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The comparison between routing protocols based on lifetime of wireless sensor networks

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ABSTRACT:*A wireless sensor network consists of thousands of low-cost, low-power and battery-powered sensor nodes. As sensor nodes have limited and non-rechargeable energy resources, energy is a very scarce resource and has to be managed carefully in order to extend the lifetime of the sensor networks. Wireless sensor network is used to collect and send various kinds of messages to a base station .Wireless sensor networks are deployed where the physical environment is so harsh. Various protocols are used to extend lifetime of the wireless sensor networks (WSN) and sensor nodes are used effectively to transfer information to the base station. Load balancing plays an important role in equally distributing the load among the sensor nodes. Protocols such as PEGASIS, HEED, and PEDAP are some of the protocol that are used to extend the life time of the network.*

KEY TERMS*: wireless sensor networks, sensor nodes, energy consumption, lifetime*

I. INTRODUCTION

Wireless sensor networks (WSNs) comprises of hundreds or thousands of low cost sensor nodes. Once deployed, sensor nodes collect the information of interest from the sensors, performs local processing of these data including quantization and compression, and forward the data to a base station (BS) directly or through a neighboring relay node [1].It is used in vast number of applications for wireless sensor networks such as, military, commercial, intrusion detection and industrial, healthcare, disaster and rescue operations, etc. Many protocols have been proposed for increasing the energy efficiency and lifetime of the wireless sensor networks such as LEACH, HEED, PEGASIS and PEDAP. All the above mentioned protocols have various techniques to enhance the lifetime of the wireless sensor networks. Sensor nodes senses the data from the environment where it is located and send it to the base station. Before transferring the data to the base station, the sensor nodes have to know the information about neighboring nodes and it's ID [14].

There are two kinds of communications between cluster heads and the base station, single-hop communication and multi-hop communication. In multi-hop communication clustering algorithms, the energy consumption of cluster heads consists of the energy for receiving, aggregating and sending the data from their cluster members (intra-cluster energy consumption) and the energy for forwarding data for their neighbor cluster heads (inter-cluster energy consumption)[5]. In clustering networks, the imbalanced energy consumption among nodes is the key factor affecting the network lifetime. In order to balance the energy consumption among nodes, clustering algorithms for networks are used. An improvement over the LEACH protocol is the GSTEB protocol which selects the cluster head based on energy level of the sensor nodes, the node which is having higher energy level will become the cluster head[14].

II. COMPARISON BETWEEN CLUSTERING ALGORITHMS

2.1. LEACH: LEACH protocol is a type of hierarchical routing protocols and it is self-adaptive and self-organized in nature. LEACH protocol uses round as unit and each round is made up of cluster set-up stage and steady-state stage, for the purpose of reducing unnecessary energy costs and the steady-state stage must be much longer than the set-up stage [16].

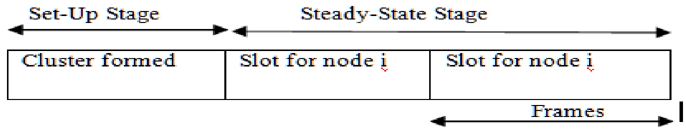

Fig. 1. LEACH Stages

The cluster head in LEACH protocol is selected by using threshold value t(n).Each sensor node in the cluster choose a random number either 0 or 1 and this value is compared with threshold value t(n).If the number selected is less than t(n),then the node becomes the cluster head otherwise it becomes an ordinary node. Fig 2 represents the transmission that take place in LEACH.

Threshold value is determined by the following formula,

$$t(n)=\begin{cases}\frac{p}{1-p*(r \bmod \frac{1}{p})} & if n \in G \\ 0 & if n \notin G\end{cases} \quad (1)$$

The equation (i.e., (1)) calculates the threshold value, where p is the percentage of the cluster head nodes in all nodes, r is the number of the round, G is the collections of the nodes that have not yet been selected as head nodes in the first 1/P rounds [6]. The fig 1 represents the following two stages of LEACH,

2.1.1. Set-Up Stage:

During the setup phase,

[1] Each node will decide whether to become a cluster head or not based on threshold value.
[2] After selecting the cluster head, each of other nodes will select its own cluster head and join the cluster based on energy.
[3] Each node will choose the nearest cluster head.

