Grid Based Data Dissemination Protocol for Mobile Sink in Wireless Sensor Network

Mohammad Reza Majma
Computer Engineering Department
Islamic Azad University, science and research Branch
Tehran, Iran
m_majma@srbiau.ac.ir

Hossein Pedram
Computer Engineering Department
Amirkabir University of Technology
Tehran, Iran
pedram@aut.ac.ir

Mehdi Dehghan TakhtFoladi
Computer Engineering Department
Amirkabir University of Technology
Tehran, Iran
dehghan@ce.aut.ac.ir

Sanaz Almassi
Sama Technical and Vocational College,
Islamic Azad University, Tehran Branch
Tehran, Iran
sanazalmassi@comp.iust.ac.ir

***Abstract*—Life time and Energy Efficiency are important factors in the design of wireless sensor network. A critical issue during data collection is the formation of energy holes near the sink. Sensors near the sink have to participate in relaying data on behalf of other sensors and thus their energy will be depleted very quickly. The mobile sink movement yields the significant performance gained through decreasing the amount of energy consumption. In this study, we propose a Grid Based approach for Data Disseminating to the Mobile Sink in Wireless Sensor Network. Mapping the position of nodes and sink to virtual grid infrastructure construct our main contribution. So that the data which is buffered by nodes could be disseminated to the mobile sink to the optimal manner. Finally, comprehensive simulation reveals the superiority of proposed algorithm in various scenarios.**

Wireless Sensor Network, Data Dissemination, Mobile Sink, Virtual Grid Infrastructure

I. INTRODUCTION

In recent years, Wireless sensor networks have been applied in many different fields. These networks are consist of wireless nodes with sensing capabilities and are settled in different environments to perform different tasks such as monitoring, controlling industrial processes, unpleasant events distinction and etc. [1].

Many protocols have been presented for data collection and propagation in WSN [2]. One of the most important goals in these solutions is to minimize energy consumption of sensor nodes to increase network life time and availability.

When the sink is stationary in network, the energy of sensor nodes which are directly in relation with the sink (sink neighbors) would be expire rapidly. Sink neighbors not only consume energy to transfer their sensed data, but also their energy is consumed to transfer other node’s data to the sink. This problem which is called “sink neighborhood problem” will lead to unripe and untimely communication termination in network. Sink will detach from network because of its neighbors death, while most of sensor network nodes are still active and useable [3].

To resolve this problem, the idea of mobile sink could be effective. Using mobile sink idea will lead to energy consumption distribution, it decrease energy consumption and increase network life time. On the other hand, the challenges of mobile sink could be mentioned as data delay, overhead arising from constructing and releasing data transmission paths from sensor nodes to current sink location, sink’s movement rate determination and to obtain sink’s settlement time in different places in order to collect data. Also in mobile sink mechanism, it’s too significant to propose routing algorithms for packet transmission to the sink with negligible overhead. In most proposed methods, a virtual substructure is used to decrease transmission overhead. In this paper, we have also used a grid base flat virtual substructure and routing is performed based on cellular addressing method. As a set of nodes locates in a region (cell), Cellular addressing has much less overhead in comparison with general or location base addressing [4].

In the next section of paper, we will illustrate the related works and algorithms based on mobile sink. In the third section, the details and trend of proposed algorithm will be investigated and by the last section, we will evaluate the algorithm performance and the simulation results will be analyzed.

II. RELATED WORKS

TTDD (Two-Tier Data Dissemination) is a protocol which is proposed for data dissemination by using a grid-like substructure [5]. When a source node detects a certain stimulus, each node constructs a grid structure and the location information is managed by the dissemination node which is the sensor closest to grid point in TTDD and the data source must be one of the dissemination nodes in the own grid structure. As a result, TTDD can reduce overhead. But TTDD has a problem which is that TTDD has to build a grid structure whenever a source detects a stimulus. In this reason, if a certain stimulus is found in several regions, TTDD creates many control packets to construct grid structure that it caused energy-inefficient.

