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Distributed and Centralized Clustering Approaches: Leach vs. C-Leach

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Abstract

In wireless sensor networks the minimization of energy dissipation is a major concern. In order to increase the network lifetime sensor nodes are grouped into clusters and a cluster head (CH) is selected. This process of cluster head selection and setting up of clusters can be done in two ways - Distributed & Centralized. LEACH is a distributed clustering protocol which reduced the energy consumption upto a great extent. After that a centralized clustering approach was introduced(C-LEACH). Centralized clustering involves the selection of cluster heads by the base station itself. It is done on the basis of amount of residual energy and distance of sensor node from BS. In this paper we study and compare both these clustering approaches.

Keywords

Leach, C-Leach, Clustering, Network Lifetime, Energy Dissipation.

Introduction

With the recent advances in technology wireless sensor networks has become a very vast area for research. Wireless sensor networks have many applications such as area monitoring in military, health care, environment monitoring, forest fires detection, air pollution check, landslide detection, water quality monitoring, monitoring chemicals agents in atmosphere, machine health monitoring in industries and many more. So as we see from this wide range of applications of WSN it becomes a necessity to explore new ways in order to develop an efficient, long lasting wireless sensor network. A WSN consists of thousands of nodes known as sensors which sense the environment and transmit the information to the base station or to other sensors which ultimately reaches the BS. Clustering approach is used to maximize the lifetime of a wireless sensor network. In this approach, the whole network is divided in clusters each one having a cluster head(CH).The member nodes transmit data to their respective cluster head and the CHs perform aggregation/diffusion operations on this data before transmitting to BS. The decision of choosing cluster heads can be done in two ways that is distributed approach or centralized approach. In distributed approach cluster heads selection is done by the sensor nodes themselves. In centralized approach the selection of cluster heads is done by Base Station. Centralized approach has advantages over distributed in terms of network lifetime, formation of optimized clusters etc.

In this paper we are going to discuss these two clustering approaches by concentrating on LEACH protocol[1]. LEACH is basically a distributed clustering protocol, but it has a centralized version of it known as C-LEACH (centralized leach)[2].

Leach Protocol

LEACH is a low energy adaptive clustering hierarchy. It is an application specific protocol [3]. Leach is a distributed clustering approach which includes:
a) Self-organizing thousands of nodes.
b) Adaptable clusters.
c) Rotation of cluster heads positions.
d) Use of distributed signal processing which reduces communication overheads.

Sensor nodes organize themselves into small clusters of few nodes. One node from each cluster is selected as cluster head and rest are the member nodes of that cluster. The member nodes sense the data and transmit it to cluster head. Cluster head performs the task of eliminating the redundant data which is known as data aggregation and then sends it to base station. The operations of leach are carried out in a number of rounds. Each round consists of two phases, the SET UP phase and STEADY phase.

SET UP PHASE
a) Advertisement phase
b) Cluster set up phase
c) Schedule creation phase

STEADY PHASE
b) Transmission phase

A. SET UP PHASE

During this phase each node autonomously decides whether to become a cluster head or not. This decision is based on two things i.e., the desired percentage of cluster heads in the network and whether the node has become a cluster head before or not. Percentage of nodes to become cluster heads is predefined which is generally 5% of the total number of nodes [4][5]. The optimal number of cluster heads in a network are determined by the fact that a cluster head should cover maximum number of nodes within its range.
Each nodes chooses a random number between 0 and 1. The nodes having this random number greater than the threshold will be selected as a cluster head.

$$T(n) = \begin{cases} \dfrac{P}{1 - P * \left(rmod\left(\frac{1}{P}\right)\right)} & if\ n \in G \\ 0 & \text{other wise} \end{cases}$$

Where T(n) is the threshold value, P is the required percentage of cluster heads in network, r represents the current round, n represents a node, G is a set of nodes that have not become cluster heads for previous 1/P rounds. Now, these cluster head nodes send an advertisement message to non-cluster heads requesting to join it as their cluster head. Non-cluster head nodes choose the node having maximum signal strength of advertisement message. After that these member nodes send JOIN request to their respective chosen cluster head. Once all the nodes send requests to the cluster heads, then cluster head create the TDMA schedule for all the member nodes.