2.1.2. Steady-State Stage:

During the steady-state phase,

[1] Cluster head fuses the data received from the cluster members and send the fused data to base station by single-hop communication.
[2] LEACH uses randomization to rotate cluster head for each round in order to evenly distribute the energy consumption.
[3] So LEACH can reduce the amount of data directly transmitted to base station and to balance load in wireless sensor networks.

The two stages of LEACH is represented in the flowchart fig3 which is given below.

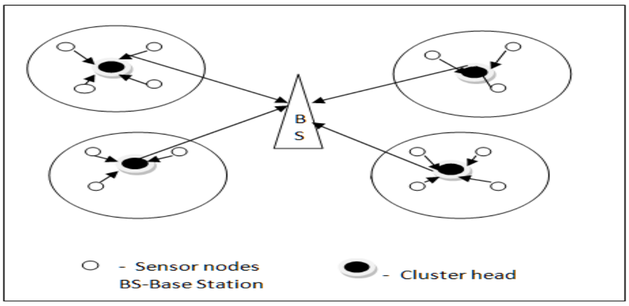

Fig. 2. LEACH

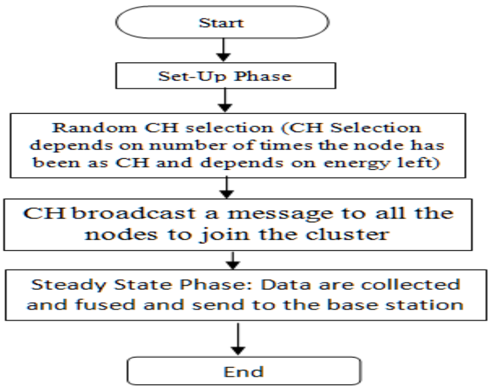

Fig. 3. FLOW CHART OF LEACH PROTOCOL

2.2.PEGASIS: In Power-Efficient GAthering in Sensor Information Systems, each node communicates only with close neighbor and takes turns transmitting to the base station and thus reducing the amount of energy spent per round. In this PEGASIS (Power-Efficient GAthering in Sensor Information Systems) protocol, the data is collected and gathered from nearby nodes .The PEGASIS will form a chain among the sensor nodes so that each node will receive from and transmit to a close neighbor. Gathered data moves from node to node and get fused and eventually a designated node transmits to the base station [10]. Nodes will transmit information to the base station so that the average energy spent by each node per round is reduced. PEGASIS performs data fusion at every node except in the end nodes in the chain [6]. Each node will fuse its neighbor's data with its own to generate a single packet of the same length and then transmit that to its other neighbor in the network. The equations (i.e., (2) and (3)) are used to calculate transmission costs and receiving costs for a k-bit message and a distance d are shown below [10].

Transmitting: ETx(k,d) = ETx–elec(k)+ETx–amp(k,d) (2)
ETx (k, d) = Eelec*k + Îamp * k* d2

Receiving:
ERx(k)=ERx-elec(k) (3)
ERx(k) = Eelec*k

The number of receives and transmissions should be minimal and LEACH and PEGASIS use the same constants (Eelec, Îamp, k) for calculating energy costs, therefore the PEGASIS achieves its energy savings by minimizing d and the number of transmissions and receives for each node [3].The leader of the network will remain the head until the process is completed .Whenever a node dies, the chain will be reconstructed and the threshold can be changed to determine which node can become leader node.Nodes transmits the fused data to the base station to balance the energy depletion in the network and preserves robustness of the sensor web as nodes die at random locations. Distributing the energy load among the nodes increases the lifetime and quality of the network. The PEGASIS protocol achieves between 100 to 300% improvement when compared to the LEACH protocol [10]. PEGASIS, a greedy chain protocol that is near optimal for a data-gathering problem in sensor networks [4].PEGASIS outperforms LEACH by eliminating the overhead of dynamic cluster formation, minimizing the distance non leader-nodes must transmit, limiting the number of transmissions and receives among all nodes, and using only one transmission to the base station per round. Thus PEGASIS protocol is an improvement algorithm over LEACH protocol and the life time of the network is more compared to LEACH protocol [8]. Fig 4 represents the transmission that take place in PEGASIS.