In [6] network life time has been increased by using mobility and routing methods. In this algorithm, mobile sink is capable of traffic balancing between sensor nodes. To achieve this goal the traffic load between the nodes has been minimized. But this method has a problem, where utilizing the shortest path for data gathering is not generally an efficient solution for all network types.

In [7], a virtual grid substructure is used for routing. In this method, network is divided into cells and routing is performed based on cellular structure. In each cell, a node with highest energy level is selected as router and guides the packet to the sink, although this method do not support mobile sink.

The QDD [8] protocol defines a common hierarchy of data forwarding nodes created by a quadtree-based partitioning of the physical network. In this approach, when a source node detects a new event, it calculates a set of rendezvous points by successively partitioning the sensor field into four equally logical quadrants, and the data reports are sent to the nodes that are closer to the centroid of each successive partition. The mobile sink follows the same strategy for the query packet transmission. The main drawback of this approach is that few static nodes will be selected as rendezvous points inducing a hot spot problem that may decrease the network lifetime and reliability.

LBDD defines a vertical line or strip that divides the sensor field into two equal parts [9]. Nodes within the boundaries of this wide line are called *inline nodes*. This line acts as a rendezvous area for data storage and look up. When a sensor detects a new event, it transmits a data report toward the virtual line. This data is stored on the first inline-node encountered and the sink sends its query toward the rendezvous area. Then, the query is propagated along the virtual line until it arrives to the inline node that owns the requested data. Thus, data reports are sent directly to the sink.

CBRPM [10] is a Cluster-Based Routing Protocol for Supporting Mobile Sinks in Sensor Network. To figure out multiple mobile sinks problem, all source nodes vertically forward data announcement packets and all sink nodes forward data request packets horizontality. Also, to prolong the life time of whole sensor network, CBRPM allows 1-hop forwarding as solution of void grid problem.

In [11] a cluster of sensors is formed around the target to collect the information which is sent to the sink in multi-hop communication. Using the target information the sink moves toward the target for reducing the communication cost and saving the energy of moles.in this method clustering around target has too much overhead.

III. THE PROPOSED ALGORITHM

We have used an algorithm which has similar characteristics with deterministic routing algorithm in network on chip. In [12] we have compared and evaluated routing algorithms in network on chip and wireless sensor networks. In deterministic routing methods the movement is done just in vertical and horizontal positions (4 main directions), but in our proposed algorithm, the movement is done in 4 main directions and 4 secondary directions, with attention to the sink position. We have used cellular addressing to increase routing overhead. If we suppose N as the number of nodes in network: N={1,...,n} and C as the number of cells defined in network, C={1,…,m} and S indicates sink in network, the assumptions in this algorithm is as follow:

- In this algorithm all the nodes are aware of their geographical position. This goal is achieved by using GPS or using methods proposed in [13] for position estimation.
- All the nodes in N, map their position to the virtual substructure and they are connected to each other and to the sink, using this substructure.
- There is at least one node ($x \in N$) in each cell ($c \in C$).
- All the nodes in N are stationary. S can be stationary or mobile.
- S would send its virtual position to all the nodes in N.
- Nodes can send data to the sink with one hop or multi hop method.

A. Virtual Grid Construction

When the network starts to work, a virtual substructure is formed. This substructure is a grid base structure with similar cells as 1..m where the longitude and latitude in cells are equal to α. α is a parameter which could be variant based on sensor network utilization.

