Improving the Directed Diffusion in Order to Reduce the Average of Energy Consumption in Wireless Sensor Networks

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***Abstract*—Network lifetime is an important issue in wireless sensor networks. One of the main problems in directed diffusion is the implementation of flooding diffusion used to forward interest and discover the routing map that reduces network lifetime through high energy consumption. The main purpose of this study is to limit flooding for the purpose of increasing network lifetime. In this paper, interests are classified based on their content; and the network is divided geographically. A counter is assigned to each Geographical location that will determine the use of Flooding for a potential existence of a source and to use Rumor for else where. Using the above mentioned recommendations, energy consumption would decrease due to the reduction in Flooding; and consequently, network lifetime would increase.**

Keywords-Wireless Sensor Network; Node; Sink; Directed Diffusion; Rumor; Flooding.

I. Introduction

Over the past years, there was a substantial progress in Wireless Sensor Networks. Wireless Sensor Network is a combination of large quantities of small nodes dealing directly with the physical environment. These sensors respond to the environment and gather its information. It also sends the data between the information nodes via wireless transmission. Each node works independently and without the need of human intervention. Its size is too small and has limitations in processing, memory capacity, and power supply. These limitations result in some problems which are the source of much research in this field. The most prominent concern in this network would be the information gathered by network sensors. Meanwhile, the network nodes can no longer be used after its energy consumption. Therefore, optimization of energy consumption in order to increase the network lifetime is one of the challenging discussions in this type of networks.

Recent breakthrough in radio short wave technology and micro-electro-mechanical systems led to the invention of intelligent sensors that are capable to sense and process data in wireless communications. These small sensors can be used to gather the ideal information and deliver the sensed data to central units called Sinks. Sending the sensed data to Sinks might take several steps which is a typical trait for data diffusion in wireless sensor networks.

In recent years [4], [5], [6], many algorithms and protocols have been suggested to increase efficiency and reliability for data diffusion in wireless sensor networks. For instance, flooding diffusion is the most reliable method for transmitting data from sensors to the sinks. The implementation is quiet easy as flooding protocols do not use any recondite algorithms. However, the main problem in this protocol is the amount of overhead due to the repetitive messages sent. This problem causes inefficiency in energy consumption. To solve this problem, a new data centric method has been suggested which is quiet different from the traditional routing mechanisms used in wireless sensor network. Data centric protocols are query-based and are dependent on proper data naming (including attribute and value).

Therefore, redundant transmission of many packets will be blocked; and consequently, it will increase the energy consumption. Directed diffusion is one of the data centric protocols which might be the most common data centric protocol due to its energy saving characteristics. For example, using interest message for query as well as data gathering, and using gradient mechanisms also reinforces routing. The gradient is a direction toward the neighbor nodes through which sink is accessible. In most data packets of a set, the sensor is sent toward sink. Hence, each sensor node tacitly has the direction of sink for the purpose of transmission of the sensed data toward it. The important issue here is that the amount of gradient should be built and maintained within each node. Generally, managing the amount of gradient by primary and periodically flood diffusion of controlling packets is performed via the sink. Notice that this periodical flood diffusion will result in too much overhead in sensor networks. In addition, in case of a change in network topology due to being dynamic or the decay of wireless connections,

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the value of some gradients will be invalid. Hence, the repetitive flood diffusion is required.

Throughout data discovery phase, directed diffusion encounters is that when discovered data is sent from source to the sink, each node sends this message to all neighbors. It happens because the node does not know which neighbor node has the ability of sending this data to the sink. Consequently, even if the source and sink are very close to each other, (Figure 1) many other irrelevant nodes will be involved in this connection.

The main reason for designing directed diffusion is increasing the efficiency of energy and thereafter, increasing the network lifetime.

This can be done by the help of two methods of data aggregation and in network processing to decrease the overhead of data transmission and consequently, lower energy consumption. However, due to the use of flooding diffusion, this has some limitations that cause too much overhead turnout in this algorithm. In this paper, by classifying the interests and dividing the network into separable areas, we can have a decline in energy consumption and an increase in network lifetime.

