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Performance Evaluation of Tree Based and Chain Based Routing Protocols in Wireless Sensor Networks

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Abstract— Wireless sensor networks are expected to find wide applicability and increasing deployment in the near future. Advances in wireless networks technology have enabled small and low-cost sensors with the capability of sensing various types of physical, environmental conditions, data processing and wireless communication. One of the most challenging issues so far is the extension of network lifetime with regards to small battery capacity and self -sustained operations in the WSN. The main object of this project is to implement Power Efficient Gathering for Sensor Information Systems (PEGASIS) and General self-organised tree-based energy balance routing protocol (GSTB) and evaluate their performance using the parameters like energy consumption, throughput, packet delivery ratio, end-end delay. GSTB is a tree-based routing protocol which builds a routing tree using a process where for each round base station assigns route node and broadcasts this information to all sensor nodes. Subsequently each node selects its parent by considering only itself and its neighbours' information.

Index Terms— Energy aware sensor network, network lifetime, network simulator, routing protocol, self-organized, residual energy, control overhead of network

1 Introduction

Wireless sensor network is a network of low-cost sensing devices that have limited computing capability and battery capacity. With the urge to monitor everything from condition of a human body to changes in concrete structure due to environmental conditions, there has been a massive deployment of WSNs everywhere and will find greater demand in the future. They are being deployed in large numbers and may even run into thousands in numbers even in smaller areas. The number of sensors we need depends on the accuracy of data we need. The most basic and persistent problem with these things is the death of nodes which these units are called, since conventional energy supply to thousands of nodes is difficult so they are mostly battery powered.

Many techniques like energy harvesting, using low bandwidth wireless transmission protocols, optimised operating system [6]. Besides these designing of optimised routing protocols is the most basic need to take care of energy saving and many other problems [8]. Signal transmission is one of the operations that consumes significant energy. By using data fusion throughput can be reduced thus saving energy. Also, lot of redundant data may be generated as nodes might be too close to detect any difference in data. Thus, this data can be fused to reduce transmissions [7]. Many of the protocols that implement data fusion consider length of the message transmitted to be same despite number of child nodes each sensing node may have. Examples of such protocols are PEGASIS, PEDAP, etc. [3]. In some protocols the data sent is sum of the length of its own sensed data and of its child nodes. Also, every node need not be alive all the time, many devices has power saving options, devices whose attention we don't need can be sent to sleep.

In this paper tree based protocol is proposed which is used to sense data by sensors periodically and nodes are placed randomly [1]. These nodes on a certain terrain send data to base station. The paper considers life time of the network to be time between start of network operation and death of its first node, though another definition too is popular which considers lifetime to be time between start of network operation and death of last node of the network. The proposed protocol implements data fusion and based on length of message sent by node to base station two cases are considered:

- Each node sends same amount of data; data can be fused.
- The data length sent by a node is sum of data sensed by itself and data received from its child nodes.

2 Network considerations

The following are the assumptions' in this paper

100 randomly deployed nodes and one base station which is far away from all the nodes

- BS is energy rich and stationary
- By using GPS and position algorithms sensor nodes can know their location and are therefore location aware
- Each node is associated with an ID

Here we compare the proposed protocol and PEGASIS routing protocol, their performance is compared as they both employ data fusion (latter in case1). In both cases energy requires from

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one particular node to other and vice-versa is assumed to be same i.e. medium is symmetric.

3 TREE BASED ROUTING AND CHAIN BASED ROUTING PROTOCOLS

3.1 PEGASIS

The power efficient gathering for sensor information system routing protocols consist of a different leader each time data is being sent to base station as nodes take turns to become one. This will lead to even distribution of load among the given sensor nodes of the network. The chain can be formed by nodes themselves or it can be computed by base station.

3.2 General self-organised tree based routing protocol

As mentioned earlier the main aim of this optimised routing protocol is to spend less energy and thus increasing lifetime of nodes and that of the network. The GSTB based protocols operates in four phases namely Initial phase, tree construction phase, data collection and information exchange phase.