By starting the network to work, all the nodes and sink, map their position to the virtual position. Afterwards, they transmit their virtual position to their neighbors with bounded radius. The frequency radius is illustrated in the next section. Sink will send its virtual position to network. As the mapping value is negligible, the nodes do not tolerate much overhead for data receiving/transmitting process. If we assume X_p and Y_p as two physical points node/sink and X_l and Y_l as mapped points, then by considering the (1) the virtual position of nodes could be generated as follow:

$$X_l = \left\lceil \frac{Xp}{\alpha} \right\rceil,\ Y_l = \left\lceil \frac{Yp}{\alpha} \right\rceil \qquad (1)$$

The nodes transmit their achieved virtual position to their neighbors. By receiving this packet, the neighbors store it in a defined table. Each node, transmit its id, physical position(X, Y) and virtual position (X_l,Y_l) to the neighbors. Fig. 1 presents an example where the node 5, sends its physical position (22.2, 43.8) and its virtual position (1, 2) to the neighbors. Fig. 2 illustrates the table for node 8 (neighbor with node 5) which has received the packets from node 5 and other neighbors (nodes number 7, 23, 11). In this example, we have assumed the α size for each cell equal to 25 meters.

ID	X	Y	X_l	Y_l
5	22.2	43.8	1	2

Figure 1. Sent packet format to node 5's neighbors

No	Node ID	X	Y	X_l	Y_l
1	5	22.2	43.8	1	2
2	7	30.8	2.9	2	1
3	23	10.1	48.5	1	2
4	11	14.1	19.7	1	1
5	⋮	⋮	⋮	⋮	⋮

Figure 2. Node 8's table

B. Cell Size (α)

As mentioned in previous section, the cell size should cover at least one neighbor cell which is at least one hop away from the cell containing the node. The cell size has direct relation with transmission radius of nodes. Node stationing in a cell should cover its neighbor cells; else it would confront a hole in the grid. In the worst state, for data transmission in main directions, if we assume r as frequency radius and $\alpha\sqrt{2}$ as cell diagonal, the r value imitates the following relation:

$$\alpha + \alpha = 2\alpha \rightarrow r \geq 2\alpha \quad (2)$$

And in the worst state, for sending data in secondary directions the r value is equal to:

$$\alpha\sqrt{2} + \alpha\sqrt{2} \rightarrow r \geq 2\alpha\sqrt{2} \quad (3)$$

Each node should cover the neighbor nodes settling in eight neighbor cells. Hence r value would be calculated as (3).

C. Data Dissemination from Source to Mobile Sink

By forming the grid, if a node detects a stimulus or a target, it generates relevant data and sends it to the sink. Finding a path from source to the sink would be performed using a cellular routing algorithm as follow:

1- By considering the virtual position for each node and each sink in network, μ1 and μ2 value could be calculated for each node as (4):

$$\mu 1 = |Xlt - Xls|,\ \mu 2 = |Ylt - Yls| \quad (4)$$

Where Xlt and Ylt is the virtual position for a source detecting a target or stimulus ant Xls and Yls is the virtual position for the sink.

2- The next cell address (c_{des}) which data should be transmit, would be calculated from the algorithm presented in Fig. 3.

3- After selecting (c_{des}), the source node investigates its table and selects one of the nodes in c_{des} cell randomly and transmits data to that node.

4- If S in c_{des} → data send to sink directly.

5- If c_{src}=c_{des} and S in c_{des} → data send to sink directly.

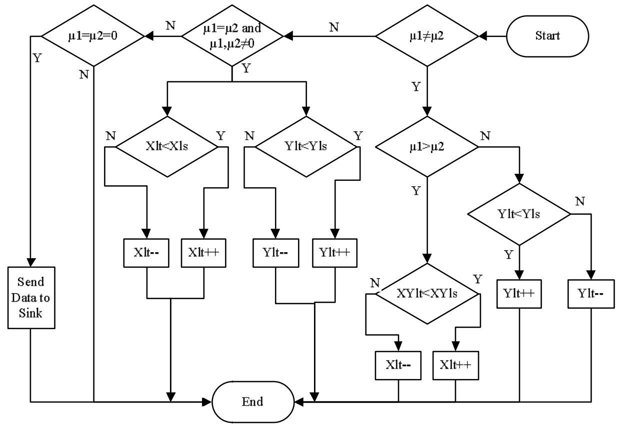

Figure 3. Proposed data dissemination algorithm

Fig. 4 and Fig. 5 illustrate the suggested algorithm mechanism. In Fig. 4 the node senses the target and should transmit data to the sink. Based on algorithm, the next cell (c_{des}) is 22. The source node searches for all the nodes locating in cell 22 in its table and selects one of them randomly. Afterwards it transmits data to the random node. The same mechanism is performed in the current cell (Fig. 5) and data will be sent to the sink. In this figure the next cell is 23. This process continues until sink receives data.

