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Efficient Lifetime Maximization Data Gathering Technique for Routing in Wireless Sensor Networks

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Abstract

Wireless sensor network (WSN) is a group of small sensor nodes deployed for physical environment measurement. The main features of these small sensor nodes are their limited capabilities in term of the energy reserve, the processing ability and the memory storage. So that, the data gathering protocols design for WSN is a crucial challenge since those protocols should be simple, energy-aware, and scalable. They should also be self-configurable to node failures and changes of the network topology dynamically. In this paper, we present a new algorithm for gathering sensor readings based on short chain forming. To allow network lifetime extension, the short chain is used, instead of starting from the furthest node and using greedy algorithm as PEGASIS do. Thus, the network lifetime is increased compared to PEGASIS, which is proved through simulation results.

Keywords: Wireless Sensor Networks, Data Gathering, nodes chaining, PEGASIS, Network lifetime.

1 Introduction

A Wireless Sensor Network (WSN) is a collection of tiny sensor nodes deployed in large number to monitor the surrounding conditions [1].Those nodes cooperate together to collect, transmit and semi-process this environmental conditions such as temperature, humidity, vibration …

Since those networks have several domain applications such; military, medicine, agriculture, home, industry, etc., they have many attention for researchers in the last years. Since the nodes are battery powered and have small dimensions, the available energy at each sensor node is limited.

Some of the literature works on WSNs have presented the profits of this kind of networks compared to MANETs [3, 5, 6]. WSNs have major advantages over the MANETs networks deployed for the same purpose such as greater coverage, accuracy and reliability.

Since the sensor node has small size and generally is deployed in harsh area, its available energy is the main constraint for designing protocols for this kind of networks[11, 10].

Supported by their applications, WSN research domain is much active. Then, in the last few years a variety of protocols have been proposed for WSN.

Most of them consider the lifetime duration service when gathering the sensor readings to the sink. Considering their architecture, those protocols can be divided as either flat or hierarchical based.

Clustering is the technique that organizes the network nodes into groups of sensor nodes called clusters. A cluster is formed by one or more number of cluster heads (CH) and members nodes [9].

Those cluster heads collect all data from their cluster members. The gathered data are routed to the Base Station (BS) that is the gateway for the front end user.

Generally, this BS is an immobile node and with high capability, that is able to transmit and receive the data within the entire network and gives the user a gateway to the deployed WSN [2]. The number of cluster head depends on the number of sensor nodes and the network area. Energy consumption is efficiently controlled by selecting more than one cluster head for cluster containing more number of nodes in the network[19]. Distributed, dynamic and randomized clustering schemes are attractive due to their simplicity, feasibility, and effectiveness in providing energy-efficient utilization, load balancing and scalability at once [17].

Data aggregation is a way to reduce energy consumption. This aggregation consists of suppressing redundancy in different data messages. This is the key idea for the most hierarchical routing protocols.

In addition, scalability is one of the key design attributes of sensor networks. Since a single-tier network can conduct the gateway to overload with the increase in sensors density, the main aim of hierarchical routing is to efficiently preserve the energy consumption of sensor nodes by involving them in multi-hop communication within a particular cluster and by performing data aggregation and fusion that decrease the number of data messages that would be transmitted to the sink.

In literature, many research works have explored hierarchical routing in WSN from different perspectives. Some of the hierarchical protocols are LEACH [7,8], PEGASIS [12], TEEN [15,13], SEP [4], DEEC [18] and APTEEN [14].

LEACH is the first and the most popular energy-efficient hierarchical clustering algorithm that was proposed for reducing power consumption in WSN. It uses clustering technique to prolong the life of the WSN where cluster-head (CH) collects the data from all nodes in its vicinity, fuses and sends the information to the base station (BS) on one data packet. In order to reduce the data quantity that would be transmitted, 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[12], a chain-based protocol that allows minimizing the energy consumption at each sensor node. The main idea of PEGASIS is doing data aggregation over all the network nodes that are chained. This protocol is considered as an optimization of the LEACH since that rather than classifying nodes in clusters, the algorithm forms chains of all the network sensor nodes. Based on this structure, each node transmits to and receives from only one closest node of its neighbors in the chain. Unlike LEACH that uses hierarchical clustering, PEGASIS uses a flat topology that permits to avoid the overhead of dynamic cluster formation as in LEACH.

In PEGASIS all sensor nodes are organized to form a chain for data transmission and reception. Each node of the formed chain take turns being the leader for communication to the BS. Data gathering round starts from each endpoint of the chain. Data are aggregated along the path to the designated leader node that transmits the aggregated data to the BS as depicted in Figure 1. Accordingly, PEGASIS achieves a best reduction in energy consumption as compared to LEACH because it requires only one designated node to send one combined data to the BS.