3.2.1 Initial phase

In the beginning of this phase Base station broadcast data packets to all the sensor nodes which contains information like beginning time, length of timeslots and number of nodes. Each node then computes their energy levels. After that, individual nodes send their packets in their respective timeslots. The neighbouring nodes receive this packet and store the information in memory and nodes which cannot receive this information during this time move to sleep mode. The information of each node collects is tabulated. By the end of this, each node has their neighbours information and sends this information to their respective neighbours. Thus, each node now is equipped with two tables. One to keep track of neighbouring node and other for neighbours neighbour information.

3.2.2 Tree constructing phase

It is done in three steps and both the cases are considered for each step. In step1, Base station broadcasts roots ID and root coordinates of a node after assigning it as root. In case1 the node with largest residual energy is chosen as root and directly communicate with base station after fusing all the sensors data. in case2, base station assign itself as a root.

In step 2 parent nodes will be selected by individual nodes based on the following criterions

1.distance between parent node to be selected and root node is less than distance between itself and root node

2. for case 1 criterion 1 is satisfied and parent node should be nearest to it. If condition is not satisfied the sensor node selects root as its parent

3. for case 2 minimum energy consumption path is selected by iterations. There will be relay nodes which are selected based on energy level and a parent node is selected from relay nodes considering energy consumption for transmission between itself to relay nodes and relay nodes to base station. the relay node with minimum energy consumption is selected as parent node and relay node too should chose its parent node considering energy levels. Sensor nodes transmit data directly to base station in case if it is unable to choose a parent node.

Step 3 - since parent node and child nodes are determined, the node which has no child nodes defines itself as a leaf node and data transmission begins from it. By now all the nodes have in formation of the neighbours parents too by computing and they can also know their child nodes. Thus, rooting tree is developed in case1 by following the above steps and in case2 by base station using iterations.

3.2.3 Self-organising data collecting and transmitting phase

After construction of tree the sensor nodes collects the data and are ready to send. this phase is divided into several time slots. A specific set of operations in the same sequence occur in each time slot. initially leaf nodes sends their id's to parent nodes. after these three situations may arise. in the first scenario the leaf node doesn't have any data to send thus both parent and child nodes go to sleep.in the second situation multiple leaf nodes want to send data to parent node then parent node selects one of these leaf nodes by sending a control packet so that child node send the data. In the third scenario only one leaf node wants to send data to parent node then parent node sends control packet to the leaf node to inform it to send data packet.

In this FHSS (frequency hopping spread spectrum) is applied according to a sequence directed by parent node in order to reduce interference. After all this is done, the parent node acts as a leaf node and the process starts again. all this while the leaf nodes and the parent nodes which are not sending or receiving any control signal and data will be in sleep mode, this is for case1.

For case 2 base station informs sensor nodes when to send data and receive data. at the beginning of each round the time is divided into multiple slots and respective nodes sends data in that time slot. Base station constructs rooting tree using same approach and nodes work in turns. after base station is done receiving data next phase starts.

3.2.4 Information exchange phase

The death of any of the sensor nodes due to exhaustion of its energy may lead to change in topography. so, nodes need to inform others before they die. for this too time slots will be assigned. in each time slot the dying node will compute a delay during which there will be one node broadcast. After that it tries to broadcast data packet to whole network. the neighbours receives this and alter their tables accordingly, this is for case1,

In case 2, the base station takes care of most of the things, base station builds routing tree based on energy levels of the nodes and their coordinates, it also estimates energy consumption of each node. Thus, we can know next rounds topology based on residual energy in each node. The nodes also detect their actual residual energy and sends it to base station to correct energy levels calculated by base station and next round topology is designed.

4 SIMULATION SCENARIO

The IEEE 802.11 protocol is used as the MAC layer protocol. The radio channel model follows a TwoRay ground with an omnidirectional antenna. We consider constant bit rate (CBR) data traffic and randomly choose different source-destination connections. Every source sends one CBR packets whose size is 512Bytes per second.

