Using intermediate sinks to increase the lifetime of wireless sensor networks

Yousef Tohidirad, Fereshteh Chabok, Roya Chabok, Abbas Akkasi

Abstract— Recent advancements in electronic and wireless telecom have provided ability of design and produce sensors with low consumption, small size, appropriate price, and variant functionalities. These small sensors which are able to do operations such as receiving different environmental information according to the type of the sensor, processing and sending that information have led to an idea to emerge and develop networks called wireless sensor networks. These sensors also have some limitations in their processing power, memory capacity, power supply, and etc. these limitations cause problems which are the origin of many research issues raised in this area. From important issues in this area is to increase network lifetime in order to better use of available resources. Appropriate routing can be a solution to decrease network's energy consumption and also increase network lifetime. In this research, we have studied routing algorithms in wireless sensor networks and also have analyzed the impact of the number of network's intermediate sinks on increasing the network lifetime.

Index Terms— Wireless Sensor Network, Reinforced Path, Time Slot, Quality of Service, Memory capacity, processing power, network lifetime.

1 INTRODUCTION

RECENT ADVANCEMENTS IN ELECTRONIC AND WIRELESS HAVE PROVIDED ABILITY OF DESIGN AND PRODUCE SENSORS WITH LOW CONSUMPTION, SMALL SIZE, APPROPRIATE PRICE, AND VARIANT FUNCTIONALITIES. THESE SMALL SENSORS WHICH ARE ABLE TO DO OPERATIONS SUCH AS RECEIVING DIFFERENT ENVIRONMENTAL INFORMATION ACCORDING TO THE TYPE OF THE SENSOR, PROCESSING AND SENDING THAT INFORMATION HAVE LED TO AN IDEA TO EMERGE AND DEVELOP NETWORKS CALLED WIRELESS SENSOR NETWORKS [1].

From many aspects, Wireless sensor networks are similar to Mobile Ad-Hoc Networks (MANET), yet the protocols used for Ad-Hoc [2] networks are not suitable for wireless sensor networks. In Ad-Hoc networks, the main issue in protocols' design is the Quality of Service (QoS) while in wireless sensor networks the main limitation of protocols' design is limited energy of sensors. In fact, protocols able to minimize power consumption in sensors are more considered for wireless sensor networks.

Generally the main differences between wireless sensor networks and Ad-Hoc networks can be mentioned as [1]:

- The number of network nodes in WSN is much more than Ad-Hoc networks.
- Sensors in WSN have been placed in a compact form.
- Sensors in WSN are more susceptible to failure.
- WSN's topology is constantly changing.
- Connections in the most of WSNs are distributed while in Ad-Hoc networks they are point to point.
- Sensors are limited in size, power, computing power, and memory.

2 Routing in WSN

In this section, first the particular features of sensor networks (which distinguish routing in these networks from usual wire and wireless networks) are explained. Then various routing protocols which have been designed regarding these features will be surveyed.

Major differences between WSNs and usual wire and wireless networks which distinguish routing in these networks can be noticed as:

- The lack of global addresses so protocols like Internet protocol have no applicability.
- In most of communications, data collected by sensor nodes is sent to the sink from different regions. Therefore we have multiple to one connection instead of end to end.
- Sensors in one area observe similar data and we are witnessing information redundancy.
- Sensors are limited in the power of sending data, energy, processing power, and memory. So in addition to providing QoS, routing protocol should have a precise management on resources and energy saving.

Categorizing routing protocols of WSNs

Considering mentioned differences, several protocols have been presented to solve routing problem in these networks. In addition to particular features of WSNs, network application and the needs of its structure have been considered in design of these protocols. Routing protocols can be studied from two

aspects. From the perspective of network structure, protocols are divided into three groups of Flat, Hierarchical, and Location-base.

2.1 Flat routing protocols

SPIN [3] is the first flat and database protocol which considered negotiation between nodes in order to decreasing redundancy and energy consumption. After that, Directed diffusion [4] was presented which made an evolution in flat and database routing. Then many other protocols was presented based on Directed diffusion or followed its concept. From the other famous protocols of this group, we can point EAR [5] and GBR [6] protocols. Simulation results have shown that GBR in more effective than Directed Diffusion in energy consumption.

