An Improvement on LEACH Protocol (Cell-LEACH)

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Abstract— **Wireless sensor network is a wireless network consisting of independent sensor, communicating with each other in distributed fashion to monitor the environment. Sensors are usually attached to microcontroller and are powered by battery. The goal of Wireless sensor network is to have long life time and high reliability with maximum coverage. Routing techniques are the most important issue for networks where resources are limited. LEACH is one of the first hierarchical routing approaches for sensor networks. Most of the clustering algorithms are derived from this algorithm. In this paper we propose an improvement on the LEACH Protocol. In our proposed algorithm, every cluster divided into 7 subsections that are called cells. Also every cell has a cell-head. Cell-heads communicate with cluster-heads directly. They aggregate their cell information and therefore they prevent sensors from communicating. In addition, we have made some changes in computation of the threshold value for a cluster-head selection formula. Something that was mentioned, cause efficiency reduce energy consumption and extend the network lifetime. We evaluate LEACH, LEACH-C and Cell-LEACH through extensive simulations using JSIM simulator which shows that Cell-LEACH performs better than LEACH and LEACH-C protocols.**

***Keywords*— wireless sensor network; cluster-head; cell-head; cluster; cell, energy, lifetime;**

I. Introduction

Wireless Sensor Networks (WSNs)[2,17] are a special kind of Ad hoc networks that became one of the most interesting areas for researchers. Routing techniques are the most important issue for networks where resources are limited. WSNs technology's growth in the computation capacity requires these sensor nodes to be increasingly equipped to handle more complex functions. Each sensor is mostly limited in their energy level[4], processing power and sensing ability. Thus, a network of these sensors gives rise to a more robust, reliable and accurate network. Lots of studies on WSNs have been carried out showing that this technology is continuously finding new application in various areas[5,6,7]. It is noted that, to maintain a reliable information delivery, data aggregation and information fusion that is necessary for efficient and effective communication between these sensor nodes. Only processed and concise information should be delivered to the sinks to reduce communications energy, prolonging the effective network life-time with optimal data delivery an inefficient use of the available energy leads to poor performance and short life cycle of the network. To this end, energy in these sensors is a scarce resource and must be managed in an efficient manner.

For energy management in WSNs presented various ways for clustering and routing.

Routing in WSNs is a challenging task firstly because of the absence of global addressing schemes; secondly data source from multiple paths to single source, thirdly because of data redundancy and also because of energy and computation constraints of the network. Cluster based routing in WSNs comes under the category of hierarchal routing. Hierarchal routing involves formation of clusters where nodes are assigned the task of sensing which have low energy and transmission task to nodes which have higher energy. The purpose is to perform energy efficient routing.

For this purpose, a cluster based routing algorithm LEACH (low energy adaptive clustering hierarchy) has been proposed to organize a sensor network into a set of clusters so that the energy consumption[15] can be evenly distributed among all the sensor nodes. Periodical cluster head voting in LEACH, however, consumes non-negligible energy and other resources[8].

In section 2 we discuss the Leach protocol in details. Section 3 presents the related work, in section 4 we introduce our proposed protocol Cell-LEACH, in section 5 we evaluate our protocol by present the simulation results, and in section 6 we conclude the paper.

II. LEACH PROTOCOL

Low Energy Adaptive Clustering Hierarchy (LEACH): LEACH is one of the most popular clustering algorithms[3] for WSNs[1,16]. It forms clusters based on the received signal strength and uses the CH nodes as routers to the base-station. All the data processing such as data fusion and aggregation are local to the cluster. 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 load. The rotation is performed by getting each node to choose a random number ‘‘T(n)’’ between 0 and 1. Refer to equation (1). A node becomes a CH for the current rotation round if the number is less than the following threshold:

$$T(n) = \begin{cases} \dfrac{\mathrm{Pi}}{1 - \mathrm{Pi}\left(\mathrm{r.mod}\,\dfrac{1}{\mathrm{Pi}}\right)} & , if\ n \in G \\ 0 & , otherwise \end{cases} \quad (1)$$

where p is the desired percentage of CH nodes in the sensor population, r is the current round number, and G is the set of nodes that have not been CHs in the last 1/p rounds. Since the decision to change the CH is probabilistic, there is a good chance that a node with very low energy gets selected as a CH. When this node dies, the whole cell becomes dysfunctional. Also, the CH is assumed to have a long communication range so that the data can reach the base-station from the CH directly. This is not always a realistic assumption since the CHs are regular sensors and the base-station is often not directly reachable to all nodes due to signal propagation problems, e.g., due to the presence of obstacles.