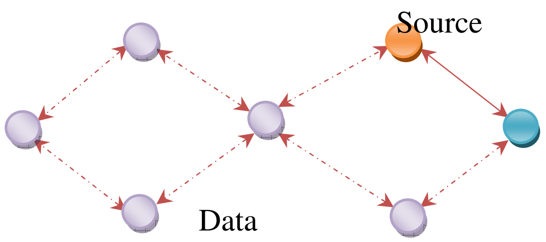

Figure 1. operation of diffusion in forwarding the discovery data

This paper includes different sections. In Section 2, we will study the works already done to improve the directed diffusion for the purpose of increasing the lifetime of network. Section 3 is regarding the suggestive method. In this part, there is a suggestion to improve the directed diffusion to increase the lifetime of network in regard to energy parameters. Afterwards, we will have the simulation in NS-2 and finally the result of simulation will be presented in the last section.

II. Review of Related Work

There has been a great deal of research in wireless sensor network routing. One of the outstanding protocols is directed diffusion. In this protocol, a sink is responsible for making the return route from all sensed sources to sink by sending an interest packet. This return route is called "Gradient". Using the interest packets and Gradients the route(s) between the source and the sink will be established. Directed diffusion uses reinforcement mechanisms to choose a high quality route among the several accessible routes to transmit the data. Based on the fact that in directed diffusion, each node sends a packet to a designated neighbor in next step through reinforced route, many of the tasks are done over the basic directed diffusion and each of them improves the overall turnover.

Basic Directed diffusion algorithm is also called diffusion algorithm with the attribute of a two-phase pull. In the first phase of this method, the destination node sends an interest packet to the network and whenever a node senses the collision of the gathered-data by its sensors, it sends a data discovery to the destination; while forwarding the interest message, gradients try to choose a gradient with the best responding time. And this process continues until it reaches the destination. After that, the source node forwards the gathered data to the destination. However being weak in a small number of situations, the two-phase pull is a suitable method for most applications.

Another improvement in directed diffusion is the hexagonal diameter based method. In this method, the sensor nodes similar to a beehive regularize a constant topology. And the main data will be transmitted over the diameter of the hexagonal. In fact, the hexagonal diameter is supposed to be the main route. In this method, the main routes change periodically to distribute the energy consumption among the sensors (Figure 2).

In order to decrease the energy consumption, 'active' status of sensors is used in the time of forwarding data and 'inactive' status is used in case the sensors are idle.

The rate of energy consumption and deferment in responding to an interest has a wonderful efficiency in comparison with basic forwarding.

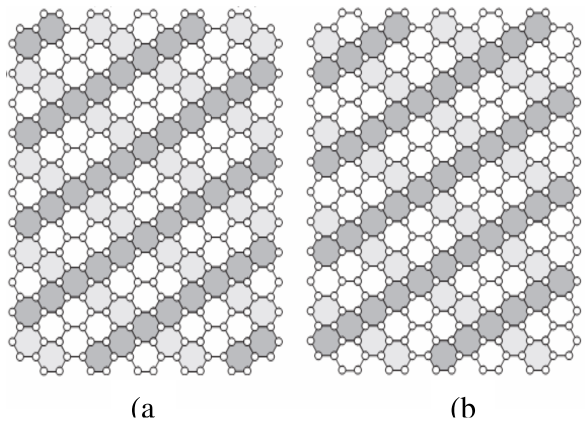

Figure 2. The periodic change to distribute the energy consumption among the sensors

Regarding the high cost of directed diffusion in flooding diffusion of data to energy source, a method has been devised to prevent the waste of energy in [9] entitled passive clustering. The main duty of clusters is to optimize the exchange of flood messages that prevents a high level of overhead. These clustering are forwarded with flooding of the controlling messages which occurs when there is no traffic within the network; as a result, it causes waste of energy for maintaining the structure of the cluster. Passive clustering, on the contrary to classic clustering algorithm, is dynamic and is created by the first flood message.