2.2 Hierarchical routing protocols

For LEACH [7] protocol is one of the first hierarchical protocols introduced for WSNs and many other protocols have been designed based on that. Some other hierarchical protocols are: PEGASIS [8], TEEN [9], and APTEEN [10].

In terms of efficiency in energy consumption and network lifetime, APTEEN is worse than TEEN and TEEN shows a better efficiency by decreasing sent information [9]. The main problem of both protocols is in forming clusters. In fact, forming clusters in TEEN and APTEEN is a bit complicated and difficult.

2.3 Location-based protocols

Some famous protocols in this group are: GAF [11], GEAR [12], and TTDD [13].

GEAR is compared with an almost similar protocol called GPSR [14] which in of coarse sensors energy is not considered. This protocol has been designed for MANET which performs better than GPSR by saving energy and more appropriate routing. Simulation results shows that under the condition of uneven distribution of traffic, GEAR transmits near 70% to 80% more than GPSR and this amount is about 25% to 32% in even distribution of traffic [12].

2.4 Routing protocols based on protocol's performance

An According to protocol's performance in routing and targets followed in routing, routing protocols can be divided into four categories:

- Multiple routing protocols
- Routing protocols based on query
- Routing protocols based on negotiation
- Routing protocols with QoS: two famous protocols of this category are: SAR [15] and SPEED [16]. Comparing to DSR [17] and AODV [18] routing, SPEED performs better in terms of end to end delay and packets loss rate. Moreover, total energy consumption is low because of simplicity of the algorithm and low overhead of control packets. But SPEED does not consider any energy consumption in packet routing.

Up to now, various efforts have been done in multi-sink WSN area. Huang and association [19] model and study load distribution with mathematical methods in multi-sink sensor networks. Wang and association [20] first prove that input process of sink nodes in WSN can be modeled with Poason? process. Then they studied M/G/∞ queue for multi-sink WSN and show that this model can be used instead of M/G/c/∞ in low loads in modeling WSN. In [21], optimized selection methods for sending data in multi-sink WSN have been surveyed in a way that load-balancing would occur in the network and also energy would be distributed steadily within the network. Also in [22], Das and association have presented two methods for sink placement in WSN, checked for each one's advantages and disadvantages and ultimately compared them with GPS strategy.

In the next section, two famous and basic routing algorithms of Directed Diffusion and LEACH will be explained and the impact of intermediate sinks on them will be studied.

3 Directed Diffusion Algorithm

This protocol is one of the very predominant and important protocols of Data-Centric type which many protocols have been established based on that. In this protocol, characteristics called Attribute-Based Naming are defined for data and requests so that instead of sending raw data, these characteristics are being sent. The protocol has been designed in a way that whenever there is a new request, routing will be started based on that. Noticed characteristics for a request can be for example the name of considered parameters for measuring, sending data period, sending time, geographic area, and etc. each sensor receiving data stores that in its memory for further uses. Sensors locally do data combination and this way they decrease sent information volume. Receiving a request, a sensor sends that to its neighbors so that a Gradient is getting formed among them. Gradients are factually return paths which neighbor sensors receive request through that. By forming a gradient, different paths emerge between sender and receiver. Among these paths, only one path is selected as the reinforced path. This selection is based on information receive rate from different paths. In fact, that path can be selected which have greater rate of return information. In figure 1, Directed Diffusion has been demonstrated.

- *Yousef Tohidirad ,master's degree program in IT engineering in Islamic Azad University E-Campus, Iran. E-mail: Yousef.tohidi@yahoo.com*
- *Fereshteh Chabok ,master's degree program in IT engineering in Islamic Azad University E-Campus, Iran. E-mail: Fereshte.chabok@yahoo.com*
- *Roya Chabok ,master's degree program in IT engineering in Islamic Azad University E-Campus, Iran. E-mail: roya.chabok@yahoo.com*
- *Abbas Akkasi, masters in Islamic Azad University E-Campus, Iran. E-mail: abbas.akkasi@gmail.com*

