Depth First Based Sink Mobility Model for Wireless Sensor Networks

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Abstract— **Using mobile sink to collect data from static sensor nodes in wireless sensor networks has been an interesting area of research. As a result, several mobility models were proposed. Every mobility model has its own properties and features that may affect the performance of the network. In this paper, we propose using a depth first based mobility model in wireless sensor networks. Consequently, a single mobile sink is present all the time in the network and is moving according to the depth first based mobility model through the network in order to collect data from static sensor nodes. The proposed mobility model works along with AODV routing protocol in order to route messages to the mobile sink when needed. Furthermore, the proposed mobility model is implemented and simulated using NS-2 simulator. Finally, the performance of the proposed work was studied under different parameters namely, throughput, End-to-End delay and packet delivery ratio.**

***Keywords*-Wireless Sensor Networks (WSNs), Mobile Sink, Depth First Traversal, AODV, CBR**

I. INTRODUCTION

In recent years, advances in wireless communications and electronics have led to the development of low-cost and small size sensor nodes, which can be embedded or deployed in various environments in order to accomplish a specific mission through forming a wireless sensor network (WSN). Consequently, WSN has become a vital research area, due to their large potentials of applications in diverse fields such as civilian, industrial, agricultural, and military applications [1-8].

Sensor nodes consist of computing subsystem, sensing subsystem and communication subsystem and are expected to operate in an unattended manner to periods ranging from days to years. According to [9], the energy consumed by the communication subsystem is several magnitudes higher than that consumed by the computation subsystem and is dependent on the transmission distance and the attenuation exponent. Thus, many techniques have been proposed to reduce the amount of energy consumed by the communication subsystem in order to prolong the life time of sensor networks [10-14].

Therefore, to reduce the amount of energy consumed by the communication subsystem, multi-hop routing or communication was introduced instead of single-hop. In other words, in multi-hop communication a sensor node will send the data it has collected to a neighboring sensor node which will act as a router and forwards the message it has received to another neighboring node until the message or data is reported to the base station. In this case, since each sensor node is transmitting to its neighbor the amount of energy consumed in communication is reduces because the transmission distance is relatively small. On the other hand, if single-hop communication is adopted, a sensor network has to report its data directly to the base station which might be relatively far. Hence, the amount of energy consumed in communication will be high since the communication distance is larger than that in the multi-hop case.

However, using multi-hop communication has some draw backs such as higher delay to deliver data to the base station which affects the success rate. Say it in another way, in multi-hop communication a message has to go through several sensor nodes until it reaches the base station, as a result the time it requires to reach its destination will increase. In addition, since sensor nodes have to act as routers, it may have to route a number of messages originating from a number sensor node which results in increasing the time until a message gets processed at that node. As a result, higher delay is incurred. Furthermore, the number of messages a sensor node has to route might be greater than it capacity or memory size which results in some messages to be dropped. Thus, the success rate will decrease. In addition, sensor nodes near to the base station will consume most of their energy routing other sensor nodes messages. As a result, they will get their energy depleted quickly and will have shorter lifetime than nodes that are far from the base station.

In order to solve the above mentioned problems namely, limited life time and higher delay when adopting multi-hop routing, the use of mobile node or nodes in WSNs has been introduced. In such configurations, the sensor network consists of a number of static nodes, which are used to collect data from their environment, and one or more mobile nodes or sinks that traverse the network and move between the static sensor nodes to collect data from them. To elaborate, when the mobile sink or node is in the proximity of a static sensor node, i.e. neighbor, the data collected by the static sensor node will be transmitted to the mobile sink using single-hop communication. As a result, the amount of energy consumed in communication by the static sensor is reduced since the transmission distance to the mobile sink is reduced.

In this paper we introduce the use of a single mobile sink that move according a specific mobility model to collect data from randomly deployed static sensor node. Moreover, we propose a sink mobility model that is base on the depth first traversal algorithm. Thus, the mobile sink will move through the network according to the proposed mobility model and collect data from static sensor nodes. Additionally, the proposed mobility model was implemented on NS-2 simulator. Finally, the performance of the sensor network based on the proposed mobility model is studied by measuring three parameters namely, throughput, success rate and end to end delay using the NS-2 simulator.