LEACH also forms one-hopintra- and inter cluster topology where each node can transmit directly to the CH and thereafter to the base-station. Consequently, it is not applicable to networks deployed in large regions.

This protocol is divided into rounds; each round consists of two phases:

Set-up Phase

- Advertisment Phase
- Cluster Set-up Phase

Steady Phase

- Schedule Creation
- Data Transmission

A. Setup Phase

Each node decides independent of other nodes if it will become a CH or not. This decision takes into account when the node served as a CH for the last time (the node that hasn't been a CH for long time is more likely to elect itself than nodes that have been a CH recently). In the following advertisement phase, the CHs inform their neighborhood with an advertisement packet that they become CHs. Non-CH nodes pick the advertisement packet with the strongest received signal strength.

In the next cluster setup phase, the member nodes inform the CH that they become a member to that cluster with "join packet" contains their IDs using CSMA. After the cluster-setup sub phase, the CH knows the number of member nodes and their IDs. Based on all messages received within the cluster, the CH creates a TDMA schedule, pick a CSMA code randomly, and broadcast the TDMA table to cluster members. After that steady-state phase begins.

B. Steady-state 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.

When 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 researches have been done to make this protocol performs better.

III. RELATED WORKS

There have been many research efforts on WSNs since 2000. In this section, we will review related routing protocols, with a focus on the hierarchical based routing in WSNs.

A. LEACH-C Protpcol (LEACH – Centralized)

As previously mentioned, the disadvantage to LEACH is that the number of cluster head nodes is little ambiguous to count. LEACH-C [5]. 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.

In LEACH-C, the base station receives information about residual node energy and node positions 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.

IV. OUR PROPOSED PROTOCOL CELL-LEACH

In this proposed method, sensor network once will be divided in sections which are called cell. Each cell includes several sensors. One sensor which is inside the cell is selected as head of the cell. Each seven near cells will form a cluster, each provided with a sensor which is known as cluster-head, as shown in figure1. Clustering and celling will remain the same as long as network is working, just cell-heads and cluster-heads change dynamically.

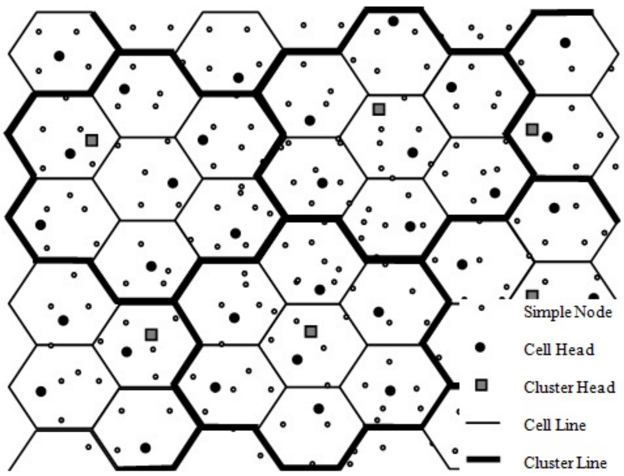

Figure 1. Clustering and celling of the network

After network setup, interest is transferred from base station to all cluster-heads; each cluster transfer this interest to all cell-heads inside its cluster. And each cell- head transfers the received interest to all sensors inside the cell. The interest would be transferred to cell-head by sensors, in the case that any sensor inside the cell shows appropriate response to this received interest.

When cell-head receives the response of inside cell toward interest, it allocates a limit of time on the basis of TDM (Time Division Multiplexing) to sensor nodes which have shown interest to transfer data. Each cell should transfer its data to the cell-head in designated time. This method is also used for transferring data from cell-head to cluster-head. When transferring data, all the cell nodes remain off (except the node that is already in charge of slicing time). This function is performed in all cells simultaneously.

The sensors cover common geographic zone inside the cell. Nearby sensors usually have common data and are overlapped. To send two versions from a data to a cell-head, energy and band width will be wasted. To solve this problem in cell-head, repeated data will be deleted and related data will be saved as well. It is done by filters in application program. Then cell-head will either delete redundant information or aggregate received information from different sources.

