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A Lifetime Extension Protocol for Data Gathering in Wireless Sensor Networks

Ouadoudi Zytoune[1-2] and Driss Aboutajdine[2]

[1]LaRIT Lab, Ibn Tofail University, Kenitra, Morocco

[2]Faculty of Sciences, Mohamed V University, Rabat, Morocco

ABSTRACT: Wireless Sensor Network (WSN) is a collection of large number of tiny sensor nodes that are deployed to monitor the physical environment such temperature, humidity, etc. The sensor readings must be routed to the base station and then to the end-user. These sensor nodes have limited capabilities, especially the energy reserve, the processing ability and the memory storage. So, the routing protocols design for this kind of networks is a crucial challenge. Since these routing protocols should be simple, energy-efficient, and robust to operate with a very large number of nodes. They should also be auto-configurable to node failures and changes of the network topology dynamically. This paper presents a new algorithm for gathering data in WSN based on chain forming using greedy algorithm. It focuses on equitably distributing the energy load over the whole network nodes. To avoid fast node dying, the leader role is better distributed over nodes based on their required energies to transmit to the sink. Thus, the entire network nodes would have the same lifetime and then as result, the network lifetime would be extended. We have conducted simulation-based evaluations to illustrate the performance of the proposed technique. The simulation results show that this algorithm allows network stability extension compared to the most known chaining algorithm.

KEYWORDS: Wireless Sensor Networks, Data Gathering, PEGASIS, Greedy algorithm, Network lifetime.

1 INTRODUCTION

A Wireless Sensor Network (WSN) is a collection of tiny, lightweight and inexpensive sensor nodes deployed in large numbers to monitor the surrounding conditions [1]. These WSN have diverse application domains such as environmental survey, smart home, medical and agriculture monitoring. Since they have small size, the available energy at each sensor nodes is considered as the major constraint. Hence energy consumption is the important criteria for designing protocols for this kind of networks [2], [3]. Some of the early works on WSNs have discussed the benefits of WSNs in detail [4], [5], [6]. WSN have main advantages over the conventional networks deployed for the same purpose such as greater coverage, accuracy, reliability and all of the above at a possibly lower cost. In the last few years a variety of protocols have been proposed for prolonging the WSN duration service when routing the collected data to the sink. Most of the protocols can be classified as either flat or hierarchical based. In a densely deployed sensor network, the physical environment would generate very similar data in close-by sensor nodes and transmitting such data is more or less redundant. An event is often detected by more than one sensor and duplicated data is generated. This redundancy is often eliminated, which cannot only diminish the global data to be transmitted and localized most traffic within individual groups, but reduces the traffic and consequently, contention in a wireless sensor network. A way to reduce energy consumption is data aggregation, which consists of suppressing redundancy in different data messages. This data aggregation is the key idea for the most hierarchical routing protocols. In addition, scalability is one of the major design attributes of sensor networks. A single-tier network can lead the gateway to overload with the increase in sensors density. The main target of hierarchical routing is to efficiently maintain the energy consumption of sensor nodes by involving them in multi- hop communication within a particular cluster and by performing data aggregation and fusion in order to decrease the number of transmitted messages to the sink. Many research projects have explored hierarchical clustering in WSN from different perspectives. Some of the hierarchical

Corresponding Author: Ouadoudi Zytoune (zytoune@univ-ibntofail.ac.ma)

protocols are LEACH [7], [8], PEGASIS [9], TEEN [10], [11], SEP [12], DEEC [13] and APTEEN [14]. LEACH is the first popular energy-efficient hierarchical clustering algorithm that was proposed for reducing power consumption. It uses clusters to prolong the life of the WSN where cluster-head (CH) collects the data from all nodes in its cluster, fuses and sends the information to BS. The CH uses an aggregation technique that combines the original data into a smaller size of data that carry only meaningful information to all individual sensors. Thus, LEACH reduces the number of nodes communicating directly with BS and allows better network lifetime extension. Lindsey et al. proposed PEGASIS [9] a chain- based protocol that minimizes the energy consumption at each sensor node. This protocol is considered as an optimization of the LEACH since that rather than classifying nodes in clusters, the algorithm forms chains of the sensor nodes. Based on this structure, each node transmits to and receives from only one closest node of its neighbors in the chain. PEGASIS organizes all sensors to form a data chain for data transmission and reception and each node take turns being the leader for communication to the base station. The algorithm starts data gathering from each endpoint of the chain and aggregated along the path to the designated leader node that transmits that data to the base station (BS)(e.g. see Fig. 1).