The remainder of the paper is organized as follows: in Sec. II, the related work is discussed. In Sec. III, the original depth first traversal of graphs is presented. After that, the depth first based mobility model is presented in sec III.B. Furthermore, in sec. IV.A simulation environment and parameters are presented. Then, performance metrics and scenarios are discussed in sec. IV.B and IV.C respectively. In sec. V simulation results are presented and discussed. Finally, the paper is concluded in sec. VI.

II. RELATED WORK

Traditionally, sensor networks have been modeled as a system consisting of a large number of homogenous, static, and resource constrained sensor nodes that are randomly deployed in the environment of study [15]. As a result of adopting this model, several challenges occurred such as high delay and short network life time. Therefore, several research works have introduced the use of mobile nodes in wireless sensor networks. Thus, several mobility models have been proposed. According to [8], mobility models for WSNs can be classified into two main categories namely heterogeneous mobility models and homogenous mobility models.

In the heterogeneous mobility models, the network consists of a mobile node or sink that moves randomly or according to a specific model to collect data form static sensor nodes. In other words, the network is made up of a group of static sensor nodes that might be randomly deployed and a mobile sink that moves between these static nodes to collect data from them. On the other hand, in homogenous mobility models the network consists of a set of cooperating nodes moving according to a specific model in the environment of study. Note that, the number of mobile nodes varies from a subset of sensor nodes deployed in the WSN to having a WSN where all sensor nodes are mobile and moving according to a particular mobility model [8]. Since we propose the use of a single mobile node to collect data from static sensor nodes, we will review and focus on heterogeneous mobility models because this category is closely related to the work proposed in this paper.

We will start our review of the related work by explaining a very simple mobility model known as the Random Way Point model [16]. The motion of the mobile node is divided into motion periods and pause periods. In the pause period, the mobile node will stay in its current position for a specific period of time. However, in the motion period, the mobile node will choose a random direction and will start moving to the new direction with a random speed. After arriving to the new position, the mobile node enters the pause period and stays in that position for the same period of time used in the previous position. Although this model is simple, it suffers from poor choice of velocity distribution and uniform distribution [17].

Similar to the random way point model, the movement of a mobile node in the random direction mobility model is divided into motion periods and optional pause periods. In the motion period, the mobile node is moving in straight segments with constant speed. After a node reaches its destination, it optionally pauses for a specific period of time before selecting a new destination and direction. Note that along with the random way point model the random direction mobility model is considered the most widely used mobility model for mobile communications research [18].

The random walk mobility model was proposed to mimic the unpredictable mobility of entities in the real word. In this model a mobile node moves with a random speed in a randomly selected direction. After a specific period of time or after travelling a specific distance in the chosen direction, a new direction and speed are calculated. Not that, when reaching the boundaries of the deployment or simulation area, the mobile node bounces off with an angle that can be calculated using the incoming direction [19].

In order to take different levels of randomness into account, the Gauss-Markov model was proposed. In the initialization phase, a mobile node is assigned a movement direction and speed. Next, the assigned movement direction and speed are updated according to fixed time intervals. Say it in another way, besides the use of a random variable the speed and direction of the n^{th} interval are calculated based on those of (n-1) interval [20].

In [21], a controlled Mobility Model was proposed where the mobile node visits sensor nodes based on a predefined schedule that is built based on the sampling rate of sensors and event occurrence rate. Note that the time between two consecutive visits for the same sensor node must be taken into consideration. To elaborate, the time between two consecutive visits of a sensor node must not be too long. As a result, sensor nodes will not suffer from buffer overflow.

The research in [22] proposed a sensor network with mobile agents (SENMA) architecture that combines the use of static sensor nodes with the use of mobile and resource rich nodes. In this architecture the resource rich mobile node might be manned or unmanned vehicles that move on the ground or aerially to collect data from static sensor nodes. In addition, the mobile node is not present all the time in the network. Thus, the mobile node is operational when it is required to collect data from static sensor nodes.

Additionally, the work proposed in [23] introduced a Predictable Mobility Model where the movement path used by the mobile sink is known to the sensor nodes. As a result, to save its energy, a sensor node goes into sleeping mode until the predicted time for data transfer. After that, the sensor node enters the active node and starts exchanging data with the mobile sink.