In this method, long frequency of cluster adjustment is prevented. To do this, controlling messages for maintaining cluster are not used explicitly. And all the related information, for maintaining clusters in data messages exchanged in network, is carried. In fact, passive clustering is an appropriate mechanism addressed to increase the efficiency of these crucial diffusion phases and consequently, the efficiency of the whole protocol. The protocols share some common properties:

1. They are on-demand mechanisms that maintain the operation only in case there is application traffic in need of their services.

2. They purely rely on local information for performing their functions. Figure 3 illustrates the structure of directed diffusion routing when passive clustering is used. The simulation results show that directed diffusion along with passive clustering in transmission rate actually increase the density of the network, and deferment has a better performance in comparison with basic forwarding.

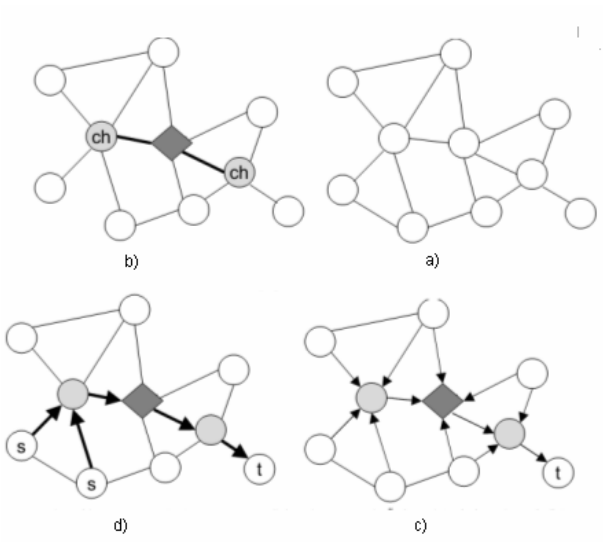

Figure 3. structure of clustered directed diffusion (Gray circles are head of groups and diamonds are the gates)

Based on the type of applications, sensor network have different needs. Directed diffusion is a data centric protocol whose performance in optimizing the energy consumption will be decreased significantly when a proper application is not used. In [12], a compatible directed diffusion routing protocol have been suggested based on their application. In this plan, a general message is used which has the potential of being applied to different practical scenarios just by a slight change. In this method, different versions of directed diffusion are defined in a general message. In fact, according to different applications, adaptive directed diffusion changes are made to result in the desired version. The results of simulation demonstrate that this idea in comparison with other directed diffusion in time of change has a good performance and application.

In [15], a method have been suggested which shows using two filters with the capability of forwarding increase energy. The first filter is a real-time filter which is used to decline the end-to-end deferment in real-time traffics. The second filter named as the best-effort delivery has been suggested in order to reach the global dominant energy as a result of network lifetime growth. Besides, a repairing mechanism for restoring node decay and connections is implemented for real-time traffic. The results of simulation illustrate that the suggested method has different service diffusion for real-time traffic and best-effort as well as low deferment for real-time traffic and totally provides more network lifetime in comparison with the basic diffusion.

In [16], in order to decrease the overhead of network resulted by the exchanged packets for periodical diffusion of interests, delivering the data discovery to sink will be declined. As a result, the energy consumption decreases due to the reduction in the number of exchanged controlling messages; therefore, the network lifetime increases. In the light directed diffusion; first of all, a spars logical topology will be produced through simple, local rules. Then, the directed diffusion will be implemented on this topology.

In the mentioned protocols, this section covers only energy efficiency using various mechanisms. Following that, in the next section, a method is suggested for increasing the network lifetime.

III. SUGGESTIVE METHOD ALGORITHM

A. *Clustering interests*

In order to overcome the limitations discussed in the previous section, in suggestive algorithm, we have clustered the interests based on demand; for example, clustering the temperatures over 35°; by clustering and naming the interests will be clustered; as a result, it will be quite easy to recognize the source.

B. *Network segmentation*

Network is segmented geographically; nodes store the vector and specifications of the neighbor nodes in a table and are informed about the neighbors. And their own sink node is defined as the vector of the source; and by the help of the neighbors' vectors, the network is divided into necessary segments. A variable to each segment is assigned and in case of finding the source in that area, the variable will be reported.

