Comparative Study of Clustering based Routing Protocols for Wireless Sensor Network

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ABSTRACT

A wireless sensor network consists of large number of sensor nodes deployed on a large field and has limited battery lifetime which get depleted at a faster rate due to their communication and computation operation.These sensor nodes has the ability of sensing, computing and transmitting data from the harsh environment. Many communication protocols are designed to make efficient and effective utilization of energy.A comparative study of clustering based routing protocols has been done which gives an overview of the performance of protocols on some factors like cluster stability, latency, energy efficiency and load balancing etc

General Terms

Clustering-based routing protocols, wireless sensor network

Keywords-

Cluster stability, latency, energy efficiency, load balancing, data aggregation, classification and algorithm complexity.

1. INTRODUCTION

Wireless sensor network is one of the important technologies for the twenty-first century. A wireless sensor network consists of large number of sensor nodes which are randomly deployed in the field [1]. These sensor nodes equipped with limited battery resource and due to communication operation they deplete at a faster rate. The applications of wireless sensor networks are increasing day by day but on the other hand it faces the crucial problem of energy constraints in terms of limited battery lifetime. For effective and efficient utilization of energy resources of a sensor node and to enhance the lifetime of wireless sensor network, various energy efficient communication protocols are designed [2].

Many routing protocols are designed and proposed for wireless sensor network in the literature. According to network organization, most of the routing protocols come in the one of three categories based on various characteristics of the routing protocols. They are mentioned as clustering based routing protocols, location-based protocols and data centric protocols [3].In clustering based protocols, all the sensor nodes are grouped as cluster. The cluster head is responsible for collecting and the data transmission activities of all sensors in its cluster. This saves communication and processing work and also saves energy [4].In Location based Routing all the sensor nodes are addressed by using their locations. Depending upon the strength of the incoming signals, it is possible to calculate the nearest neighboring node's distance [5].In data-centric approach, when source node transmits data to the sink, intermediate nodes can perform data aggregation and transmits the aggregated data to the sink. In this manner, they minimize the energy consumption by transmitting less data [6].

2. CLUSTERING OBJECTIVES

Depending on the requirements of applications the objectives of clustering algorithm are defined. There are many objectives of the clustering algorithm which are explained below -

Load Balancing- To enhance the lifetime of the network formation of equal sized clusters is important because it prevents the consumption of the energy of a subset of cluster heads at high rate. Data delay is caused by even distribution of sensor nodes. It is important to have same number of sensor nodes in the clusters during data aggregation so that the total data information is ready for further processing at the next tier in the network or at the base station almost at the same time.

Fault tolerance- The sensor nodes may sometimes have to operate in harsh and hostile environment and the risk of physical damage and malfunction is increased due to exposed nature of sensor nodes. In order to prevent the loss of data of the sensor nodes the failure of cluster heads must be tolerated. Re-clustering the network is the one way to recover from the cluster head failure. The other scheme which adopted in the literature to recover from cluster head failure is assigning backup cluster heads. In addition to load balancing advantage rotating the role of cluster heads in the cluster also leads to fault tolerance.

Increased Connectivity and Reduced delay- In many applications inter cluster head connectivity is an important requirement unless cluster heads have long range communication abilities. This is especially true when cluster heads are selected from the sensors population. To ensure the availabilities of the route from every cluster head to the base station the goal of connectivity can be limited or restricted the length of the route.

Minimal cluster count- The objective of minimal cluster count is especially common when cluster heads are specified resource rich nodes. The designer of the network often lies to deploy the minimum number of such type of nodes because they are more vulnerable and costly than other sensor nodes.

Maximal Network longevity- In the application where sensor nodes are deployed in harsh environment the main concern is the lifetime of the network due to energy constrains nature of the sensor nodes. It is important to minimize the energy consumption for the intra cluster communication when cluster heads are specialized resource rich nodes. The lifetime of the cluster heads when they are normal nodes can be increased by rotating their roles among the cluster members and limiting their load. For achieving network longevity adaptive clustering is also feasible [7].

