Comparative Study of PEGASIS and PDCH Protocols in Wireless Sensor Network

Jigish Rana
M.E. I.T. (pursuing)
Thakur College of Engineering
And Technology
University of Mumbai

Sangeeta Vhatkar
Assistant professor, TCET
Ph.D. Scholar
P.I.E.T, Nagpur

Mohommad Atique
Associate Professor
P.G. Department Computer
Science S.G.B.A.U,
Amravati

ABSTRACT
In wireless sensor network (WSN) [1], energy efficiency is one of the very important issues. Protocols in WSNs are broadly classified as Hierarchical, Flat and Location Based routing protocols. Hierarchical routing is used to perform efficient routing in WSN. Here we concentrate on Hierarchical Routing protocols, different types of Hierarchical routing protocols, and PEGASIS (Power-Efficient Gathering in Sensor Information Systems) [2, 3] based routing protocols like PDCH (PEGASIS with Double Cluster Head) [4] protocol which makes every nodes load balance and extend the network lifetime. EEPB (Energy-Efficient PEGASIS-Based protocol) [5] which is a chain-based protocol to adopt a threshold when constructing chain to decrease the formation of long link to select the leader. This paper presents the hierarchical routing protocol PEGASIS and a comparative study on various versions of PEGASIS protocols.

General Terms
Routing protocols, Hierarchical routing, Wireless sensor networks

Keywords
WSN, PEGASIS, PDCH, EEPB, IEEPB, MH-PEGASIS, Routing protocols

1. INTRODUCTION
WSN consists a group of spatially dispersed and dedicated sensors in order to sense the physical conditions of the environment like sound, temperature, humidity, pollution levels and pressure and so on. WSN has enabled the evolution of low cost, low power, multi-functional smart sensor nodes.

Sensor Node is a basic element of WSN, is composed of Sensing, Computation and wireless Communication unit. Sensor nodes coordinate among themselves to get high-quality information about the physical surroundings. The conclusion of each sensor node is defined by its mission, the information it currently holds, energy resources and knowledge of computing. Each sensor has the ability to communicate either among each other or directly to an external base-station (BS).

Routing in WSN differs from conventional routing. Many routing algorithms were developed for wireless networks. All routing protocols proposed for WSNs may be split into different classes. There might different routing protocols depending on the application. This paper surveys recent routing protocol for sensor networks and introduces a classification of the various protocols shown in Table 1. Protocols in WSNs are broadly classified as Hierarchical, Quality of service (QoS) and Location Based routing protocols. The main category explored in this paper is hierarchical based routing protocols, PEGASIS protocol and PEGASIS based protocols.

Table 1. Routing Protocols for WSNs

Category	Protocols
Hierarchical Protocols	LEACH, PEGASIS
QoS-based protocols	SAR, SPEED
Location-based Protocols	GAF, GEAR

2. HIERARCHICAL ROUTING PROTOCOLS
Hierarchical Routing Protocols [6] are also known as cluster based routing protocols. The concept of clustering or hierarchical routing is an energy-efficient communication that can be used by the sensors to report their sensed data to the BS. A clustering technique breaks the whole network into various layers of clusters. Figure 1 shows the basic structure of Hierarchical Routing Protocol.