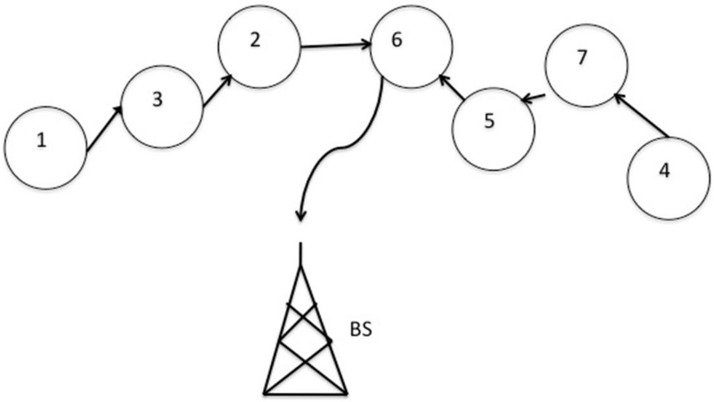

Fig. 1. Transmission chain used in PEGASIS

Thus, PEGASIS achieves reduction in energy consumption as compared to LEACH since it requires only one designated node to send the combined data to the base station. Unlike LEACH that uses hierarchical clustering, PEGASIS uses a flat topology that permits to avoid the overhead of dynamic cluster formation as in LEACH. For constructing the chain, network nodes use the greedy algorithm; each node selects the closest neighbor that is not chained yet and so as until all network nodes are chained. The greedy algorithm for constructing the chain is done before the first round of data transmission. To construct the chain, PEGASIS starts with the furthest node from the BS to make sure that nodes farther from the BS have close neighbors, since in the greedy algorithm the neighbor distances will augment gradually because nodes already on the chain cannot be revisited again. In data transmission phase, node can deplete its residual energy, and then the chain will be reconstructed in the same manner to avoid the dead node. Seetharam et al. [15] presented two techniques to enhance the PEGASIS technique; The first idea that was presented consists to allow each node to become leader for a number $Xi = (d^2_{Bref}/d^2_{Bi}).X_{ref}$, where d_{Bref} is a distance to BS reference, d_{Bi} is the distance between node *i* and the BS and X_{ref} is an arbitrary coefficient to overcome the error by X_i rounding to the nearest integer. The second idea is to use the ant colony optimization to form the network chain. For the first scheme no extension of the network lifetime is observed. A slit enhancement can be observed but not for the first node depletes its residual energy. As the first scheme, the second one presents a slit enhancement of the network lifetime. In this paper we present a new technique for routing data in order to extend the network lifetime. The main object is to equitably distribute the leader role among the network nodes. The remainder of the paper is arranged as follows. Section-2 provides the problem statement. The detail of the proposed technique has been discussed in section-3. Simulation parameters and results have been given in section-4. Based upon the simulation results, conclusions have been drawn and some recommendations for future work have been proposed in section-5.

2 PROBLEM STATEMENT

2.1 PROBLEM DEFINITION

In this work we are interested in WSN composed from N nodes. The major object of this work is to extend the network service duration until the first node in the network has its residual energy depleted which means that the node is failed to play its function in the network. We assume that this network has the features given bellow:

- The nodes are at first distributed randomly in the play field;
- The BS is fixed at a far distance from the sensor nodes;
- The sensor nodes are homogeneous and energy constrained with uniform energy;
- The nodes are able to adjust their transmission radius to reach their destination;
- No mobility of sensor nodes.

In this paper we consider that the data gathering is based on chain. So, all network nodes are organized in chain. At any transmission round, one chain node is elected as leader to collect data in the chain and transmit it to the BS. PEGASIS assumes that each node becomes leader for one transmission round and passes this role for another node. Thus, all network nodes would play leader role equitably. Since nodes in the chain consume different energy when playing leader role, a certain network nodes such as the farthest ones from the BS will die quickly. As idea it is important to take into consideration the energy load and the energy for each chain node to determine for many times a node will be a leader.