3. OVERVIEW OF CLUSTERING BASED ROUTING PROTOCOLS

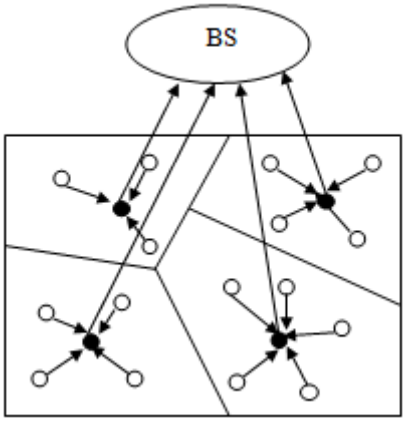
In clustering based routing protocols, the network is divided into different clusters. The sensor nodes play different roles such as cluster members and cluster head. The formation of cluster creates two-level hierarchy where the cluster head nodes form the higher level and the member nodes of the cluster form the lower level[8]. The member nodes periodically send their data to the corresponding cluster head nodes. The cluster head nodes aggregate the data and remove the redundant data and then transmit to the base station either by single hop or multi-hop. Since the cluster head consume more energy as compared to the other members of cluster. This protocol may re-clusters and reselects the cluster heads periodically to perform the same operation again. Clustering is done to reduce the communication overhead for both single and mutli-hop network It reduces the number of nodes taking part in transmission and enhances the lifetime of the network [9].

3.1 Low Energy Adaptive Cluster Hierarchy (LEACH)

LEACH is a clustering based routing protocol which reduces energy consumption in wireless sensor networks. The operation of LEACH is divided into two phases, the set-up phase and steady-state phase. In the set-up phase, a sensor node chooses a random number between 0 and 1. If the random number is less than the threshold T(n) the node becomes a cluster head for the current round. The threshold is calculated as given in (1):

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

Where, p is the desired percentage of cluster heads, r is the current round and G is the set of nodes that have not been cluster heads in the past 1/p rounds. The selected cluster heads advertise to all sensor nodes that they are the new cluster heads in the network. After receiving advertisement, they join the cluster based on the signal strength. Then cluster heads assign the time to the member nodes on which they can send data to them based on a TDMA. In the steady phase, the sensor nodes send data to the cluster heads .The cluster heads perform data aggregation before transmitting data to the base station as shown in Fig.1. After a certain period of time, the network again goes into set-up phase and then to steady phase [10].

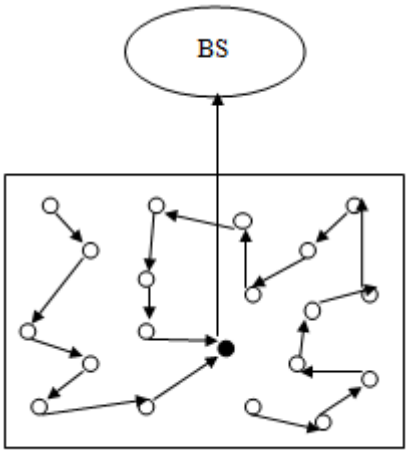


BS-Base station

Fig.1 LEACH Architecture

3.2 Power Efficient Gathering in Sensor Information Systems (PEGASIS)

PEGASIS is a chain based routing protocol. All the sensor nodes in the network will be arrange to form a chain with a leader node which is responsible for transmitting data to the base station[11].



BS-Base station

Fig.2 PEGASIS Architecture [12]

The chain can be formed by using a greedy algorithm starting from the node which is farthest from the base station. When a node dies, the chain is reformed in the same manner to bypass the dead node. In each round, the sensor node receives data from one neighbor, fuses with its own data, and transmits the data to the other neighbor on the chain. In PEGASIS, the data fusion takes place at every node except the end nodes (leader node) in the chain. Then, the leader node transmits one message to the base station as shown in Fig.2.

3.3 Hierarchical-PEGASIS

Hierarchical-PEGASIS is an extension to PEGASIS, which reduces delay occur during packet transmission to the base station. Data transmission is simultaneously pursued to reduce the delay in PEGASIS. Two approaches are designed to avoid signal interference and collisions among sensor nodes. The first approach incorporates CDMA as signal coding scheme. In the second approach only spatially separated nodes are permitted to send data at the same time [13].

3.4 Threshold Sensitive Energy Efficient Sensor Network Protocol (TEEN)

TEEN is a hierarchical clustering based protocol in which nodes react immediately to drastic and sudden changes in the environment. The formation of Cluster and the data transmission are same as in the LEACH protocol as shown in Fig.3. After cluster formation, the cluster head broadcasts two thresholds to the sensor nodes namely hard threshold and soft threshold. Hard threshold permits the sensor nodes to send data only when the attribute sensed by them is in the range of interest. The soft threshold will reduce the data transmission if there is no or little change in the value of sensed attribute. In order to control the data transmissions, both thresholds can adjust [14].