The authors in [24] proposed a mobility model that is derived from the properties of the network topology. In other words, the static sensor nodes are deployed according to De Buijn graph and the mobility paths used by the mobile sink are derived from its properties. Thus, two paths were obtained and used to move the mobile sink. Consequently, the proposed mobility model was divided into rounds where the one path is used in the first half of the round and the other is used in the second half. As a result, the number of nodes visited in each round is increased.

III. DEPTH FIRST BASED MOBILITY MODEL

A. Depth First Traversal Algorithm

A depth first traversal of a graph can be described as wandering in a maze in order to solve it. Unlike trees, graphs do not have a specific root vertex. As a result, the depth first traversal of a graph can start from any node which can be chosen randomly or can be chosen based on the properties of the problem being solved. After that, the algorithm tries to explore the children of the current node. In other words, children are favored on siblings [25, 26].

To elaborate, the depth first traversal algorithm starts at a random node or vertex. After that, it will try to explore one of its children. After exploring the first child of the starting vertex, the algorithm will go in depth and will try to explore one of the children of the current vertex which is the first child of the starting vertex that has been explored in the previous step. This process continues and the algorithm will keep on following a path until it reaches a dead end i.e .run out of option at the current node. As a result, the algorithm will backtrack until it reaches a vertex that can provide options. So that, it can carry on with traversing the graph until all vertices are visited [25, 26].

B. Mobility Model

The proposed mobility model presented in this paper is based on the algorithm described section III.A. Consequently, our network consists of (n) static sensor nodes. Additionally, an extra mobile node will be present in the network in order to traverse the through the static sensor nodes based on the depth first traversal algorithm in order to collect data. As a result, the total number of nodes in the network is (n+1). To elaborate, the static sensor nodes in the network are numbered from 0 to (n-1). After that, the mobile sink will try to traverse the network starting from node 0 and will try to visit all the static nodes in the network.

After collecting data from node 0, the mobile sink will try to visit one of node 0 children. When the child to be visited is selected the mobile sink moves towards it with a specific speed. Upon reaching its new destination, the mobile sink will pause for a specific period of time and will communicate with the selected child, which is the current node being visited, in order to collect date from it. When the pause time expires, based on the depth first traversal algorithm, the mobile sink chooses a child from the current node's children and starts moving towards it. This process continues until all the nodes in the network get visited and get their data collected by the mobile sink.

Figure 1 shows a network consisting of 9 static sensor nodes numbered from 0 to 8 and a mobile sink numbered as 9. The mobile sink will pause for a specific period of time at node 0 to collect data from it. After that and based on the depth first traversal algorithm the mobile sink selects node 1 as the new destination. As a result, the mobile sink, node 9, will start moving towards node 1 until it reaches its vicinity. After that, the mobile sink pauses for the same period of time used in the previous case and collects data from node 1. This process continues until all the static nodes in the networks are visited.

In summary the depth first traversal of the graph shown in Fig.1 starting from node 0 is 0, 1, 7, 2, 3, 4, 8, 5, 6. Thus, the mobile sink will move according to the path specific above to collect data and will pause at each node for a specific period of time.

Furthermore, AODV routing protocol is used along with the proposed mobility model. From the example above it can be observed that the node or nodes that will be visited at the end of the specified path will suffer from long delay to report it data to the mobile sink because it has to wait until the mobile sink comes to its vicinity. As a result, these nodes, such as node 6 in the previous example, might suffer from buffer overflow because it has to store the information it has collected until the mobile sink arrives. Therefore, AODV is used in the manner explained below.

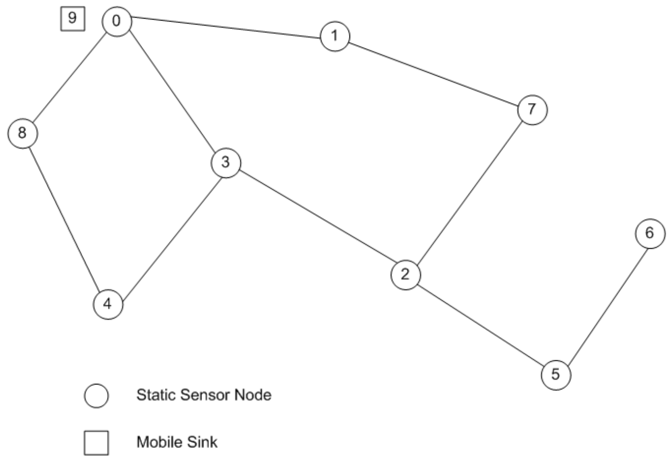

Fig. 1 Example Network.