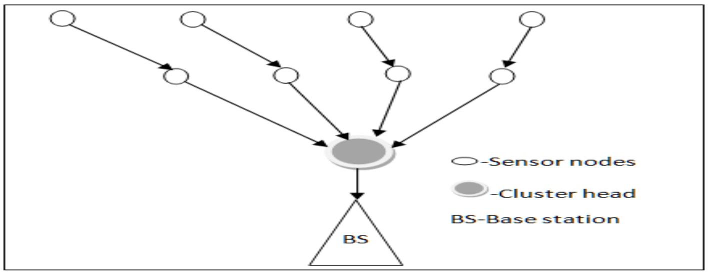

Fig. 4.PEGASIS

PEGASIS uses multi hop routing by forming chains and use only one node to transmit to the base station [9]. Compare to LEACH protocol, PEGASIS has been shown performance of about 100-300% for different network topologies of WSN [17]. Compare to LEACH protocol the lifetime of a PEGASIS is long. In PEGASIS , there is only one node which does the data aggregation and data fusion .In LEACH , where each cluster head is taking part in communication with base station [7]. In LEACH, the energy will be dissipated by each cluster head, PEGASIS will dissipate less energy because only leader node in chain will actively take part in data aggregation and data fusion. In PEGASIS each node should be aware of the remaining energy status of its neighbors. Compare to LEACH, PEGASIS removes the energy dissipated by the reformation of cluster in each round[18]. In PEGASIS, if node death occurs, the chain must be rebuilt which increases the energy consumption. Node far away from the leader node will forward the data many times by the chain which causes the long time delay of transmission. So, there is a problem of time delay in PEGASIS protocol and lifetime of the network is reduced.

2.3.HEED: Hybrid Energy Efficient Distributed protocol was designed to select different cluster heads in a field according to the amount of energy that is distributed in relation to a neighboring node. In each cluster one node acts as a cluster head which is in charge of coordinating with other cluster heads. To increase energy efficiency and prolong network lifetime intra cluster communication is used and it communicates with other cluster heads.

HEED distribution of energy extends the lifetime of the nodes within the network thus stabilizing the neighboring node and it operates correctly when nodes are not synchronized [2]. In Hybrid Energy Efficient Distributed clustering algorithm, each node is mapped to exactly one cluster.The node can directly communicate with its cluster head (via a single hop). Each node independently makes its decisions based on local information.Clustering terminates within a fixed number of iterations. At the end of each TDMA, each node is either a cluster head, or an ordinary node that belongs to exactly one cluster.Clustering should be efficient in terms of processing complexity and message exchange and cluster heads are well-distributed over the sensor field.

The probability of becoming cluster head in HEED is represented as follows [15].

$$CHprob = Cprob \times \frac{Eresidual}{Emax} \quad (4)$$

In the equation (i.e.,(4)), where Eresidual is the estimated current residualenergy in the node, and Emaxis a reference maximum energy (corresponding to a fully charged battery), which is typically identical for all nodes [2].The cluster heads selected by HEED have high residual energy. HEED is completely distributed, a node can become a cluster head according to its CHprob, or join a cluster according to overheard cluster head messages within its cluster range and thus node decisions are based solely on local information [13]. In HEED, cluster heads are randomly selected based on their residual energy and to increase energy efficiency and further prolong network lifetime, consider intra-cluster communication cost as a secondary clustering parameter. A node can elect to become a cluster head at consecutive clustering intervals if it has high residual energy and low cost. Thus the life time of the network in HEED protocol is more compared to other protocols in wireless sensor networks [8].

If the power level used for intra-cluster communication is fixed for all nodes, then the cost can be proportional to

(i) node degree, if the load is distributed among cluster heads, or

(ii) $\frac{1}{\text{node degree}}$, if the dense clusters is created.