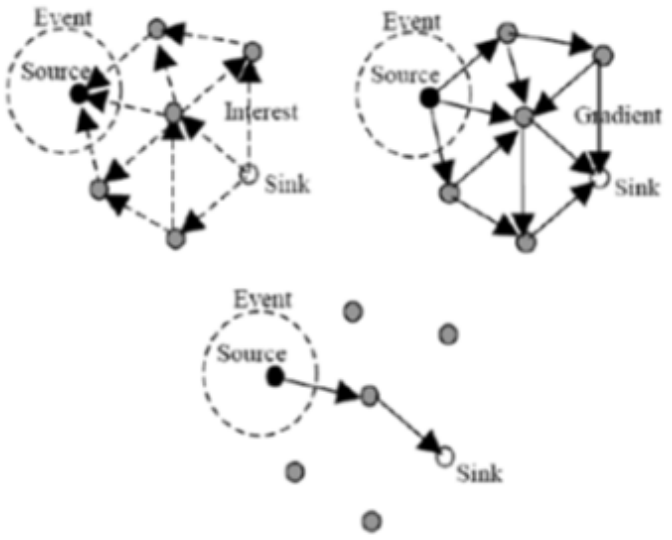

Fig. 1. Directed Diffusion performance

4 LEACH ALGORITHM

IJSER This protocol is one of the most famous hierarchical protocols for WSN. In this protocol, time is divided in parts called Round. Each round also is divided into two phases. First phase is called Launching which is in fact the phase of forming clusters and second phase is relevant to normal network's operation which is called Stable phase. In the first phase, cluster heads (CH) are selected based on an adaptive probability function. Selecting CHs comes to be in this way that each sensor node accidentally chooses a number between 0 and 1. If this number was smaller than a determined threshold, then that node will be selected as CH in that round.

This probability function has been designed in a way that within a certain number of rounds, each sensor becomes CH just for one time so that energy consumption is spread on the whole network. After selecting CHs in launching phase of each round, each CH announce its selection as CH to the other nodes and also each node chooses a suitable CH for itself and announce that to the notices CH so that clusters get formed. After that, every CH schedules for sensors of its clusters and allocates a Time Slot to each sensor which through that, it prevents Collision between sensors' data of each cluster. Moreover, Direct Sequence Spread Spectrum (DSSS) method is used to prevent Collision among different clusters' data.

In the second phase, each sensor sends its data in its own time slot and after receiving all existed sensors' information, CH combines them in its cluster and sends them to the base station. Considering that each CH combines all sensors' data in its cluster, a significant saving in sent data volume and consequently in energy consumption will be achieved.

Of the most important advantages of LEACH algorithm is that the difference between lifetime of different nodes have been diminished compared to former protocols and also network lifetime has been increased using the idea of dynamic clustering. But forming clusters causes energy loss at the beginning of each round which is one of disadvantages of this protocol. LEACH shows a better performance where sensors have been located in a compact form beside each other. Simulation results show better performance of LEACH than older protocols such as Direct Communication and Minimum Transmission Energy.

5 SIMULATION AND RESULT ANALYSIS

Simulation has been done in a network including 100 nodes which nodes' placement have been determined by accident and initial value of each node's energy have been considered 0.5J. Location of the nodes follows figure 2. Networks with 1 sink, 2 sinks, 3 sinks, and 4 sinks have been shown respectively in figure 3, 4, 5, and 6. Sinks' location has been chosen in order to cover the most possible space in network space and also to have the less overlap with each other. Simulation has been done in ns-2 environment and has been run for 500 seconds.