IV. PERFORMANCE EVALUATION

We have used Castalia 3.2 simulator which is based on OMNET++ for performance evaluation of our proposed algorithm. In this simulation, the whole network size is assumed as 300*300 square meters with 300 sensor nodes and a mobile sink. The simulation run time is 200 seconds.

Simulation parameters are listed in table 1. In addition, a free space model with β = 2 is assumed for communication channel. For wireless channel we used single disk model. This way all nodes at a certain distance from a transmitter, get the exact same signal strength and all links are perfectly bidirectional (Sigma=0)

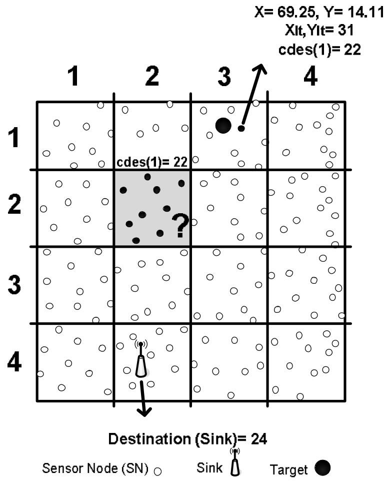

Figure 4. Next cell selection (c_{des}) for sending data from source to sink

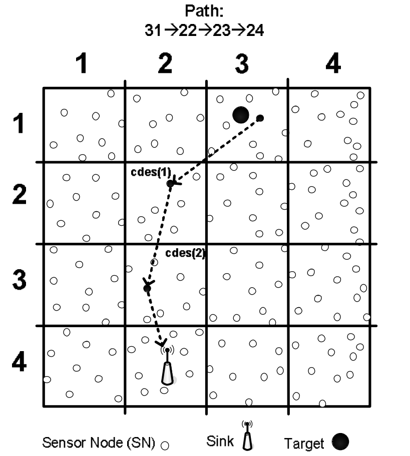

Figure 5. Selected path for data dissemination with suggested algorithm

TABLE I. SIMULATION PARAMETERS

Parameter	*Value*
Initial Energy	0.5 mW
DataRate	250 kbps
Modulation Type	PSK
bitsPerSymbol	4
Bandwidth	20 MHZ
Packet rate	1
Cell size (α)	25 m
Application Name	ThroughputTest
MaxData	100000
Startup Delay	10s
Sink	Node[0]
Velocity of Sink	1m/s

All presented results represent the average of 5 simulation runs with a resulting confidence interval level of 95 percent. To evaluate the performance, we have compared the results in different situations based on various parameters such as node placement, cell size and sink velocity.

We have evaluated the proposed algorithm with node placement parameter and the results are presented in Fig. 6. To evaluate this parameter, we have distributed the nodes in 12*12 m^2 grid using normal distribution randomly. The results illustrate proportional improvement for node placement with grid sub structure.

This improvement is more perceptible with 200 and 300 nodes in simulation, because the grid cells contain approximately equal nodes. But when the dimension of nodes increases to 400 and 500 nodes, sink have approximately received same number of packets from the nodes. The main reason for similar total packets received by sink is higher collision rate which occurs in network.

We have evaluated the relation between the number of sensor nodes and cell size and the result is presented in Fig. 7. The results illustrate that when we have fewer nodes in network, by increasing the cell size, more packets will be received by sink. By increment in cell size and number of nodes, better results could be achieved. In such a manner that by increasing the number of nodes, but no increment in cell size, sink do not receive too many packets.