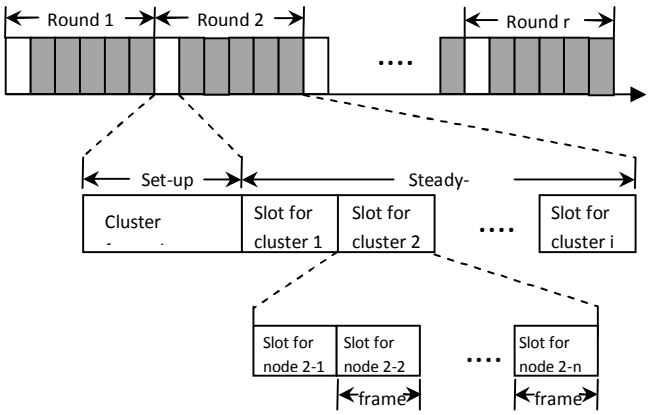

Fig. 1. Schedule of set up and steady state.

B. STEADY PHASE

After cluster set up phase is complete steady state starts, which consists of actual data transmission. The sensor nodes sense the environment and transmit desired information to their respective cluster heads. Cluster heads perform the data aggregation operations on the information received from its member nodes. Data aggregation or data fusion operations remove the redundant/ duplicate data and then combine the rest of it and send to base station. The duration of steady state is very long as compared to the set up state.

After a fixed time period of steady state the round ends and the same procedure is repeated for the next rounds. The only difference between first round and the rounds after that is: the nodes that have become cluster heads in previous rounds are eliminated as a candidate for becoming cluster head in current round. After 1/P rounds[6] when all the nodes have become cluster head atleast once then every node has again equal probability to become cluster head.

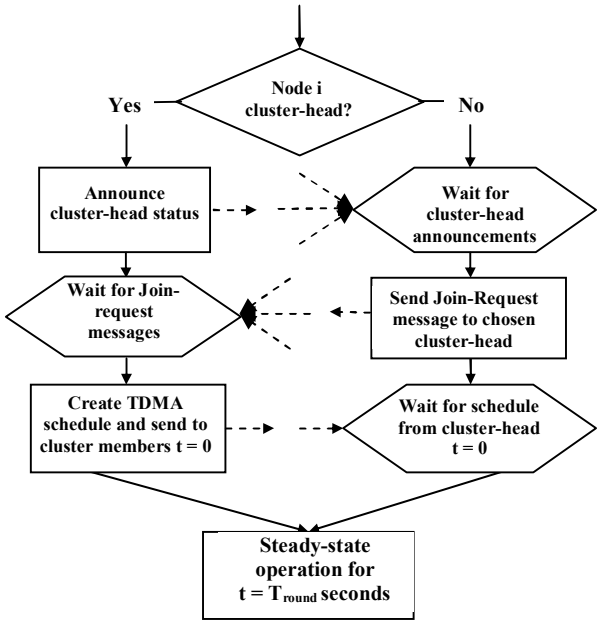

Fig. 2. Flow chart of operations of LEACH.

C. ADVANTAGES OF LEACH

a) Leach introduces scalability to the network because most of the communication is limited within the clusters thus reducing communication overhead.
b) It uses data fusion and aggregation technique which significantly reduces the amount of traffic in the network.
c) Cluster head rotation helps in evenly distributing the work load and avoids the excessive battery drainage of few nodes.
d) By using TDMA schedule for data transmission, nodes have only to stay active for their respective time slots and can stay idle (sleep mode) for rest of the time thus saving power [7].
e) Location information of sensor nodes is not required for cluster set up phase making Leach a simpler and powerful routing protocol [7].
f) Leach is adaptive in nature and capable to adjust according to network changes.

