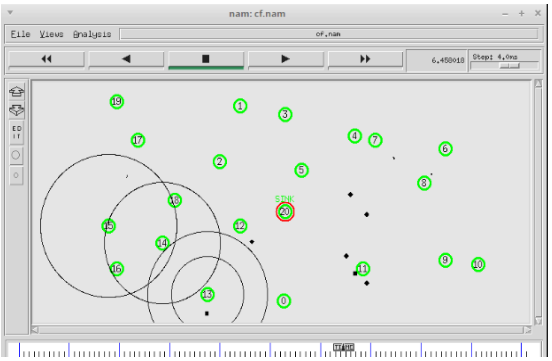

Figure 3: Packet loss due to heavy traffic

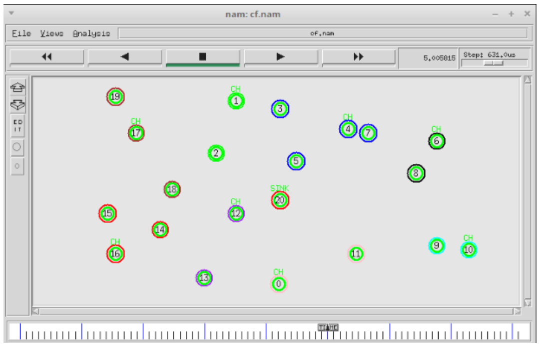

Figure 4: Nodes deployment in existing

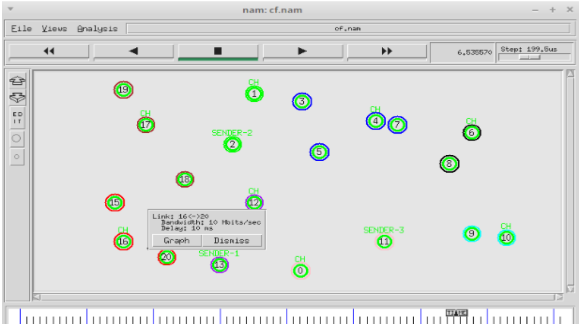

Figure 5: CH to Mobile sink data moving

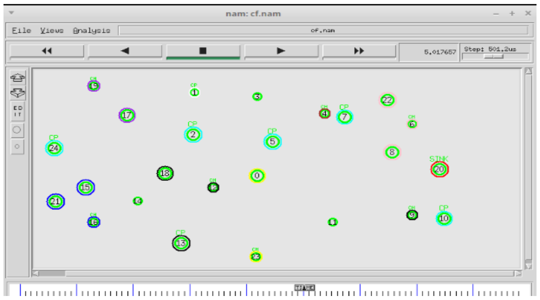

Figure 6: Proposed network deployed

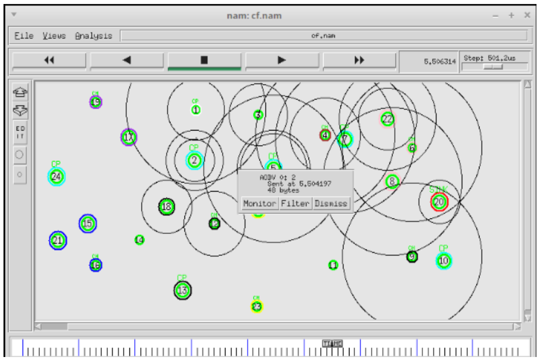

Figure 7: Broadcasting in proposed system

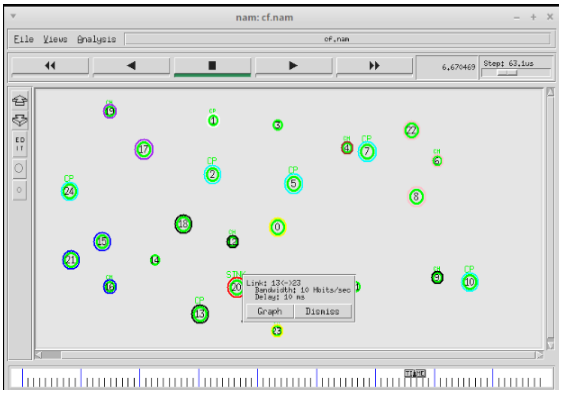

Figure 8: CP-13 to Mobile sink data process

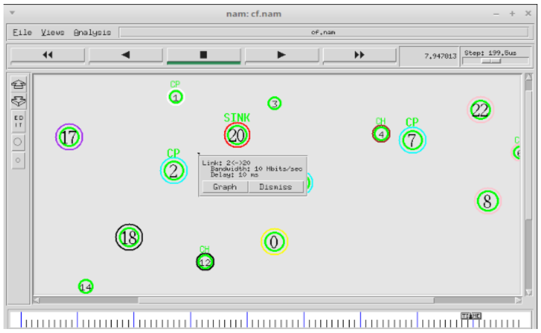

Figure 9: CP-2 to Mobile sink data process

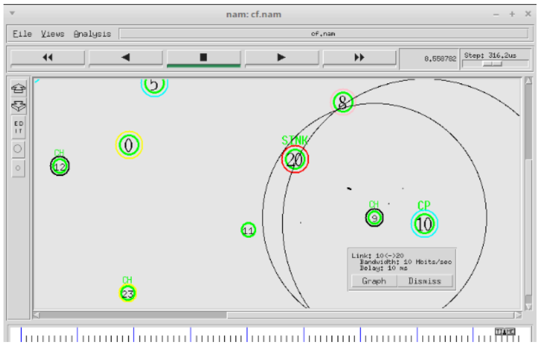