When a static sensor node has data to report to the mobile sink, it checks whether the mobile sink is in its vicinity or not. Thus, if the mobile node is pausing at this node the collected information will be directly transmitted to the mobile sink using single-hop. On the other hand, if the mobile sink is not that node's vicinity, AODV will be used to route messages to the mobile sink.

IV. SIMULATION

A. Simulation Environment and Parameters

To study the performance of the proposed depth first based mobility model along with AODV routing protocol under different network sizes, NS-2 simulator was used. This simulator is considered the most commonly used to simulate wired and wireless networks. Additionally, AODV routing protocol is used to route messages from static sensor nodes to the mobile sink when the mobile node is not in the vicinity of the static sensor node. Note that, AODV is used according to the manner discussed and explained in section III.B. Furthermore, static sensor nodes generated 512 bytes long packets based on the constant bit rate (CBR) traffic model.

Additionally, the performance of the proposed model was studied under different network sizes and under different speeds of the mobile sink. However, regardless the speed according to which the mobile sink is moving, it will pause for 5 seconds at the new location in order to collect data from static sensor nodes. Table I shows the simulation parameters that were used to obtain our results.

TABLE I. SIMULATION PARAMETERS

Parameter	**Value**
Simulation Time	1000 seconds
Number of Nodes	26, 51, 76, 101
Pause Time	5 second
Simulation Area Size	1000*1000
Traffic Type	CBR
Speed	5, 10, 15, 20 m/s

B. Performance Metrics

In order to study the performance of our mobility model end-to-end delay, throughput and packet delivery ratio were selected as the metrics to be used to evaluate the performance.

According to [27], the performance metrics mentioned before can be defined as follows:

- **End-to-End Delay** is the time needed by a packet to reach its destination after leaving its source.
- **Throughput** can be defined as the ratio or percentage of data that has been successfully transmitted per second.
- **Packet Delivery Ratio** is the percentage of data packets that has been successfully delivered to the destination to the total number of data packets that have been sent.

C. Simulation Scemarios

The mobility model presented in this paper was implemented in NS-2 simulator. After that, several simulation scenarios were conducted in order to study and analyze the performance of the presented work. In these scenarios different network sizes were used namely, 26, 51, 76 and 101 nodes. Note that every network consisted of (n) static sensor nodes and one extra node to act as the mobile sink. To elaborate, for 26 nodes network size, the network consisted of 25 static sensor node numbered from 0 to 24 plus node number 25 which will act as a mobile sink and will traverse the network based on the mobility model presented in this paper.

Furthermore, for each network size, different speeds were used by the mobile sink to move through the network. For example, for 26 nodes network size, the performance of the mobility model was studied when the mobile sink speed was 5 m/s. After that, the speed of the mobile sink was changed to 10 m/s and the performance of the same network size was studied. The same approach was adopted to study the performance of the mobile model under the same network size when the speed of the mobile sink was changed to 15 m/s and 20 m/s. In other words, the performance of the mobility model was studied under for different speeds of the mobile sink for every network size.

It is important to note that the movement of the mobile sink in divided into movement periods and pause periods. In the movement period the mobile sink moves according to the specified speed to its new location based on the presented mobility model. Upon arrival to its new location the mobile sink pauses for 5 seconds in order to collect data from static sensor nodes in its neighborhood. For further details of the simulation parameters see table I.

V. SIMULATION RESULTS

In this section the results obtained from simulating proposed mobility model based on the scenarios explained in section IV.C are presented. Note that, the results obtained for each case is the average of running each scenario for tem times.

