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Design of Enhanced LEACH Routing Protocol for Wireless Sensor Network

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ABSTRACT: *A wireless network consists of a large number of small sensors. The sensor is low-power transceivers & can be an effective tool for gathering data in a variety of environments. The communication between the sensor nodes must be designed to conserve the limited energy resources within the sensor. LEACH clustering is based protocol. The protocol utilizes randomized rotation of local cluster-heads to evenly distribute the energy load among the sensors in the network. Enhanced LEACH protocol (En-LEACH) has been adaptable to handle non-uniform energy distribution characteristic of a dynamic sensor network.*

Keywords: C*luster formation, energy-efficient, micro-sensor networks, routing topology, threshold value*

I. INTRODUCTION

Wireless sensor networks have the ability to adapt to the changing environments. The nodes scattered throughout a field assemble to establish a routing topology, and transmit data back to a collection point. This application demands the robust, scalable, low-cost and easy to deploy networks. If one of the nodes in the network fails, a new topology need to be selected and the overall network would continue to work.

The main resource limitation to meet is power consumption. As physical size of the node decreases, so does energy capability of the node. However, the advantage of wireless sensor networks is their plasticity and universality.

1.1 Objective

The objective of this paper is to arrive at an energy-efficient communication procedure for sensor networks which is adaptable to non-uniform and vigorous energy distribution among the sensor nodes and the changing network arrangements.

In the application area where the sensors are operating in remote or dangerous territory, it may be impossible to access the nodes in order to revitalize batteries. Therefore, the network should be considered to have a certain period during which nodes have energy and can gather, process, and transmit information to the other node or base station. Decreasing energy usage can increase system lifetime. This results in increasing the overall use full lifetime of the system. In addition to reducing energy dissipation, protocols should be beneficial to node failures in order to enlarge system lifetime. In addition, the protocols should be scalable such that the addition of new nodes requires low overhead to merge the nodes into the existing network.

To summarize, wireless micro-sensor network protocols should be:

- self-configuring, to enable ease of positioning of the networks,
- energy-efficient and robust, to prolong system lifetime,
- latency-aware, to get the information to the end-user as quickly as possible, and
- Perceptive of the application-specific nature of sensor network quality

1.2: LEACH Introduction

Wireless micro-sensor networks will enable reliable monitoring of remote areas for data-gathering. They require ease of deployment, long system lifetime, and low-latency data transfers.

To meet the requirements of wireless micro-sensor networks, LEACH (Low-Energy Adaptive Clustering Hierarchy), application-specific protocol architecture was developed [5].

LEACH includes adaptive, self-configuring cluster formation, localized control for data transfers, low-energy media access, and application-specific data processing.

The cluster-head node receives all the messages for nodes that would be the part of the cluster. Based on the number of nodes in the cluster, the cluster-head node creates a TDMA schedule. This is used to inform each node when it can transmit. This schedule is newscast back to the nodes in the cluster.

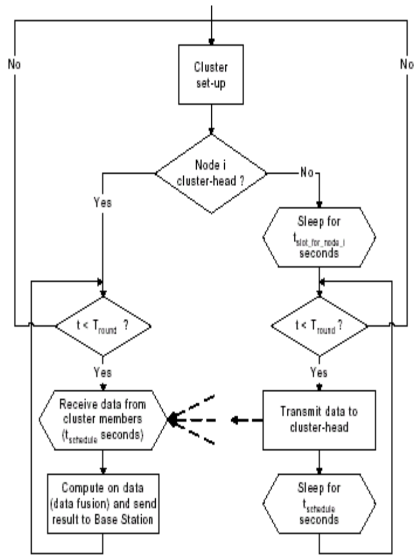

Figure 1-1: Flow-graph of the steady-state operation for LEACH.

II. NEW PROPOSALS TO ENHANCE THE LEACH PROTOCOL

The modifications and enhancements to the LEACH protocol as follows

2.1. Changes Proposed in Cluster Setup Phase to handle Non-Uniform Energy Distribution

In LEACH, probability of becoming a cluster-head is based on the hypothesis that all nodes start with an equal amount of energy, and that all nodes have data to send during each frame. This can be achieved by setting the probability of becoming a cluster-head as a function of a node's energy level relative to the cumulative energy of the cluster in the network, rather than purely as a function of the number of times the node has been cluster-head.

2.2. Changes proposed in Data Transmission Phase

Idea is when during data transmission phase all members of clusters send data to their respective cluster-head then individual cluster-head will check if the energy required to transfer a aggregated data to is true then first it will broadcast a "CLUSTER_HEAD_DOWN" message to all its members and then transmit a amount of aggregated data depending upon its energy left. On receiving "CLUSTER_ HEAD_DOWN" message all the members of cluster head will stop transmitting their data towards cluster-head until next cluster head election takes place.

