Performance Analysis of Concentric Cluster based PEGASIS for Wireless Sensor Networks

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ABSTRACT
Wireless Sensor Networks (WSNs) consist of large number of sensor nodes with limited battery power and storage capacity. So it is essential to design effective and energy aware protocols in order to prolong the network lifetime. PEGASIS is one of the well-known chain-based routing protocols for improving energy efficiency, based on a chain-based greedy algorithm. However, PEGASIS protocol causes redundant data transmission since one of the nodes on the chain is selected as a head node. This problem of redundant data transmission is overcome by enhanced PEGASIS based on concentric clustering scheme. In this paper, we have analyzed the performance of concentric cluster based PEGASIS for WSNs. The results are found to be satisfactory.

Keywords
Wireless sensor networks; PEGASIS protocol; nodes; concentric cluster

1. INTRODUCTION TO WIRELESS SENSOR NETWORKS
Due to recent progress in technology, there is a growth in wireless sensor network which comprises of large figure of homogeneous and heterogeneous sensor nodes which communicate seamlessly to achieve common objective. Homogeneous nodes are preferred over heterogeneous nodes because of less complexity and better manageability. Each sensor node communicates with other nodes within its radio communication range [1].

Nodes can be easily deployed in random or deterministic fashion and are normally battery operated. So, energy consumption is one of the most important factors. Wint Yi Poe mainly focused on three competitors: uniform random, a square grid, and a pattern-based Tri-Hexagon Tiling (THT) node deployment under three performance matrices: coverage, energy consumption and worst–case delay which minimize the energy consumption, provide better coverage and guaranteed to extend the lifetime of the WSNs [2]. In a class of three models, THT [2] defeats the other two models in terms of energy consumption and worst-case delay and square grid is preferred for better coverage performance. THT is well performing node deployment model for WSN applications. Eunil Park *et al.* in [3] proposed another method, a node scheduling method and a *protocol that considers both sides of Link Quality and Energy (PBLE)*, an optimal routing protocol which is energy-efficient and prolong the lifetime of the sensor networks. PBLE [3], overcomes the problems arise in PRR× *Distance Greedy Forwarding* Method such as retransmission caused by loss of ACK transmission in real WSNs.

Usually, wireless sensor networks are composed of hundreds or thousands of sensor motes. Each node are capable of processing (using one or more microcontrollers, CPUs or DSP chips) and may hold several types of memory (program, data and flash memories), a RF transceiver (usually with a single omni-directional antenna), a power source (e.g., batteries and solar cells), and accommodate various sensors and actuators [4]. One or more nodes in the network will aid as sink(s) which exchange information with the user either directly or by the way of existing wired networks [5]. Peer-to-peer networking protocols support a mesh-like relation to switch data between the thousands of nodes in a multi-hop fashion. The flexible mesh architectures envisioned dynamically adapt to support introduction of new nodes or expand to cover a larger geographic region. Additionally, the system can automatically adapt to compensate for node failures [6].

The reminder of this paper is divided into six sections. Section II discussed the literature review. Section III shows the performance analysis of PEGASIS. Results and discussion are reported in section IV and Section V concludes the paper.

2. LITERATURE REVIEW
Simple approach to collect data from sensor nodes is direct approach where each sensor nodes transmit the data directly to the base station (BS) which is located far away. Cost to transmit data from each sensor node to BS is very high, thus nodes die quickly and hence reducing the lifetime of the network. Therefore to utilize energy efficiently, number of transmissions should be restricted. LEACH Protocol is designed where sensor nodes are organized to form local cluster with one node in each cluster selected as cluster head. Sensor nodes from one cluster send data to its cluster head where data is aggregated and fused data is transmitted to BS. Cluster heads are chosen randomly and achieve a factor of 8 improvements compared to direct approach. Although LEACH protocol reduces energy consumption by factor 8,

energy is consumed is forming cluster. In LEACH 5% of the nodes are the head nodes at the same time that also amounts to energy consumption [7].

2.1 PEGASIS (Power-Efficient Gathering in Sensor Information System)

PEGASIS (hierarchical routing protocol) is the improved protocol where only one node is chosen a head node which sends the fused data to the BS per round. This achieves factor of 2 improvement compared to LEACH protocol [7]. PEGASIS protocol requires formation of chain which is achieved in two steps:

2.1.1 Chain Construction

To construct the chain we start from the furthest node from the BS and then greedy approach is used to construct the chain.