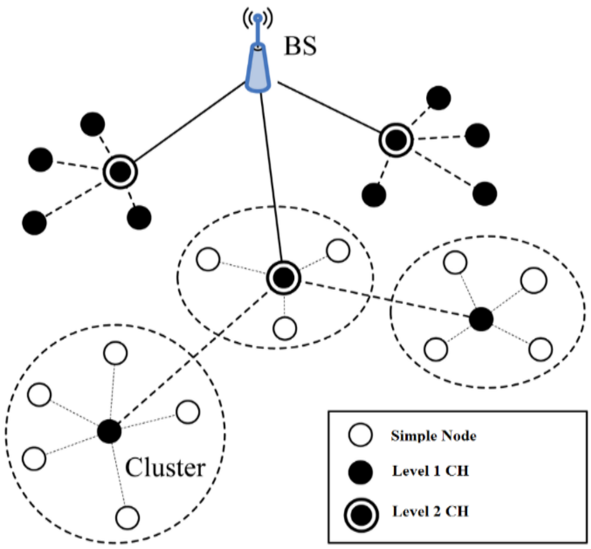

Fig 1: Hierarchical Routing Protocol

Here we describe a sample of layered protocols in which a network is composed of various clusters of sensors. Every cluster has a cluster head (CH) which is in charge of routing the sensed information from the cluster to the BS. In hierarchical structure data is transmitted from the lower cluster to the upper cluster and hence along. In this the data are first aggregated at the lower level cluster and then it sent to the higher level cluster to its CH. Transferring the data from lower level to the higher level cluster, it bears to travel large distances. For that reason we require high speed data transfer sensor nodes.

3. HISTORY OF PEGASIS PROTOCOL

LEACH (Low Energy Adaptive Clustering Hierarchy) [7] is the first cluster based and most popular energy-efficient hierarchical algorithm that was proposed for reducing power consumption and also uses randomization to distribute the energy load equitably among the sensors in the network. The primary objective of this protocol is to choose sensor nodes as CHs by rotation technique, hence the most energy dissipation in communicating with the base station is spread to all sensor nodes in the network. To achieve this objective LEACH protocol performs local data fusion in order to compress the information gathered by the clusters before sending it to the BS, so that reducing energy waste and enhances the system lifetime. Figure 2 shows the basic topology of LEACH protocol.

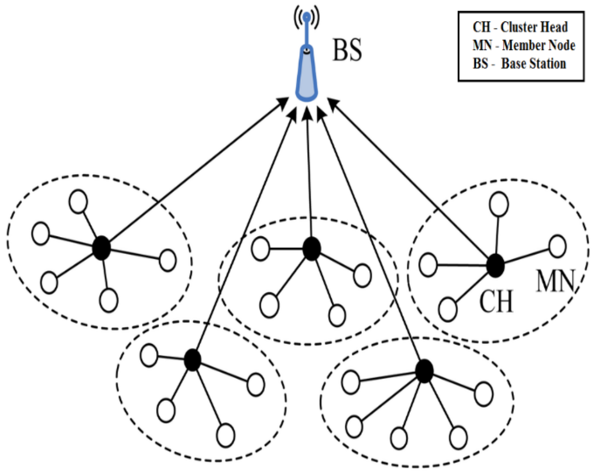

Fig 2: The Basic Topology of LEACH

Although, LEACH has a few disadvantages as follows.

- LEACH performs the single-hop cluster method, directly from CHs to the BS, which is not applicable to large networks.
- Since CH election is done in terms of probabilities, it is difficult for the predetermined CHs to be uniformly spread throughout the network.
- Behind the idea of dynamic clustering brings additional overhead.

To remove these deficiencies, PEGASIS [2, 8] is an improvement of LEACH protocol, which is described below.

3.1 PEGASIS Protocol

PEGASIS [2] is a near optimal chain-based routing protocol and the main thought in this protocol is for every node to only communicate with their nearest neighbors and alternate being the leader in transmission to the BS. In PEGASIS, All the sensor node locations are random, and each node has the power of data detection, data fusion, wireless communication and positioning. Energy load is distributed equally among all sensor nodes in the network. In this the chain is shaped by the nodes themselves, they can first acquire the location data of all nodes and plot the chain using the greedy algorithm.

For data gathering, each node gets data from one neighbor, fuses its own data and transmits data to the next neighbor in the chain. Alternatively, control token passing approach started by the leader is applied to begin data passing from the ends of the chain. The token passing scheme in PEGASIS is shown in figure 3.

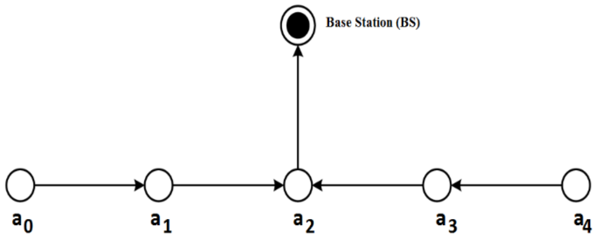

Fig 3: The Token Passing Scheme in PEGASIS

In this figure, node a_2 is the leader, it passes the token along the chain to the node a_0 at first. Then, node a_0 passes its data toward node a_2. After node a_2 receives data from node a_1 it passes the token to node a_4 and node a_4 passes its data towards node a_2 with data fusion occurring along the chain.