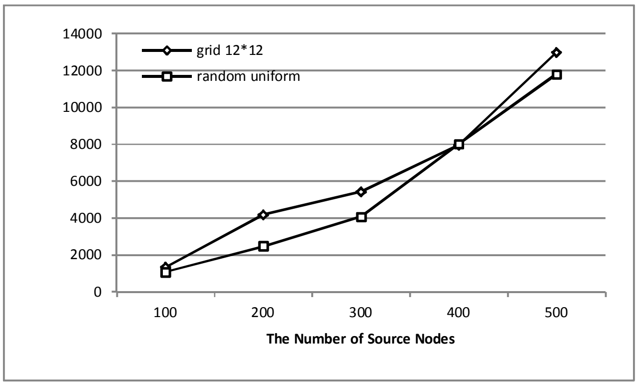

Figure 6. The node placement

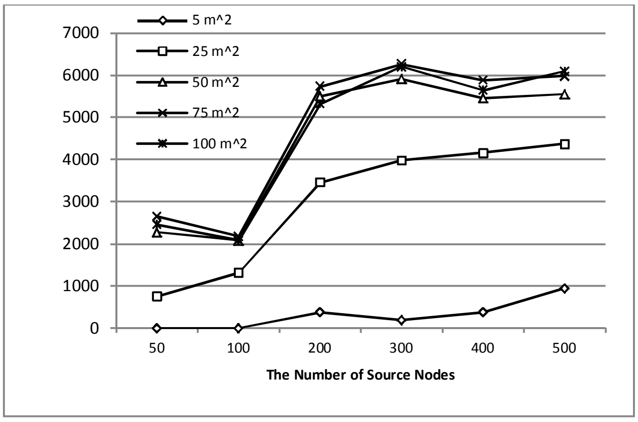

Figure 7. The relation between cell size and number of nodes

For instance, by increasing the nodes from 50 to 500, but no increment in cell size (5 m^2), less than 1000 packets will be received on the whole. But when the number of nodes increases from 100 to 200 and the cell size increases from 5 to 25, more than 2000 packets will be delivered by sink.

The best result will be achieved when the cell size is 75 m^2 and we have 300 nodes in network. The results illustrate that by cell size increment from75 to 100, the results will not change for a great deal.

We have evaluated the relation between sink velocity and cell size and the results are presented in Fig. 8. When the sink do not move, by increasing the cell size from 5 to 25 m^2, more packets would be delivered to sink; however when we consider the cell size increment from 25 to 100 m^2, the results won't change that much. The results illustrate that when sink moves with 5 m/s speed, fewer packets will be delivered to sink but when sink velocity increases to 10m/s, 6000 packets will be received by sink in the best condition. The results do not change greatly by sink speed increment from 10 to 15 and 20. Finally when sink velocity exceed to 20 and over, fewer packets will be received. The results illustrate that with cell size equal to 25 m^2 and sink velocity between 10 m/s to 20 m/s, best results will be achieved. Also with cell size increment from 25 to 50, 75 or 100 m^2, with different sink speed, no progress will be achieved.