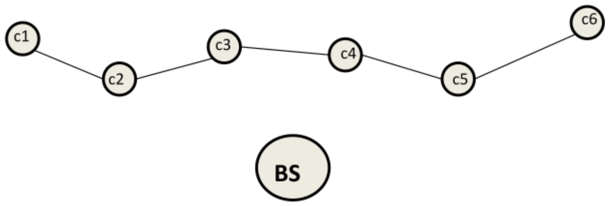

Fig 1: Construction of chain in PEGASIS using Greedy approach

In figure 1, node c0 lies furthest from the base station, chain construction starts from node c0 which connects to node c1, node c1 connects to node c2, node c2 connects to node c3, and node c3 connects to node c4, node c4 connects to c5.

2.1.2 Gathering Data

Leader of each round is selected randomly. Randomly selecting head node also provides benefit as it is more likely for nodes to die at random locations thus providing robust network. When a node dies chain is reconstructed to bypass the dead node [8].

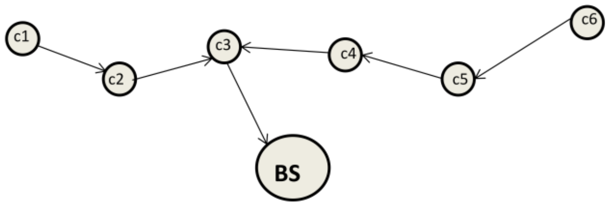

Fig 2: Describing data fusion at the head node and transmitting it to BS

After the leader is selected it passes token to initiate data gathering process. Passing token also requires energy consumption but cost of passing token is very small because token size is very small. In figure 2 node c3 is selected as head node for particular round. Node c5 passes the data to c3 along the chain. c0 passes the data to c3 along the chain. c3 receives the data, fuses all the data it has received and transmit to the base station.

Advantages of PEGASIS over LEACH

- Compare to LEACH transmitting distance for most of the node is reduced in PEGASIS.
- Messages received by each head node are at most 2 in PEGASIS and is less compared to LEACH.
- Experimental results show that PEGASIS provides improvement by factor 2 compared to LEACH protocol for 50m * 50m network and improvement by factor 3 for 100m * 100m Network.
- Since each node gets selected once, energy dissipation is balanced among sensor nodes.

Drawbacks of the PEGASIS protocol

- When a head node is selected, there is no consideration how far the BS is located from the head node [9].
- When a head node is selected its energy level is not considered.
- Since there is only one node head, it may be the bottle neck of the network causing delay.
- Redundant transmission of data as only one head node is selected.

2.2 PEGASIS with CDMA nodes

In PEGASIS linear chain based scheme, as transmission is sequential average delay per round is still high thus simultaneous transmission is desired. If the nodes are CDMA capable, then binary scheme can be used to perform parallel communication to reduce overall delay. In Chain-based Binary Approach using CDMA, to minimize delay data is combined using as many pairs as possible in each level. At the lowest level, chain is constructed in the same way as was done in the PEGASIS. For data gathering round each node transmits the data to its nearest neighbor in given level of hierarchy. Nodes that receive data at lower level rise at the next level.

2.3 Concentric Cluster-based Scheme

The PEGASIS protocol causes the redundant data transmission since one of nodes on the chain is selected as the head node regardless of the base station's location. The enhanced PEGASIS protocol based on the concentric clustering scheme solves this problem. The main idea of the concentric clustering scheme is to consider the location of the base station to enhance its performance and to prolong the lifetime of the wireless sensor networks. In concentric clustering scheme, network is divided in the form of concentric shaped clusters as shown in figure 3. This protocol consists of four processes:

2.3.1 Level Assignment

Each node in the network is assigned a level based on the grouping of concentric clusters [9].

2.3.2 Chain Construction

At level area, chain is constructed, which is same as PEGASIS protocol.

2.3.3 Head Node Assignment

One of the nodes at each level is selected as a head node. If there are N nodes in a level then for *i*th round "*i* mod N" is selected as a head node. After the head node is selected at each level it informs the head nodes of one higher level and one lower level [9].