C. *Selection of Diffusion filter*

After clustering, segmentation and assigning a variable to each class and area, in the diffusion phase, the variables will be analyzed and filter selection will be done based on value.

Moreover, before transmission, first of all the sink will check its variables, when one variable is more than the other variables, sink uses flooding phase otherwise, it uses the rumor phase.

The filters used in suggestive method are divided into two types by accuracy in search and the rate of energy consumption.

1. Flooding
2. Rumor

1. Flooding filter

In Phase One of this method, the destination node will forward an interest to the network. As soon as a node senses the adaptation of the gathered data using its sensors with the forwarded interest, a discovery data (packet) will be sent to the destination and this data will try to select the best gradient with the highest quality and the best response time. It will continue until it reaches the destination, afterwards, the source node will forward the gathered data toward the destination.

The main station will request the data with an interest broadcast. Interest will describe the work that must be done by the network. Interest will be forwarded all over the network hop by hop. At the same time, each node will forward it to its neighbor nodes. As the interest is broadcast throughout the network, the routes for forwarding the acceptable data to the applicant node will be created. Each sensor receiving the interest will create a gradient 3 to the sensor nodes that had received the interest. This will continue until the time the gradient from source to the main station is created. Generally, a gradient defines an attribute and a route. Stability of gradient may vary from one neighbor to the other. Consequently, the rate of data stream will be different. Figure 4 shows the directed diffusion when the interests match the gradients. The data stream routes are a combination of some routes, and then the best route will be reinforced by local rules to prevent the flooding diffusion. In order to decrease the cost of connections, the data will be aggregated in a route. The main goal is to find a proper aggregate tree that receives the data from the sources and sends it to the main station. The main station periodically will be refreshed and will send interest to make sure the reliable transmission of data when it begins to receive data from the source(s).

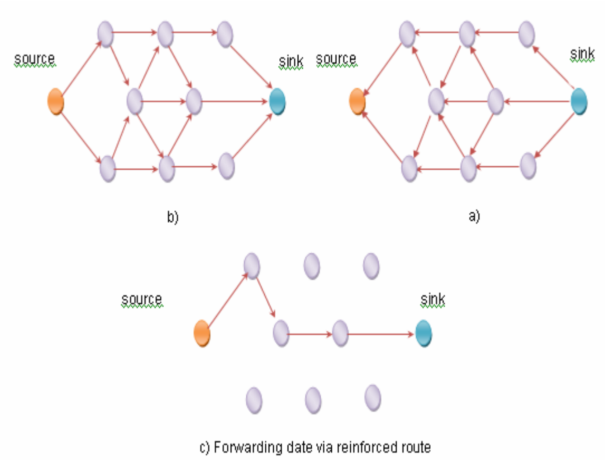

Figure 4. directed diffusion operation

2. Rumor filter

Directed diffusion uses flood forwarding to inject the query to the whole network, but in some cases there are only a few requests from the nodes; therefore, there is no need for the flood diffusion in this case. The flood diffusion is suggested when there are few events and many queries. The main goal is to clarify the routes for queries from the receiving nodes instead of drowning into the whole network to restore information about the events. In order to flood diffusion of events in the network, the algorithm of Rumor routing packets with higher lifetime called 'agent' is used. When a node discovers an event, it will add that event to its local table called as the 'Events table' and will produce an agent. The agent surveys the network to forward the local events to the far nodes. When a node produces a query for an event, the nodes that know the path might respond to this query by referring to their Events-table. Therefore, there is no need to flood the whole network. Consequently, it will cause a decline in the cost of connections. In other words, Buzz routing against two-phase pull keeps only one route between the source and the destination. As we can see in Figure 5, the steps decrease with the cutout of route with source searching, and the energy will be saved. On behalf of events, an agent with a definite lifetime will be created to survey the network. Meanwhile, the sink will deliver its interest to one of the neighbors and the survey will continue until the route of agent and diffusion cutout each other. With the cutout of the two routes, the table will be updated and the new path with fewer steps will be replaced.