As indicated by these, PEGASIS protocol is able to outperform LEACH for distinctive network sizes and topologies. PEGASIS diminishes the overhead of dynamic cluster formation in LEACH. It also decreases the number of data transmission volume through the chain of data collection and the energy load is spread out consistently in the network.

PEGASIS improves by saving energy at following stages.

- In PEGASIS there is just single node which manages the data collecting and data fusion. Thus, compared to LEACH where each cluster head is taking part in communication with the base station. Along these lines, thus the energy will likewise be spread out by each cluster head. PEGASIS will spread out less energy because only leader will take part in data aggregation and data fusion.
- At the local gathering, the distance of the node transmits is very less as compared to the CH in LEACH.
- The leader will receive at most only two messages from the neighbors which is not in the case of LEACH.

Figure 4 shows the illustration of PEGASIS protocol.

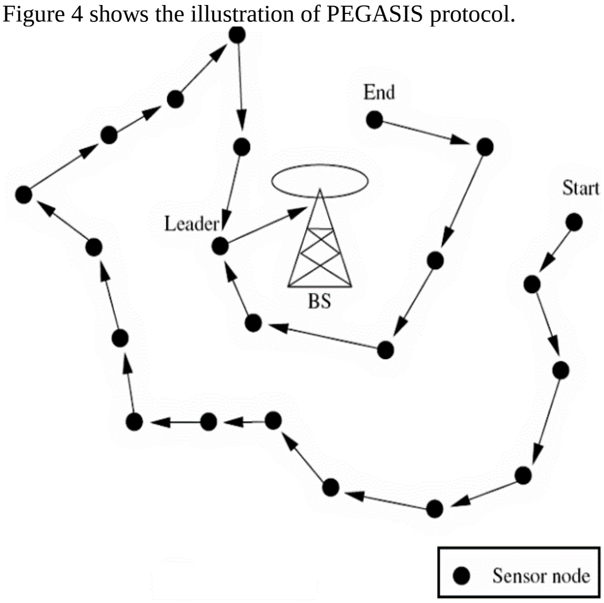

Fig 4: Illustration of PEGASIS Protocol

The goals of PEGASIS are as follows:

- To minimize the transmission distance of each node
- To minimize the overhead
- To minimize the messages that need to be sent to the BS
- To pass out the energy consumption equally across all nodes

4. PEGASIS BASED PROTOCOLS

Still PEGASIS had certain deficiencies. The below describes protocols are various PEGASIS based protocols that are designed to overcome those deficiencies. Each protocol takes into consideration unique factors and proposes its different version. Figure 5 shows the various PEGASIS based protocols.

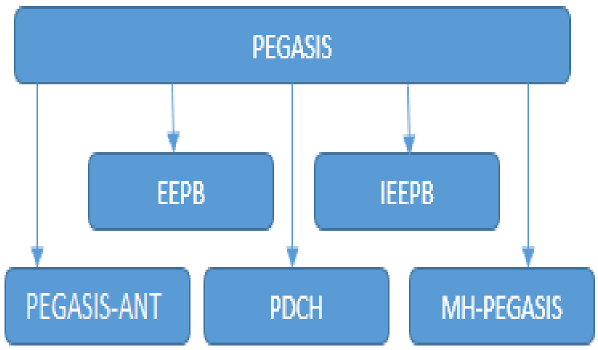

Fig 5: Various PEGASIS Based Protocols

4.1 EEPB

EEPB is an enhanced PEGASIS [5, 9] algorithm. As PEGASIS compute the chain using the greedy algorithm, it can result much long distance in communication between two sensors. Thus more energy consumes in transmitting the data and nodes die early. EEPB avoids this phenomena using a distance threshold. EEPB adopts threshold when constructing chain to decrease the formation of long link. EEPB selects the leader by holding both the residual energy of nodes and the distance between nodes and BS, and sets the reselection frequency of leader according to the remaining nodes in the network. EEPB not only saves energy on the threshold, but also balances the energy consumption of all sensor nodes.