Table 1: Simulation parameters

Simulation Parameter	Value
Simulator	Network Simulator 2.35
PHY	802.11
Number of Nodes	10,20,30,40,50,60,70,80,90,100
Data Rate	2 Mbps
Traffic Type	CBR
Packet Size	512 Bytes
Topology Size	1000m*1000m
Inter Packet Arrival	0.05, 0.1, 0.5, 1.0
Routing Protocol	PEGASIS, GSTB
Flows (connections)	4, 8, 12, 16, 20
Simulation	100 sec

The mobility model is based on the random waypoint model in a field of 1000m*1000m. In this mobility model, each node moves to a random selected destination with a constant speed from a uniform distribution amongst the nodes. After the node reaches its destination, it stops for a pause time interval and chooses a new destination and constant speed. The detailed simulation parameters are shown in Table1.

4.1 Execution of protocols in NAM window:

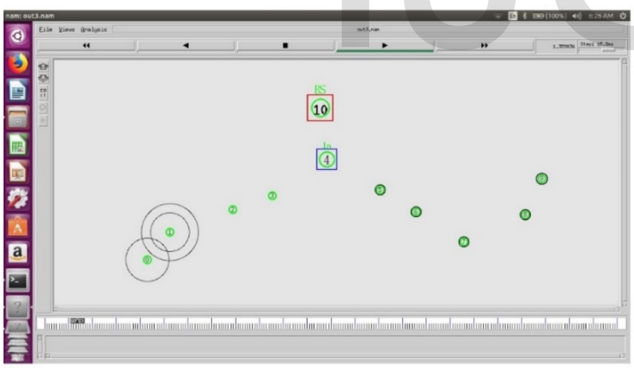

Figure 1: Execution of PEGASIS routing protocol

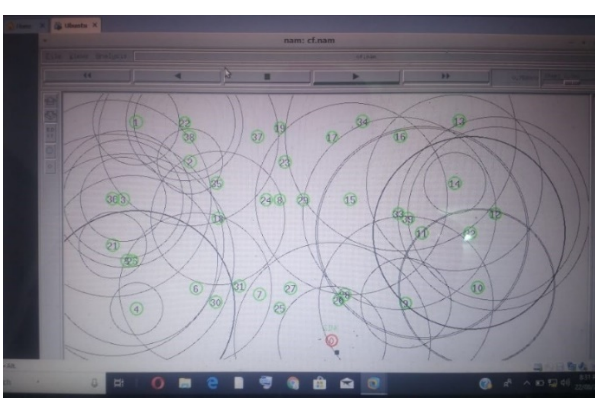

Figure 2: Execution of tree based routing protocol

5 RESULTS

5.1 Throughput

It is defined as the total number of packets transmitted successfully per unit time.

5.1.1 Throughput obtained by varying number of Nodes

As the number of nodes increases, the number of intermediate nodes increases, so multiple routes are available between source and destination. If one route fails nodes find another route for data transmission. So, throughput increases. Throughput in tree based routing protocol is 294.14 kbps which is 110 kbps more than PEGASIS.

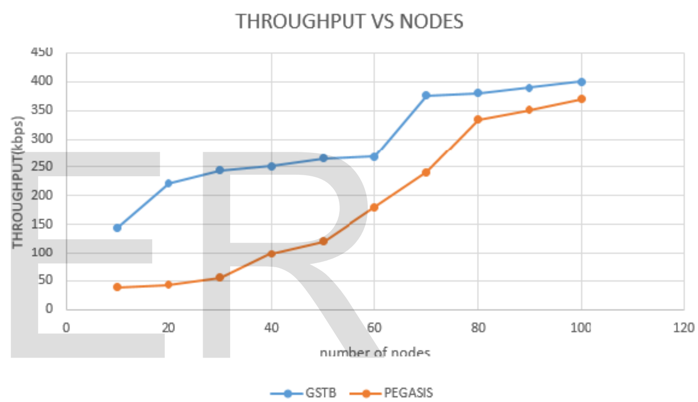

Figure 3: Varying Throughput with number of Nodes

5.1.2 Throughput varying with Inter packet arrival time

As data interval time increases a smaller number of packets are transmitted in unit time. So, throughput decreases.

