Efficient Data Gathering in Mobile Wireless Sensor Networks

Mohammad Hossein Anisi, Abdul Hanan Abdullah, Shukor Abd Razak

Faculty of Computer Science and Information Systems, Universiti Teknologi Malaysia (UTM), 81310, Skudai, Johor, Malaysia. anisii@gmail.com

Abstract: In Mobile Wireless Sensor Networks (MWSNs), nodes are supplemented with implicit or explicit mechanisms that enable these devices to move in space. The packet loss is one of the main challenges that occur due to mobility of such networks and it comes in parallel with energy consumption. Moreover, data collection with the minimum energy consumption is one of the important issues in wireless sensor networks. In the proposed energy-efficient approach, for maximizing the network lifetime, we benefit both cluster and tree structures for data gathering and we select the most reliable and energy-efficient hops for data forwarding. The simulation results show that by using the proposed approach, lifetime, reliability and the throughput of the network will be increased.

[Anisi MH, Abdullah AH, Razak SA. **Efficient Data Gathering in Mobile Wireless Sensor Networks.** *Life Sci J* 2012;9(4):2152-2157] (ISSN:1097-8135). http://www.lifesciencesite.com. 320

Keywords: Mobile Wireless Sensor Networks; Data aggregation; Residual Energy; Reliability

1. Introduction

Wireless Sensor Networks (WSNs) consists of several sensor enable nodes which are distributed in an environment and use batteries as the energy resource. These tiny sensor nodes, which consist of sensing, data processing, and communicating components, result in the idea of sensor networks based on the collaborative effort of a large number of nodes. Such sensor nodes could be deployed in home, military, science, and industry applications such as transportation, health care, disaster recovery, warfare, security, industrial and building automation, and even space exploration. Among a large variety of applications, phenomena monitoring is one of the key areas in wireless sensor networks and in such networks, you can query the physical quantities of the environment [1], [2] and [3].

In fact, a typical wireless sensor network is composed of a large number of sensor nodes, which are randomly dispersed over the interested area, picking up the signals by all kinds of sensors and the data acquiring unit, processing and transmitting them to a node which is called sink node. The sink node requests sensory information by sending a query throughout the sensor field. This query is received at sensor nodes (or sources). When the node finds data matching the query, the data (or response) is routed back to the sink. For example, if the sensors nodes be in a tree like structure, the base station roles as the root of the tree and each node will have a parent [4], [5]. Therefore, the data items can be transmitted hop by hop from the leaf nodes to the root.

In WSN, In-network data aggregation is one of the effective approaches that can reduce the communication traffic in WSN. Such Schemes can decrease wireless communication among nodes by reducing redundancy in sensor measurements according to an aggregation function. However, the extracted data in response to a query is only a summary (aggregate) of sensor readings.

In mobile sensor networks, nodes can self-propel via springs, wheels, or they can be attached to transporters, such as vehicles. Sensors have limited energy supply and the sensor network is expected to be functional for a long time, so optimizing the energy consumption to prolong the network lifetime becomes an important issue. Moreover, there is a problem of instability of wireless network and high-fraction of event loss caused by the mobility of network nodes around the mobile Fusion node routes for data collection.

In this paper, we propose an energy-efficient in-Network data aggregation approach in WSN. The proposed approach uses the advantages of both cluster based and tree based approaches. In this approach, the whole network consists of some clusters with the same size. Each node is related to a routing sub tree and each sub tree overwhelms a cluster and the root node of each sub tree is the head node of the related cluster. The energy consumption in wireless transmissions is equal to the square of distance between two nodes in communication. In the proposed approach, all the nodes transmit their data to their neighbor instead of their cluster head. Therefore, the communication distance is reduced and the energy consumption of each node, each cluster and the average energy consumption of the whole networks is reduced and the network lifetime is increased. Furthermore, in the proposed approach, the most appropriate parent according to some benchmarks will be selected for each node which can balance the network load and increase the rate of packet delivery.

2. Related Works

There are several approaches which use tree structure for collecting and aggregating data. The presented approach in [6], with combining Clustering and Directed Diffusion Protocol [7], could process, collect, and aggregate data of sensor nodes without any dependency to the related environment. This paper, with presenting a dynamic clustering structure, could enable the nodes to join to the nearest head cluster while sending data to the gateway node.

Most of data gathering algorithms focus on two key issues .These issues have a network lifetime and saving energy on them [8-11, 4].

