IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 3 Issue 2, February 2016.

www.ijiset.com

ISSN 2348 – 7968

Energy-Hole Minimization in WSN using Hierarchical Routing Protocols

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Abstract

A wireless sensor network (WSN) is a system composed of a large number of low-cost micro-sensors. This network is used to collect and send various kinds of messages to a base station (BS). The sensor nodes are very small in size, low battery power, limited storage and processing capacity. Each node is usually equipped with a wireless radio transceiver, a small micro-controller, a power source and multi-type sensors such as temperature, light, pressure, sound, vibration etc.These nodes form a network by communicating with each other either directly or through other nodes .The lifetime of Wireless Sensor Networks (WSN) is crucial. To achieve the aim, we need not only to minimize total energy consumption but also to balance WSN load. There are different routing protocols mar minimizing the energy consumption but, this paper aims to study different energy balance hierarchical routing protocols used in WSNs. In this paper, we have compared different hierarchical protocols used in WSN, ensuring maximum network lifetime by balancing the load as equally as possible and a comparison study drawn based on all hierarchical based routing protocols.

Keywords: Energy-balance, Network lifetime, Hierarchical routing protocol, Wireless sensor network, Cluster head.

1. Introduction

A sensor network is an infrastructure comprised of sensing and computing elements that gives an entity the ability to instrument, observe, and react to events and phenomena in a specified environment. The entity typically is a civil, governmental, commercial, or industrial entity. The environment can be the physical world, a biological system, or an information technology (IT) framework. A wireless sensor network is a collection of nodes organized into a cooperative network. Each node consists of processing unit (one or more microcontrollers, CPUs or DSP chips), it also contain multiple types of memory (program, data and flash memories), have a RF transceiver, have a power source (e.g., batteries and solar cells), and have various sensors and actuators. The nodes communicate wirelessly and often self organize after being deployed in an ad hoc fashion. Systems of thousand's or even lakh's of nodes are evaluated.

Such systems can overturn the way we live and work. All sensor nodes have to coordinate with each other in order to produce high quality information about physical environment. All nodes communicate with each other at same time and route the information to base station which is a master node. Sensor nodes are deployed either randomly or uniformly. Once sensor nodes are deployed it cannot work properly unless there is sufficient power supply.

This paper primarily consists comparative study of various energy efficient routing protocols of WSNs. Each Protocol has its own advantages and disadvantages under specific working environment. In comparative discussion of performance of different existing protocols of WSNs, table shows the comparison summary of the performance evaluation of different protocols. In this paper we are comparing LEACH, PEGASIS, HEED, TREEPSI, and GSTEB.

A. Characteristics of WSNs

- Sensor nodes battery operated
- Inadequate wireless communication
- Reduced coordination
- Ability to withstand harsh environmental conditions
- Mobility of nodes
- Lifetime

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***B.* Major Issues in WSN:**

- Limited Range
- Inadequate Power
- Limited Processing power / memory
- Cost

C.* Categorization of Protocols in WSN*:

In general many routing algorithms were developed to overcome from issues in sensor networks. WSN protocols strongly impact on system performance .Choosing the wrong protocol may cause severe inefficiency and prevent the WSN to accomplish user need..WSN protocols are divided into seven categories. They are given diagrammatically shown as follows.

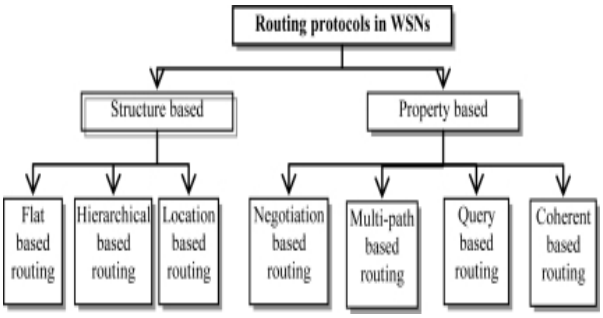

Fig 1. Classification of Routing Protocols

In this paper we focus on hierarchical protocols with their working principle, characteristics and comparative study with some parameters.

2. HIERARCHICAL ROUTING PROTOCOLS

The motive behind hierarchical routing is to proficiently maintain the energy consumption of sensor nodes by connecting them in multi-hop communication. This paper is a comparison study on LEACH, PEGASIS, HEED, TREEPSI and GSTEB.