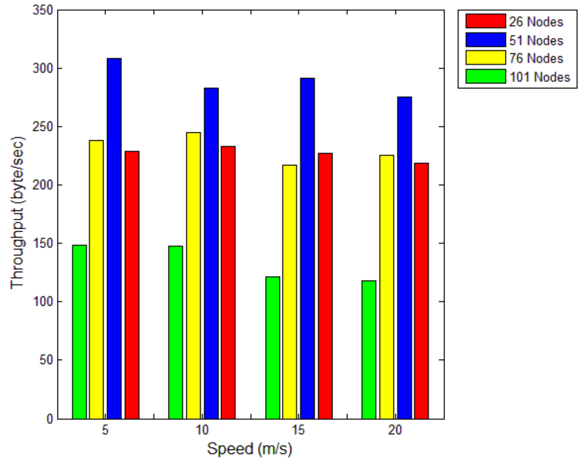

Fig. 2 Network Throughput

From Fig. 2, it can be observed that the proposed mobility model obtained the best performance in terms of throughput for 51 nodes network size. This can be regarded to the use of the mobile sink. In other words, for 51 nodes network size the path according to which the mobile sink moves through the network is not very long. As a result, a static sensor node can get visited several times by the mobile sink. Thus, the static sensor node will not suffer from buffer overflow or long waiting time until the sink arrives to its vicinity. Additionally, Fig.2 shows that the best performance was obtained when the mobile sink speed was 5 m/s under 51 nodes network size because when the mobile sink is moving according to this speed, it will not leave the vicinity a static sensor node quickly when compared to 10 m/s, 15 m/s and 20 m/s speeds. As a result, more data can be reported to the mobile sink by the static sensor node before the mobile sink leaves the vicinity of the static node.

Furthermore, from Fig.2 it can be observed that the throughput of 51 nodes network was better than that of 26 nodes even though the path indicated by the mobility model for 26 nodes network is shorter than that of 51 nodes. this can be regarded to the use of multi-hop communication. As mentioned before, if the static sensor node has data to report to the mobile sink while the mobile sink is far from it. AODV routing protocol can be use to deliver data using multi-hop communication. Since 26 nodes network is considered a small size network, the paths used to route messages to the sink might get easily congested especially when there are several static sensor nodes reporting information to the mobile sink using AODV and multi-hop. As a result, the number of messages that might get dropped increase which affects and decreases the throughput of the network.

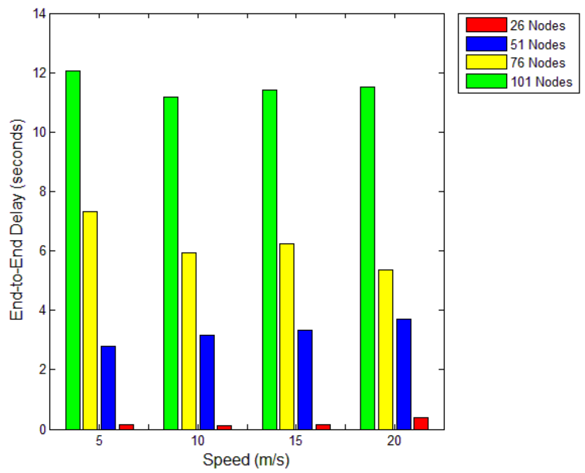

Fig. 3 End-to-End Delay

The results obtained regarding End-to-End delay under different network sizes and different speeds of the mobile sink are presented in Fig.3. It can be observed that the End-to-End delay increases when the density of nodes, network size, increases because longer paths are indicated by the mobility model. As a result, static sensor nodes have to wait for long time until the mobile sink arrives when the network size increases. Thus, multi-hop routing will be used more. On the other hand, messages have to go through larger number of hops to get routed to the mobile sink when multi-hop communication is used. Consequently, End-to-End delay increases when increasing the network size.

