Classification of Hierarchical Based Routing Protocols for Wireless Sensor Networks

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Abstract: Recent advances in wireless sensor networks introduce many protocols specially designed for sensor networks. These protocols aim to lower energy consumption. Energy efficiency has been known as the most important problem in wireless sensor networks. Wireless Sensor Networks (WSNs) consist of small nodes with sensing, computation and wireless communications capabilities. Wireless Sensor Networks have the limitations such as energy source, memory size and processing power. Therefore, developing an energy efficient routing protocol is an interested research work in this field. The usefulness/ effectiveness of any protocol depend on how well its parameters are set for a particular application. The routing protocols in sensor networks could be classified into three categories: flat based, hierarchical based and location based routing. In this paper we present a comparative study of hierarchical based routing protocols that comes under the classification we highlighted for wireless sensor networks.

Keywords: Routing Protocol, Wireless Sensor Networks, flat based, hierarchical based, location based.

I. INTRODUCTION

A wireless sensor network (WSN) is usually composed of a large collections of small autonomous sensor devices that can sense environmental conditions about the ambient environment. Recent technological advances enables the widespread deployment of WSNs for many different applications, including smart battlefield, healthcare, environment and habitat monitoring, home automation, and traffic control, etc. [1]. The main task of a wireless sensor node is to sense and collect data from a certain domain, process them and transmit it to the sink where the application lies. However, ensuring the direct communication between a sensor and the sink may force nodes to emit their messages with such a high power that their resources could be quickly depleted. Therefore, the collaboration of nodes to ensure that distant nodes communicate with the sink is a requirement. In this way, messages are propagated by intermediate nodes so that a route with multiple links or hops to the sink is established [2-9]. Communication architecture of wireless sensor networks consists of user, sink, and sensor node shown in Figure 1**.** In the communication architecture, a user connects legacy networks and communicates a sink through a task manager node. A sink instructs sensor nodes to carry out tasks interested by the user, and sensor nodes gather data and forward it to the sink by wireless multi-hop communication manner [3].

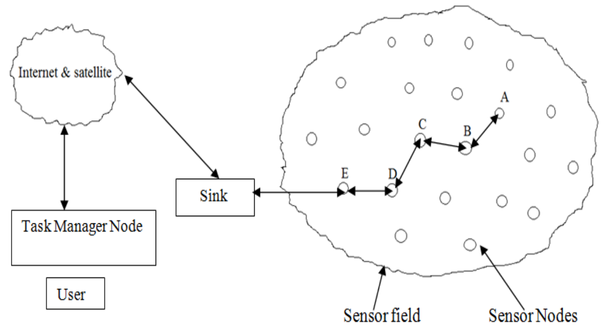

Figure 1: Communication Architecture of Wireless Sensor Networks

Sensor network applications require wireless ad hoc networking techniques. Although many protocols and algorithms have been proposed for traditional wireless ad hoc networks, they are not well suited to the unique features and application requirements of sensor networks. To illustrate this point, the differences between sensor networks and ad hoc networks are:

The number of sensor nodes in a sensor network can be several orders of magnitude higher than the nodes in an ad hoc network.

- Sensor nodes are densely deployed.
- Sensor nodes are prone to failures.
- The topology of a sensor network changes very frequently.
- Sensor nodes mainly use a broadcast communication paradigm, whereas most ad hoc networks are based on point-to-point communications.
- Sensor nodes are limited in power, computational capacities, and memory.
- Sensor nodes may not have global identification (ID) because of the large amount of overhead and large number of sensors.

A sensor node is made up of four basic components, as shown in Figure 2, sensing unit, a processing unit, a transceiver unit, and a power unit. They may also have additional application-dependent components such as a location finding system, power generator, and mobilizer. Sensing units are usually composed of two subunits:

a. Sensors
b. Analog-to-digital converters (ADCs).

The analog signals produced by the sensors based on the observed phenomenon are converted to digital signals by the ADC, and then fed into the processing unit. The processing unit, which is generally associated with a small storage unit, manages the procedures that make the sensor node collaborate with the other nodes to carry out the assigned sensing tasks. A transceiver unit connects the node to the network. One of the most important components of a sensor node is the power unit. Power units may be supported by power scavenging units such as solar cells. There are also other subunits that are application-dependent. Most of the sensor network routing techniques and sensing tasks require knowledge of location with high accuracy. Thus, it is common that a sensor node has a location finding system. A mobilizer may sometimes be needed to move sensor nodes when it is required to carry out the assigned tasks [9].

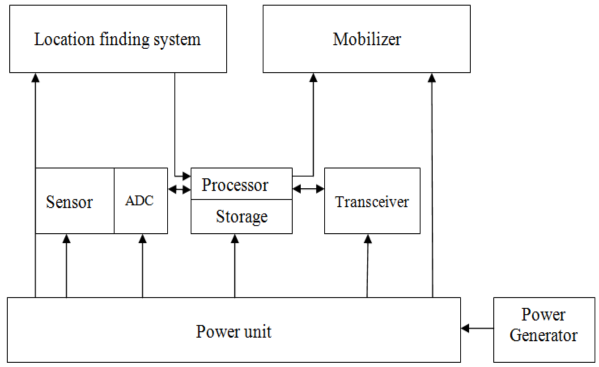

Figure 2: Components of Sensor Node [9].

