Energy Efficient Routing Protocols For Wireless Sensor Network

Kanika Punjani
Dept. of CSE, FET, MRIU
Faridabad, Haryana, India

Dr. S. S Tyagi
Dept. of CSE, FET, MRIU
Faridabad, Haryana, India
Shyam.fet@mriu.edu.in

***Abstract*—** The area of wireless sensor networks is one of the emerging and fast growing fields in the scientific world. This has brought about developing low cost, low-power and multi-function sensor nodes. However, the major fact that sensor nodes run out of energy quickly. In the research area of wireless sensor networks the power efficient time is a major issue. There are various routing protocols in which optimal routing can be achieved in the context of power. In this paper we intend to discuss some of the major power-efficient hierarchical routing protocols for wireless sensor networks. First we will discuss the some of power-efficient Hierarchical routing protocols .We also highlight the important features, Drawbacks and area of application of each routing techniques . Finally, we provide a comparative study on these various protocols.

Keywords— Wireless sensor network, Hierarchical routing model, routing protocol.

I. INTRODUCTION TO WIRELESS SENSOR NETWORK

Wireless sensor networks usually consists of a large number of nodes called sensor node that bring themselves together to form a wireless network. These sensor nodes are scattered in sensor field situated far from the user which consist of sensor nodes, BS and monitored events . A typical sensor node is made of four building blocks: power unit, communication unit, processing unit and sensing unit . The figure 1 shows the component of sensor nodes. The sensing component in a node measures certain physical characteristic like temperature or detects soil moisture of a location in which it is placed. The processing component is responsible for collection and processing captured data from its surrounding.

The wireless communication component of a sensor node is responsible for transmission or reception of captured data from one sensor node to another node or to an end user through the cluster head to the base station (BS). The sensor node, its processing and communication component requires energy to function as expected, and the power component, which is of limited amount, is solely responsible for provision of energy to the three other components.

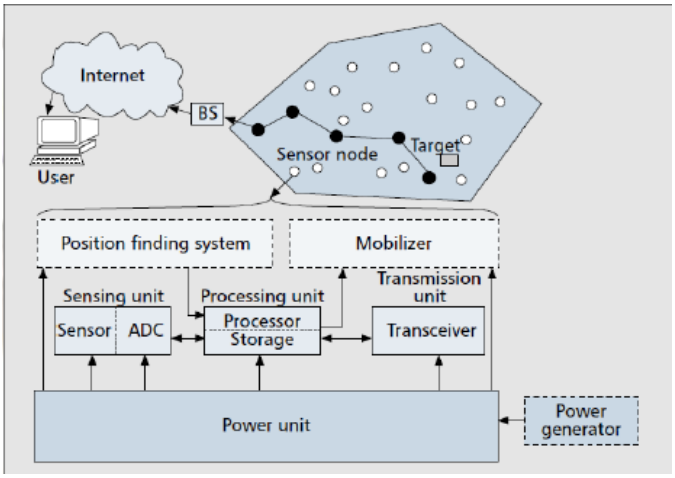

Figure1. The components of sensor node

WSN creates a local network hierarchy on one or more levels represented by nodes chosen by certain criteria that are aggregating and sending data to a central base station (BS).Most times it is not necessary to identify the exact location of the node and it's ID. Communication is done mostly from node to BS , the BS sends requests to obtain data from nodes. the answer of a particular node is not important, but the area of origin is. All data has to be aggregated by the cluster-head before reaching the BS [1].This data aggregation in the head nodes greatly reduces energy consumption in the network by minimizing the total data messages to be sent to BS. The less the

energy consumption, the more the network life time. The main idea of developing cluster-based routing protocols is to reduce the network traffic toward the sink. This method of clustering may introduce overhead due to the cluster configuration and maintenance, but it has been demonstrated that cluster-based protocols exhibit better energy consumption and performance when compared to flat network topologies for large-scale WSNs.

The paper is organized in the following way. In Section 1 introduction to WSNs. In Section 2, describe the cluster based Hierarchical model. In Section 3, various power-efficient hierarchical cluster routing protocols are explained .In section 4, we compare Hierarchical routing protocols using some parameters. Finally, Section 5 concludes the paper .

II. HIERARCHICAL ROUTING MODEL

As shown in Figure.(2), a hierarchical approach breaks the network into clustered layers . Nodes are grouped into clusters with a cluster head that has the responsibility of routing from the cluster to the other cluster heads or base stations. Data travel from a lower clustered layer to a higher one. Although, it hops from one node to another, but as it hops from one layer to another it covers larger distances. This moves the data faster to the base station. In the cluster-based hierarchical model, data is first aggregated in the cluster then sent to a higher-level cluster-head. As it moves from a lower level to a higher one, it travels greater distances, thus reducing the travel time and latency. This model is better than the one hop or multi-hop model[1].