A greedy algorithm is proposed to be used in PEGASIS to form the chain; each node selects the closest neighbor that is not chained yet and so as until all network nodes are chained. This algorithm is executed before starting the first round of data transmission. To construct the chain, PEGASIS starts with the furthest node from the BS. This is 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. After chain formation, data transmission phase will start. In this phase, node can deplete its residual energy, then the chain will be reconstructed in the same manner to avoid the dead node.

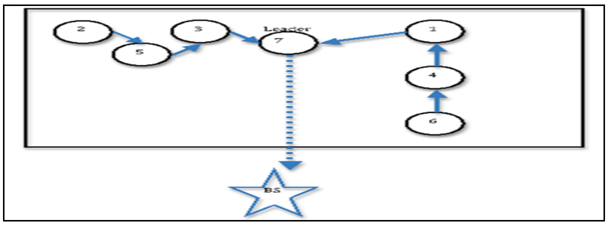

Figure 1: Chain in PEGASIS

In order to enhance PEGASIS, Seetharam et al. proposed in [16] two techniques; The main idea of the first technique consists to allow each node to become leader forXi=(d2Bref/d2Bi).Xref times, where dBref is a distance reference to BS, dBi is the distance between node i and the BS and Xref is an arbitrary coefficient to overcome the error by rounding Xi to the nearest integer. The second technique proposed in [16] is to use the Ant Colony Optimization to form the network chain. Both the two techniques start the chain from the farthest node to the BS to ensure that this node has a neighbor. By the provided assessment, a slit enhancement of the network lifetime is observed.
In this paper we present a new technique for gathering data that allows extending the network lifetime. The main object is to reduce the energy consumed by network nodes and then extends the network service duration by choosing the shortest chain.
The remainder of the paper is organized 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

I.1. Problem definition

In this work we are interested in WSN composed from ***N*** nodes deployed randomly in the monitored area. The major object of this work is to extend the network service duration until the first node dies. Which means that the first node has its residual energy depleted and then is failed to play its function in the network. We assume the BS is fixed at a far distance from the sensor nodes that are not mobile.
In this paper we consider a flat network, that the data gathering is based on chain. The network nodes are organized in chain and at any transmission round, one node is selected as leader to collect data in the chain and transmit it to the BS.PEGASIS [7] and Seetharam et al. [16] propose that the chain forming starts from the farthest node to the BS. As the chain length will not be the shortest one, the network lifetime is not optimized.

I.2. Energy Dissipation Model

We assume a simple scheme for modeling the radio hardware energy dissipation as discussed in [7]. The transmitter dissipates energy when running the radio electronics and the power amplifier. The receiver dissipates energy to run the radio electronics, as shown in Figure 2. For the experiments described here, the free space channel model is used. Thus, to transmit an l-bits message over a distance d, the radio expends (eq1)

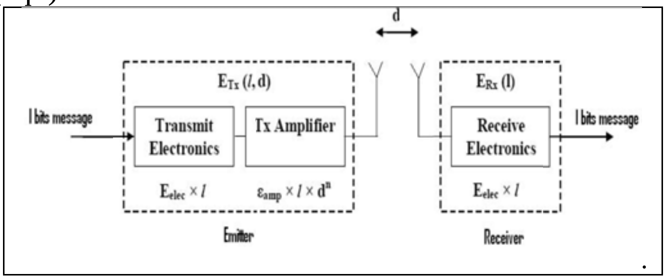

Figure 2. Radio energy dissipation model

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

Where Eelec 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 (Eelec) depends on many factors such as the digital coding, the modulation, the filtering, and the spreading of the signal, whereas the amplifier energy, Eamp.d2, 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):

$$E_{RX} = l.E_{elec} \quad (2)$$

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.

3 Energy Efficient Data Gathering Technique for Wireless Sensor Network

In this work we aim at developing a data gathering system that extends the network lifetime by reducing energy dissipation of all the network nodes. Since PEGASIS starts chaining from the farthest node to the sink, it cannot provide the shortest chain. Figure 3 gives an illustration. Ten nodes are deployed randomly in the network area. We use the greedy algorithm to determine the network data gathering chain. Thus as depicted in this figure, the PEGASIS formed chain is represented by solid line, but the shortest chain is represented by dashed line. Comparing the chains length, PEGASIS chain is about 19.50% long to the short chain. That means that the energy consumption is greater, as if we consider the energy consumption proportional to the square distance the energy worst in PEGASIS is much 47.43% than the short chain.