III. EN-LEACH ALGORITHM

Protocol rounds are repeated with a periodicity with each round consisting of the following phases.

3.1 Advertisement Phase

The first round (i.e. round number zero) is started by each node calculating Threshold value (or probability to become cluster-head) using same method as used in LEACH protocol and comparing the threshold value with random no (0 to 1) selected by the node. If the threshold value is greater than the random number chosen then the node becomes the cluster-head for this round. Hence the probability of becoming cluster-head in round zero is given as:

$$P(n) = p/(1-(p*(r \bmod 1/p))) \quad (1)$$

Here p indicates optimum number of cluster-head in a round (5 % as suggested by LEACH) and r denotes round number.

So in the round zero each node's probability to become cluster-head can be re-written as: For this "cluster-head-advertisement" phase, the cluster-heads use a CSMA MAC protocol, and all cluster-heads transmit their advertisement using the same transmit energy. The advertisement message contains the following fields:

• The advertisement message flag ADVERTISE_MESSAGE
• Cluster-head id
• Cluster-head location

After this phase is complete, each non-cluster-head node decides the cluster to which it will belong for this round. This decision is based on the received signal strength (RSSI) of the advertisement.

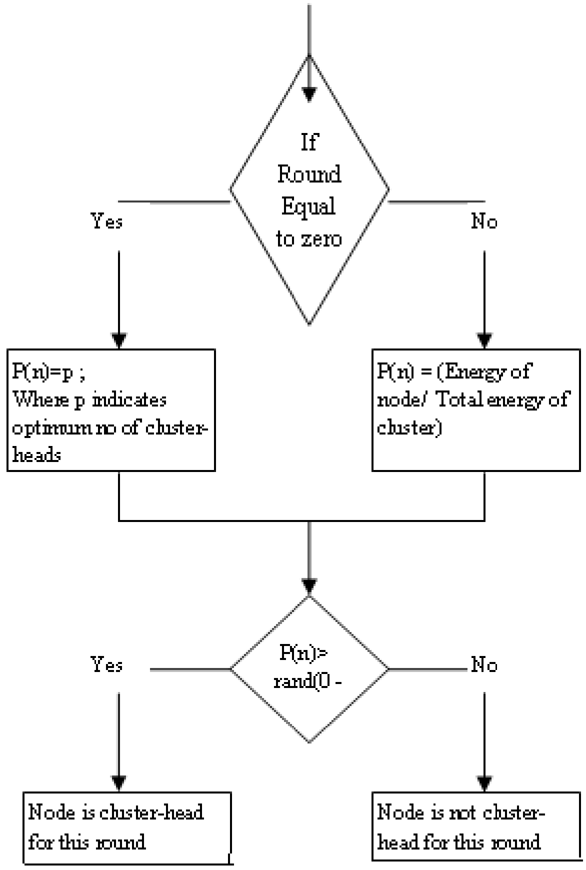

Figure 3-1: Cluster-head decision in En-LEACH protocol

3.2 Cluster Set-up Phase

After the node has decided to which cluster it belongs, it must notify the cluster-head node that it will be a member of the cluster. Each node transmits this information back to the cluster-head again using a CSMA MAC protocol through selection message. The contents of the selection message are:

- The selection message flag CLUSTER_SELECT_MESSAGE
- Cluster-head identity
- Self node id

3.3 Schedule Creation Phase

The schedule creation broadcast message consists of the following fields:

- The schedule message flag SCHED_MESSAGE
- The CDMA spreading code to be used for communications within the cluster
- The TDMA schedule consisting of *N* number of {node-identity(node-id) – TDMA time-slot} pairs

3.4 Data Transmission Phase

A data message which is sent to cluster-head consists of the following fields:

- The Data message flag DATA_MESSAGE
- Identity of the source node *n*
- Cluster-head id
- Residual energy left in node n ,E(n)
- The actual data if any

When all the data has been received, the cluster head node performs signal processing functions to compress the data into a single signal. Then cluster-head checks if its energy is greater then what is required to send the aggregated data to base station plus sending cluster-head status to all its members.

The cluster-head status message contain following field:

- The message flag CLUSTER_HEAD_DOWN

- The cluster-head id
- The probability of becoming cluster-head for each node i.e. (P(n) , node id) pair.

Where P(n) = Energy of the node/total energy of the cluster

3.5 Future Cluster-head Update Phase

If the cluster-head is alive even after data transmission phase then it can update the probability of each of its members becoming future cluster head by sending following update message:

- The message flag CLUSTER_UPDATE_MESSAGE
- Cluster-head id (it's own id)
- Probability of each of its members { node id(n), P(n)} in pair.