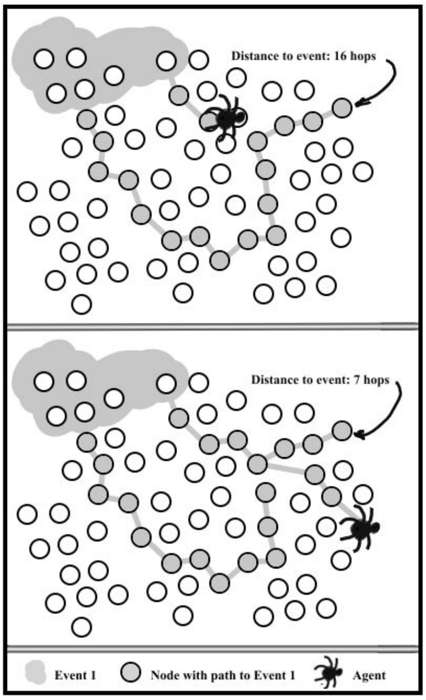

Figure 5. Operation of propagation rumor

D. *Diffusion filter management*

Before the discovery stage, first the counter variable is analyzed. When the network is initiating, all the counters are set by the value of zero. When the values of the counters are equal, the two-phase pull method is used. In other words, at the time of network start due to the equality of the counters, the whole areas of the network will be searched thoroughly to discover the source in cases where the values of the counters are less than the other ones. In other words, the Rumor filtering with low energy consumption rate is used wherever there is less probability of source presence.

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IV. Evaluation of Suggestive Method

E. *Implementation*

In order to implement the algorithm, we use the Diffusion 3.2.0 code which is given out along with ns-allionone-2.29 software. In these two packs, there are two versions of directed diffusion algorithm including diffusion and diffusion3. The diffusion version is for implementation of simple algorithm and therefore takes less detail. In this paper, with a change in filter of two-phase pull which is in Diffusion 3.2.0 algorithm, the suggestive method is implemented and using API, it is diffused as a filter toward the core.

F. *Simulation scenarios*

In this experiment, the number of the nodes is 250 at most, and is distributed throughout 160 * 160 square meters. The protocol 802.11 is used to simulate the wireless scenario Diffusion 3.2.0 in Ns-allinone-2.29. According to energy consumption in PCM-CIA WLAN card as ns2 and the nodes are expanded in grid.

Table I. Simulation Scenarios

Parameter	Value
Routing Protocol	Diffusion
MAC Protocol	IEEE 802.11b
Radio Transmission Power	0.660mw
Radio Reception Power	0.395mw
Radio Idle Power	0.0375mw
Sensing Power	0.0325mw
Radio Propagation Model	Two-Ray
Packet Size	100 bytes
Data Rate	1Mbps
Radio Range	90 meter
Sensing Range	13 ~ 48 meter
Area	160 m * 160m
Number of nodes	250

V. Simulation Results Survey

In this section, the results of simulation for each of the discussed scenarios in previous section are presented. The graph regarding the results is illustrated. Then the results of each simulation will be studied.

We have compared our suggestion algorithm with pervious algorithms, Two-Phase-Pull and passive clustering directed diffusion (pcdd).

