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The Study of Distributed and Centralized Cluster Formation Protocol in WSNs

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Abstract*:* Wireless sensor networks (WSN) are made up of small sensor nodes communicating over wireless links without using a fixed network infrastructure. Routing protocols for WSNs have to ensure reliable multi-path communication under the constrains of batter power, processing, memory etc. there are many routing protocols which are facing many issues and not suitable for all the scenarios of the network, we need optimal routing protocol for WSNs.

This paper presents how the distributed and centralized cluster formation algorithm works for WSNs, taking the example of LEACH and LEACH-C protocols. We have also analyzed the performance of the both the protocols with respective to the location of the Base Station using the concept of center of gravity of spread nodes. Finally the paper concludes by analyzing the network lifetime of the both the protocols using the NS-2.

Key words: Wireless sensor Networks, NS-2, LEACH protocol, LEACH-C protocol, Center of Gravity of spread nodes.

INTRODUCTION

With the advances in wireless communications, embedded microprocessors and low-power electronics, wireless sensor networks (WSNs) are emerging for various applications due to attributes such as small size, low-cost, low-power, and multifunction. WSNs[1][4][11][12], have a broad range of potential applications, such as: environmental monitoring (e.g., temperature, humidity), military purposes, monitoring disaster areas providing relief, file exchange, conferencing, home, health (monitoring patients and assisting disabled patients), and commercial applications including managing inventory and monitoring product quality.

As the resources of sensor nodes in WSN, such as energy, computing capability and transmission bandwidth etc. are very limited, it is critical to employ superior routing protocol so as to reduce node energy consumption and prolong network life cycle, which is also the major objective of WSN routing design. Currently, WSN routing protocols can be mainly divided into two categories, i.e., flat routing protocols and hierarchical routing protocols [8]. When deploying large-scale WSN, the communication overhead, delay and complexity management of flat routing protocols will lead to retard response of WSNs. However, to a certain extent, the above problems can be solved by hierarchical routing protocol. In a relatively optimal hierarchical structure, the neighboring nodes are clustered and then a cluster head node is selected, a cluster is supervised by a leader node called Cluster Head (CH). Purpose of CH is to maintain the list of affiliated nodes and communicate with other cluster heads. Many parameters can be used for electing the node as a cluster head such as location, mobility, battery, throughput etc. Numerous techniques for selecting cluster head have been proposed by researchers, focusing on parameters.

The following Fig 1 shows the general Architecture of Cluster Based Routing Protocol. There are several variants of Cluster Based Routing protocols whose performance and application scenarios differ greatly.

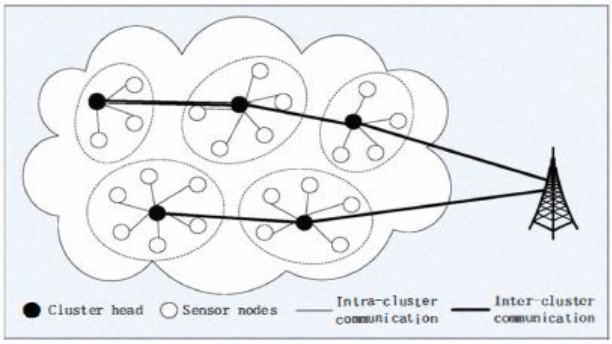

Fig 1: Architecture of cluster-based routing protocols

In this paper, we have discussed how the Distributed and Centralized cluster formation has been carried out and analyzed the performance of LEACH and LEACH-C protocols with respect to change the base station location.

HIERARCHICAL ROUTING PROTOCOL

i. LEACH protocol

LEACH protocol (Low-Energy Adaptive Clustering Hierarchy), it is the first hierarchical routing protocol for WSN, was designed by Wendi B. Heinzelman from MIT. LEACH network topology could be shown in Fig 2. Most hierarchical protocols are derived from LEACH protocol and LEACH-C protocol is one of them.

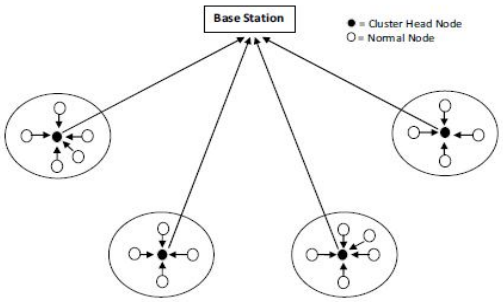

Fig 2: Clusters Organization in LEACH Protocol

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LEACH forms clusters based on the received signal strength and use the CH nodes as routers to the base-station. All the data processing such as data fusion and aggregation are local to the clusters [8][10]. LEACH forms clusters by using a distributed algorithm, where nodes make autonomous decisions without any centralized control. Initially a node decides to be a CH with a probability p and broadcasts its decision. Each non-CH node determines its cluster by choosing the CH that can be reached using the least communication energy. The role of being a CH is rotated periodically among the nodes of the cluster in order to balance the energy consumption from a single node.