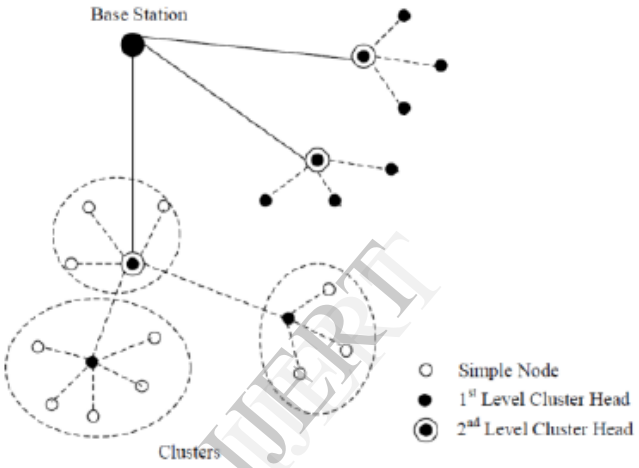

Figure 2. Cluster Based Hierarchical Model

Further, in cluster-based model only cluster-heads performs data aggregation whereas in the multi-hop model every intermediate node performs data aggregation. As a result, the cluster-based model is more suitable for time-critical applications than the multi-hop model.

However, it has one drawback, namely, as the distance between clustering level increases, the energy spent is proportional to the square of the distance. This increases energy expenditure. Despite this drawback, the benefits of this model are more important than drawback. A cluster-based hierarchical model offers a better approach to routing for WSNs.

III. POWER-EFFICIENT HIERARCHICAL CLUSTER ROUTING PROTOCOLS

Clustering algorithms for traditional wireless ad hoc networks are not well suited for WSNs . Some of the special features of WSNs are as follows:

- Sensor nodes are densely deployed.
- Sensor nodes are prone to failure.
- The large number of sensors nodes in a WSN and are limited in power, computational capacities, and storage memory.
- The topology of a WSN may change rather frequently because a sensor node may alternate between the active and sleep states.
- Sensor nodes may not have global identification (ID) because of the large amount of overhead and the large number of sensors.

Sensor network requires certain protocol for efficient performance[1]. For instance, protocol can come in form of a specific application with a defined order to aggregate data and optimizing energy consumption. This kind of protocol is referred to as hierarchical routing. Hierarchical routing have special advantages related to scalability and efficient communication. As such, the concept of hierarchical routing is also utilized to perform energy-efficient routing in WSNs. In a hierarchical architecture, higher energy nodes can be used to process and send the

information while low energy nodes can be used to perform the sensing in the proximity of the target. This means that creation of clusters and assigning special tasks to cluster heads can greatly contribute to overall system scalability, lifetime, and energy efficiency. Hierarchical routing is an efficient way to lower energy consumption within a cluster and by performing data aggregation and fusion in order to decrease the number of transmitted messages to the BS. Hierarchical routing is mainly two-layer routing where one layer is used to select cluster heads and the other layer is used for routing. A variety of protocols have been proposed for prolonging the life of WSN and for routing the correct data to the base station. Some of the hierarchical protocols are LEACH, PEGASIS etc.

A. Low Energy Adaptive Clustering Hierarchy protocol (LEACH)

LEACH is a cluster-based protocol, which includes distributed cluster formation. LEACH randomly selects a few sensor nodes as cluster-heads and rotates this role to evenly distribute the energy load among the sensors in the network. The idea is to form a clusters of sensor nodes based on their received signal strength and used local cluster head as router to the sink.[2-3] In LEACH, the cluster-heads compress data arriving from nodes that belong to the respective cluster, and send an aggregated packet to the BS in order to reduce the amount of information that must be transmitted to the BS. LEACH uses a TDMA/code-division multiple access (CDMA) MAC to reduce inter-cluster and intra-cluster collisions. All the data processing such as data fusion and aggregation are local to the cluster.The operation of LEACH is separated into two phases, The set-up phase/advertisement phase and The steady state phase. In the set-up phase, the clusters are organized and cluster-heads are selected. In the steady state phase, the actual data transfer to the BS takes place[8-10].

SET-UP PHASE:

During the set-up phase, a predetermined fraction of nodes, *p, elect themselves as cluster-heads as follows.*A sensor node chooses a random number, *r, between 0 and 1[4]. If this random number is less than a threshold value,T(n), the node becomes a cluster-head for the current round.* The threshold value is calculated based on the desired percentage to become a cluster-head, the current round, and the set of nodes that have not been selected as a cluster-head in the last (1/*P) rounds, denoted G[6-7].*

$$T(n) = \begin{cases} \frac{P}{1-P(r \bmod (1/p))}, & \text{if } n \in G, \\ 0, & \text{otherwise.} \end{cases} \quad (1)$$

Where n is the given node,
P is the a priori probability of a node being elected as a cluster head,
r is the current round
G is the set of nodes that have not been elected as cluster heads in the last 1/P rounds.