2.2 ENERGY DISSIPATION MODEL

We assume a simple model for the radio hardware energy dissipation as discussed in [11] where the transmitter dissipates energy to run the radio electronics and the power amplifier, and the receiver dissipates energy to run the radio electronics, as shown in Fig. (2). For the experiments described here, the free space channel model are used. Thus, to transmit an l-bits message over a distance d, the radio expends (1)

$$E_{TX} = l.(E_{elec}+E_{amp}.d^2) \tag{1}$$

Where E_{elec} is the energy dissipated per bit in the transmitter circuitry (to run the transmitter or receiver circuitry) and Eamp.d2 is the energy dissipated for transmission of a single bit over a distance d. The electronics energy (E_{elec}) depends on many factors such as the digital coding, the modulation, the filtering, and the spreading of the signal, whereas the amplifier energy, $E_{amp}.d^2$, depends on the distance to the receiver and the acceptable bit-error rate. The radios have power control and can expend the minimum required energy to reach the intended recipients. The radios can be turned off to avoid receiving unintended transmissions. To receive an l-bit message, the radio expends (eq2):

$$E_{RX} = l.E_{elec} \tag{2}$$

It is also assumed that the radio channel is symmetric, which means the cost of transmitting a message from A to B is the same as the cost of transmitting a message from B to A.

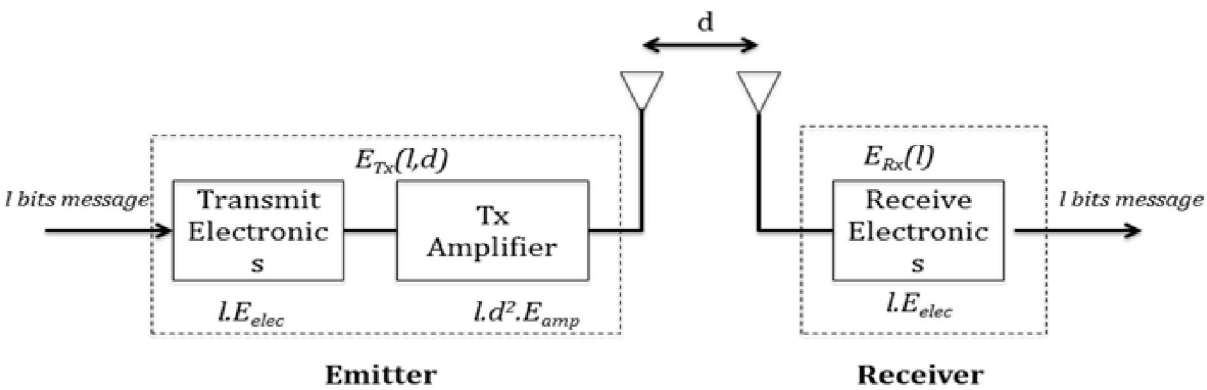

Fig. 2. Radio energy dissipation model

3 ENHANCED POWER EFFICIENT GATHERING IN SENSOR INFORMATION SYSTEM

In this work we aim at developing a system that would provide that the total energy dissipation is distributed equally among all the network nodes. The objective is that the network nodes die equitably. We use a greedy algorithm in order to organize the nodes in the form of a chain. This is an open chain that starts from the farthest node from the base station. We assume that global knowledge of the network is available. An upstream node on the chain searches its downstream node between not chained nodes that is the closest one. This process will continue until all network nodes are chained. Once the chain formation is done, the data gathering process begins. In every data-gathering round, a leader node is selected to receive data from the chain and transmit it to the sink. During a data gathering round each node in the network receives a data packet from its neighboring node, aggregates it with its own data packet and transmits it to its other neighbor in the chain. A simple token passing approach initiated by the leader is used to organize the data transmission. So, the data transmission starts from the chain end-nodes to its next nodes in the chain. This node do data aggregation and so that until the leader. Let us assume that the network is composed from 7 nodes as depicted in Fig. 1. The chain is formed as (1, 3, 2, 6, 5, 7, 4) and the node denoted by 6 is elected as the leader in particular round. The leader elected in a particular round receives the fused data packets of the nodes in the chain from its two neighbors, fuses it with its own data packet and finally this single data packet is transmitted to the base station. Thus, node 1 transmits its data to node 3 that fuses it with its own and transmits it to node 2 and so on until reaching the leader. The same process is done in second part of the chain starting from node 4. Because playing leader is energy consuming, and in order to distribute energy load, PEGASIS ensure that at each transmission round a new node is selected as leader. But, the chain nodes consume different energy when being leader depending on its location in the chain and its distance to the BS, which means that a certain nodes would die quickly.