Figure 10: CP-10 to Mobile sink data process

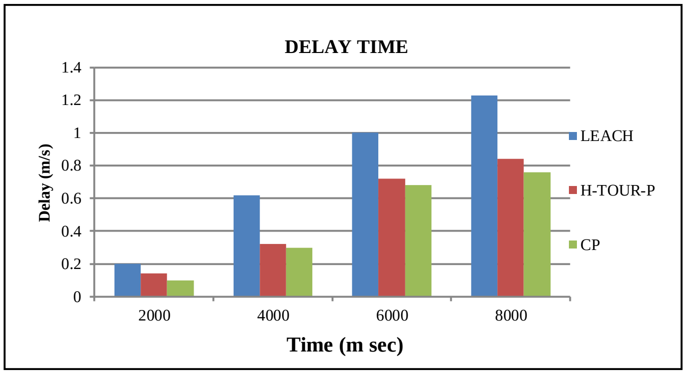

Figure 11: Performance on Delay

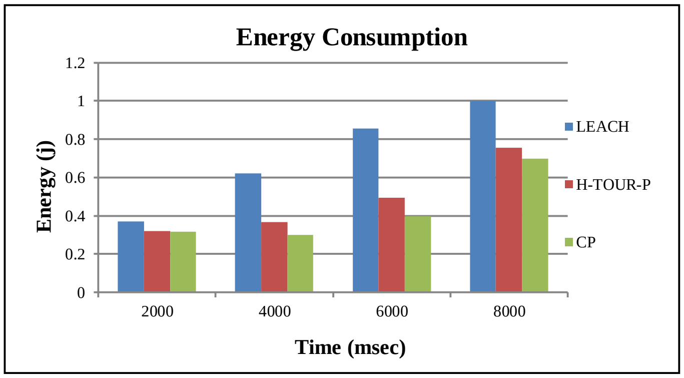

Figure 12: Energy level routing

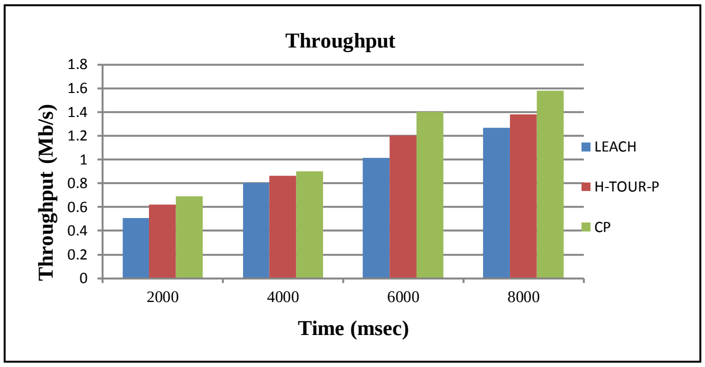

Figure 13: Network performance

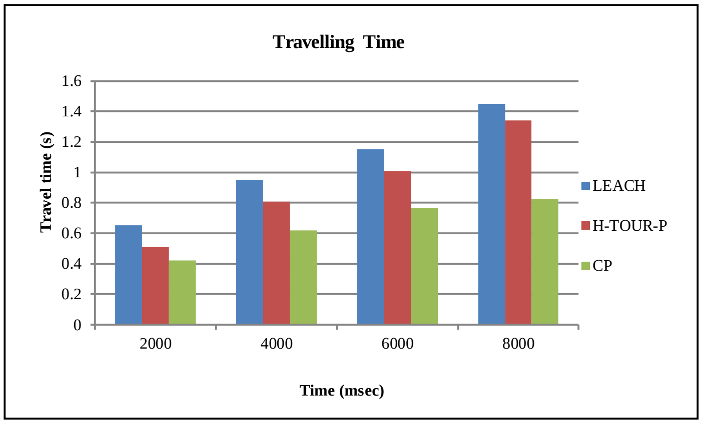

Figure 14: Travelling time in routing

In above presented screenshots, Fig 1 demonstrates that all nodes are placed in the network and the nodes deployment is properly done in the network. At this point, the entire nodes that are represented are on the basis of random topology values and it should mention the overall properties of NAM window.