ADVERTISEMENT-PHASE

The elected cluster heads broadcast an advertisement message to inform other nodes about their states[18]. Based on the received signal strength of the advertisement, a non-cluster head node decides to which cluster it will belong for this round and sends a membership message to its cluster head. Based on the number of nodes in the cluster, a cluster head creates a TDMA schedule and assigns each node a time slot in which it can transmit. This schedule is broadcast to all the cluster nodes. This is the end of the so-called advertisement or setup phase of LEACH. Then begins the steady state where different nodes can transmit their sensed data[17].

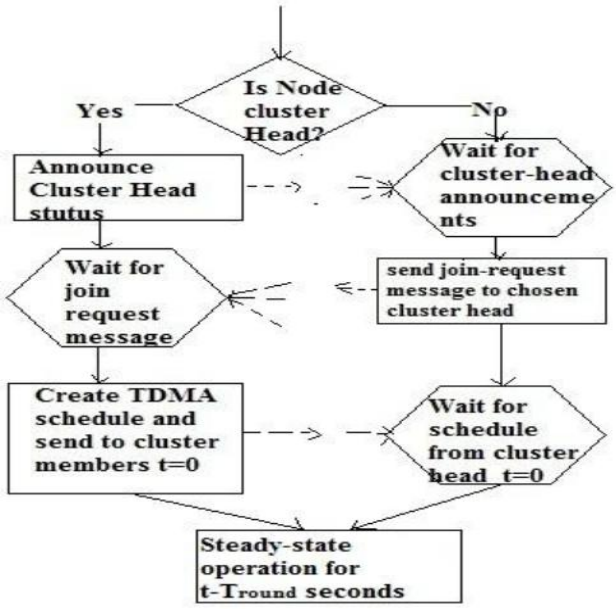

Figure3. Flow chart Of distributed cluster formation algorithm for LEACH.

STEADY-STATE PHASE

In the steady state phase , the actual data transfer to the base station. During the steady-state phase, the sensor nodes can begin sensing and transmitting data to the cluster-heads. The cluster-head, after receiving all the data, aggregates it before sending it to the BS. The duration of the steady state phase is longer than the duration of the setup phase in order to minimize overhead. After a certain time, which is determined a priori, the network goes back into the setup phase again and enters another round of selecting new CHs. Each cluster communicates using different CDMA codes to reduce interference from nodes belonging to other clusters[12-14].

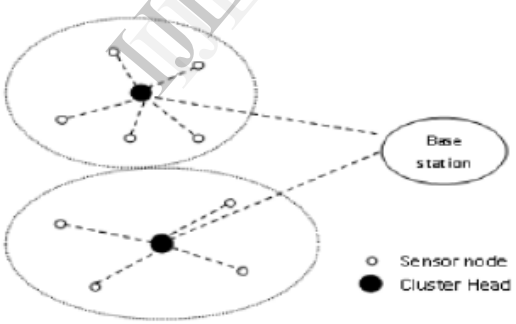

Figure4.Clustering in LEACH protocol

There are some advantages of this protocol such as:

- It rotates the cluster heads in a randomized fashion to achieve balanced energy consumption,
- Sensors have synchronized clocks so that they know the beginning of a new cycle.
- Sensors do not need to know location or distance information.
- LEACH is able to perform local aggregation of data in each cluster to reduce the amount of data that transmitted to the base station.
- The radio of each non cluster head node can be turned off until the nodes allocated TDMA slot, thus minimizing energy dissipation in these nodes.

There are some drawbacks of this protocol such as:

- LEACH uses single-hop routing where each node can transmit directly to the cluster-head and the sink. Therefore, it is not applicable to networks deployed in large regions.
- The idea of dynamic clustering brings extra overhead, e.g. head changes, advertisements etc., which may decrease the gain in energy consumption.

- Random election of CH, hence there is Possibility that all CHs will be concentrated in same area.
- The protocol assumes that all nodes begin with the same amount of energy capacity in each election round, assuming that being a CH consumes approximately the same amount of energy for each node.
- They have not discussed about how many nodes can be in a one cluster?
- Cluster will be non homogenous.
- If nodes are not uniformly distributed then LEACH will not perform better. The performance will be decreased.

Application: This protocol is most suited for constant monitoring such as monitor machinery for fault detection and diagnosis.