2.1. LEACH (Low Energy Adaptive clustering hierarchy)-:

Leach is the first hierarchical based routing protocol based on the process of clustering. It uses adaptive clustering scheme for the communication between nodes In LEACH, the nodes organizes themselves into clusters, with one node acting as cluster-head. The cluster-heads take the responsibility of routing the data to the Sink. Cluster-heads change randomly over time in order to balance the energy dissipation of nodes. In LEACH, each round includes two phases: a setup phase and steady state phase. In set up phase, each node will decide whether to be a cluster head or not. After CHs are chosen, each of other nodes will select its own CH and join the cluster according to the power of many received broadcast messages. Each node will choose the nearest CH. In Steady state CHs fuse the data received from their cluster members and send the fused data to BS by single-hop communication. The cluster heads will change randomly according to the time in order to balance the energy over nodes.

LEACH works, at first normal sensor nodes transmit their data to their respectiveCHs. On receiving these data, the CHs aggregate them in a compacted form and transmit them to the BS. Finally BS will receive all compressed data from different CHs present in the network. LEACH is fully distributed and it uses single-hop to transmit the data from node directly to the cluster head.

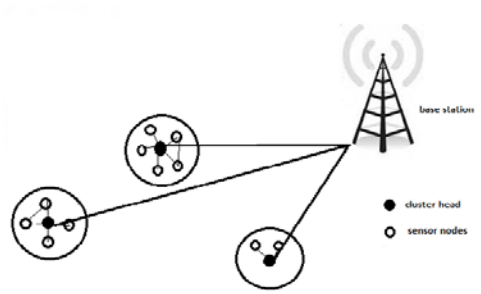

Fig. 2 Architecture Of LEACH

Advantages Of LEACH

- The random dieing pattern of the nodes and dynamic clustering increases the network lifetime.
- LEACH is completely distributed and requires no global knowledge of network.

Disadvantages Of LEACH

- It is not applicable to networks deployed in large regions.
- The elected Cluster Heads may be concentrated in one part of the network.
- The idea of dynamic clustering brings extra overhead, e.g. head changes, advertisements

etc. The node selected as cluster head drains the battery more quickly.

2.2. PEGASIS(Power efficient gathering in sensor information systems)-:

PEGASIS is a near optimal chain-based protocol. It is a tree based technique.PEGASIS protocol is more efficient protocol from LEACH. In PEGASIS it selects only one node as cluster head and sends the fused data to the base station in each round. Nodes need only communicate with their closest neighbors and they take turns in communicating with the base-station. PEGASIS has two phases: chain construction and gathering data. In chain construction phase it starts with farther node from the base station and in this protocol greedy algorithm were used to construct the chain. In data gathering phase the leader node will be selected randomly for each round. If N is a number of nodes (i mod n) node is selected as head node for i round. Life time of PEGASIS is more if we compared it with LEACH.

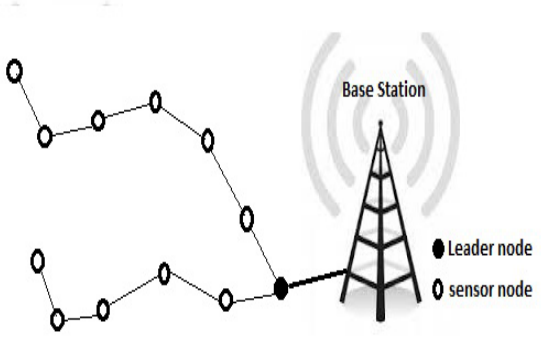

Fig.3Architecture of PEGASIS

Advantages Of Pegasis

- ❖ The bandwidth consumed in communication is reduced.
- ❖ PEGASIS avoids cluster formation.
- ❖ Uses only one node in a chain to transmit to the BS instead of using multiple nodes.
- ❖ PEGASIS can increase the life time network twice as much the lifetime of the network under the LEACH protocol.

Disadvantages Of PEGASIS

- ❖ PEGASIS still requires dynamic topology adjustment.
- ❖ PEGASIS introduces excessive delay for distant node on the chain.
- ❖ The single leader can become a bottleneck.
- ❖ It consumes more energy than LEACH.