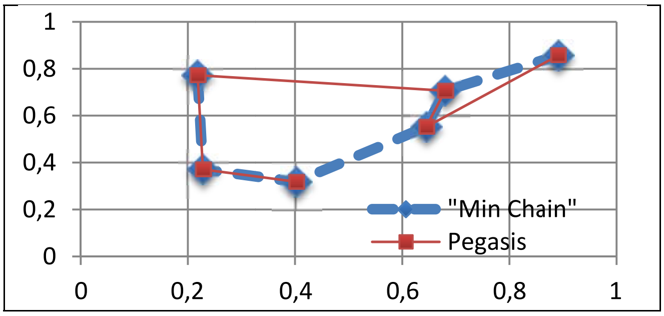

Figure 3: Chaining comparison

The proposed technique is described as follows:
We start by finding the shortest chain in the network that permits to visit all the N network nodes.
Data gathering phase starts after the shortest chain is formed. In every data-collecting round, a leader node is selected to receive data from the chain and transmit it to the sink. For the duration of a data gathering round, each node in the chain receives a data packet from its neighboring node, makes data aggregation with its own data packet and transmits it to its next neighbor in the chain. A simple token passing method initiated by the leader can be used to organize the data transmission. The data transmission starts from the chain end-nodes to its next nodes in the chain, which do data fusion and so that until attainment to the leader that aggregates the received data with its own and transmits it the sink.
Since the leader consumes more energy than other nodes, and in order to distribute energy load, at each transmission round a new node is selected as leader.

4 Simulation results

To evaluate the performance of our 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 the table1.

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

Table1: Simulation parameter values

We run simulation of our scheme and PEGASIS varying the network nodes number from 10 to 200. Network nodes have the same initial energy that is 0.5J. The base station is located at (50m, 200m).We are interested at the network lifetime until the first node run out its residual energy. The results are represented in Figure3.

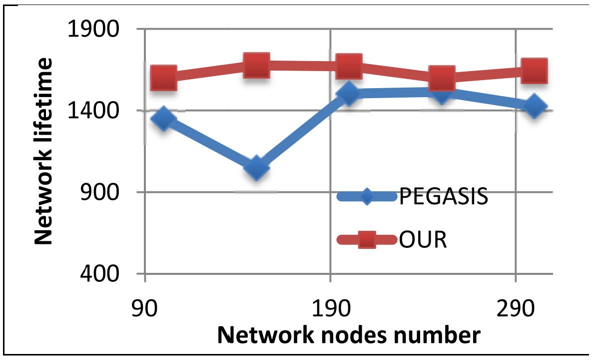

Figure.4. Network lifetime VS Network nodes number

As depicted, our scheme performs better than PEGASIS since the lifetime extension is up to 30% for example for network composed of 200 nodes.

In the second situation we intend to investigate the effect of the Base Station location on the performance of the proposed algorithm. We consider a network of 100 nodes with initial energy of 0.5J, and we vary the base station location from (0.5Xm, 0.5Ym) to (0.5Xm, 3Ym).

The simulation results are shown in Figure.5. As depicted, the network lifetime of booth the protocols decrease when the BS is far from the network because the needed energy to reach the sink increases with the distance. The proposed technique allows extension of the network lifetime for every base station position.

Figure.6. 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. The relative lifetime extension is between 17,2% and 29,7%.

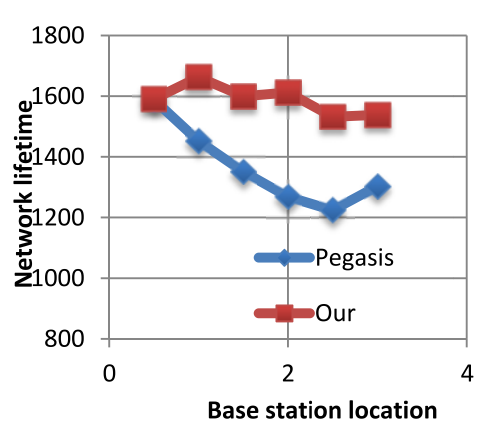

Figure.5 Network lifetime vs. Base station location

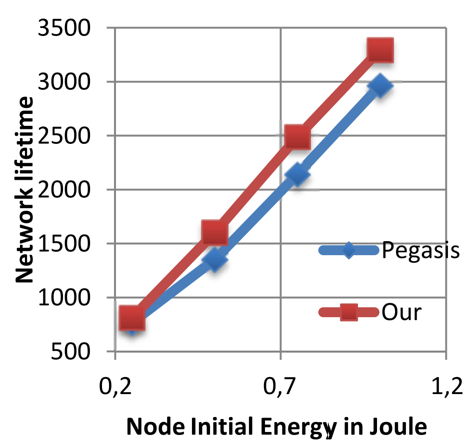

Figure 6: Network lifetime vs. nodes initial energy.

The simulation results presented above proves that the proposed scheme exploits judiciously the network energy since it selects the short network chain so that the transmission energy is the optimized.

5 Conclusion

Network nodes chaining is a better solution to extend network lifetime since only the leader node that do long transmission to the BS. This paper has proposed the use of nodes chain ensuring that this chain is the short one. The proposed technique allows extension of the network lifetime for extra network transmission rounds as compared to PEGASIS. This extension is possible for different number of network nodes, for different BS location and for different nodes initial energies. The simulation results clearly show the improvement provided by our technique compared to PEGASIS protocol. In future, we will continue the work investigating the meta-heuristic to form this shortest chain.

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