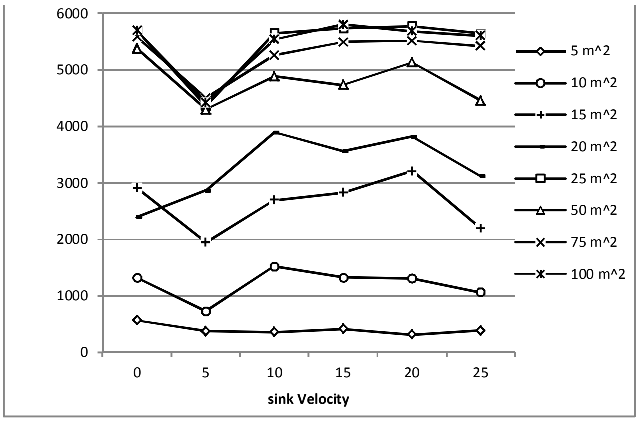

Figure 8. The relation of cell size and sink velocity

V. CONCLUSION & FUTURE WORK

Sink mobility is one of the most important techniques to decrease energy consumption and to increase network life time in wireless sensor networks. In this paper we proposed a Grid Based approach for Data Disseminating to the Mobile Sink in Wireless Sensor Network. In this algorithm, nodes settle in cells. At the beginning, nodes map their physical locations to virtual positions and they will broadcast it to their neighbors. After recognizing the neighbors, the source node disseminates the data to the target cell using cellular addressing. This trend continues until sink receives data. If sink begins to move and leaves the current cell, the new virtual position will be broadcast to network nodes. We can tolerate the virtual position overhead since virtual position has a small packet size.

The optimized cell size and next node selection in next cell are challenges which could be considered in future works. Also sink location update is the other challenge which should be observed in future works in mobile sink wireless sensor networks.

REFERENCES

[1] I.F. Akyildiz, W. Su, Y. Sankarasubramaniam and E. Cayirci, “A survey on sensor networks,” IEEE Commun. Magazine, pp. 102-114, Aug. 2002.

[2] R. Shah, S. Roy, S. Jain and W. Brunette, “Data MULEs: modeling a three-tier architecture for sparse sensor networks,” Elsevier Ad Hoc Networks Journal, Vol. 1, pp. 215-233, Sept. 2003.

[3] A. Kansal, A. Somasundara, D. Jea, M. Srivastava and D. Estrin. Intelligent Fluid Infrastructure for Embedded Networks. Proc. 7th Annual Intl. Conf. on Mobile Systems, Applications and Services(MobiSys), 2004, pp.111-124.

[4] J.Heidemann, F. Silva, C. Intanagonwiwat, R. Govindan, D. Estrin, D. Ganesan, Building efficient wireless sensor networks with lowlevel naming, in: Proceedings of the Symposium on Operating Systems Principles, Banff, Canada, October, 2001.

[5] H. Luo, F. Ye, J. Cheng, S. Lu and L. Zhang, "TTDD: Twotier Data Dissemination in Large-scale Wireless Sensor Networks", ACM/Kluwer Mobile Networks and Applications(MONET), pp. 148-159, Sept. 2003.

[6] J. Luo and J.-P.Hubaux, “Joint Mobility and Routing for Lifetime Elongation in Wireless Sensor Networks,” Proc. IEEE INFOCOM, 2005.

[7] Jae Young Choi, HyungSeok Kim, IljooBaek and Wook Hyun Kwon, "Cell based energy density aware routing: a new protocol for improving the lifetime of wireless sensor networks," Computer Communications 28, Elsevier B.V. 2005.

[8] Z. H. Mir and Y.-B.Ko, “A Quadtree-Based Data Dissemination Protocol for Wireless Sensor Networks with Mobile Sinks,” PWC 2006, Albacete, Spain, Sept. 2006.

[9] E. B. Hamida and G. Chelius, “A Line-Based Data Dissemination Protocol for Wireless Sensor Networks with Mobile Sink,” Proc. IEEE ICC ’08, Beijing, China, May 2008.

[10] Jieun Cho and JongWonChoe, "A Cluster-Based Routing Protocol for Supporting Mobile Sinks in Sensor Network," Information Networking, ICOIN 2008.

[11] Trinh, T. Hai, Youn and H. Yong, "On Mobile Sink Node for Target Tracking in Wireless Sensor Networks," Fifth Annual IEEE International Conference on Pervasive Computing and Communications Workshops, 2007.

[12] M.R.Majma, M.Dehghan and F.tashtarian, "Comparison and Performance Evaluation of Routing Algorithms between Wireless Sensor Networks and Interconnection Networks," 5thSASTech, Khavaran Highereducation Institute, Mashhad, Iran. May 2011.

[13] J. Albowitz, A. Chen, L. Zhang, Recursive position estimation in sensor networks, in: Proceedings of the Ninth IEEE International Conference on ICNP, 2001 pp. 35–41.