In the TAG (Tiny Aggregation) approach [4], each epoch divides to some time slots and these time slots specify to different levels of routing tree in reversal form. In this manner, each node depends on its situation in the tree, and in its related time slot will send its data. The node synchronization of this approach for sending and receiving data could effectively reduce the average energy consumption.

In Directed Diffusion Approach [7], [12] receivers and resources using some attributes for recognizing the produced or required information and the goal of this approach is finding an efficient multi way route between senders and receivers. In this approach, each task is represented as an interest and each interest is a set of attribute-value pairs.

EDDD [13], obtains energy efficiency by using two kinds of gradients, each one uses for different kinds of applications. Whenever the delay is the main issue, real-time filter forwards data through the shortest path between source and sink In order to perform load balancing between nodes. On the other hand, best effort BE filters will be selected which choose the longer but more energy-efficient paths toward the sink node.

The Link Quality Estimation Based Routing (LQER) is proposed by Chen et al. [14]. LQER forwards data by considering a dynamic window (m, k) that maintain the history of successful transmissions over the link.

In [15] an energy-efficient distributed clustering protocol in the name of Geodesic Sensor Clustering (GESC) is proposed. GESC aims to prolong the network lifetime by estimation of the significance of the sensors relative to the network topology. The significance is calculated in the view of the local network at individual nodes.

The aim of authors in Hierarchical Geographic Multicast Routing (HGMR) for wireless sensor networks [16] is enhancing data forwarding efficiency and increasing the scalability to a large-scale network. HGMR almost incorporates the key design concepts of the Geographic Multicast Routing (GMR) [17] and Hierarchical Rendezvous Point Multicast (HRPM) protocols [18] and optimizes the two routing protocols in the wireless sensor network environment.

The LEACH (Low-Energy Adaptive Clustering Hierarchy) protocol [19] uses a random approach for distributing energy consumption among the nodes. In this approach, the nodes organize themselves as local clusters and one node roles as a local base station or a cluster head. If the cluster heads can be selected base on a priority permanently and they also can be permanent in the whole life time of system, it is obvious that the bad luck nodes which are selected as the cluster heads will be died soon and the life of all the nodes in their cluster will be finished. Thus, LEACH chooses the cluster head among the nodes which have enough energy randomly. This can prevent the discharging of the battery of a special node. In addition, LEACH uses local data fusion for compressing the data which should be sent from cluster heads to the base station.

FTEP [20] is a dynamic and distributed CH election algorithm based upon two level clustering schemes. If energy level of current CH falls below a threshold value or any CH fails to communicate with cluster members then election process is started which is based on residual energy of sensor nodes.

In EEMC (An Energy Efficient Multi Level Clustering) [21], CHs at each level are elected on the basis of probability function which takes into consideration the residual energy as well as distance factor very efficiently. In this scheme whole information is sent and received by sink node for cluster formation.

Steiner Points Grid Routing was proposed by, Chiu-Kuo Liang, et al.[22] In order to reduce the total energy consumption for data transmission between the source node and the sink node, a different virtual grid structure instead of virtual grid in GGR is constructed. The idea is to construct the virtual grid structure based on the square Steiner trees [23].

In [24] the clustering routing algorithm is used to find out intra cluster and inter cluster link in wireless sensor network clusters are acted as a router, which maintain and distribute of the routing information After node is selected as cluster head, it will broadcast information that he is the cluster head to the rest of the nodes in the same cluster. The remaining nodes decide to join the cluster according to the size of the received signal.

In [25] three layer mobile node architecture to organize all sensors in MWSN is designed. In this paper, the Shortest Path (SP) routing protocol is used to adapt sensors to update the network topology. SP provides an elegant solution to node movement in multilayer MWSN and reduces energy dissipation.

Ming etal [26] proposed distributed clustering algorithm for data gathering in mobile wireless sensor network. The cluster formation was done using Cluster with Mobility mechanism (CM). Cluster head was elected using two distributed algorithms. It was observed that a better clustering factor and lesser energy consumption were achieved.

3. Proposed Approach

In the proposed approach, it is assumed that the whole network is divided into several clusters; each cluster has a cluster-head (CH). The clustering and the selection of the cluster-head (CH) can be done by using any existing protocol like LEACH, or more efficient approaches such as [26]. The proposed approach is discussed in two main phases including Information Packet Flow and Packet Forwarding.

3.1 Information Packet Flow

In this phase, the cluster head transmits the information packet to its neighbors. The information packets include some information as follow:

Node location: Each node should now it location in prior.

Current Energy: Remaining energy of a node.

Hop count: Number of hops from cluster head.