Sensor networks are application specific that is design requirements of a sensor network change with application. Position awareness of sensor nodes is important since data collection is normally based on the location. Routing mechanisms consider the inherent features of WSNs and the application and architecture requirements. The task of finding and maintaining routes in WSNs is nontrivial since energy restrictions and sudden changes in node status cause frequent and unpredictable topological changes [8].

II. CLASSIFICATION OF ROUTING PROTOCOLS

Number of routing protocols have been developed so far which some or the other way enhances the performance of the network [13]. Some are Flat Based, Hierarchical Based while some are Location Based Routing protocols. Here in this paper a comparative analysis of hierarchical based routing protocol is presented based on the survey of Ref. [8, 10] as shown in Table 1.

Hierarchical routing protocols also known as cluster-based routing, proposed in wireless networks. They are well known techniques having special advantages related to scalability and efficient communication. The concept of hierarchical routing is also utilized to perform energy efficient 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 [10]. Hierarchical routing is mainly two-layer routing where one layer is used to select cluster heads and the other layer is used for routing. However, most techniques in this category are not about routing, rather on "who and when to send or process/aggregate" the information, channel allocation etc., this can be orthogonal to the multi-hop routing function [4].

A. LEACH (Low Energy Adaptive Clustering Hierarchy)

LEACH is one of the first hierarchical routing approaches for sensors networks. LEACH [5,8] is a self-organizing, adaptive clustering protocol. It uses randomization for distributing the energy load among the sensors in the network. The following are the assumptions made in the LEACH protocol [10]:

- All nodes can transmit with enough power to reach the base station.
- Each node has enough computational power to support different MAC protocols.
- Nodes located close to each other have correlated data.

According to this protocol, the base station is fixed and located far from the sensor nodes and the nodes are homogeneous and energy constrained. Here, one node called cluster-head (CH) acts as the local base station. LEACH randomly rotates the high-energy cluster-head so that the activities are equally shared among the sensors and the sensors consume battery power equally. LEACH also performs data fusion, *i.e.* compression of data when data is sent from the clusters to the base station thus reducing energy dissipation and enhancing system lifetime. LEACH divides the total operation into rounds each round consisting of two phases: set-up phase and steady phase. In the set-up phase, clusters are formed and a CH is selected for each cluster. The CH is selected from the sensor nodes at a time with a certain probability. Each node generates a random number from

0 to 1. If this number is lower than the threshold node [T(n)] then this particular node becomes a CH. T(n) is given as follows [9]:

$$T(n) = \frac{p}{1-p}[r \bmod (1/p)],\ n \in G = 0, \text{otherwise}$$

Where p is the percentage of nodes that are CHs, r is the current round and G is the set of nodes that have not served as cluster head in the past 1/p rounds. Then the CH allocates time slots to nodes within its cluster. LEACH clustering is shown in Figure 3. In steady state phase, nodes send data to their CH during their allocated time slot using TDMA. When the cluster head gets data from its cluster, it aggregates the data and sends the compressed data to the BS. Since the BS is far away from the CH, it needs high energy for transmitting the data. This affects only the node which are CHs and that's why the selection of a CH depends on the remaining energy of that node.

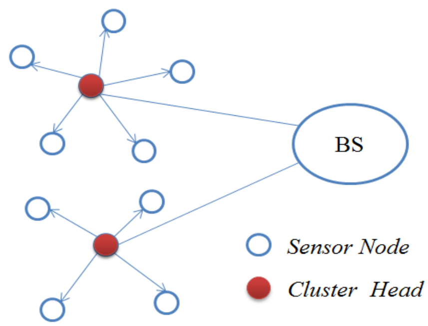

Figure 3: Clustering in LEACH Protocol.

B. TEEN (Threshold sensitive Energy Efficient sensor Network)

TEEN [6] is a cluster based routing protocol which is based on LEACH. This protocol transfers the data less frequently and senses the medium continuously. The network consists of simple nodes, first-level cluster heads and second-level cluster heads. LEACH strategy used in this protocol for cluster formation. It has two assumptions:

- The BS and the sensor nodes have same initial energy.
- The BS can transmit data to all nodes in the network directly.

First level CHs are formed away from the BS and second level CHS are formed near to the BS. It is targeted at reactive networks and is the first protocol developed for reactive networks. A wireless sensor network is shown in Figure 4.

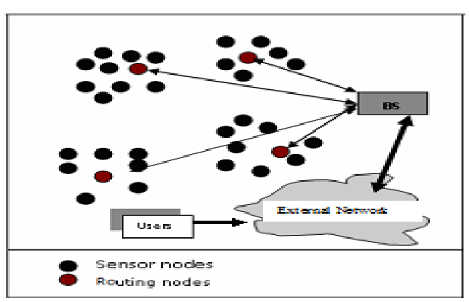

Figure 4: Wireless Sensor Network

Some of the important features of this scheme are as follows:

- It is best suited to time-critical data sensing applications.
- The energy consumption in this scheme can potentially be must less than in the proactive network, because data transmission is done less frequently.
- The soft threshold (change in the value of the sensed attribute which triggers the node to switch on its transmitter and transmit) can be varied.