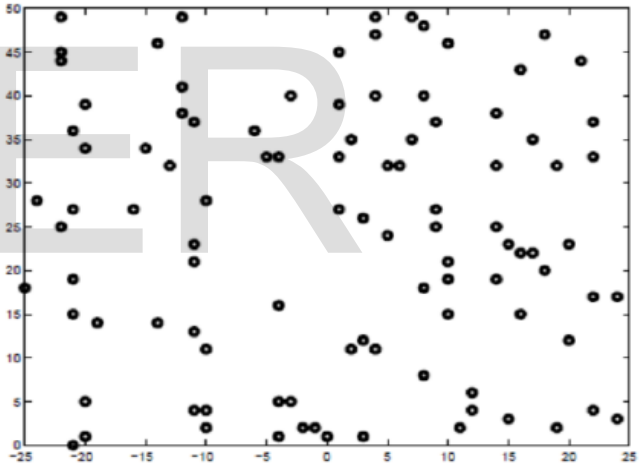

Fig. 2. An accidental network with 100 nodes

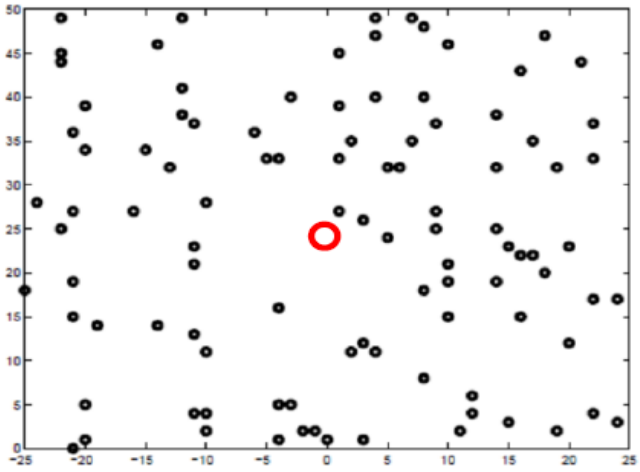

Fig. 3. Network with 1 sink

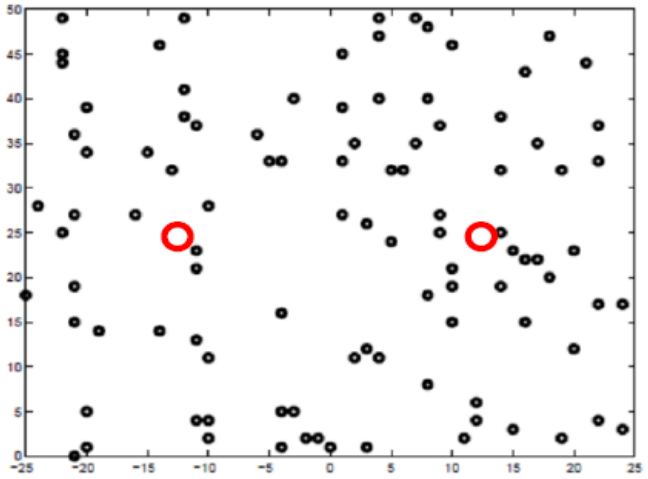

Fig. 4. Network with 2 sinks

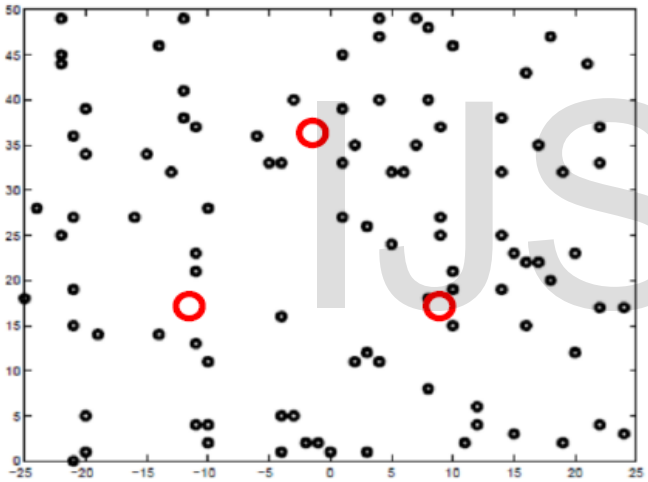

Fig. 5. Network with 3 sinks

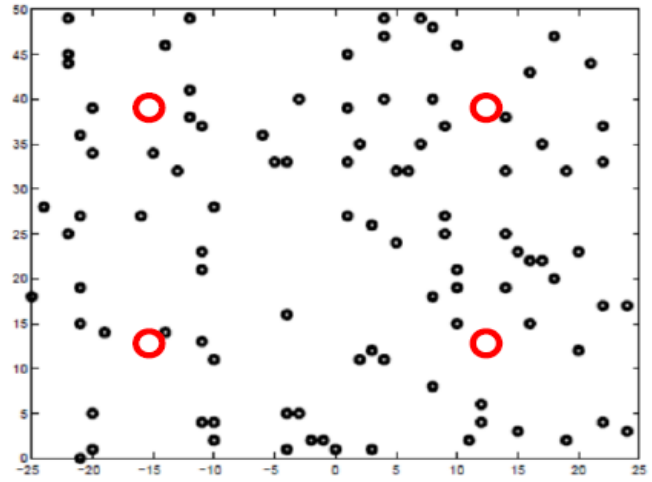

Fig. 6. Network with 4 sinks

Results for different number of sinks on Directed Diffusion and LEACH algorithms demonstrate that by increasing intermediate sinks, network lifetime will be increased too. Relevant results for Directed Diffusion and LEACH has been respectively shown in figure 7 and 8.

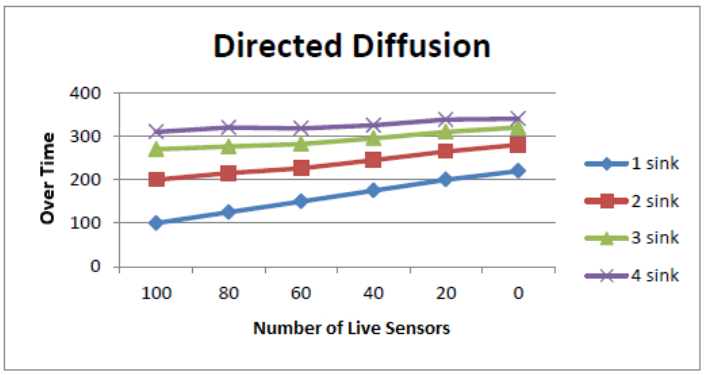

Figure 7. Number of live sensors over time in Directed Diffusion algorithm

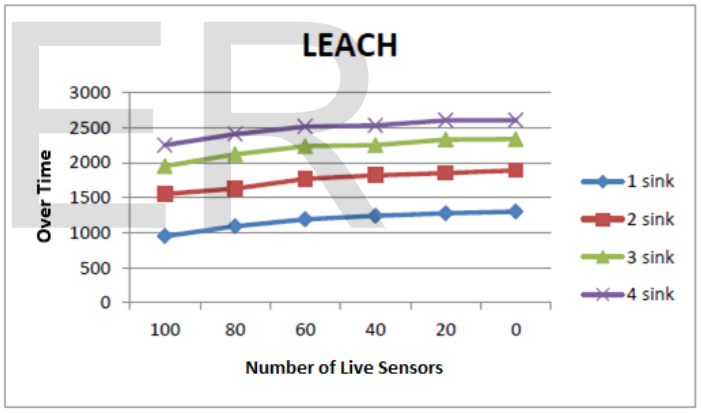

Fig. 8. Number of live sensors over time in LEACH algorithm

4 Conclusion

In WSNs, sensors' limited energy is a complicated issue and computer science scholars have done many efforts to solve this problem. Proposed solutions are usually in form of optimized routing and with lower energy. In this research, another solution to increase network lifetime and overcoming the problem of sensors' limited lifetime has been presented. Also considering the results, we proved that increasing intermediate sinks to collect sensors' information is an appropriate and cost effective solution.

References

[1] I.F. Akyildiz, W. Su, Y. Sankarasubramaniam, E. Cayirci, "Wireless sensor networks: a survey", Computer Networks 38, 2002, pp. 393–422.

[2] C. Perkins, Ad Hoc Networks, Addison-Wesley, Reading, MA, 2000.

[3] A. Perrig, R. Szewczyk, V. Wen, D. Culler, J.D. Tygar, "SPINS: security protocols for sensor networks", Proceedings of ACM MobiCom'01, Rome, Italy, 2001, pp. 189–199.

[4] C. Intanagonwiwat, R. Govindan, D. Estrin, "Directed diffusion: a scalable and robust communication paradigm for sensor networks", Proceedings of the ACM Mobi-Com'00, Boston, MA, 2000, pp. 56–67.

[5] K. Sohrabi, J. Gao, V. Ailawadhi, G.J. Pottie, "Protocols for self-organization of a wireless sensor network", IEEE Personal Communications, October 2000, pp. 16–27.