Fig 2 shows the occurrence of broadcasting all over the network which is meant for the purpose of communication. In this process, entire nodes ought to be involved. Fig 3 shows that during communication process, packet loss is more due to the traffic. Leading three are indicated as cluster-based process in the aforementioned screens.

Fig 4 shows that, all nodes participate here and shows that which node considers a type of node that is mentioned in the above screenshot of nam. All the cluster head nodes which are considered are displayed. Here 20th node is considered as mobile sink.

The data delivery form CH to mobile sink is shown Fig5. Data delivering protocol, time interval and the amount of data delivered is also presented. Fig6 presents the network deployment of the proposed model. Fig 7 demonstrates a mechanism named as collection point scheme is proposed and added into a heuristic algorithm. Here the broadcasting occurs in network and it is meant for all the nodes that are placed in the network. Fig 8, Fig 9 and Fig 10 displays the data processing between collection points and mobile sink.

In Fig 11, graph represents an end-to-end delay and a simulation time versus delay is shown. The delay between communication nodes compared to heuristic-tour scheduling algorithm and normal cluster-method is decreased and the performance of energy efficient collection point algorithm improves delay time. Fig 12 represents energy consumption and simulation time versus energy graph. Compared to heuristic tour planning algorithm and normal cluster-based method, the presentation of energy efficient collection point mechanism increases the energy values. Fig 13 represents throughput and simulation time versus throughput graph. Compared to heuristic tour-planning procedure and cluster-based method, the presentation of energy efficient collection point algorithm enhances the throughput. Fig 14 represents tour time and range versus tour time graph. Compared to heuristic tour-planning procedure, the performance of energy efficient collection point algorithm enhances the tour time which means time saving interval.

V. CONCLUSION

To extend the lifetime of the network, the mobile sink is used in this paper. The sensing field might contain various obstacles in physical atmospheres. The grid-based technique towards the WSN with obstacles is introduced to simplify the mobile sink scheduling. To find an obstacle-avoiding shortest path for the mobile sink, a spanning graph is constructed at the same interval. To dispatch the mobile sink, a heuristic obstacle-avoiding algorithm based on the cluster-based method is applied. To minimize the number of obtained tours, an energy efficient collection scheme is proposed and based on collector ability more data is collected and the network lifetime is increased. Experimental results show that our cluster-based approach is feasible for mobile sink dispatching and simulation is carried out using NS2. Finally, an obstacle-avoiding shortest path for the mobile sink is found and the lifetime of the network is prolonged.

VI. REFERENCES

[1] J. C. Cuevas-Martinez, J. Canada-Bago, J. A. Fernandez-Prieto, and M. A. Gadeo-Martos, ``Knowledge-based duty cycle estimation in wireless sensor networks: Application for sound pressure monitoring," Appl. Soft Comput., vol. 13, no. 2, pp. 967_980, 2013.

[2] H.-L. Fu, H.-C. Chen, and P. Lin, ``Aps: Distributed air pollution sensing system on wireless sensor and robot networks," *Comput. Commun.*, vol. 35, no. 9, pp. 1141_1150, 2012.

[3] Z. Shen *et al.*, ``Energy consumption monitoring for sensor nodes in snap," Int. J. Sensor Netw., vol. 13, no. 2, pp. 112_120, 2013.

[4] B. Zhou, S. Yang, T. H. Nguyen, T. Sun, and K. T. V. Grattan, ``Wireless sensor network platform for intrinsic optical _ber pH sensors," IEEE Sensors J., vol. 14, no. 4, pp. 1313_1320, Apr. 2014.

[5] M. Dong, X. Liu, Z. Qian, A. Liu, and T. Wang, ``QoE-ensured price competition model for emerging mobile networks," IEEE Wireless Commun., vol. 22, no. 4, pp. 50_57, Aug. 2015.

[6] G. Han *et al.*, ``Cross-layer optimized routing in wireless sensor networks with duty-cycle and energy harvesting," Wireless Commun. Mobile Comput., vol. 15, no. 16, pp. 1957_1981, 2015.

[7] M. Zhao, Y. Yang, and C. Wang, ``Mobile data gathering with load balanced clustering and dual data uploading in wireless sensor networks," IEEE Trans. Mobile Comput., vol. 14, no. 4, pp. 770_785, Apr. 2015.

[8] L. Ji, Y. Yang, and W. Wang, ``Mobility assisted data gathering with solar irradiance awareness in heterogeneous energy replenishable wireless sensor networks," Comput. Commun., vol. 69, pp. 88_97, Sep. 2015.