D. DISADVANTAGES OF LEACH

a) Leach does not ensure the even distribution of cluster heads over the network [7].
b) The amount of energy of sensor nodes is not considered for cluster head selection.
c) Leach is not suitable for large networks [7] because of these two reasons:
   - Only single hop communication is used.
   - In leach the assumption is made that all the nodes can communicate with each other and are also able to reach Base station, but this assumption is not true in large network areas.
d) Distributed clustering approach of leach incorporates control messages [8] (advertisements, join requests, acknowledgements etc) overhead.
e) Base station has no control over cluster head selection, therefore large amount of energy will be wasted if CH is situated far away from BS[8].
f) Time duration of set up phase cannot be pre-determined and it becomes very long in case of dense networks.

Centralized Leach Protocol

Centralized leach (C-Leach) is a descendant of leach routing protocol. Although leach has many advantages over previous clustering protocols but it has also some disadvantages such as poor clustering, the number of clusters may or may not be optimal. Number of clusters should be optimum, in both the cases when number of clusters are large and when number of clusters is small efficiency is degraded. So, in order to overcome these problems c-leach utilizes a centralized approach for clustering. Base station selects the optimum number of cluster heads and also forms appropriate clusters by utilizing the location information of the sensor nodes and the current energy level.

First of all the base station sends a “HELLO” message[10] to all the nodes telling about its location. Then every node sends its location (which is determined by using a GPS system) and current energy level information to the base Station[2]. Since the workload needs to be evenly distributed over the nodes therefore the BS calculates an average energy. Nodes having energy level less than this average are eliminated as a candidate of becoming a cluster head. Out of the remaining nodes Base station selects the k optimal clusters using simulated annealing algorithm[2]. This algorithm works in such a way that the amount of energy that is required by non-cluster head to transmit data to the cluster heads could be minimum. The sum of the squared distances of all non-cluster

head nodes form their cluster heads is calculated and the one minimum one is selected as the final cluster arrangement for that particular set of rounds.

Now, the clusters heads and member nodes associated to those cluster heads are set. After this the BS sends a message to each nodes telling it about its cluster head ID. If the node has the same cluster head ID as its own then it is a cluster head and therefore creates the TDMA schedule and sends it to member nodes. If this is not so then the node is a member node and therefore goes to sleep until its time to transmit data. This winds up the SET UP PHASE of CENTRALIZED-LEACH. The steady state consists of the actual data transmission which similar to that of leach protocol. C-leach overcomes the disadvantages of leach like poor cluster formation, uncertainty in the number of cluster heads etc. some of the differences between the two protocols are given in the following table.

Table I: Difference between leach and C-leach.

LEACH	C-LEACH
Leach is a distributed clustering algorithm.	C-Leach is a centralized clustering algorithm.
Cluster head selection is done by the nodes themselves.	Cluster head selection is done by the base station.
A threshold value is decided and the nodes choose a random number between 0 to1, those having greater random number than the threshold are chosen as cluster heads.	Cluster head selection is done by the base station on the basis of energy level and distance of node from BS.
There is no guarantee of having an optimum number of cluster heads because any number of nodes can choose a random number which could be greater than threshold value.	An optimum number of cluster heads are chosen as the selection is entirely dependent on one centralized source i.e., Base station.
Clusters heads are not evenly distributed over the network.	There is even distribution of cluster heads all over the network.
The cluster head selection process ensures that every node becomes cluster head atleast once.	Since the cluster head selection is dependent on energy and distance, so every node might not become a cluster head atleast once.
Leach has less lifetime as compared to C-Leach.	C-Leach has greater lifetime as compared to leach.
Data signals received at base station are less in case of leach.	Data signals received at base station are more in case of C-Leach.
Energy required for the start up is less.	Energy required for start up is more.
Total amount of energy dissipated is greater than C-Leach.	Total amount of energy dissipated is less than Leach.

Conclusion

Wireless sensor networks have a wide range of applications and every application has its specific requirements. So, we need to develop the routing algorithms specific to its area of application in order to achieve an efficient routing. In this paper we have studied the distributed (leach) and centralized (c-leach) routing techniques and have found that both their advantages and disadvantages. C-Leach performs better than leach in terms of network lifetime and data packets send to the Base station. But in case of large networks where Base Station is situated very far away from the deployment region the centralized approach dissipates large amount of energy.

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