4.2 IEEPB

IEEPB [10] is an improved chain-based routing algorithm, which overcomes the deficiencies of EEPB. When EEPB builds a chain, the threshold received is uncertain and complex to determine. This reasons in the formation of Long Link (LL). Also, when EEPB chooses the leader, it ignores the nodes energy and distance between nodes and BS that optimizes the selection of a leader. Instead of EEPB, IEEPB compares the distance between nodes twice and finds the shortest path. IEEPB operating by rounds, which contain 3 stages: chain construction stage, leader selection stage and data transmission stage. The chain structure is simplified such that the formation of LL is avoided. Also, IEEPB considers nodes energy, distance between nodes and BS, normalizes these two elements and assigns different weight co-efficient for them.

An algorithm for chain construction as follows.

STEP 1

Initialize the network parameters. Determine the total number of nodes, energy of nodes, BS location etc. Then chain construction starts

STEP 2

BS broadcasts a hello message to the network to get network information such as ID of nodes alive and distance from each node to BS.

STEP 3

Set the node which is farthest from BS as an end node, it joins the chain first. And it is called as node 1

STEP 4

End node of the chain obtains the distance between itself and other nodes which have not joined the chain yet, finds the nearest node and sets it as node *i* waiting to join the chain, *i* shows the i^{th} node joined

STEP 5

Node *i* gets the distance between itself and *i*-1 nodes, finds the nearest node j ($1 \le j \le i - 1$) and directly connects with it, at this point node *i* becomes the new end node of the chain.

STEP 6

Recycle *STEP 4* and *5* to connect node *i*+1, *i*+2, i+3…The process continues till all nodes have joined the chain, so that there forms a branching chain finally.

In leader selection phase, IEEPB chooses the leader using a weighting method which considers both the residual energy of nodes and the distance from the node to BS. Finally the node with the minimum weight becomes the leader. IEEPB has higher energy efficiency and hence longer network lifetime.

4.3 PEGASIS-ANT

To construct the chain, PEGASIS-ANT [11] protocol uses an ANT Colony Optimization (ACO) algorithm rather than a greedy algorithm. This helps to achieve global optimization. It constitutes the chain that reduces the transmission distance and makes the path more distributed.

In this, instead of making all nodes transmit to the BS the same number of times, the individual nodes to transmit an unequal number of times to the base station depending on their distances from it. This increases the network lifetime and performance. As mentioned earlier, when the chain is formed using the greedy approach the distances gradually increase as the chain is constructed. However ACO makes sure that distances not becomes extremely large. The ACO approach constructs the chain in such a manner that the inter-nodal distances never exceed the threshold distance thereby enabling all nodes to become leaders. However, while comparing ANT Colony schemes with PEGASIS we always take care that their scheme if the distance becomes greater than this threshold the nodes are never allowed to become leaders. Ant Colony Optimization is inspired by the behavior of real ants searching for food.

While constructing new solutions, the main objective of ACO is to utilize both local information as well as information about good solutions obtained in the past. In this memory is exploited in two ways. First, intensification is achieved by a strong bias towards the best choice in each decision process. Second is diversification is driven by making frequently used paths less desirable to choose.

It also balances the energy consumption between the nodes. In each round, on the basis of residual energy of each node the leader is selected. Which is directly communicating with the BS. This algorithm extends the network lifetime.

4.4 MH-PEGASIS

In PEGASIS, Routing in a single hop within the cluster-heads have an important drawback because CHs located far from the BS must use strong signals to communicate with BS which increases their energy consumption. There are main three phases in PEGASIS protocol, which are Announcement phase, cluster formation phase and data communication phase. Figure 6 shows the PIGASIS protocol algorithm.