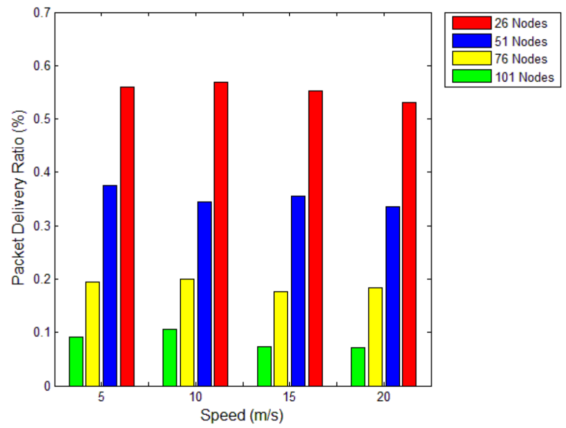

Fig. 4 Packet Delivery Ratio

Figure 4 shows that 26 nodes network size obtained better performance in terms of packet delivery ratio under all cases. However, the packet delivery ratio is in sufficient and decreases for all cases i.e. under different speeds and network sizes. This can be regarded to the extensive use to multi-hop routing to deliver messages to the mobile sink which increases the drop rate of messages because of congestion. Additionally, it can be observed that network sizes that suffered from lower End-to-End delay in Fig.3 obtained better packet delivery ratio because the number of messages that get dropped is lower.

VI. Conclusions and Future Work

In this paper, a depth first based mobility model was presented. Furthermore AODV routing protocol was used to deliver messages destined to the mobile sink through multi-hop communication. The proposed mobility model was implemented and simulated using NS-2 simulator. After that, the performance in terms of throughput, End-to-End delay and packet delivery ratio of the proposed mobility model and AODV was studied under different network sizes and under different speeds of the mobile sink. Our results show that 51 nodes network size obtained better throughput when the mobile sink speed was 5m/s. On the other hand, 26 nodes network size obtained better performance in terms of End-to-End delay and packet throughput because of the delay incurred by long paths for the mobile sink and for routing messages when the network size is increase.

For future work, we aim to study the effect of the presented mobility model on the energy consumption of the static sensor nodes. Additionally, the performance of our mobility models can be compared to the performance of other mobility models that exist it the literature. Furthermore, the performance of the presented model can be studied when using routing protocols other than AODV or when AODV is modified in order to enhance the performance.

References

[1] Jiang, P. "A New Method for Node Fault Detection in Wireless Sensor Networks." Sensors Vol. 9, no. 2 pp. 1282-1294, 2009.

[2] Mainwaring, A., Culler, D., Polastre, J., Szewczyk, R., and Anderson, J. , "Wireless Sensor Networks for Habitat Monitoring," In Proceedings of the 1st international ACM Workshop on Wireless Sensor Nerworks and Applications, pp. 88-97, Atlanta, Georgia, USA, September 2002.

[3] Hamdi, M., Boudriga, N., and Obaidat, M. S., "WHOMoVeS: An optimized broadband sensor network for military vehicle tracking," International Journal of Communication Systems, Vol. 21 , Issue 3, pp. 277-300, 2008.

[4] Son, B., Her, Y., and Kim, J., "A design and implementation of forest-fires surveillance system based on wireless sensor networks for South Korea Mountains." International Journal of Computer Science and Network Security.(IJCSNS), Vol. 6, Issue 9, pp. 124–130, 2006.

[5] Antoine-Santoni, T., Santucci, J. F., De Gentili, E., Silvani, X., and Morandini, F. "Performance of a protected wireless sensor network in a fire. Analysis of fire spread and data transmission." Sensors 9, no. 8, pp. 5878-5893, 2009.

[6] Lloret, J., Garcia, M., Bri, D., and Sendra, S. "A Wireless Sensor Network Deployment for Rural and Forest Fire Detection and Verification." Sensors Vol. 9 Issue: 11. pp. 8722-8747 October 2009.

[7] Resch, B., Mittlboeck, M., Girardin, F., Britter, R. and Ratti, C. "Real-time Geo-awareness - Sensor Data Integration for Environmental Monitoring in the City." In Proceedings of the IARIA International Conference on Advanced Geographic Information Systems & Web Services. GEOWS'09. pp. 92-97, Cancun, Mexico, February 2009.

[8] Anas Abu Taleb, Tareq Alhmiedat, Osama Ah-Haj Hassan and Nidal M. Turab, "A Survey of Sink Mobility Models for Wireless Sensor Networks". Journal of Emerging Trends in Computing and Information Sciences, Vol. 4, No. 9, September 2013 .

[9] Patel, K., Patel, C., Rizvi, S. S., and Elleithy, K. M., "An Efficient Approach to Reduce the Energy Consumption in Wireless Sensor Networks through Active Nodes Optimization," Nefor Engineering Education Confernce, April 2007.