[9] M. Dong *et al.*, ``Mobile agent-based energy-aware and user-centric data collection in wireless sensor networks," Comput. Netw., vol. 74, pp. 58_70, Dec. 2014.

[10] S. Guo, C. Wang, and Y. Yang, ``Joint mobile data gathering and energy provisioning in wireless rechargeable sensor networks," IEEE Trans. Mobile Comput., vol. 13, no. 12, pp. 2836_2852, Dec. 2014.

[11] W. B. Heinzelman, A. P. Chandrakasan, and H. Balakrishnan, ``An application-speci_c protocol architecture for wireless microsensor networks," IEEE Trans. Wireless Commun., vol. 1, no. 4, pp. 660_670, Oct. 2002.

[12] G. Smaragdakis, I. Matta, and A. Bestavros, ``SEP: A stable election protocol for clustered heterogeneous wireless sensor networks," in Proc. SANPA, 2004, pp. 1_11.

[13] A. W. Khan, A. H. Abdullah, M. A. Razzaque, and J. I. Bangash, ``VGDRA: A virtual grid-based dynamic routes adjustment scheme for mobile sink-based wireless sensor networks," *IEEE Sensors J.*, vol. 15, no. 1, pp. 526_534, Jan. 2015.

[14] O. Cayirpunar, E. Kadioglu-Urtis, and B. Tavli, ``Optimal base station mobility patterns for wireless sensor network lifetime maximization," *IEEE Sensors J.*, vol. 15, no. 11, pp. 6592_6603, Nov. 2015.

[15] F. Tashtarian, M. H. Y. Moghaddam, K. Sohraby, and S. Effati, ``On maximizing the lifetime of wireless sensor networks in event-driven applications with mobile sinks," *IEEE Trans. Veh. Technol.*, vol. 64, no. 7, pp. 3177_3189, Jul. 2015.

[16] M. Ma, Y. Yang, and M. Zhao, ``Tour planning for mobile data-gathering mechanisms in wireless sensor networks," *IEEE Trans. Veh. Technol.*, vol. 62, no. 4, pp. 1472_1482, May 2013.

[17] L. Xie, Y. Shi, Y. T. Hou, W. Lou, H. D. Sherali, and S. F. Midkiff, ``Multi-node wireless energy charging in sensor networks," *IEEE/ACM Trans. Netw.*, vol. 23, no. 2, pp. 437_450, Apr. 2015.

[18] Y.-C. Wang, ``A two-phase dispatch heuristic to schedule the movement of multi-attribute mobile sensors in a hybrid wireless sensor network," *IEEE Trans. Mobile Comput.*, vol. 13, no. 4, pp. 709_722, Apr. 2014.

[19] Y.-C. Wang, ``Ef_cient dispatch of multi-capability mobile sensors in hybrid wireless sensor networks," in *Proc. IEEE VTS Asia Paci_cWireless Commun. Symp. (APWCS)*, 2012, pp. 1_5.

[20] H. Zhou, N. Shenoy, and W. Nicholls, ``Ef_cient minimum spanning tree construction without Delaunay triangulation," *Inf. Process. Lett.*, vol. 81, no. 5, pp. 271_276, 2002.

[21] Z. Shen, C. C. N. Chu, and Y.-M. Li, ``Ef_cient rectilinear Steiner tree construction with rectilinear blockages," in *Proc. IEEE Int. Conf. Comput. Design Conf.*, Oct. 2005, pp. 38_44.

[22] C. Ai, L. Guo, Z. Cai, and Y. Li, ``Processing area queries in wireless sensor networks," in *Proc. 5th Int. Conf. Mobile Ad-Hoc Sensor Netw.* 2009, pp. 1_8.

[23] I.-H. Peng and Y.-W. Chen, ``Energy consumption bounds analysis and it applications for grid based wireless sensor networks," *J. Netw. Comput. Appl.*, vol. 36, no. 1, pp. 444_451, 2013.

[24] K. Xu, G. Takahara, and H. Hassanein, ``On the robustness of grid-based deployment in wireless sensor networks," in *Proc. Int. Conf. Wireless Commun. Mobile Comput.*, 2006, pp. 1183_1188.

[25] Z. Zhou, J. Tang, L.-J. Zhang, K. Ning, and Q. Wang, ``EGF-tree: An energy-ef_cient index tree for facilitating multi-region query aggregation in the Internet of Things," *Pers. Ubiquitous Comput.*, vol. 18, no. 4, pp. 951_966, 2014.

[26] G. Han, A. Qian, J. Jiang, N. Sun, and L. Liu, ``A grid-based joint routing and charging algorithm for industrial wireless rechargeable sensor networks," *Comput. Netw.*, in press, 2016. [Online]. Available: http://dx.doi.org/10.1016/j.comnet.2015.12.014.