In this paper we try to let the network nodes play leader depending on its energy capacity to ensure best energy transmission balancing. The proposed method is based on distributing the energy load over all the network nodes. Let a network formed of N chained nodes and E_{i0} is the initial battery energy of the node i. Let E_{iBS} is the required energy for the node i to transmit to the base station, E_{ij} is the energy to transmit from the node i to node j and E_{rec} is the energy cost required for receiving a packet. In this work we use a greedy algorithm to form the transmission chain. This chain is formed from the farthest node from the BS. The node i deployed in the monitored area can do Ti transmissions in its lifetime (until the depletion of its residual energy) in which it is the leader. For notation simplicity, we suppose that the chain nodes are organized as follow: {1, 2, ..., N } and then the end chain nodes are 1 and N. For the node 1, that will be leader for T_1 times, will do T_1 transmission to the BS and $T_2 + T_3 + ... + T_N$ transmissions to the next node in the chain, lets node 2. Then, the equation (3) must be respected.

$$E_{10} = T_1.(E_{1BS} + E_{rec}) + (T_2 + T_3 + ... + T_N).E_{12} \qquad (3)$$

For a not end chain node i, this node will do Ti transmission to BS and 2.Erec from the two chain elements when it is a leader and consumes the $(T_1 + T_2 + ... + T_{i-1}).(E_{i-1} + E_{rec})$ for transmitting to the left element of chain and $(TN + T_{N-1} + ... + T_{i+1}).(E_{i+1} + E_{rec})$ to transmit to the right element of the chain. The equation (4) gives the relation between the numbers of becoming leaders for the entire network nodes.

$$\begin{pmatrix} E_{1BS}+E_{rec} & E_{12} & \cdots & E_{12} \\ E_{21}+E_{rec} & E_{2BS}+2.E_{rec} & E_{23}+E_{rec} & \cdots \\ \cdots & \cdots & \cdots & \cdots \\ E_{21} & E_{21} & \cdots & E_{NBS}+E_{rec} \end{pmatrix} . \begin{pmatrix} T_1 \\ T_2 \\ \cdots \\ T_N \end{pmatrix} = \begin{pmatrix} E_{10} \\ E_{20} \\ \\ E_{N0} \end{pmatrix} \qquad (4)$$

As constraint, all T_i must be positives. We solve the equation above to determine how many times a node can be a leader for the chain. If the solution gives negative results, a linear optimization can be used. With this manner the nodes energies would be consumed equitably. Since T_i is given, the node i when it is selected as leader it plays this role pour T_i consecutive transmission rounds rather than one

4 SIMULATION RESULTS

To evaluate the performance of the proposed technique, several Matlab simulations were performed and the represented results are an average. We consider a square network with N nodes deployed randomly in the field. The used parameter values in our work are given in Table 1.

Table 1. Simulation Parameter Values

Description	Symbol	Value
Network dimension	Xm*Ym	100m*100m
Number of network nodes	N	10-200
Data packet length	L	2500 Bits
Electronic Energy	E_{elec}	50nJ/bit
Amplifier Energy	E_{amp}	100pJ/bit.m^2

In WSN literature, several different definitions have been proposed for the lifetime of a network. In this work we define the network lifetime as the time till the first node consumes its residual energy (Noted FND as First Node Dies).

First we run simulation of our scheme and PEGASIS varying the network nodes number from 100 to 600. All the network nodes have the same energy that is 0.5J. The base station is located at (50m, 300m). We are interested at the network lifetime until the first node run out its residual energy. The results are represented in Fig. 3.