The LEACH protocol operation is based upon rounds; each round consists of two phases:

1. **Set-up Phase**
   - Advertisement Phase
   - Cluster Set-up Phase
2. **Steady Phase**
   - Schedule Creation
   - Data Transmission

1. Set-up Phase

In the cluster constructing stage, the cluster head, which is randomly generated, broadcasts its information to all nodes around it using the same amount of power. Based on the strength of received signal, the node decides which cluster to join in and sends the message back to the corresponding cluster head.

The method of LEACH [13][14] cluster head selecting can be expressed as follows: each node selects a number between 0 and 1 randomly. If the value is less than the threshold value T (n), the node becomes the cluster head. T(n) is shown as equation (1).

$$T(n) = \begin{cases} \frac{P}{1-P[r \bmod (1/P)]} & ,n \in G \\ 0 & ,Otherwise \end{cases} \quad \text{-------(1)}$$

Where

P - Percentage of cluster heads to all nodes.
r - Selected rounds number.
r mod(1/P) - number of selected cluster head nodes before this round.
G - Group of nodes which have not been elected as cluster head nodes previously.

When r = 0, the possibility of each node becoming the cluster head is P. If it becomes the cluster head node in the first r rounds, it can be no longer re-elected in the future (1/P-r) round which enhances the possibility of other nodes to become a cluster head. After 1 / P rounds, all nodes have a possibility of P to be a cluster head once again, over and over again.

2. Steady Phase

Data transmission begins; Nodes send their data during their allocated TDMA slot to the CH. This transmission uses a minimal amount of energy (chosen based on the received strength of the CH advertisement). The radio of each non-CH node can be turned off until the nodes allocated TDMA slot, thus minimizing energy dissipation in these nodes.

Whenever all the data has been received, the CH aggregate these data and send it to the BS. LEACH is able to perform local aggregation of data in each cluster to reduce the amount of data that transmitted to the base station. Although LEACH protocol acts in a good manner, it suffers from many drawbacks such like:

- CH selection is randomly, that does not take into account energy consumption.
- It can't cover a large area.
- CHs are not uniformly distributed; where CHs can be Located at the edges of the cluster.

Since LEACH has many drawbacks, many research have been done to make this protocol performs better.

ii. LEACH – C Protocol

As previously mentioned, the disadvantage to LEACH is that the number of cluster head nodes is little ambiguous to count. LEACH-C has been proposed to clarify this problem. LEACH-C provides an efficient clustering configuration algorithm, in which an optimum cluster head is selected with minimization of data transmission energy between a cluster head and other nodes in a cluster [8][9].

In LEACH-C, the base station receives information about residual node energy and node locations at the set up phase of each round. The received data can compute an average residual energy for all nodes. The nodes with less than average energy are excluded in selection of cluster heads. Among the nodes that have more than average energy, cluster heads are selected with use of the simulated annealing algorithm. The base station sends all nodes a message of the optimum cluster head IDs (Identifiers). The node, the ID of which is the same as the optimum cluster head ID, is nominated as a cluster head and prepares a TDMA schedule for data transfer. Other nodes wait for the TDMA schedule from their cluster heads.

A. Advantages and Disadvantages LEACH and LEACH – C Protocol

Advantages

LEACH protocol is the first hierarchical routing protocol for wireless sensor network and most hierarchical protocols are derived from LEACH protocol. In order to minimize the power consumption, the time of steady stage is far greater than the cluster constructing stage. LEACH protocol is self organizing, adaptive clustering protocol that uses randomization to distribute energy load evenly. LEACH-C protocol is derived from LEACH protocol to overcome the drawbacks of LEACH protocol. In LEACH-C protocol, optimum CHs is selected and controlled by the Base Station (centralized) with minimization of data transmission energy between CH and other nodes and the entire sensor nodes are controlled by BS.

Disadvantages

In LEACH protocol, the nodes with low remnant energy have the same priority to be a CH as the node with high remnant energy and this protocol cannot be used in

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large-scale WSN. In LEACH protocol, data transmission between CH to BS needs more energy than common nodes. Excessive number of CH's will increase energy consumption of the network and shorten network lifetime. In LEACH-C, at the initialization of every node, it has to report its residual energy to the base station resulting much energy consumption.