Speed: The speed of node’s movement.

When a node receives the information packet, it considers the sender as one of its possible parents and stores its information. Then, it updates the node location, current energy and data label fields of the packets with its own, increments the hop count and transmit the packet to its neighbors. This process will be done until all the nodes in the cluster receive the information packet.

3.2 Data Forwarding

This phase is studied in two sub phases including Reliable Forward Routing Mechanism and Tree Construction and Data Flow.

3.2.1 Reliable Forward Routing Mechanism

Packet loss is one of the main challenges that occur due to mobility of the sensor nodes in Mobile Wireless Sensor Network (MWSNa) and it comes in parallel with energy consumption. In MWSNs, a node may leave the radio range of its previous hop node which can cause route breakage; therefore, we need a solution for this problem. In the proposed algorithm, data packet will be sent to the node which is the closest node to the destination and does not leave the radio range of its previous hop with the speed of *v* after time *t* (Algorithm 1). ‘*t*’ is a constant value that can be assumed different values in different scenarios. For better understanding of the operation of the proposed optimized algorithm, please consider Figure 1.

Algorithm1. Next Hop Selection

When a node receives the request:

```
J=0
While ( n[j] != -1)
{
mindis = 1;
For (i=1; n[i] != -1 ; i++)
{   If ( distance( n[i] ، destination) < mindis )
{  mindis = distance( n[i] ، destination)
nexthop = n[i] }
}
if ( j == 0 )
nhop = n[i]
if ( distance( n[i]، node->nodeAddr) + vt
<=  radio_range )
{  found = True
break
}
j++
}
if ( found == True )
ForwardRequest(node،request،nexthop)
Else
ForwardRequest(noderequest,nhop)
```

Considering the distance between neighboring nodes and the destination node it seems that node 27 should be the candidate of the next hop. But, we can observe that this node can move in any direction with the speed of *v* and time *t* which is equal to *vt*. So, there is a probability that after time t, node 27, which was moving with the speed of v, leaves the radio range of the source node. Therefore, in the proposed algorithm, node 27 is not selected as the next hop. So, node 6 will be selected as the next hop because it is the closest node to the destination comparing to all neighboring nodes which do not leave the radio range.

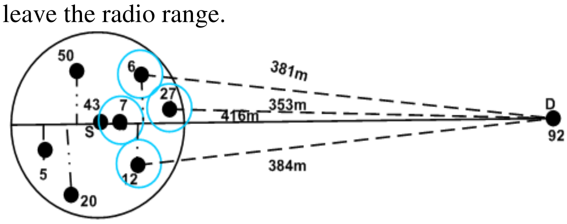

Figure 1. Selecting the next hop in the proposed algorithm

The distance that a node passes with the speed of v at the time t (vt).

Radio range of node S

Figure 2 illustrates the mechanism of data forwarding in conventional algorithms and the proposed algorithm.

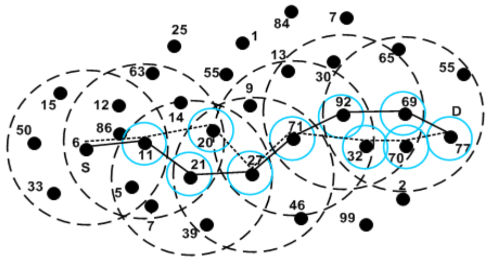

Figure 2. The route discovery in the proposed approach and conventional algorithms

— — Radio range of a node

.... Selected route in conventional algorithms

—— Selected route in the proposed algorithm

—— The distance which the node pass with the speed of v at the time t (vt)

In conventional algorithms, the source node will select node 11 as the next hop because it has the minimum distance to the destination comparing to all single hops neighboring nodes of the source node. Also, node 11 will select node 20 as the next hop and following that, node 20 will select node 27 as the next hop. Selecting the next hop will be continuing until reaching the destination node. In the proposed algorithm, the source node will select node 11 as the next hop because it has the minimum distance to the destination and also after the time t, it does not leave the radio range of the source node. So, Node 11 will not select node 20 as the next hop because although it is the closest node to the destination, but there is the probability that it leaves the radio range of node11 after time t. So, node 21 will be the candidate of the next hop of node11. Selecting the next hop will be continuing until reaching the destination node.

3.2.2 Tree Construction and Data Flow

When the entire nodes received the information packet, each node selects it parent which should send its data to it. This selection will be done based on the following filters:

1. First, among the possible parent, the one which has the least hop distance from the cluster head (Closest node to cluster head) and does not leave the radio range of its previous hop with the speed of *v* after time *t* will be selected.
2. If there is more than one node having condition 1, the node which has the most residual energy will be selected as the parent.