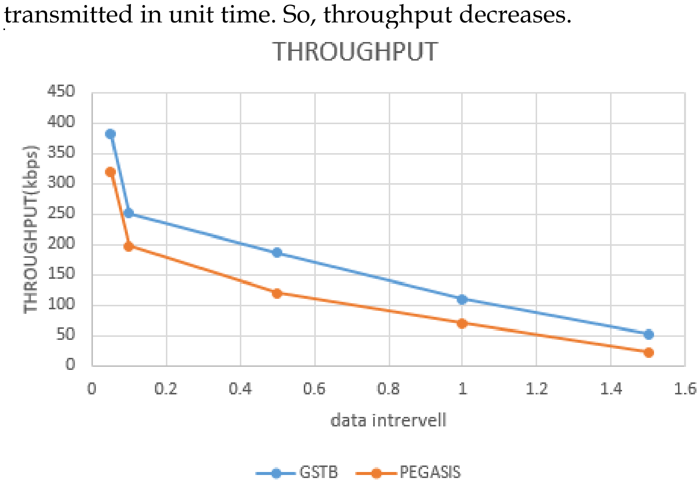

Figure 4: Varying Throughput with Inter packet arrival time

5.2 Control overhead varying with nodes

It is the ratio between the number of routing packets required to establish connection and the number of data packets sent to the destination.

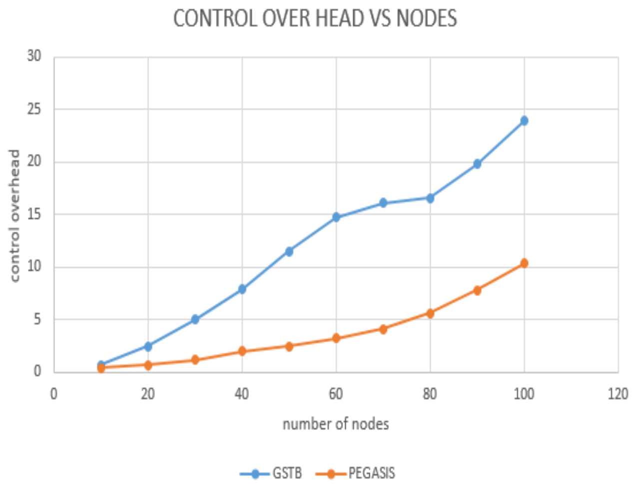

Figure 5: Varying Control Overhead with number of nodes.

As nodes increases number of routing packets required to establish connection in tree routing protocol (GSTB) is more compared to that of chain based routing protocol (PEGASIS).

Residual Energy: Energy retained by the nodes after transmission or reception of data/control packets.

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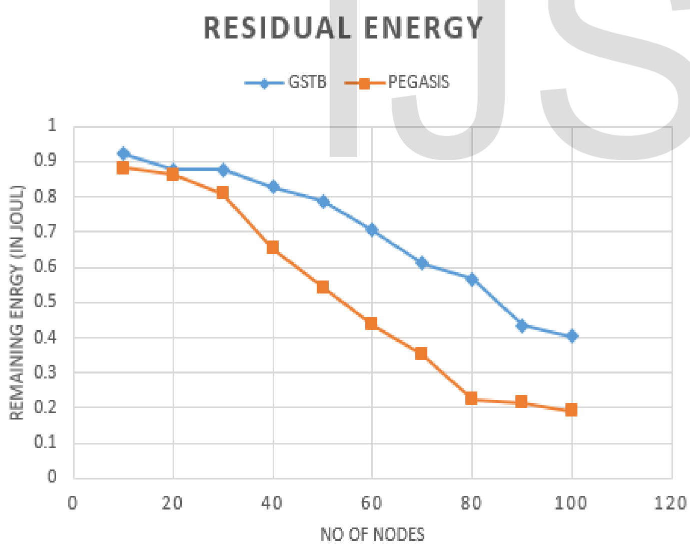

Figure 6: Varying Residual Energy with number of Nodes

As number of nodes increases energy consumption in PEGASIS routing protocol is more than that of tree based routing protocol. Because of a smaller number of nodes involved in tree based routing protocol, the residual energy is more in tree routing than PEGASIS routing protocol. Average residual energy in tree routing protocol is 0.711 which is 0.195 more compared to that of PEGASIS.