- A smaller value of the soft threshold gives a more accurate picture of the network, at the expense of increased energy consumption. Thus, the user can control the trade-off between energy efficiency and accuracy.
- At every cluster time, the attributes are broadcast afresh and so, the user can change them as required.

The main drawback of this scheme is that, if the thresholds are not reached, the nodes will never communicate the user will not get any data from the network at all and will not come to know even if all the nodes die. Thus, this protocol is not well suited for applications where the user needs to get data on a regular basis. Other problem that arises is practical implementation would have to ensure that there are no collisions in the cluster.

C. APTEEN (Adaptive Threshold TEEN)

APTEEN [6, 10] is the improved version of the TEEN which enables reliable monitoring and analysis of the environment. In this once the CHs are decided, in each cluster period, the CH first broadcasts the following parameters:

- Attributes
- Thresholds
- Schedule
- Count Time

If a node does not send data for a time period equal to the count time, it is forced to sense and retransmit the data thus maintaining energy consumption. Since it is a hybrid protocol, it can emulate a proactive network or a reactive network depending on the count time and threshold value.

The main features of this protocol include:

- It combines both proactive and reactive policies by giving complete picture of the network and also responds immediately to drastic changes.
- It offers a flexibility of allowing the user to set the time interval and the threshold values for the attributes. Energy consumption can be controlled by the count time and the threshold values.
- The hybrid network can emulate a proactive network or a reactive network, by suitably setting the count time and the threshold values.

One of the limitations of this protocol is that in order to implement the threshold function and count time additional complexity is required.

D. PEGASIS (Power efficient Gathering Sensor Information System)

In PEGASIS [7-8] each node communicates only with a close neighbor and takes turns transmitting to the base station, thus reducing the amount of energy spent per round. This approach will distribute the energy load evenly among the sensor nodes in the network. Nodes will be organized to form a chain, which can either be accomplished by the sensor nodes themselves using a greedy algorithm starting from some node. Alternatively, the BS can compute this chain and broadcast it to all the sensor nodes. For gathering data in each round, each node receives data from one neighbor, fuses with its own data, and transmits to the other neighbor on the chain. PEGASIS performs data fusion at every node except the end nodes in the chain.

Each node will use its neighbor's data with its own to generate a single packet of the same length and then transmit that to its other neighbor (if it has two neighbors). Thus, in PEGASIS each node will receive and transmit one packet in each round and be the leader once every 100 rounds [10].

The performance of this protocol can be improved by:

- Using Greedy algorithm for chain construction.
- Not allowing nodes which dissipate more energy to become the leader.
- Applying a threshold adaptive to the remaining energy levels in nodes.

This protocol saves energy at various stages. First, in the local gathering, the distances that most of the nodes transmit are much less compared to transmitting to a cluster-head in LEACH. Second, the amount of data for the leader to receive is at most two messages instead of 20 (20 nodes per cluster in LEACH for a 100-node network). Finally, only one node transmits to the BS in each round of communication.

III. COMPARATIVE ANALYSIS OF FLAT BASED ROUTING PROTOCOLS OF WSNs

The routing protocols mentioned in the above sections are developed for different applications [11]. Here a comparative analysis of all these protocols is been sited according to their performance based on different parameters [8-9]. This comparison is presented in Table 1.

Table: 1. Comparison among Different hierarchical Based Routing Protocols

Routing Protocols	LEACH	TEEN	APTEEN	PEGASIS
Classification	Hierarchical	Hierarchic-al	Hierarchical	Hierarchica l
Data Delivery Model	Cluster head	Active Threshold	Active threshold	Chains based
Data Aggregation	Yes	Yes	Yes	No
Power Usages	High	High	High	Max
Scalability	Good	Good	Good	Chains based
QoS	No	No	No	No
Query Based	No	No	No	No
Over head	High	High	High	Low
N/W Life Time	Very good	Very good	Very good	Very good
Resource Awareness	Yes	Yes	Yes	Yes
Mobility	Fixed BS	Fixed BS	Fixed BS	Fixed BS

IV. CONCLUSION

Important issues contributing to the comparison of hierarchical Based routing protocol in WSN's may be concluded through this paper. The discussed protocols are LEACH, TEEN, APTEEN, PEGASIS come under hierarchical based routing protocol. It distributes the information as needed to any router that can be reached or receive information. Based on this categorisation a comparative analysis of the protocol is presented. This comparison is based on the various parameters of the protocol. Each of this protocol is designed for a particular application as results some protocols work for one situation while other for other situations. Hence for future perspective of this work may be well focused on modifying any of the above routing protocols such that the modified protocol could minimize energy of the sensor network.

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