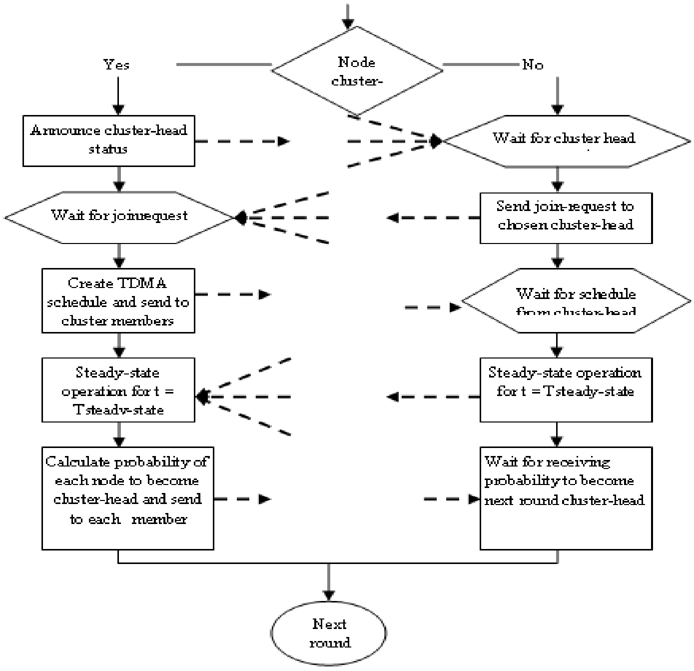

Figure 3-2: Flow-graph of the distributed cluster formation algorithm for En-LEACH.

IV. EXPERIMENTAL SET-UP

For these entire scenario, the random, 100-node network shown in Figure 4-1.The base station was placed at location (1000, 0). The test network parameters are shown in table 4-1.

Table 3-1: Characteristics of Test Network

Parameter	**Value**
Nodes	100
Network size	1000m × 1000m
Base station location	(1000, 0)
Node Energy	Based on Node Energy Model
Node position	Based on Network topology
Data size	1000 bits
Desired percentage of cluster head	5%
No of rounds executed	100
No of data transmission cycle per round	100

VI. SIMULATION RESULTS

4.1.1 Uniform Energy Distribution

In this scenario assume each node begins with equal energy i.e. 20 J of energy. We tracked the rate at which the data are conveyed to the base station and the amount of energy required to get the data to the base station. Once a node runs out of energy, it is considered dead and can no longer transmit or receive data. For these simulations, energy is removed whenever a node transmits or receives data.

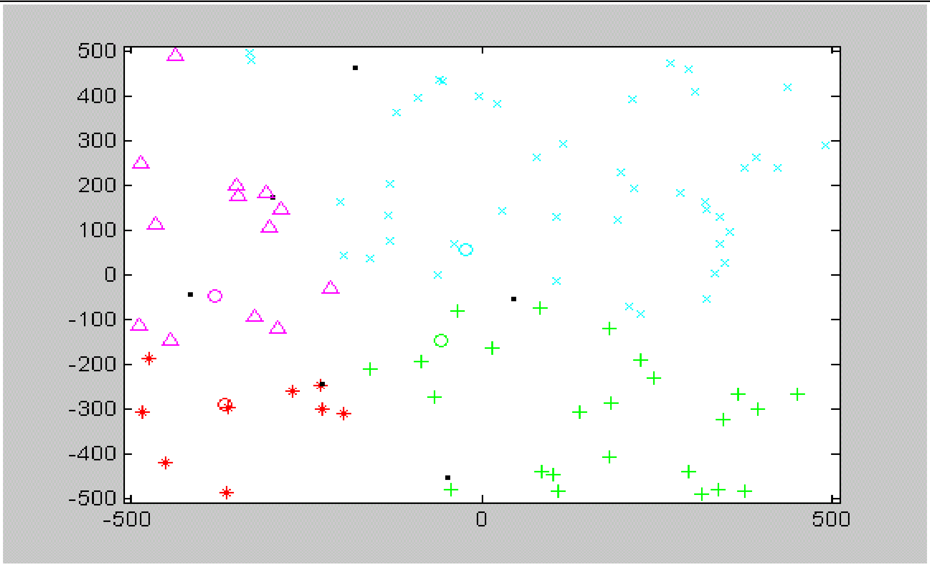

Figure 4-1: Sensors that remain alive (Non dot) and those that are dead (dots) after 31 round for LEACH protocol. Clusters are indicated using different colors.