2.3.4 Data Transmission

All the nodes at a level transmit their data to the respective head node. Head node after receiving data fuses the received data and sends it to lower level cluster's head node. Head node nearest the BS collect data from all higher level head nodes and transmits to BS. Another way is to send data directly to BS. If the head node at the lower level forms acute angle with respect to BS and head node at higher level, data is sent directly to the BS.

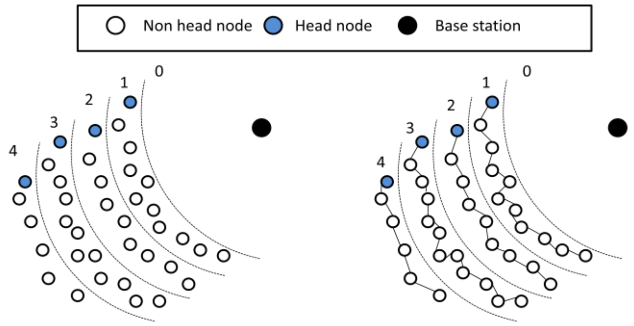

Fig 3: Concentric clustering scheme, showing level assignment and construction of chain cluster level

3. PERFORMANCE ANALYSIS OF PEGASIS

So clustering-scheme PEGASIS solves the limitations of PEGASIS. In this work, the performance of clustering-scheme PEGASIS are evaluated in wireless sensor network environment. The performance is carried out in MATLAB software. In figure 11, 100 nodes are shown to be distributed randomly and distance from one node to every other nodes is calculated. The terrain area is taken as 1000m×1000m.

3.1 Energy Consumption

When 100 nodes transmit the data to head node on the chain in the clustering-based PEGASIS protocol, the energy consumption in one round with different data bits can be formulated as follows [9]:

$$E = n * E_{elec} * k * E_{amp} * \sum_{m=1}^{n} [d^2{}_{(m-1,m)}]$$

where,

E_{elec} = per bit energy consumption in the transmitter circuitry

k = Data bits

E_{amp}= Amplifier transmitting energy

In this equation, d_{ij} indicates the distance from *i* node to *j* node.

3.1.1 Data Reception

When n nodes receive the data from neighbor nodes, the energy consumption in one round can be formulated as follows [9]:

$$E=n*E_{elec}*k$$

3.1.2 Data Aggregation

Let us assume that the energy consumption of the aggregation at one node is E_{agg}, then an energy consumption of entire nodes in one round can be defined as follows [9]:

$$E=n*E_{agg}$$

3.2 Radio Model

A radio is assumed to dissipate E_{elec}=50nJ/bit to run the transmitter or receiver circuitry. For the transmitter amplifier, E_{amp}=100nJ/bit/m^2. The radios have power control capability and can expend the minimum required energy to reach the intended recipients. The radios can be turned off to avoid receiving unintended transmissions. We have also assumed energy loss due to channel transmission. Thus, to transmit a k bits message at a distance d, the radio expends [9]:

$$E_{TX}(k,d) = E_{elec} * k + E_{amp} * k * d^2$$

and to receive this message the radio expends [14]:

$$E_{RX}(k) = E_{elec} * k$$

where,

$E_{TX-elec}$=Transmitter Electronics

$E_{RX-elec}$=Receiver Electronics

$E_{TX-elec}$=$E_{RX-elec}$=E_{elec}

$E_{TX-elec}$=50 nJ/bit

The Performance is carried out with the values of parameters as shown in table 1.

Table 1. Variables

Type	Parameters	Value
Transmitter Electronics	E_{elec}	50nJ
Transmit Amplifier	E_{amp}	100pJ
Data Bits	k	500
Energy for aggregation	E_{agg}	5nJ

4. RESULTS AND DISCUSSION

Matlab 7.0 is used as the tool in our work and the results are discussed in this section.

Figure 4 shows the dependence of energy required to transmit message $E_{TX}(k,d)$ on data bits (k) and figure 5 shows the dependence of energy required to receive message $E_{RX}(k)$ on data bits (k). It is clear from the figures that when the data bits increases, the energy required to transmit and receive message increases linearly. So data bits (k) in the message should be kept low.