3.5 Adaptive Threshold Sensitive Energy Efficient Sensor Network Protocol (APTEEN)

The Adaptive Threshold sensitive Energy Efficient sensor Network protocol (APTEEN) is an extension to TEEN designed to time critical events which aim at capturing periodic data collections. The architecture of APTEEN is same as TEEN. After cluster formation, the cluster heads broadcast the threshold values, attributes and transmission schedule to all sensor nodes. In order to save energy, cluster heads also aggregate data before sending to base station. APTEEN supports three different types of query namely historical which analyze past data values, one-time which take a snapshot view of the network and persistent which monitor an event for a certain period of time[15]. Clustering in APTEEN and TEEN protocols is done in two level of hierarchy from simple nodes to 1st level cluster head and from 1st level cluster head to 2nd level cluster head and finally from 2nd level cluster head to base station as shown in Fig.3

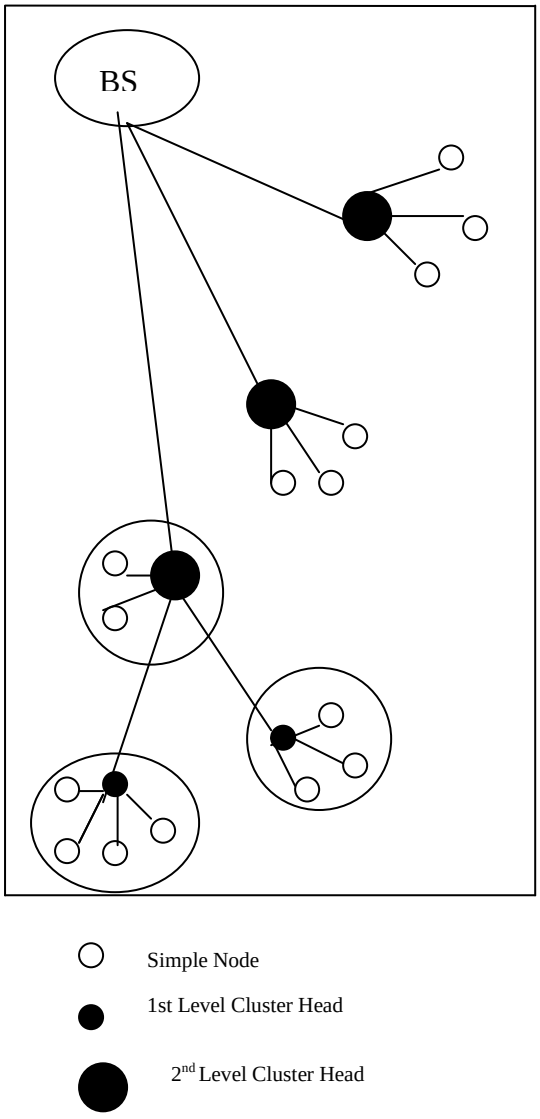


Fig.3 Hierarchical Clustering in TEEN & APTEEN

4. COMPARISON OF VARIOUS CLUSTERING BASED ROUTING PROTOCOLS

LEACH, TEEN, APTEEN and PEGASIS have almost similar features and their architectures are to some extent similar. They have fixed infrastructure. PEGASIS is a chain-based routing protocol whereas LEACH, TEEN, APTEEN are cluster based routing protocols. The performance of APTEEN lies between TEEN and LEACH in terms of lifetime and energy consumption of the network whereas LEACH transmits data continuously. Again PEGASIS avoids the overhead of cluster formation of LEACH, but it needs dynamic topology adjustment. PEGASIS adds excessive delay for distant nodes on the chain. Finally, we have compared various clustering based routing protocols for WSN as shown in Table 1.

Table1. Comparison of Clustering based Routing Protocols

Features	**Routing Protocol**			
	LEACH	***PEGASIS***	***TEEN***	***APTEEN***
Classification	Clustering	Reactive/ Clustering	Hybrid	Reactive/ Clustering
Data Aggregation	No	Yes	Yes	Yes
Energy Efficiency	Very Low	Low	Very High	Moderate
Cluster stability	Moderate	Low	High	Very Low
Latency	Very Low	Very High	Low	Low
Load Balancing	Moderate	Moderate	Good	Moderate
Algorithm Complexity	Low	High	High	Very High

5. CONCLUSION

In WSN, it is important to consider the function of the energy constraints, the application and the need for ease of deployment of the nodes for the design of protocol architecture. In this paper we studied various clustering based routing protocols for wireless sensor networks. These routing protocols can well match the challenges and the constraints of WSN. The future work is possible to improve the performance of these routing protocols in terms of energy efficiency by developing energy efficient algorithms and reduces latency by developing new approaches which minimize the transmission time in the network.

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