All the above conditions lead to the best parent selection. Filter 1, selects the Reliable shortest path from a node to cluster head and filter 2 increases the network lifetime by participating most durable nodes.

4. Performance Evaluations

The proposed approach is simulated and evaluated with J-Sim (Java-Based simulator) [28]. J-SIM is simulation software selected to implement the model. It was chosen because it is component-based, a feature that enables users to modify or improve it. J-Sim uses the concept of components instead of the concept of having an object for each individual node. J-Sim uses three top level components: the target node which produces stimuli, the sensor node that reacts to the stimuli, and the sink node which is the ultimate destination. For stimuli reporting, each component is broken into parts and modeled differently within the simulator; this eases the use of different protocols in different simulation runs. In our simulation analysis, sensor nodes are randomly distributed in a 160m×160m area. The radio range of each node is 30*m* and the default parameters for radio communication model of J-sim are used. Two mobility models are used in evaluation: Random Waypoint without pause time [29], and the Reference Point Group [30] mobility model. We have chosen these models since they are simple and apply to a large number of possible scenarios. The cluster-head is formed by the sink. Source node randomly sends packages with constant bit rate (CBR) to the sink. Packet size is 64 bytes and package rate is 5 pkt/s.

Our energy model is like the energy model in [27]. In this model energy consumption for transmitting k bit is equal to:

$$E_{TX}(K,d) = E_{elec} \times K + \varepsilon_{amp} \times K \times d^2$$

And the energy for receiving k bit is equal to:

$$E_{RX}(K) = E_{elec} \times K$$

In these equations, d is a constant value which relates to the distance between two nodes and ε_{amp} and E_{elec} are also the constant values which are defined previously and they are equal to:

ε_{amp} = 100 pJ/bit/m^2 E_{elec} = 50 nJ/bit

We have compared the proposed approach with LEACH as an innovative Energy-Efficient clustering approach and the approach in [26] which we have called it in our simulations Method 2 as a modern Energy-Efficient clustering approach. As it has mentioned before, our idea is not related to clustering and the selection of the cluster-head (CH) and they can be done by using any existing protocol like LEACH, or more energy efficient approaches. Therefore, For Clustering, we have used the mechanism of Method2 in our simulation which is more energy-efficient in comparison with LEACH.

According to Figure 3, the total residual energy of the nodes will be decreased, gradually. But Comparing to other approaches, the proposed approach, because of using the mentioned technique, can remain more energy.

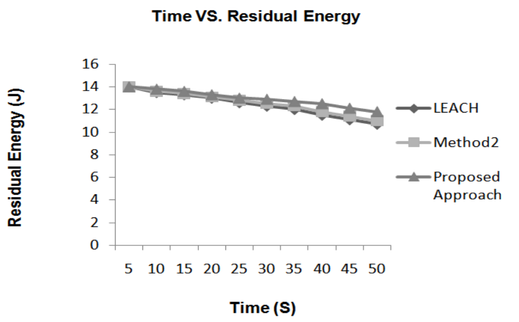

Figure 3. The reaming energy of the nodes after passing time

Figure 4 illustrates the throughputs of the mentioned approaches. Throughput of a node is defined as the average rate of successful message delivery over a communication channel. Thus, we can observe that has the highest throughput among LEACH and Method 2.

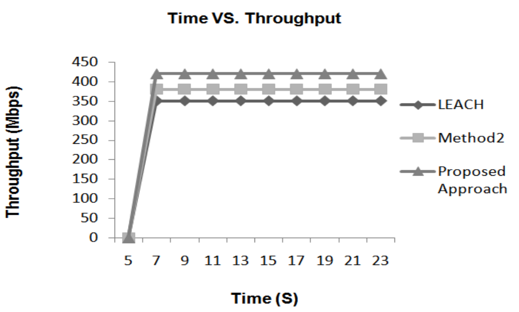

Figure 4. Different Throughput of the approaches

Figure 5 presents the impact of nodes' movement speed on the packet delivery ratio. It illustrates that increasing the nodes' movement speed; reduce the rate of packet delivery. In our proposed approach as the next hop is always the most reliable hop, the rate of packet delivery is better than other approaches.