B. Power-Efficient Gathering in Sensor Information Systems (PEGASIS)

PEGASIS (Power-Efficient Gathering in Sensor Information Systems)[3-15]. PEGASIS is an enhancement over the LEACH protocol and it is a near optimal chain-based protocol. The basic idea of the protocol is that in order to extend network lifetime, nodes need only communicate with their closest neighbors, and they take turns in communicating with the BS. The chain in PEGASIS will consist of those nodes that are closest to each other and form a path to the BS[8]. The chain construction is performed in a greedy fashion. Each node selects its nearest node as a neighbor, starting from the farthest node from Base Station. To locate the closest neighbor node in PEGASIS, each node uses the signal strength to measure the distance to all neighboring nodes .On receiving data, node fuses with its own data and forwards to the next node. Node acting as a chain leader is responsible to communicate with the BS.In each round the chain leader is changed to balance the remaining energy of the network, which in turns results the longer network lifetime of sensor nodes. PEGASIS also choose the chain head randomly for routing to the BS. Each node is chosen as chain head once in every N number of rounds (where N= no. of nodes).Once the chain is created and chain head is chosen, the chain head of the current round initiates a token for the end node of the chain to start the transmission. Each node except the farthest node of the chain fuses its data with the received data and sends a single packet to the next neighbor. The chain head communicates with BS after receiving the data from each side of the chain and fusing its own data [5-11-16].

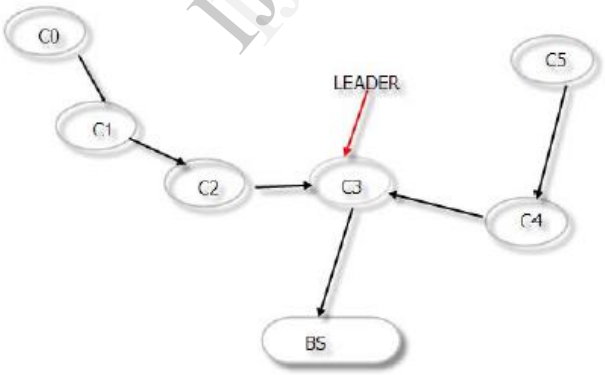

Figure5.Chaining in PEGASIS

- First the chosen leader C3 sends token to the nodes C0 in the chain.
- Immediately after the chain nodes receive the token both nodes C0 start sending their data to node C1.
- C1 fuse the data with their own data and send to node C2.
- Node C2 fuse the data with their own data and then transmit to the leader.
- After node C3 passes the token to node C5, node C5 transmit the data to node C4.
- Node C4 fuse the data with their own data and then transmit to the leader.
- Node C3 wait to receive data from both neighbours and fuse its data with its neighbour data.
- Finally node C3 transmit the message to the base station.

PEGASIS achieves energy conservation in two ways:

- The number of data messages received by the head node is at most two.
- The distance over which the data are transmitted to one-hop neighbor is much less
  So, PEGASIS conserves energy by reducing the number of data messages gathering at head node.

There are some advantages of this protocol such as:

- PEGASIS avoids cluster formation and uses only one node in a chain to transmit to the BS instead of multiple nodes.
- PEGASIS increase the lifetime of each node by using collaborative techniques.
- PEGASIS reduces the power required to transmit data per round as the power draining is spread uniformly over all nodes.
- Performance gain is achieved through the elimination of cluster formation.

There are some disadvantages of this protocol such as:

- PEGASIS assumes that all sensor nodes have the same level of energy and are likely to die at the same time.
- PEGASIS introduces excessive delay for distant nodes on the chain.
- The single leader can become a bottleneck.
- It does not describe how to find out the furthest node.
- PEGASIS selecting the chain leader randomly.

Application: This protocol is most suited for surveillance application such as motion detection, motion characteristic detection etc.

IV. COMPARATIVE STUDY OF ROUTING PROTOCOLS

Table 1 comparative study between LEACH & PEGASIS

Protocols / Parameters	LEACH	PEGASIS
Routing	Cluster Based	Chain Based
Node Mobility	Fixed BS	Fixed BS
Data Aggregation	YES	NO
Energy Efficient	NO	YES
Balanced Clustering	OK	N/A
Cluster Stability	Moderate	N/A
Multi-hop	NO	YES

Table 1 depicts a comparison between LEACH, PEGASIS, Routing Protocols according to their design characteristics[8-13].

V. CONCLUSION

In this article we provide descriptions of several power efficient Hierarchical routing schemes proposed for wireless sensor networks .We have highlighting their important features, drawbacks and application where they particularly used. They have the common objective of trying to extend the lifetime of the sensor network, while not compromising data delivery. All above mentioned protocols have some advantages and some limitations. So we can select an effective protocol, depending up on the network, applications and other conditions.

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