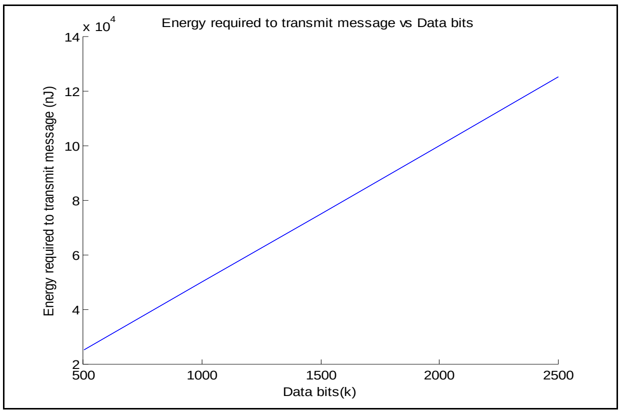

Fig 4. Energy required to transmit message vs Data bits

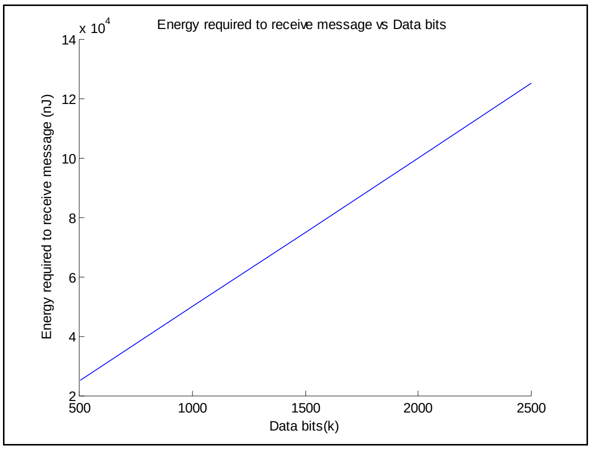

Fig 5: Energy required to receive message vs Data bits

Performance of energy consumption in one round using PEGASIS protocol based on clustering scheme with different set of data bits are considered here. Figure 6 shows that how number of nodes change energy consumption for different set of data bits (k). It can be concluded from the result that with the increase in number of nodes and data bits, energy consumption increases, as expected.

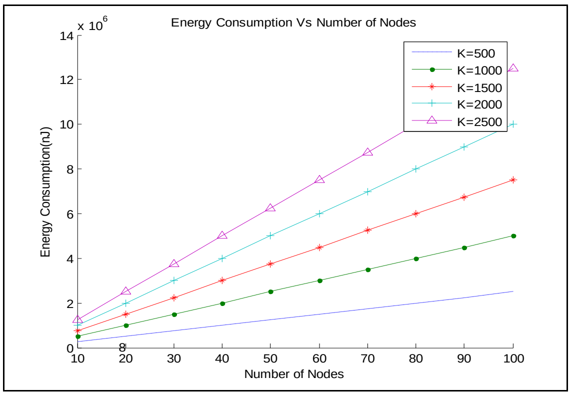

Fig 6: Energy Consumption vs. number of nodes with different sets of data bits.

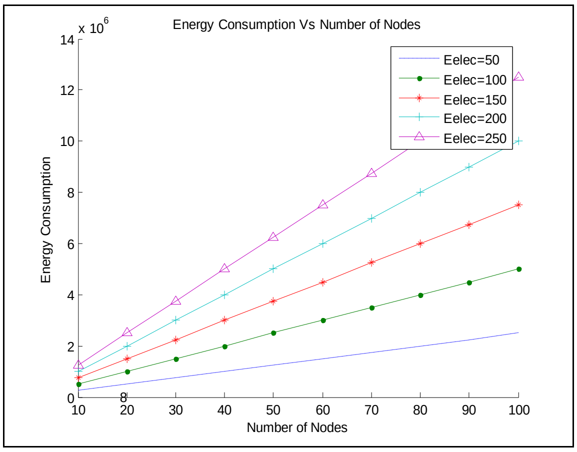

Fig 7: Energy Consumption vs. number of nodes with different sets of $E_{elec.}$

The dependence of energy consumption on number of nodes for different values of E_{elec} is shown in figure 7. It is seen from the result that with the increase in number of nodes and E_{elec}, energy consumption increases. So E_{elec} in the message should be kept low so that energy consumption will not increase with increase in number of nodes and $E_{elec.}$

Energy consumed against number of nodes for different values of transmit amplifier energy are plotted in figure 8. It is seen that energy consumption is independent of transmit amplifier energy.