2.3. Hybrid Energy Efficient Distributed Protocol (HEED):

Like LEACH HEED is also a clustering based technique. HEED protocol is enhanced from LEACH protocol scheme. It extends the basic schema of LEACH protocol. It is a multi-hop routing protocol. It uses residue energy as its primary parameter for cluster selection and node degree and distance to neighbors as secondary. The clustering process is divided into number of iterations and in each iteration the node that are not covered by any cluster head; it doubles the probability of becoming a cluster head. HEED does not guarantee optimal elected set of cluster heads. This is suitable for heterogeneous WSN.It has three phases, Initialization phase, Set-up phase and Steady phase. HEED protocols effectively increases the network lifetime but greatly reduces total energy consumption since they consume more energy in cluster head node due to which node dies early and once head node dies all other nodes associated with it becomes isolated.

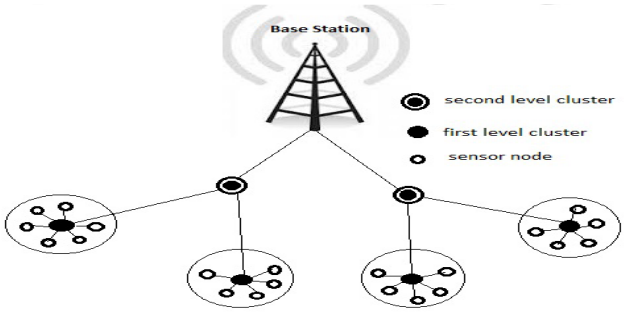

Fig.4 Architecture of HEED

Advantages of HEED

ISSN 2348 – 7968

- It is more efficient than that of LEACH protocol.
- It ensures more scalability.
- It balances the load distribution in a network efficiently.
- It helps in providing fault tolerance in the network.

Disadvantages Of HEED

- It consumes more energy.
- The periodic cluster head rotation or election needs extra energy to rebuild clusters.
- The random selection of the cluster heads, may cause higher communication overhead.

2.4. TREEPSI (Tree Based Energy Efficient Protocol forSensor Information)

It is also a tree based routing protocol technique like PEGASIS. In this protocol a node is randomly selected as root node among all the sensor nodes. After selection of root node it starts building tree like hierarchical path. There are two ways to build the tree path. One is computing the path centrally by sink and broadcasting the path information to network. The other approach is, all nodes construct the same tree structure locally by using a common algorithm in each node.

Data gathering can be done in two ways using tree. In the first approach, root will initiate data gathering process by sending a small control packet towards the children nodes using any standard tree traversal algorithm. In the second approach, all the leaf nodes will start sending the sensed information towards their parent nodes. The parent nodes will fuse the received data with their own data and forward the resultant data to their parent. This process is repeated till data are received by the root node. The data aggregation will take place at root node and after aggregation root node sends the collected data to sink node. The process will go until the root node dies.

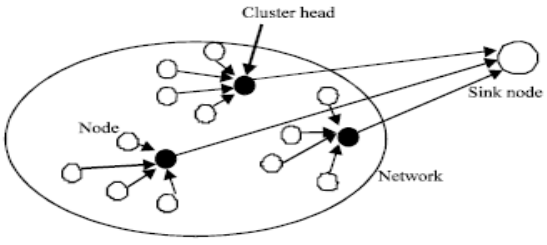

Fig. 5 Architecture of TREEPSI

Advantages Of TREEPSI

The tree path will not change until the root node dead.

- The length of path form end leaf node to root/chain node in TREEPSI is shorter than PEGASIS.
- TREEPSI consumes less power and longer life in data transmission than PEGASIS.

2.5. General Self-Organized Tree-Based Energy-Balance Protocol (GSTEB):

GSTEB outperforms LEACH, PEGASIS, TREEPSI and TBC. GSTEB is a self-organized protocol; it only consumes a small amount of energy in each round to modify the topography for the point of balancing the energy consumption. When lifetime is distinct as the time from the start of the network operation to the death of the first node in the network, this protocol prolongs the lifetime by 100% to 300% compared with PEGASIS. The operation of GSTEB is divided into Initial Phase, Tree Constructing, Self-Organized Data Collecting and Transmitting Phase, Information Exchanging.

Initial Phase

BS broadcasts a packet to all the nodes. Then All Sensors sends its packet in a circle and sends a packet which contains its entire neighbor's information.