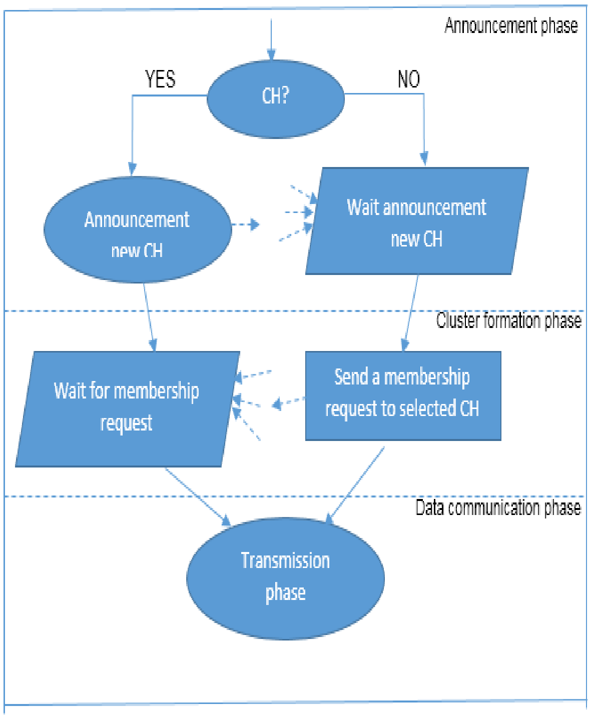

Fig 6: PEGASIS protocol algorithm

To rectify this problem, an improvement to the hierarchical PEGASIS protocol that allows the use of multi-hop routing between the cluster-heads (inter clusters) in order to reach efficiently the BS as shown in figure 7.

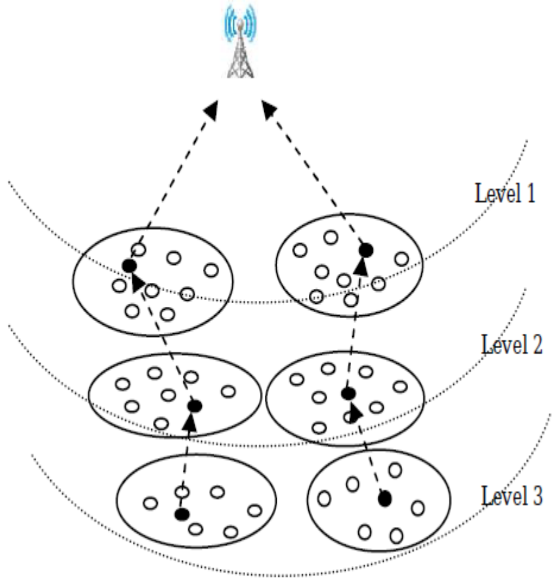

Fig 7: Multi-hops routing [12]

In MH-PEGASIS [12] protocol, each round is made up of two main phases: an initialization phase and a data transmission phase. In the initialization phase, the first three sub phases are similar to those in PEGASIS, which are described above.

4.5 PDCH

PDCH (PEGASIS with Double Cluster Head) [4, 13] balances the load of every node and increase network lifetime. Generally PEGASIS protocol uses one CH that communicates with the BS. Here instead of one, double CH are used in a single chain. It also gives a hierarchical structure so that long chaining is avoided. PDCH outperforms PEGASIS by eliminating the overhead of dynamic cluster formation, minimizing the distance between nodes, reducing the number of transmissions and receives among all nodes, and using only one transmission to BS per round. As the energy load is distributed among the nodes, the network lifetime increases and thus causes the quality of the network.

Figure 8 shows the double cluster head (DCH) method used in PDCH.

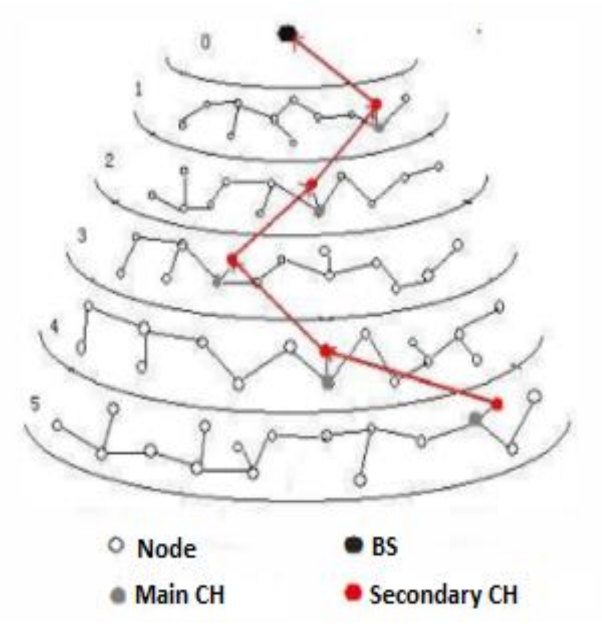

Fig 8: Double CH method [4]

In PDCH, main CH or primary CH is responsible to collect the data from cluster nodes and combine that data. After aggregating the data, main CH or primary CH sends this data to the secondary CH through the chain transmission. And the secondary CH is responsible for gathering information from main CH and sends it to the BS.