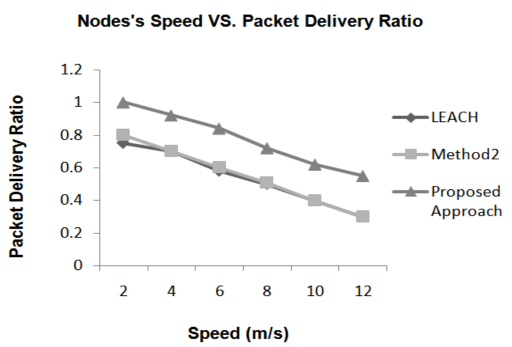

Figure 5. Impact of nodes' movement speed on the packet delivery ratio

5. Conclusions

In mobile sensor networks, nodes can self-propel via springs, wheels, or they can be attached to transporters, such as vehicles. Sensors have limited energy supply and the sensor network is expected to be functional for a long time, so optimizing the energy consumption to prolong the network lifetime becomes an important issue. Moreover, there is a problem of instability of wireless network and high-fraction of event loss caused by the mobility of network nodes around the mobile Fusion node routes for data collection. In this paper, we have proposed an energy-efficient and reliable data aggregation approach in mobile wireless sensor networks which uses an efficient strategy for forwarding data toward the best route. In our algorithm, there are three factors which enable the nodes to choose an appropriate parent in term of energy. These factors are distance, residual energy and chance of leaving the radio range. With the suggested mechanism, the remaining energy of the nodes and the packet delivery ratio will be increased and the life time of the whole network will be increased, too. We have evaluated the proposed approach with some famous and efficient approaches in this area. According to the simulation result, our approach achieves better results in term of maintaining the residual energy of the nodes, throughput and packet delivery ratio.

Corresponding Author:
Mohammad Hossein Anisi
Faculty of Computer Science
and Information System,
Universiti Teknologi Malaysia,
81310, Skudai, Johor, Malaysia
E-mail: anisii@gmail.com

References

1. Yao, Y.; Gehrke, J. (2003). Query Processing for Sensor Networks. In *Proceedings of the First Biennial Conference on Innovative Data Systems Research, Asilomar (CIDR '03)*, Ca, USA.
2. Dubois-Ferrière, H.; Estrin, D.; Vetterli, M. (2005). Packet Combining in Sensor Networks. In Proceedings of the 3rd International Conference on Embedded Networked Sensor Systems, San Diego, California, USA.
3. ehrke, J.; Madden, S. (2004) Query processing in sensor networks. *IEEE Pervasive Computing*, 3(1), 46-55.
4. Madden, S.; Franklin, M.J.; Hellerstein; J.M.; Hong, W. (2002). TAG: A Tiny AGregation Service for ad-hoc Sensor Networks. In *Proceedings of OSDI'02*, Boston, MA, USA.
5. Madden, S.; Frinklin, M.J.; Hellerstein, J.M.; Hong, W. (2005). TinyDB: An Acquisitional Query Processing System for Sensor Networks. *ACM Transactions on Database Systems*, 30(1), 122-173.