Tree Constructing Phase

BS assigns a node as root and coordinates to all sensor nodes. Each node tries to select parent in neighbors using Energy Level. Parent nodes are computing every Node neighbors' Record.

Self-Organized Data Collecting and Transmitting Phase

Leaf Node (L) Sends Beacon. Parent Node (P) and tries to receive Beacon from Leaf Node. More than one (L) need to send data. (P)Monitor channel one which is chosen send the data others keep sleep

Information Exchanging

Each node needs transmit data in each round; it may exhaust its energy and die. The dying of any sensor

ISSN 2348 – 7968

node can influence the topography. So nodes that are going need to inform others.

Even though GSTEB needs BS to compute the topography, which leads to an increase in energy waste and a longer delay, this kind of energy waste and longer delay are acceptable when compared with the energy consumption and the time delay for data transmitting.

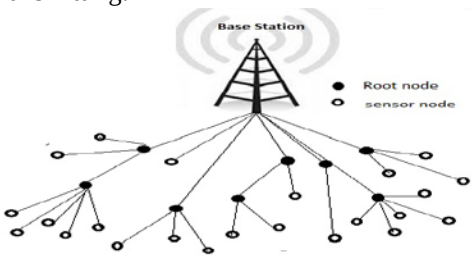

Fig. 6 Architecture of GSTEB

Advantages of GSTEB:-

- GSTEB performs better compared with PEGASIS.
- It consumes less energy than all protocols.
- It helps to achieve longer lifetime.

3. RESULTS AND DISCUSSION

Table 1: MATLAB Simulation values

Energy (J/node)	Protocol	The round a node begins to die	The round all the nodes are dead
0.25	LEACH	118	243
	PEGASIS	246	568
	TREEPSI	267	611
	TBC	328	629
	GSTEB	389	677
0.5	LEACH	209	435
	PEGASIS	485	1067
	TREEPSI	532	1123
	TBC	589	1165
	GSTEB	730	1330

Above table gives a MATLAB simulation results of protocols in terms of number of rounds, when nodes begins to die and when all the nodes in the network are completely dead. We can find that GSTEB performs better than all other protocols.

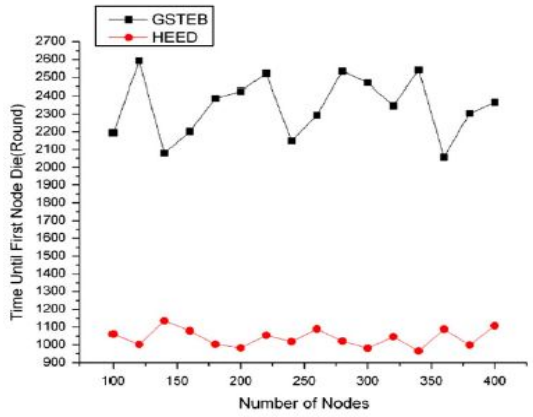

Fig.3.1 Comparing the time when first node dies for GSTEB and HEED

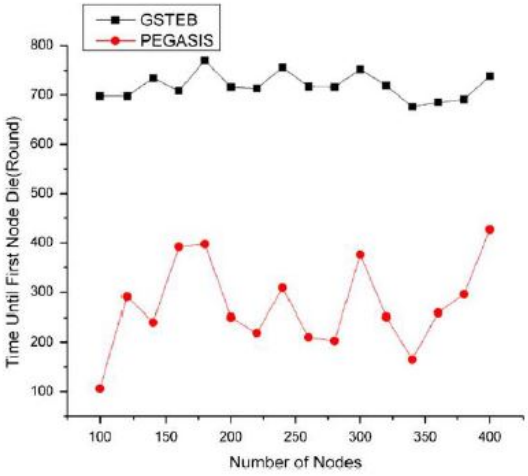

Fig 3.2 comparing the time when first node dies for GSTEB and PEGASIS

4. Conclusion-:

In this paper we focused on all the hierarchical routing protocols used in wireless sensor networks. We have compared all the protocols mentioned by me above in this paper regarding issues such as power consumption scalability etc. It is found that among all the protocols GSTEB is most efficient protocol that can be used if we require long network life time, good scalability, and increased performance. Apart from that GSTEB needs more memory as each node needs to record information of its neighbor node. Hence our future work focuses on designing a protocol for optimizing memory use.

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