After removing redundant information and aggregating data in cell-head, this information will be send to cluster-heads. All the functions that are done in cell-head will be performed in cluster-head as well.

To send data from cluster-head to base station, each cluster-head keeps the location information of the other clusters in its table. This table will be updated by choosing each cluster-head. By using the table, the shortest path is selected to send data from cluster-head to base station. The path between cluster-head toward base station will changed in life time of the network, since selecting the cluster-heads is done dynamically. This change leads to empower energy in a particular path. After that the information will be send to base station, as shown in Fig.2.

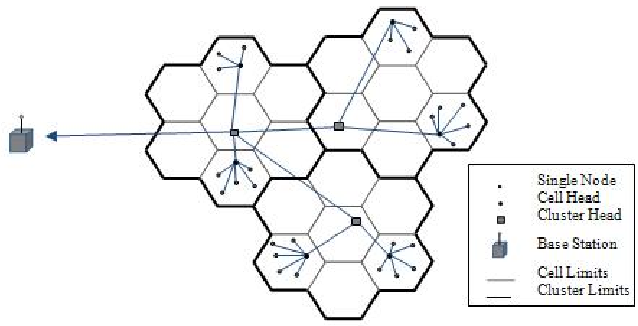

Figure 2. Packets sent from cell-heads to cluster-heads and then to BS

To select cell-head and cluster-head the same technique will be used. The first time after the network setup, a cell-head inside each cell and a cluster-head inside each cluster will be determined randomly, since all the sensors have the same energy. In next times, as an example, each old cell-head have to select a new cell-head dynamically and replace it.

Methodology is in a way that, when residual energy is getting minimum, cell-head will send a message with a $E_{avg\text{-}cell}$ $E_{avg\text{-}cell}$ [1] that is needed for being a cell-head to its near sensors. By receiving the message nearby sensors will compare their energy to least needed energy. If sensor's energy is more than the least energy, sensor will send a message to cell-head with its energy, otherwise no message will be sent. After receiving the messages from sensors inside the cell, cell-head will perform the required comparison, and among the sensors one that has the most remained energy will be selected as the new cell-head. The new cell-head will declare its condition to other sensors inside the cell and its cluster-head as soon as possible and will be retired until its next time.

A. *Method of evaluating the average consumed energy that is remained in cluster*

At the end of a period of time, all sensors of a cell transmit their remained consumed energy to cell-head. Their Eave-cell will be calculated and transmitted to cluster-head. And among the nodes of a cell one that has the most energy rather than Eavg-cell will be selected as the new cell-head in next round. After sending Eavg-cell to cluster-head, cluster-head will

[1] The average energy of cell

calculate the mean of $E_{avg\text{-}cell}$ to consider it as average of remained energy in cluster ($E_{avg\text{-}cluster}$[2]). The above function will be done concurrent in network clusters and cells.

After computing the Eavg-cell, this mean will not be calculated in other rounds, but a node that its remain energy is in maximum level in compare to $E_{avg\text{-}cell}$ will be selected as the new cell-head in each level. Steps of calculating Eavg-cell will be repeated when there is no node that has more energy than $E_{avg\text{-}cell}$. To calculate $E_{avg\text{-}cluster}$ the procedure is the same as $E_{avg\text{-}cell}$.

A. The method for selecting new cell-head shown in below

$I=\{i \mid \forall\ sensor_i \in cell\ ,\ Esensor_i \geq E_{avg\text{-}cell}\}$
$\forall\ i \in I$: if $Esensor_i > Esensor_{i+1}$
Index $\longleftarrow$ i
New Cell-Head $\longleftarrow$ $sensor_{Index}$

Where $sensor_i$ is any sensor in a cell, $Esensor_i$ is the residual energy of sensor, $E_{avg\text{-}cell}$ (as noted in above) is the average energy of cell and i, i+1 and Index are indexes.

B. The method for selecting new cluster-head shown in below

$J=\{j \mid \forall\ sensor_j \in cluster\ ,\ Esensor_j \geq E_{avg\text{-}cluster}\}$
$\forall\ j \in J$: if $Esensor_j > Esensor_{j+1}$
Index $\longleftarrow$ j
New Cluster-Head $\longleftarrow$ $sensor_{Index}$

Where sensorj is any sensor in a cluster, Esensorj is the residual energy of sensor, E avg-cluster (as noted in above) is the average energy of cluster and j, j+1 and Index are indexes.