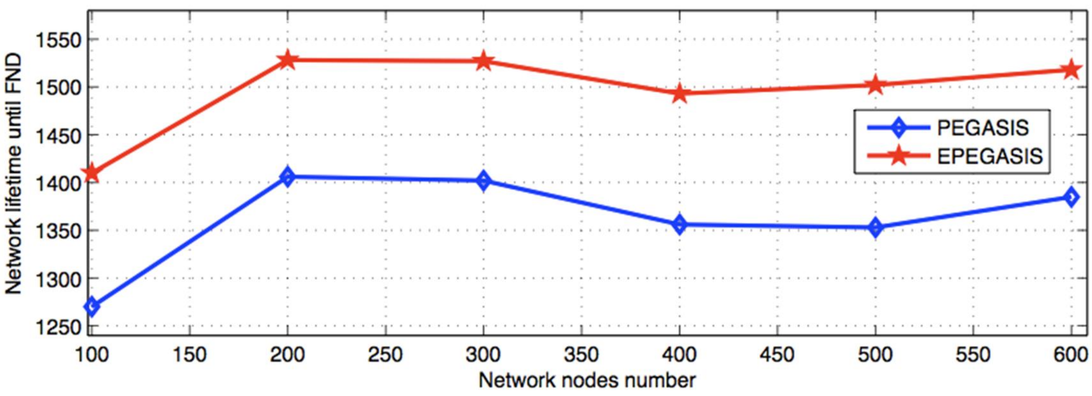

Fig. 3. Network lifetime vs Network nodes number

As depicted, our scheme performs better than PEGASIS since the lifetime extension is up to 11%. In the second situation we aim to investigate the effect of the BS location on the performance of the proposed algorithm. We consider a network of 100 nodes and we vary the base station location from (0.5Xm, 2Ym) to (0.5Xm, 5Ym). The simulation results are presented in Fig. 4. The network lifetime is defined until the first node dies. As depicted, the network lifetime of both the protocols decreases when the BS is far from the network because the needed energy to reach the sink increases with the distance. Table 2 gives the network lifetime for different node initial energy. As we can observe, the network lifetime is extended for all the considered node initial energy. This extension is relevant for the network with nodes initial energies at 0.5 Joule.

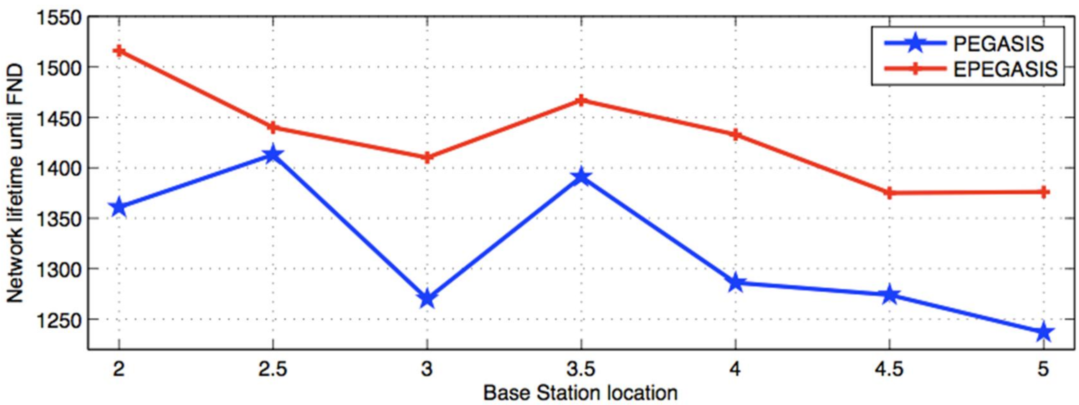

Fig. 4. Network lifetime vs Base station location

Table 2. Network lifetime extension

Initial Energy in J	0.25	0.5	0.75	1
Lifetime extension %	9.19	11.43	4.10	2.43

5 CONCLUSION

The proposed technique allows balancing correctly the transmission energy over the whole network nodes, which leads to network lifetime extension. This extension is guaranteed for different number of network nodes, for different Base station location and for different nodes initial energies. The simulation results clearly show the improvement provided by our technique compared to the well-known protocol for chaining in wireless sensor networks (PEGASIS protocol). In future, we will continue the work investigating the effect of data correlation on the network performance for this kind of routing protocols.