HEED distribution of energy consumption extends the lifetime of all the nodes in the network, which adds to the stability of the neighbor set. Nodes also automatically update their neighbor sets in multi-hop networks by periodically sending and receiving messages [12]. Since it uses communication cost as a secondary parameter to improve the life time of the wireless sensor network, HEED outperforms well compared to other protocols in the network. Fig 5 represents the flow process that take place in HEED protocol.

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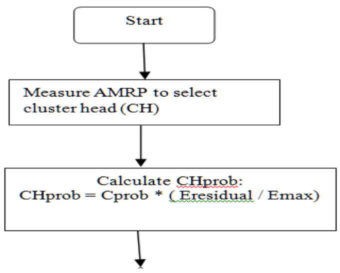

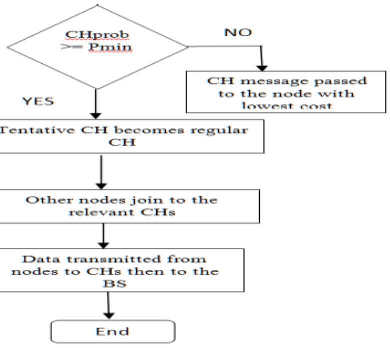

Fig. 5. Flow chart representing HEED Protocol

AUTHORS	PROTOCOLS	ADVANTAGES	LIMITATIONS
Chunyao FU, Zhifang JIANG, Wei WEI and Ang WEI [16]	LEACH	It is a clustering based technique and the cluster head directly communicates with the base station in single hop. It includes two phases, set-up and steady state phase. Life time of LEACH is more compared to other clustering protocols	It is only suitable for homogeneous type of wireless sensor networks
Stephanie Lindsey,Cauligi S. Raghavendra [10]	PEGASIS	It is a tree based technique and energy usage is low compared to LEACH protocol. It has two phases, Chain formation phase, Broadcasting phase. Life time of PEGASIS is more compared to LEACH	In this, data are not aggregated so only one node can communicate with the base station.
Ossama Younis, and Sonia Fahmy[15]	HEED	It is a clustering based technique, it is suitable for heterogeneous wireless sensor networks. It has three phases, Initialization phase, Set-up phase, Steady phase. Life time of HEED is more compared to PEGASIS.	The energy level in cluster head may decrease and so there will be a loss in data transmission.
Fengyuan Ren, Jiao Zhang, Tao He, Chuang Lin [7]	EBRP	It provides more protection for weaker nodes. Lifetime of EBRP is more.	The load is not balanced since there is no fixed path.
Sudakshina Dasgupta, Paramartha Dutta [12]	Improved LEACH	It extends the stability time and first node dead time. Thus it increases the life time of network.	There is no energy efficiency since overheads are not reduced.
Jiguo Yua, Yingying Qi, Guanghui Wang, Xin Gu [5]	Cluster based routing protocol	It extends the life time by using residual energy of each node.	It cannot be done in large number of nodes since cost is high.
Sankardas Roy, Mauro Conti, Sanjeev Setia, and Sushil	Secure data aggregation	It reduces communication overhead and improves the lifetime of network.	It is not suitable for heterogeneous network.

Jajodia [9]			
Hongjuan Li, Kai Lin, Keqiu Li [4]	EEHA	It provides high accuracy and secure data aggregation among nodes, thus improves the lifetime.	It can be used only in tree based clustering.

TABLE 1. COMPARISON BETWEEN HIERARCHICAL PROTOCOLS

II. PROPOSED WORK

3.1.GSTEB:

A General Self-Organized Tree-Based Energy-Balance routing protocol is used to achieve a longer network lifetime for different applications. In each round, base station assigns a root node and broadcasts its ID and its coordinates to all sensor nodes. The GSTEB protocol is divided into Initial Phase, Tree Constructing Phase, Self-Organized Data Collecting and Transmitting Phase, and Information Exchanging Phase.

3.1.1. Initial Phase:

When Initial Phase begins, base station broadcasts a packet to all the nodes to inform them of beginning time. Each node sends its packet in a circle with a certain radius during its own time slot. Each node sends a packet which contains all its neighbors' information during its own time slot. Then its neighbors can receive this packet and record the information in memory. Initial Phase is a significant preparation for the next phases [14].
After Initial Phase, GSTEB operates in rounds. In a round, the routing tree may need to be rebuilt and each sensor node generates data packet that needs to be sent to base station. When base station receives the data of all sensor nodes, a round ended.