[10] Min, R., and Chandrakasan, A.," Energy-efficient communication for ad-hoc wireless sensor networks." Conference Record of the Thirty-Fifth Asilomar Conference on Signals, Systems and Computers. Vol. 1, pp. 139–143, IEEE 2001.

[11] Pottie, G.J., "Wireless sensor networks." In Information Theory Workshop, pp. 139–140, IEEE 1998.

[12] Salhieh, A., Weinmann, J., Kochha, M., and Schwiebert, L., "Power efficient topologies for wireless sensor networks." In International Conference on Parallel Processing, pp. 156–163, IEEE 2001.

[13] Min, R., Bhardwaj, M., Cho, S. H., Sinha, A., Shih, E., Wang, A., and Chandrakasan, A., "An architecture for a power-aware distributed microsensor node." In IEEE Workshop on Signal Processing Systems, pp. 581–590, IEEE 2000.

[14] Estrin, D., "Wireless sensor networks: Application driver for low power distributed systems." In International Symposium on Low Power Electronics and Design, pp. 194-194, ACM 2001.

[15] Traynor, P., Shin, J., Madan, B., Phoha, S., & La Porta, T., "Efficient group mobility for heterogeneous sensor networks". The 64th IEEE Vehicular Technology Conference (VTC 2006), pp 1-5, Sept. 2006.

[16] Divecha, B., Abraham A., Grosan, C., and Sanyal, S., "Impact of Node Mobility on MANET Routing Protocols Models," Journal of Digital Information Management, Vol. 5, no. 1, pp. 19-24, 2007.

[17] Yoon, J., Liu, M., and Noble, B., "Random waypoint considered harmful." In INFOCOM 2003. Twenty-Second Annual Joint Conference of the IEEE Computer and Communications. IEEE Societies. Vol. 2, pp. 1312-1321. IEEE 2003.

[18] Gloss, B., Scharf, M., and Neubauer, D., "A more realistic random direction mobility model." *TD (05)* 52, 13-14, 2005.

[19] Aslam, M., Z., and Rashid, A., "Comparison of Random Waypoint & Random Walk Mobility Model under DSR, AODV & DSDV MANET Routing Protocols." *arXiv preprint arXiv:1104.2368*, 2011.

[20] Camp, T., Boleng, J., and Davies, V., "A survey of mobility models for ad hoc network research." Wireless communications and mobile computing 2, no. 5, pp. 483-502, 2002.

[21] Somasundara, A., A., Ramamoorthy, A., and Srivastava, M., B., "Mobile Element Scheduling for Efficient Data Collection in Wireless Sensor Networks with Dynamic Deadlines." In Proceedings pf the 25th IEEE International Real-Time System Symposium, pp. 296-305, IEEE 2004.

[22] Tong, L., Zhao, Q., and Adireddy, S., "Sensor Networks with Mobile Agents," In Military Communications Conference, 2003. IEEE MiLCOMM'03, pp. 688-693, Boston, MA, October 2003.

[23] Chakrabarti, A., Sabharwal, A., and Aazhang, B., "Using Predictable Observer Mobility for Power Efficient Design of Sensor Networks," In Proceedings of the 2nd International Workshop on Information Processing in Sensor Networks, pp. 129-145, Springer Berlin Heidelberg, 2003.

[24] Anas Abu Taleb, Tareq Alhmiedat, Reem Abu Taleb and Osama Al-Haj Hassan, "Sink Mobility Model for Wireless Sensor Networks", The Arabian Journal for Science and Engineering, Vol 39, no. 3, pp. 1775-1784, March 2014.

[25] MIT Open CourseWare, Massaachusetts Institute of Technology, http://ocw.mit.edu/index.htm [Accessed 5 March 2013].

[26] Mehlhorn, K., & Sanders, P., " Algorithms and data structures. *The Basic Toolbox"*. Springer, 2008.

[27] Amnai, M., Fakhri, Y., and Abouchabaka, J., " Impact of Mobility on Delay-Throughput Performance in Multi-Service Mobile Ad-Hoc Networks." International Journal of Communications, Network & System Sciences, vol. 4, no. 6, pp. 395-402, 2011.

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