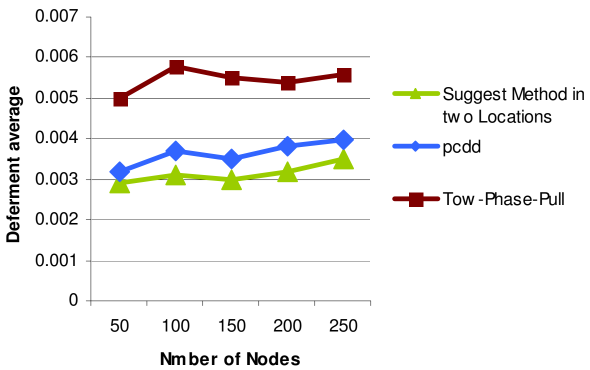

Figure 6. comparison of the amount of delay in two locations

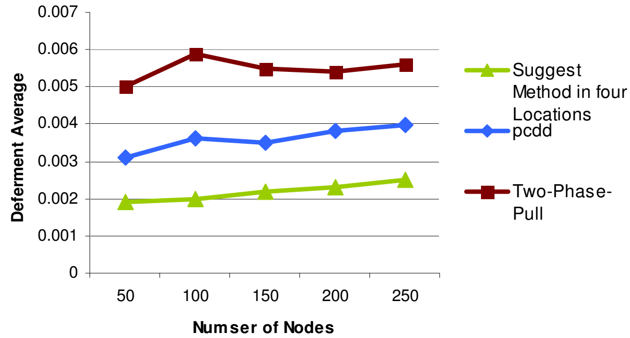

Figure 7. comparison of the amount of delay in four locations

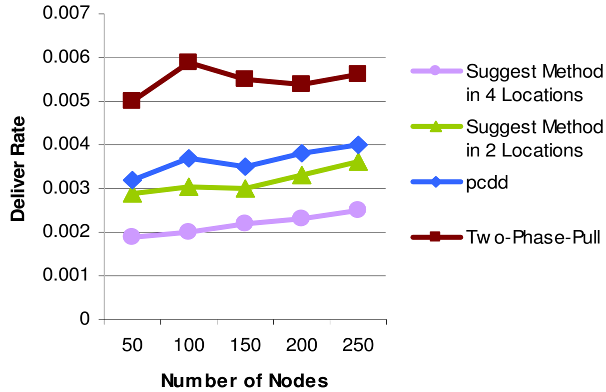

Figure 8. comparison of the amount of delivery

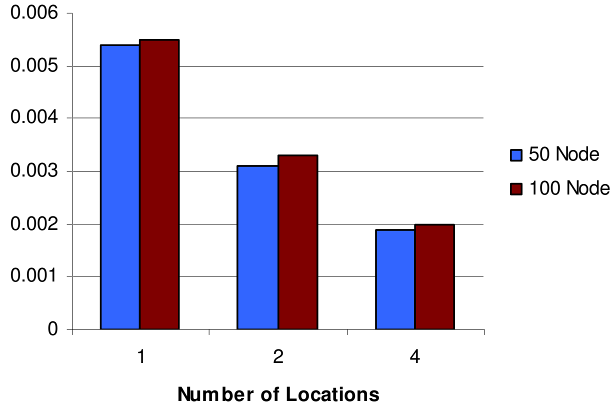

Figure 9. Comparison of the average energy consumption in one, two, and four locations

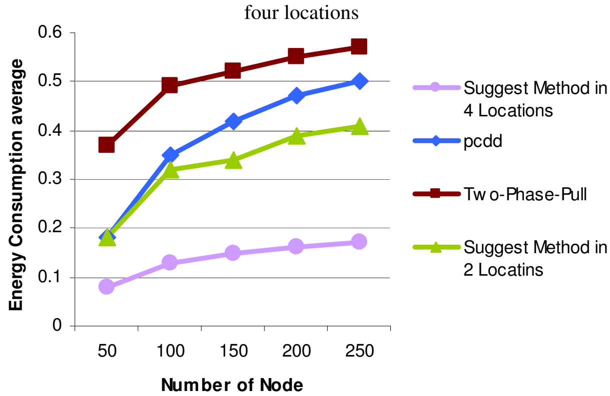

Figure 10. Comparison of the amount of energy consumption average

When we increased the number of locations, network's delay decreased. By raising the number of regions, sink could find the source sooner than pervious methods and Figure 6 and Figure 7 demonstrate this matter. Although pervious methods had fluctuations, our algorithm rose slightly; when the number of regions increased, the average energy consumption decreased. Figure 9 and Figure 10 also present that the amount of delivery decreased.

VI. CONCLUSION AND FUTURE WORK

With increasing the number of locations in each area, fewer nodes are used and in case an interface node is spoiled, source would not be accessible. As a result, with increasing the number of locations when the node is spoiled, access to the source might not be possible. However, if the network encounters a lot of decay with the addition of locations, the delivery rate will get worse. If the locations reach the point that there is a node in each location with minimal overhead and traffic and 100% delivery, through increasing locations in case of presence of an interface node, accessing the source may not be possible. Hence in future works, this problem could be solved. For example, if eight locations were not found and the decay happened, access to the source could be improved by decreasing the number of locations to four segments. Our goal is to decrease the overhead. Using the limited Directed Diffusion, we tried to increase the network lifetime by reducing energy consumption.