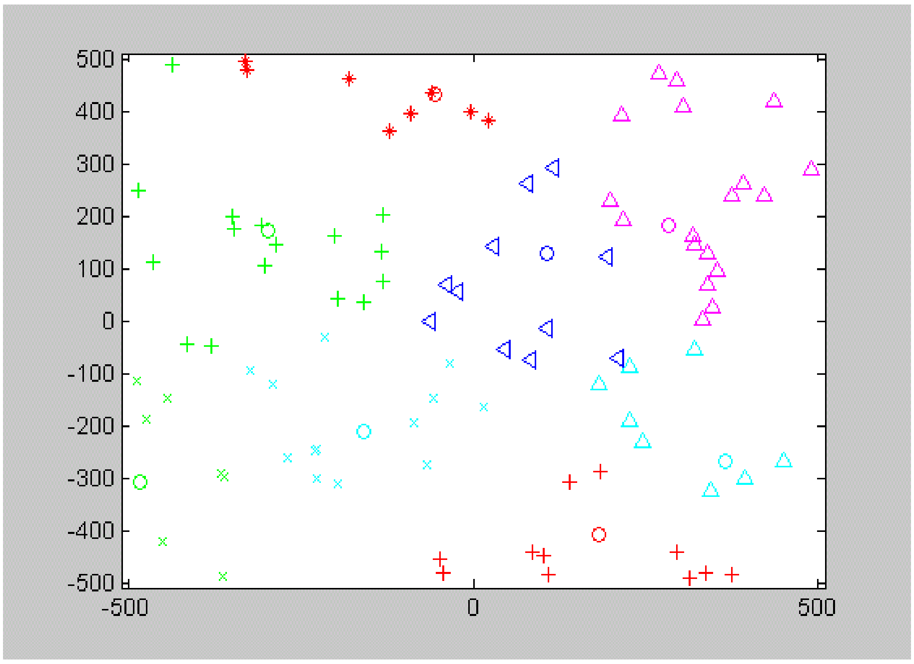

Figure 4-2: Sensors that remain alive (Non dot) and those that are dead (dots) after 31 round for En-LEACH protocol.

The results can be summarized as follows

The first death in En-LEACH occurs at round 38, whereas in case of LEACH the first node dies at round 22, hence first node death is approximately 2 times later than the LEACH protocol.

Also the last node death in En-LEACH occurs much later than the last node death in case of LEACH.

4.1.2 Non-uniform Energy Distribution case

In this scenario assume node begins with non-uniform energy distribution where energy of each node is uniformly distributed E (max) =30 J and E (min) = 10 J.

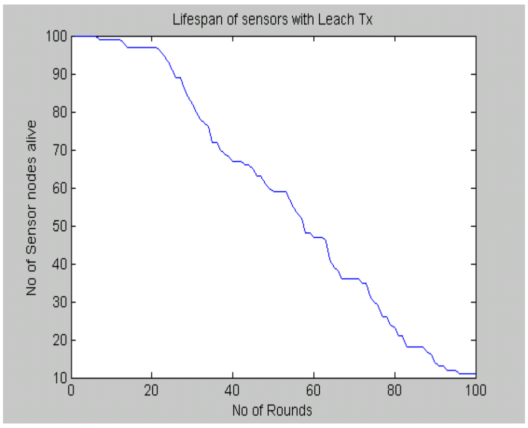

Figure 4-3: System lifetime - LEACH protocol

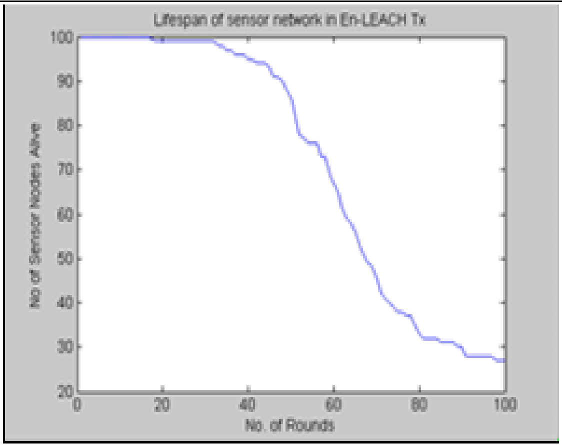

Figure 4-4: System lifetime - En-LEACH protocol

VII. CONCLUSION

In LEACH, there may be a case when cluster-head chosen which having less amount of energy as compared to its cluster member nodes, which will result in early death of cluster-head. But in case of En-LEACH, cluster-head depending upon energy left in the node, hence it is bound to perform better than LEACH.

In En-LEACH, all cluster members are kept informed about the status of their cluster-head (whether it is alive or dead), since the probability of failure of cluster-head is high during data transmission phase En-LEACH is more effective; producing high level information about the environment the nodes are monitoring in an energy-efficient way. En-LEACH is able to handle non-uniform energy distribution of sensor nodes which is an important characteristic of a dynamic sensor networks.

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