REFERENCES

[1] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam and E. Cayirci, "A survey on sensor networks," *IEEE Communications Magazine*, vol. 40, no. 8, pp. 102-114, 2002.

[2] L. T. Nguyen, X. Defago, R. Beuran, and Y. Shinoda, "An Energy Efficient Routing Scheme for Mobile Wireless sensor Networks," *IEEE ISWCS 2008*, pp. 568-572, 2008.

[3] J. Yrjola, "Summary of Energy Efficiency Communication Protocol for Wireless Micro Sensor Networks," *T-79.194 Seminar on Theoretical Computer Science, Helsinki University of Technology*, 2005.
[Online] Available: http://www.tcs.hut.fi/Studies/T-79.194/papers/yrjola_050316.pdf (August 2013)

[4] A. Chandrakasan, R. Amirtharajah, S. Cho, J. Goodman, G. Konduri, J. Kulik, W. Rabiner, and A. Wang, "Design considerations for distributed micro-sensor systems," *Proc. IEEE 1999 Custom Integrated Circuits Conference (CICC99),* San Diego, CA, USA, May 1999, pp. 279-286.

[5] D. Estrin, L. Girod, G. Pottie, and M. Srivastava, "Instrumenting the world with wireless sensor networks," *Proc. IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP 2001),* Salt Lake City, Utah, USA, May 2001, vol. 4, pp. 2033-2036.

[6] D. Estrin, R. Govindan, J. Heidemann, and S. Kumar, "Next century challenges: Scalable coordination in sensor networks," *Proc. 5th Annual ACM/IEEE International Conference on Mobile Computing and Networking (MobiCom'99),* Seattle Washington, USA, August 1999, pp. 263-270.

[7] W.R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, "Energy-efficient Communication Protocol for Wireless Microsensor Networks," in *IEEE Computer Society Proceedings of the Thirty Third Hawaii International Conference on System Sciences (HICSS '00),* Washington, DC, USA, Jan. 2000, vol. 8, pp. 8020.

[8] W.R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, "An Application-Specific Protocol Architecture for Wireless Microsensor Networks," in *IEEE Transactions on Wireless Communications*, vol. 1(4), pp. 660-670, October 2002.

[9] S. Lindsey and C.S. Raghavendra, "PEGASIS: Power efficient Gathering in Sensor Information System", *Proceedings IEEE Aerospace Conference*, vol. 3, Big Sky, MT, Mar. 2002, pp. 1125-1130.

[10] A. Manjeshwar and D. P. Agrawal, "TEEN: A Protocol for Enhanced Efficiency in Wireless Sensor Networks," in *the Proceedings of the 1st International Workshop on Parallel and Distributed Computing Issues in Wireless Networks and Mobile Computing,* San Francisco, CA, April 2001, pp. 2009 – 2015.

[11] W. Lou, "An Efficient N-to-1 Multipath Routing Protocol in Wireless Sensor Networks", *Proceedings of IEEE MASS05*, Washington DC, pp. 1-8, Nov. 2005.

[12] A. Bestavros G. Smaragdakis, I. Matta. "Sep: A stable election protocol for clustered heterogeneous wireless sensor networks", In *Second International Workshop on Sensor and Actor Network Protocols and Applications (SANPA 2004),* 2004.

[13] M. W. Wang L. Qing, and Q. X. Zhu, "Design of a distributed energy- efficient clustering algorithm for heterogeneous wireless sensor networks", *Computer Communication (Elsevier),* 29(12), pp. 2230-2237, 2006.

[14] A. Manjeshwar and D. P. Agrawal, "APTEEN: A Hybrid Protocol for Efficient Routing and Comprehensive Information Retrieval in Wireless Sensor Networks", in *the Proceedings of the 2nd International Workshop on Parallel and Distributed Computing Issues in Wireless Networks and Mobile computing,* San Francisco CA, April 2001, pp. 2009-1015.

[15] A. Seetharam, A. Acharya, A. Bhattacharyya, and M. K. Naskar, "An Energy Data Gathering Protocol for Wireless Sensor Networks", *Journal of Applied Computer Science*, no. 1(2), pp. 30-34, 2008.