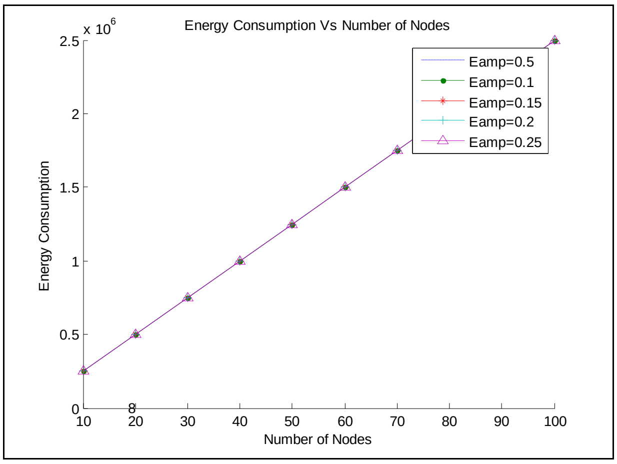

Fig 8. Dependence of energy consumption on number of nodes for different sets of $E_{amp.}$

Figure 9 shows that when number of neighbor nodes increases, the energy consumption in one round is also enhanced. So it is clear that number of nodes receiving data should be kept minimum to reduce the energy consumption.

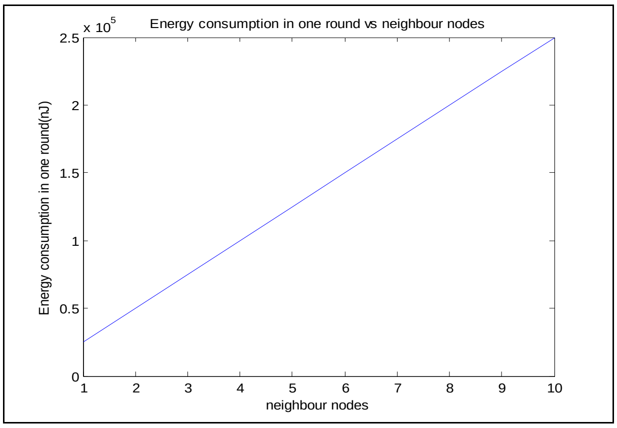

Fig 9: Energy consumption in one round vs neighbour nodes.

Energy consumption in one round against aggregating nodes is plotted in figure 10. Energy consumption of all the nodes in one round increases when number of nodes aggregating data increases. So it is clear from figure 10 that number of nodes aggregating data should be minimized to reduce the energy consumption.

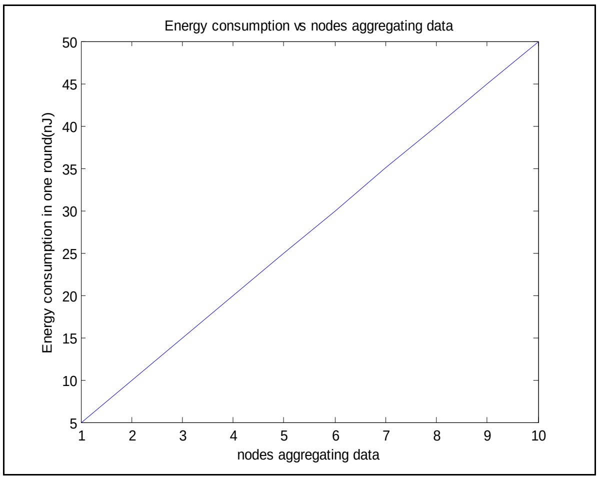

Fig 10: Energy consumption vs nodes aggregating data

5. CONCLUSION

The results indicate that when number of nodes, energy consumption per bit and number of data bits increases, energy consumption increases. Number of aggregating data nodes also enhances energy consumption. So, all these parameters should be kept low as far as practicable to minimize energy consumption. The future plan includes clustering the network and implementing the complete protocol.

6. ACKNOWLEDGMENTS

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7. REFERENCES

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