SIMULATION EXPERIMENT AND RESULT ANALYSIS

i. Development of Simulation Platform

The experimental platform used in this paper is NS-2. The NS-2 network simulator is installed on the Ubuntu 10.04. Considering that NS-2 lacks the protocol LEACH and LEACH-C in it by default, another extension package of these two protocols is patched. The main aim of our research is to compare and analyze the working principle of LEACH and LEACH-C protocol and analyses the performance of this protocol with respect to the base station location change. Hence we make direct use of the protocol simulation package. (http://www.Internetworkflowcom/downloads/ns2leach/mit.tar.gz), and download mit.tar.gz and decompress it. In order to make them available, we modify the relevant files (makefile, test, leach_test, leach-c_test, etc.) and configure the environment variables.

ii. Simulation Parameters

Here we use the same simulation parameters for the LEACH protocol and the LEACH-C protocol. Simulation parameters are as follows:

a. In the range of (100,100), distributing 100 sensor nodes randomly.
b. The initial energy of each node is 2J.
c. The percentage of cluster head nodes to the total number of surviving nodes is 5% in each round.
d. The total length of simulation duration is 3600s.
e. The effective signal transmission distance is 175m.

iii. Calculating the center of gravity of spread nodes

To compare the LEACH and LEACH-C protocol we use the concept Center of Gravity of Spread Nodes. The concept of the center of gravity of distribution nodes so as to calculate the distance between base station location and the center of gravity of distribution nodes[8]. The distribution nodes file, 100nodes.txt, takes record of the coordinates (x, y) of 100 nodes which is randomly distributed; its distribution is shown in Figs 3.

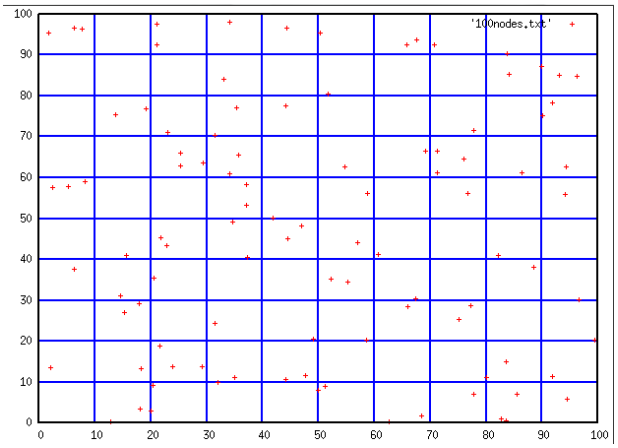

Fig 3: The Distribution of the sensor nodes

The distance between the base station and the center of gravity decreases as the distance between the base station and the closed node decreases. The average distance is smaller in general, and the power consumption is less, which can extend the network lifetime.

Calculation of Center of Gravity of spread nodes using the following equations (2):

$$X_G = \frac{\sum_i W_i X_i}{\sum_i W_i}, \quad Y_G = \frac{\sum_i W_i Y_i}{\sum_i W_i} \qquad (2)$$

Where:

i - the node serial number (1-100).
Wi - target node weight, whose value is taken as 2, i.e. the energy value of node.
(Xi, Yi) - coordinate of the node i.
(XG, YG) - coordinate of the center of gravity.

Using the same computer program, we calculate the center of gravity is (49.34, 47.33) according to node distribution file 100nodes.txt.

iv. Simulation and Analysis

We simulate LEACH and LEACH-C protocols by changing the location of base station constantly and analyze comparatively simulation curves of the different parameters like network lifetime measures in survival nodes at the end of the simulation, throughput, packet delivery ratio etc. The

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LEACH and LEACH-C protocol performance parameters curves are shown in Fig 4, Fig 5 and Fig 6 representing the network base station location at (49,175), (49,225) and (175,47) respectively.

The curve in Fig 4, Fig 5 and Fig 6 describes number of the survival node which is changing over time on the scale of x axis and the number of nodes chosen for the simulation.

The Blue color line in the graph indicates performance related to the LEACH protocol and Brown color line indicates performance related to the LEACH-C protocol.

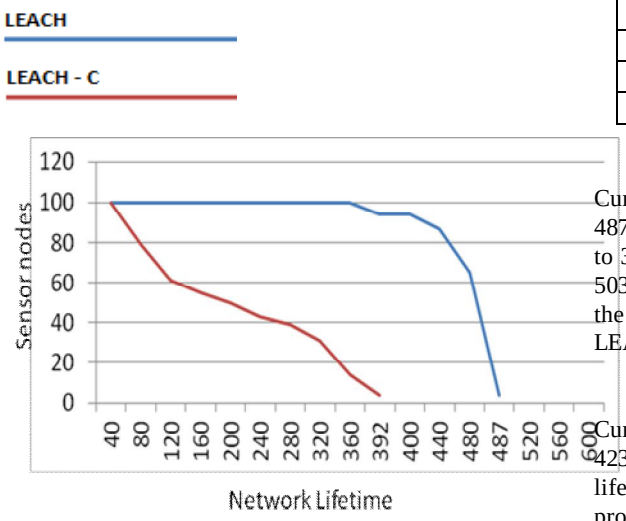

Fig 4: Simulation curve with BS co-ordinate (49,175)