PDCH Algorithm:

STEP 1

Initially network is created using 'rand' command using the above initial parameters. A base station is plotted at the given location.

STEP 2

Now the distance from BS to all other nodes in the network is found using the Euclidean distance formula.

$$d_i=\sqrt{(x_{bs}-x_i)^2+(y_{bs}-y_i)^2}$$

Where
d_i is the ith node distance from base station
x_{bs} & y_{bs} are the coordinates of the base station
x_i & y_i are the coordinates of the ith node

Now the levels are formed based on the distance from base station and each level is given an id. In this the nodes which are less than or equal to 100 meters comes under first cluster (level id=1). 100 to 150 come under second cluster (level id=2), 150 to 200 come under third cluster (level id=3) and 200 to 250 come under fourth cluster (level id=4).

STEP 3

After forming the clusters, head node is elected in each cluster. In this protocol the head node is elected based on the residual energy of the nodes. The node which has maximum residual energy will be elected as a cluster head. But in the initial case all the nodes will have the same energy. So in the first round of transmission some random node is elected as cluster head.
CH= Node with maximum residual energy

STEP 4

After electing the cluster head, a chain is formed using the nodes in the cluster. Node with same level id can only involve in chain formation.

STEP 5

After forming the chains in each cluster data transmission is done in the cluster. For data transmission and reception, the first order radio model is used.

STEP 6

Now the data available in the cluster nodes are transmitted to cluster head. These CHs are known to be primary heads. Now all the CHs are considered to form a separate cluster. And of these nodes the node nearer to the base station is elected as head which is known as secondary cluster. And again a chain is formed among these nodes and data is transmitted to secondary head. This secondary head node will transmit that data to base station.

Now this completes one round of transmission. STEPS 3 to 6 are repeated for several rounds of transmission. Check for the dead nodes after completion of each round. Dead nodes are the nodes with residual energy less than or equal to zero. If dead nodes are found, then the node is removed from the corresponding cluster. And number of nodes that are dead in each round are counted and saved in an array. The value of sum of residual energies of all alive nodes is found in every round and saved in another array. Now the plot is made for the number of alive nodes in each round and residual energy of the network in each round.

5. CONCLUSION AND FUTURE WORK

From the protocols reviewed, though PEGASIS protocol outperforms LEACH. Although PEGASIS has certain drawbacks. As it uses a greedy algorithm for the formation of data chain, it results Long Chain. Thus, consuming more energy due to which nodes die early. Data transmission will produce time-delay in PEAGSIS. Also the method of choosing the cluster head is not suitable for load balance. EEPB protocol tries to overcome the drawbacks of PEGASIS by using a distance threshold. That is to say the distance between nodes is the first factor. For the short distance, we could permit the branch chain existing. According to the branch chains, a new improving algorithm PDCH based on double cluster head introduced. PDCH outperforms PEGASIS and EEPB by eliminating the overhead of dynamic cluster formation, minimizing the distance between nodes, reducing the number of transmissions and receives among all nodes, and using only one transmission to BS per round. Very extremely work is done on the comparison of QoS parameters of EEPB and PDCH. Parameters such as Delay, throughput, Energy consumption and packet drop ratio can further be analyzed and compared. Improvisations on these parameters can also be performed to recover the end to end performance of PDCH protocol.

Future work in PDCH protocol is to consider distance parameter in CH selection. In PDCH, the distance parameter is only considered for the level assignment. For a selection of CH in PDCH protocol, we consider only residual energy and do not focus on the distance of nodes to BS. The result of PDCH protocol may further improve by considering both parameters, the residual energy and the distance parameter. So that, the nearest node with high residual energy becomes the CH.

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