3.1.2. Tree Constructing Phase:

BS assigns a node as root and broadcasts root ID and root coordinates to all sensor nodes. In each round, a node with the largest residual energy is chosen as root. The root collects the data of all sensors and transmits the fused data to base station over long distance. Each node tries to select a parent in its neighbors using energy level and coordinates which are recorded in the table [14].

The nodes will compute their energy level by using the function,

$$\mathbf{EL(i)}=\frac{\boldsymbol{Residualenergy(i)}}{\propto} \qquad (5)$$

In the equation (i.e.,(5)), where 'i' is the ID of each node, and α is a constant which reflects the minimum energy unit and can be changed based on our demands.

The distance between its parent node and the root should be shorter than that between itself and the root. Because every node chooses the parent from its neighbors and every node records its neighbors' neighbors' information in the table .Each node will know all its neighbors' parent nodes by computing, and it also knows all its child nodes. If a node has no child node, it defines itself as a leaf node from which the data transmitting begins.

3.1.3. Self-Organized Data Collecting and Transmitting Phase

After the routing tree is constructed, each sensor node collects information to generate a data packet which needs to be transmitted to base station. After a node receives all the data from its child nodes, this node itself serves as a leaf node and tries to send the fused data in the next time slot. The first segment is used to check if there is communication interference for a parent node. In this segment, each leaf node sends a beacon which contains its ID to its parent node at the same time. There are three situations that may occur and they divide all the parent nodes into three kinds. For the first situation, if no leaf node needs to transmit data to the parent node in this time slot, it receives nothing. For the second situation, if more than one leaf node needs to transmit data to the parent node, it receives an incorrect beacon. For the third situation, if only one leaf node needs to transmit data to the parent node, it receives a correct beacon. The operation of the second segment depends on the three situations [14]. During the second segment, the leaf nodes which can transmit their data are confirmed. For the first situation, the parent node turns to sleep mode until next time slot starts. In the third Segment, the permitted leaf nodes send their data to their parent nodes, while other leaf nodes turn to sleep mode. Each node chooses its parent by considering not the distance but the total energy consumption.

3.1.4 Information Exchanging Phase:

Each node needs to generate and transmit a data packet in each round, before it exhaust its energy and die. The dying of any sensor node can influence the topography .So the nodes that are going to die need to inform other nodes .The process is also divided into time slots and in each time slot ,the nodes whose energy is going to be exhausted will compute a random delay which makes only one node broadcast in this time slot. When the delay is ended, these nodes will try to broadcast a packet to the whole network. While all other nodes are monitoring the channel, they will receive this packet and perform an ID check. Then they modify their tables. If no such packet is received in the time slot, the network will start the next round 14]. After completing all the rounds in a time slot, a new technique called re-elective clustering is introduced. Re-elective clustering is the process of selecting the cluster head after each time slot based on the energy level of all the nodes in the network. This technique is used in order to reduce loss of information transferred over the cluster head because after completion of each time slot, the energy level of all the nodes including cluster head is reduced. So, the cluster head is selected based on the energy level so that information can be transferred securely.

III. CONCLUSION

GSTEB outperforms compared with all the above mentioned protocols in prolonging of life time of the wireless sensor networks. In LEACH protocol cluster head is selected randomly and it reduces the energy level due to their distances to base station are far, because of the heavy energy burden and these cluster heads will soon die. In case of PEGASIS, nodes take turns to transmit the fused data to the base station to balance the energy depletion in the network and preserves robustness as the sensor nodes die at random locations. HEED distribution of energy extends the lifetime of the nodes within the network thus stabilizing the neighboring node .At the end of each TDMA, each node is either a cluster head or an ordinary node that belongs to exactly one cluster.In GSTEB, the cluster head is selected based on energy and a tree is constructed to transfer the information.Thus GSTEB prolongs the life time of the network compared to other protocols in the network.

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