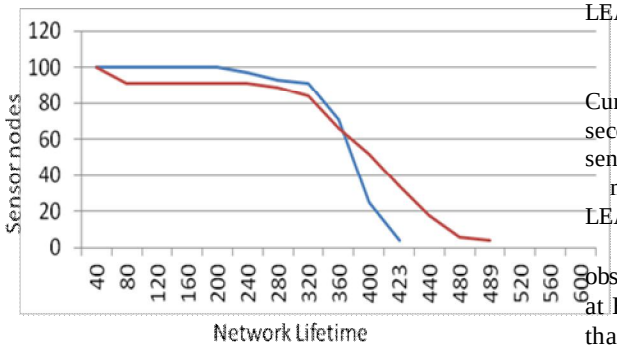

Fig 5: Simulation curve with BS co-ordinate (49,225)

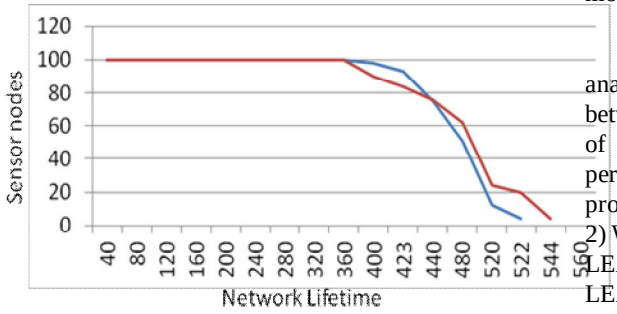

Fig 6: Simulation curve with BS co-ordinate (175, 47)

The below table shows the performance or network lifetime comparison of LEACH and LEACH-C protocol with twelve sample network base station's location, as shown in Table 1.

Table 1: Simulation Results

BS Coordinate	Performance Parameter	LEACH	LEACH-C
(49,175)	Survival nodes 20(sec.) Network lifetime	487	392
(49,195)		487	430
(49,215)		481	460
(49,225)		423	489
(49,245)		404	471
(49,265)		365	460
(175,47)		522	543
(195,47)		519	540
(215,47)		463	520
(225,47)		448	500
(255,47)		427	452
(275,47)		347	440

When the BS's location is at (49,175) as shown in Fig 4. Curve a, there are 4 nodes alive when the LEACH protocol in 487 seconds, however the LEACH-C protocol can only sustain to 392 seconds, and the total data sent in LEACH protocol is 50322, in LEACH-C protocol its 44248. In this BS's location the LEACH protocol have more network life time than LEACH-C protocol.

But at the BS's location (49,225) as shown in Figure 5. Curve a, there are 4 nodes alive when the LEACH protocol in 423 seconds, however the LEACH-C protocol have network lifetime is 489 seconds, and the total data sent in LEACH protocol is 41216, in LEACH-C protocol its 61334.Which means LEACH-C protocol have more Network life time than LEACH protocol.

In the BS's location at (175, 47), as shown in Figure 6. Curve a, there are 4 nodes alive when LEACH protocol in 522 seconds, and total data sent is 54206, but in LEACH-C protocol sent 75361 data with a network lifetime of 543 seconds. This means that LEACH-C have more Network lifetime than LEACH protocol.

The simulation results as shown in the Table 1. We can observe that the LEACH protocol has more network lifetime at BS's location (49,175), (49,195) and (49,215), but other than these three simulation results all other results have shown LEACH-C protocol have more network lifetime and more data has been sent than LEACH protocol .

After a large number of simulative comparative analyses, we have the following conclusions: 1) the distance between the location of base station and the center of gravity of distribution area of sensor nodes will affect the performance of routing protocols—the performance of the protocol affected by the distance is, the closer & better. 2) When the distance is greater than a certain threshold area, LEACH-C protocol's performance will be superior to LEACH protocol and the threshold area is between 160 to 170.

CONCLUSION AND OPEN ISSUES

In this paper, we have analyzed how the performance of Distributed (LEACH) protocol and Centralized (LEACH-C) protocols change with the sink location in NS-2. The simulation results correspond to the 100 sensor node

distribution in an area of 100 x 100. The purpose of this paper is to study the working principle of centralized and distributed cluster formation algorithms and its performance. The following conclusion is achieved: According to the simulation, the performance of the protocol varies depending upon the location of the Base station. The results of the Centralized (LEACH-C) protocol have more Network lifetime than Distributed (LEACH) protocol. Absolute and optimal routing protocol does not exist for all scenarios of WSNs. Even LEACH-C protocol has some drawbacks i.e. more expense based on the central base station's control. Each node transmits its information to the respective base station, and the sink will make the choice of selecting the cluster head and how to divide clusters. Then the cluster head sends this information to each node. All these need extra energy cost which will affect the performance of the protocol.

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