The above mentioned function is performed to prevent a cell-head or cluster-head from ejecting energy all at once in one round. And also to prevent them from dying and after some rounds let it operate as a normal node and to make the condition of the network balanced.

V. PERFORMANCE EVALUATION

The performance analysis of routing protocols is evaluated with the J-Sim simulator [14]. Then our proposed protocol is compared to the LEACH algorithm in terms of the network lifetime.

A. *Simulation Environment*

In this simulation[18], our experiment model performed on 100 nodes which were randomly deployed and distributed in a 100m×100m square meter area. We assume that all nodes have no mobility since the nodes are fixed in applications of most wireless sensor networks. Our simulation model uses the same parameters in [13] as shown in table 1.

[2] The average energy of cluster

TABLE 1. SIMULATION PARAMETERS

Simulation Parameter	
Parameters	***Values***
Network size	100m * 100m
Location of the sink node	(20,175)
The number of nodes	100
The number of clusters	5
The number of cells	35
The initial energy of nodes	2J
Data packet length	512bytes

B. *Simulation Results*

To compare to the network lifetime of the three algorithms, we investigated the residual energy of nodes every 10 seconds during simulation and measured the number of nodes alive which maintained residual energy as shown in Fig. 3.

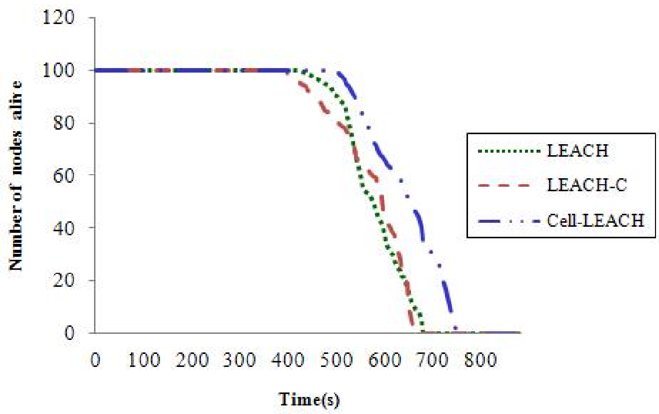

Figure 3. The number of nodes alive vs.the elapsed time

Our method leads to balanced energy consumption of nodes in process of cluster-head and cell-head selection. Based upon the simulation results, we confirmed that our proposed protocol can control the residual node energy and effectively extend the network lifetime without performance degradation as shown in Fig. 4.

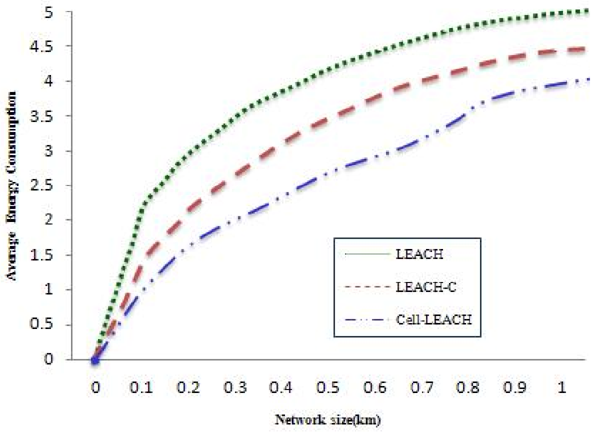

Figure 4. Transmitted, received and dropped packets in our network

VI. CONCLUSIONS

In this work, we proposed a cluster and cell based routing protocol that considers the residual energy of nodes to extend the lifetime of sensor networks. Based upon the JSIM simulation, the protocol has confirmed that it provides a longer network lifetime than LEACH and LEACH-C. The consideration of node residual energy during cluster-head and cell-head selection processing can maintain the balanced energy consumption of the sensor network.

Additionally, if we used a simulation mode of the large number of nodes, our protocol clearly makes network lifetime much longer than the LEACH and LEACH-C protocols. Consequently, it is our belief that our proposed protocol can effectively extend the network lifetime without other critical overheads and performance degradation.

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