REFERENCE

[1] C. Intanagonwiwat, et al.,"Directed Diffusion: A scalable and robust communication paradigm for sensor networking," MobiCom, Rome, Italy, 2004, pp. 438-449.

[2] I.F. Akyildiz, et al., "Wireless Sensor Networks: a Survey" Computer Networks, Vol. 38, March 2002, pp. 393-442.

[3] J. Heidemann, F. Silva, and D. Strin, "Matching Data Dissemination Algorithms to Application Requirements," Proceedings of The First ACM Conference on Embedded Networked Sensor Systems (Sensys), November 2004, pp. 218-229.

[4] Y. ShyanChen, Y. WenNian, and J. PingSheu, "An Energy Efficient Diagonal-Based Directed Diffusion for Wireless Sensor Networks," Proceedings of the Ninth International Conference on Parallel and Distributed Systems (ICPADS), 2006 IEEE, pp. 445-450.

[5] R.D. Pietro, L.V. Mancini, Y.W. Law, S. Etalle, and P. Havinga, "LKWH: A Directed Diffusion-Based Secure Multicast Scheme for Wireless Sensor Networks," Proceedings of the International Conference on Parallel Processing Workshops (ICPPW), 2005 IEEE, pp. 56-67.

[6] C. Wong, M. Gouda, and S. Lam, "Secure Group Communications Using Key Graphs," IEEE/ACM Transactionson Networking (TON), 2004, pp. 16-30.

[7] D. Wallner, E. Harder, and R. Agee, "Key management formulticast: Issues and architectures," RFC 2627, IETF, June 2002.

[8] W. Ding, S.S. Iyengar, R. Kannan, and W. Rummler, "Energy Equivalence Routing in Wireless Sensor Networks," Microprocessors and Microsystems, 2006 Elsevier, pp. 467-475.

[9] V. Handziski, A. Kopke, H. Karl, C. Frank, and W. Drytkiewicz, "Improving the Energy Efficiency of Directed Diffusion Using Passive Clustering," EWSN, 2007 Springer, pp. 172-187.

[10] D. Bein and A. K. Datta, "A Self-Stabilizing Directed Diffusion Protocol for Sensor Networks," Proceedings in International Conference on Parallel Processing Workshops (ICPPW), 2008 IEEE, pp. 393-422.

[11] Z. Y. Yuan, X. Bo, and Z. Z. Ming, "Adaptive Directed Diffusion Routing in Wireless Sensor Networks Based on Application," CCECE/CCGEI, 2005 IEEE, pp. 51-58.

[12] W. Marc Lee, V. Wong, "LPT for Data Aggregation in Wireless Sensor Networks", IEEE Globecom, 2005, pp. 2069-2074.

[13] W. Marc Lee and V. Wong, "E-Span and LPT for Data Aggregation in Wireless Sensor Networks", Computer Communications, Elsevier, 2006, pp. 2506–2520.

[14] C. Min and K. Taekyoung, C. Yanghee, "Energy-efficient Differentiated Directed Diffusion (EDDD) in wireless Sensor Networks", Computer Communications, Elsevier, 2006, pp. 231-245.

[15] M. Alessia, N. Michele, P. Chiara, and V. Andrea, "Directed Diffusion Light: Low Overhead Data Dissemination in Wireless Sensor Networks", IEEE, 2005, pp. 148–159.

[16] C. Sun, H. Lee, and T. Cho "A Path Selection Method for Improving the Detection Power of Statistical Filtering in Sensor Networks", 2009, pp. 1163-1175.

[17] L. Thanh and J. Levendovszky, "A Novel Reliability Based Routing Protocol for Power Aware Communications in Wireless Sensor Networks", IEEE, 2009, pp. 1163-1175.