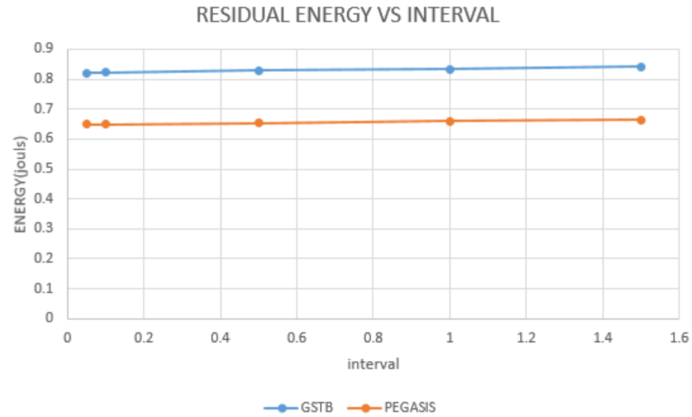

Figure 7: Varying Residual Energy with Inter packet arrival time.

As interval time increase a smaller number of packets will be sent to destination from source. So, energy consumption decreases due to a smaller number of packet transmissions. This leads to a little bit increase in remaining energy of nodes.

Delay: The average time required for a packet to reach destination from source. So, it is the summation of delay of all packets divided by the number of generated packets.

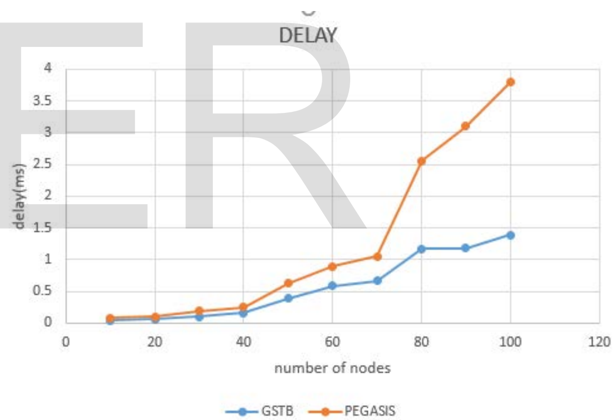

Figure 8: Varying Delay with number of Nodes

Table 2: Comparison of PEGASIS & GSTB with respect to varying number of nodes

Measured parameters	GSTB	PEGASIS
Delay (m-sec)	0.5753	1.2646
Throughput (kbps)	294.14	183.35
Residual energy(joules)	0.711923	0.51675

As nodes increases, the packet takes longer path to destination therefore the delay is more in PEGASIS compared to GSTB. Average end to end delay in tree based routing protocol is 0.5753 sec which is 0.6896 sec less compared to that of PEGASIS.

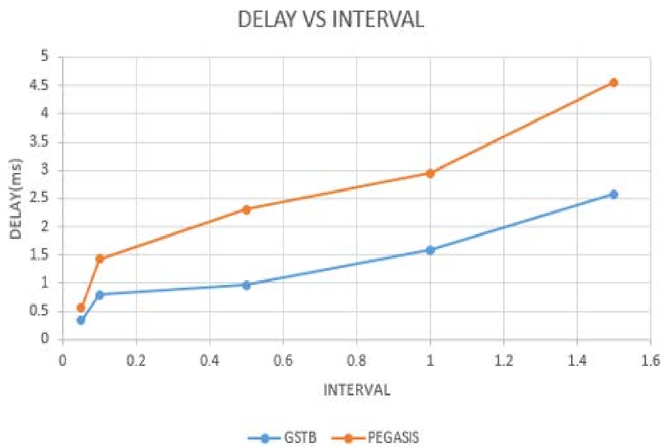

Figure 9: Varying Delay with Inter packet arrival time

Data interval time is inversely proportional to data rate, if data rate decreases then packet transmission delay increases which in turn increases end to end delay.

Conclusion and Future Scope

Simulation of power efficient gathering of sensor information system and tree based routing protocols is done in NS2 by varying number of nodes, data interval. when compared to PEGASIS, Tree (GSTB) protocol provides better performance in terms of parameters such as Energy, Delay, throughput, in case of varied nodes and varying inter packet arrival time.

This project can be extended by applying multimedia traffic to the wireless sensor network. Performance or QOS may be evaluated by varying nodes speed. Performance or QOS may be evaluated by varying number of sources.

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