[6] O. Powell, A. Jarry, P. Leone, and J. Rolim, "Gradient Based Routing in Wireless Sensor Networks: a Mixed Strategy," arXiv.org automated e-print archives, Report CS-0511083, Tech. Rep., 2005. [Online]. Available: http://arxiv.org/abs/cs/0511083

[7] W.R. Heinzelman, A. Chandrakasan, H. Balakrishnan, "Energy-efficient communication protocol for wireless micro sensor networks", IEEE Proceedings of the Hawaii International Conference on System Sciences, January 2000, pp. 1–10.

[8] S.Lindsey, C. S. Raghavendra, "PEGASIS: Power Efficient Gathering in Sensor Information Systems", IEEE Aerospace Conference (Mar, 2002).

[9] A. Manjeshwar and D. P. Agrawal, "TEEN: A Protocol For Enhanced Efficiency in Wireless Sensor Networks," in *Proc. 1st International Workshop on Parallel and Distributed Computing Issues in Wireless Networks and Mobile Computing*, San Francisco, CA, April 2001.

[10] A. Manjeshwar and D. P. Agrawal, "APTEEN: A Hybrid Protocol for Efficient Routing and Comprehensive Information Retrieval in Wireless Sensor Networks," in *Proc. International Workshop on Parallel and Distributed Computing Issues in Wireless Networks and Mobile Computing*, Ft. Lauderdale, Fl, April 2002.

[11] Y. Xu, J. Heidemann, and D. Estrin, "Geography-informed Energy Conservation for Ad-hoc Routing," in *Proc. ACM/IEEE MOBICOM 2001*, pp. 7084, 2001.

[12] Y. Yu, D. Estrin, and R. Govindan, "Geographical and Energy-Aware Routing: A Recursive Data Dissemination Protocol for Wireless Sensor Networks," *UCLA Computer Science Department Technical Report* UCLA-CSD TR-010023, May 2001.

[13] F. Ye *et al*., "A Two-Tier Data Dissemination Model for Large-Scale Wireless Sensor Networks," *Proc. ACM/IEEE MOBICOM*, 2002.

[14] B. Karp and H. T. Kung, "GPSR: Greedy Perimeter Stateless Routing for Wireless Sensor Networks," *Proc. MobiCom 2000*, Boston, MA, Aug. 2000.

[15] K. Sohrabi, J. Gao, V. Ailawadhi, G.J. Pottie, "Protocols for self-organization of a wireless sensor network", IEEE Personal Communications, October 2000, pp. 16–27.

[16] T. He *et al.*, "SPEED: A Stateless Protocol for Real-time Communication in Sensor Networks," *Proc. Int'l. Conf. Distrib. Comp. Sys.*, Providence, RI, May 2003.

[17] David B. Johnson, David A. Maltz, Yih-Chun Hu, "The Dynamic Source Routing (DSR) Protocol for Mobile Ad Hoc Networks", . http://www.ietf.org/internetdrafts/draft-ietf-manet-dsr-10.txt, July 2004.

[18] C. E. Perkins and E. M. Royer. "Ad hoc on-demand distance vector routing." In *Proc. of IEEE WMCSA*, February 1999.

[19] Chiming Huang, Rei-Heng Cheng, Tung-Chih Shu, "Load Distribution of Sensors in Multi-Sink Wireless Sensor Network", International Conference on Information Technology and Computer Science - ITCS , 2010.

[20] Wang, Zhenfei Sch. of Comput. Sci. & Electron. Eng., Univ. of Essex, Colchester, UK Yang, Kun; Hunter, David K. "Modelling and analysis of multi-sink wireless sensor networks using queuing theory", Computer Science and Electronic Engineering Conference (CEEC), 2012 4th, pp. 169 – 174.

[21] Sheng-Tzong Cheng, Tun-Yu Chang, "An adaptive learning scheme for load balancing with zone partition in multi-sink wireless sensor network", Expert Systems with Applications, 39(2012).

[22] Das, Debasree, et al. "Multiple-sink placement strategies in wireless sensor networks." *Communication Systems and Networks (COMSNETS), 2013 Fifth International Conference on*. IEEE, 2013.