6. Chatterjea, S.; Havinga, P. (2003). A Dynamic Data Aggregation Scheme for Wireless Sensor Networks. In *Proc. Program for Research on Integrated Systems and Circuits (ProRISC 2003)*, Veldhoven, Netherlands.
7. Intanagonwiwat, Ch.; Govindan, R.; Estrin, D. (2000). Directed Diffusion: a Scalable and Robust Communication Paradigm for Sensor Networks. In *Proceedings of the 6th Annual International Conference on Mobile Computing and Networking*, Boston, Massachusetts, USA.
8. Chakraborty, A. ; Chakraborty, K.; Mitra, S.K.; Naskar , M.K. (2009). An energy efficient scheme for data gathering in wireless sensor networks using particle swarm optimization. *Journal of Applied Computer Science & Mathematics*, 3(6), Pages/record No.: 9-1.
9. Wu, Y.; Yang Li, X.; Liu, Y.; Lou, W. (2010) Energy-Efficient Wake-Up Scheduling foData Collection and Aggregation. *IEEE Transactions on Parallel and Distributed Systems*, 21(2), 275 – 287.
10. Sun, Z. G.; Zheng, Z.W.; Chen, S.H; Xu, S.J. (2010) An energy-effective clustering algorithm for multilevel energy heterogeneous wireless sensor networks. In *2nd International Conference on Advanced Computer Control (ICACC)*, Shenyang, China.
11. Brisha, A.M. (2010) Classifying Sensors Depending on their IDs to Reduce Power Consumption in Wireless Sensor Networks. *International Journal of Online Engineering*, 6(2), 41-45.
12. Heidemann, J.; Silva, F.; Intanagonwiwat, C.; Govindan, R.; Estrin, D.; Ganesan. D. (2001) Building Efficient Wireless Sensor Networks with Low-Level Naming**.** *In Proceedings of the eighteenth ACM symposium on Operating systems principles*, New York, NY, USA.
13. Chen, M.; Kwon, T.; Choi, Y. (2006). Energy-efficient differentiated directed diffusion (EDDD) in wireless sensor networks. *Computer Communications,* 29(2), 231–245.
14. Chen, J.; Lin, R.; Li, Y.; Sun, Y. (2010). LQER: A Link Quality Based Routing for Wireless Sensor Networks. *Sensors,* 8, 1025–1038.
15. Dimokas, N.; Katsaros, D and Manolopoulos, Y. (2010). Energy-efficient distributed clustering in wireless sensor networks. *Journal of Parallel and Distributed Computing,* 70, 371-383.
16. Koutsonikola, D.; Das, S.; Charlie, H.Y and Stojmenovic, I. (2010) Hierarchical geographic multicast routing for wireless sensor networks'. *Wireless Networks*, 16, 449-466.
17. Sanchez, J.A.; Ruiz, P.M and Stojmenovic, I. (2006). GMR: Geographic multicast routing for wireless sensor networks'. In *Proceedings of 2006 3rd Annual IEEE Communication Society Conference on Sensor and Ad Hoc Communications and Networks*, Reston, VA, USA.
18. Das, S.M.; Pucha, H and Hu, Y.C. (2008). Distributed hashing for scalable multicast in wireless *ad hoc* networks. In *IEEE Transactions on Parallel and Distributed Systems*, 19, 347-362.
19. Schurgers, C.; Srivastava, M. B. (2001). Energy Efficient Routing in Wireless Sensor Networks. In *Proceeding of IEEE Military Communications Conf*, USA.
20. Mahadevaswamy, U.B.; Shanmukhaswamy, M. N. (2010). An Energy Efficient Reliable Multipath Routing Protocol for Data Gathering In Wireless Sensor Networks. *International Journal of Computer Science and Information Security*, 8(2), 59-64.
21. Hwang, S.; Jin, G.J.; Shin, C.; Kim, B. (2009). Energy-Aware Data Gathering in Wireless Sensor Networks. In *6th IEEE conference on Consumer Communications and Networking, CCNC*. USA.
22. Liang, C.K.; Lin, J.D.; Li, C.S. (2010). Steiner Points Routing Protocol for Wireless Sensor Networks. In *5th International Conference on Future Information Technology (FutureTech)*, Busan, Korea.
23. Narang, S.K.; Shen, G.; Ortega, A. (2010). Unidirectional graph-based wavelet transforms for efficient data gathering in sensor networks. In *IEEE International Conference on Acoustics Speech and Signal Processing (ICASSP)*, USA.
24. Bian, Q,; Zhang, Y.; Zhao, Y. (2010). Research on Clustering Routing Algorithms in Wireless Sensor Networks. In *International Conference on Intelligent Computation Technology and Automation*, Changsha, China.
25. Duan, Z.F.; Guo, F.; Deng, M.X.; Yu. M. (2009). Shortest Path Routing Protocol for Multi-layer Mobile Wireless Sensor Networks. In *International Conference on Network Security, Wireless Communication and Trusted Computing*, China.
26. Liu, C.M.; Lee, C.H.; Wang, L.C. (2007). Distributed clustering algorithms for data-gathering in wireless mobile sensor networks. *Journal of Parallel and Distributed Computing*, 67(11), 1187–1200.
27. Heinzelman, W.R.; Chandrakasan, A.; Balakrishnan, H. (2000). Energy-Efficient Communication Protocol for Wireless Microsensor Networks. *In Proc. of the 33rd Hawaii International IEEE Conf. on System Sciences, Massachusetts Institute of Technology*, USA.
28. J-Sim: Java Simulator, Available at http://www.j-sim.zcu.cz/.
29. Yoon, j.; Liu, M.; Noble, B. (2003). Sound Mobility Models, In *Proceedings of the 9th annual international conference on Mobile computing and networking*. New York, USA.
30. Hong, X.; Gerla, M.; Pei, G.; Chang, CC. (1999). A Group Mobility Model for Ad Hoc Wireless Networks. In *Proceedings of the 2nd ACM international workshop on Modeling, analysis and simulation of wireless and mobile systems*, New York, USA.

10/10/2012