



Distributed Weighted LEACH Protocol for Wireless Sensor Networks

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Abstract: *Wireless Sensor Networks are networks of large number of tiny, battery powered sensor nodes having limited on-board storage, processing, and radio capabilities to monitor physical or environmental conditions, such as temperature, vibration, pressure, sound or motion, and then collectively send this information to a central computing system, called the base station or sink. Different routing protocols govern the movement of this information. LEACH (Low Energy Adaptive Clustering Hierarchy) is a hierarchical-based routing protocol which uses random rotation of the nodes required to be the cluster-heads to evenly distribute energy consumption in the network. We have proposed a new routing protocol Distributed Weighted LEACH (DW-LEACH), where selection of cluster head is based on weight of the node and network is considered with heterogeneity. Simulation results using NS-2 shows that the proposed DW-LEACH heterogeneous system significantly reduces energy consumption and increase the network lifetime of the wireless sensor networks*

Keywords: *Wireless sensor networks; LEACH; DW-LEACH; Network Lifetime; Energy Consumption;*

I. Introduction

Wireless Sensor Networks (WSN) is an active research area in today's computer science and telecommunication. 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. 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 [2]. 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 [3]. 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.

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. The development of clustered sensor networks has recently been shown to decrease system delay, save energy while performing data aggregation and increase system throughput. These are strong motivational points behind selecting LEACH as the baseline protocol for the analytical study. Also LEACH has a few but very significant disadvantages like it assumes all the nodes to have same energy, which is not the case always in real-time problems, its cannot be applied for mobile nodes, failure of cluster-heads creates a lot of problems and it doesn't take into account that the systems might have multiple base stations.

We describe the design of our novel proposed DW-LEACH protocol in section 2. Simulation environment is discussed in section 3 with section 4 elaborate the results. Finally, Conclusion is made in section 5.

II. DISTRIBUTED WEIGHTED LEACH

Distributed Weighted LEACH algorithm propose to reduce energy consumption by perfecting cluster formation procedure. The cluster head selection is based on different weight coefficients parameter such as energy, distance and node degree. Nodes with combined maximum weight would become cluster head.

A. Setup Phase

Initially each node is assigned a unique ID value. It broadcasts its ID value to its neighbors and builds its neighborhood table. Each node calculates its own weight based on the following factors:

i) Node degree (Nd): The number of nodes that can communicate directly with the given node i.e. that are in its transmission range. Neighbor nodes transmit the same number, the more you can reduce the amount of information data transmission energy consumption.

ii) Residual power (Ep): The power currently left in each node. The energy is consumed by sending and receiving of messages. The greater the node's residual energy represent the less energy consumed, the more suitable is selected as the CH to balance the network energy consumption.

iii) Average distance (D): Sum of distance of the sensor node from all its neighbors and base station. Sum of distance is computed as

$$nD = \sum_{i=1}^m \sqrt{(X_n - X_i)^2 + (Y_n - Y_i)^2} \quad (1)$$

Where m is number of neighbor nodes, n is the node, (X_i, Y_i) is coordinate of i^{th} node, (X_n, Y_n) is coordinate of n^{th} node.

iv) Compute the combined weight for each node n using the equation

$$nW = (w1 \times Nd) + (w2 \times Ep) + (w3 \times D) \quad (2)$$

Where w1, w2, and w3 ($w1 + w2 + w3 = 1$) are the coefficient of the weight factor.

v) The node with the highest Wn is elected as a cluster head. All the neighbors of the chosen cluster head are no more allowed to participate in the election procedure.

vi) Cluster head (CH) broadcast a message to all nodes to join the cluster in the sensor network.

vii) The non-cluster head nodes then informs their respective cluster-heads that they will be under their cluster by sending an acknowledgement message.

A(i) -> CH(j) : id(A(i)), id(CH(j)), join req

viii) Then cluster-head creates a TDMA schedule and assigns each cluster member a time slot in which it can transmit the sensed data.

CH(j) -> A(i) : id(CH(j)), < t(i), id(A(i)) >

All the above steps are repeated for remaining nodes which is not yet elected as a cluster head or assigned to a cluster.

B. Steady Phase

i) The non-cluster head nodes start sensing data and send it to their cluster-head according to the TDMA schedule.

A(i) -> CH(j) : id(A(i)), id(CH(j)), info

ii) The cluster-head node, after receiving data from all the member nodes, aggregates it and then sends it to the base-station.

CH -> BS : id(CH), id(BS), aggr_info

C. Cluster Maintenance

We have considered our network is static. The battery power of the nodes participating in the clustering changes continuously. The cluster heads power decreases more rapidly when compared to the cluster members. When the cluster heads Battery Power falls below a threshold then the node is no longer able to perform its activates and a new cluster head from the members available need to be chosen.

Algorithm Cluster-Maintenance

Step1: Verify the threshold on the cluster head's battery power;

If (Battery power < Threshold)

Cluster head sends a LIFE_DOWN message to all its Neighbors;

All the member nodes participate in the Re-election procedure using Distributed Weighted

Algorithm and the node with highest weight is selected as the new cluster head;

Else

Re-election is not needed;

III. Simulation Environment

Here we have considered a heterogeneous network. A heterogeneous network is one in which all the nodes does not have equal energy. Let us assume that 10 percent of the nodes have e times more energy than the other nodes and the total number of nodes be n. They are called as advanced nodes. Therefore

Number of normal nodes = $(1 - 0.1) \times n$

Energy per normal node = j

Number of advanced nodes = $0.1 \times n$

Energy per advanced node = $j \times (1 + e)$

Hence the total energy of the network is equal to

$$((1 - 0.1) \times n) \times j + (0.1 \times n) \times (j \times (1 + e)) \quad (3)$$

We have considered CMU Monarch extension to NS-2, because it is targeted for ad-hoc network. Extensive simulations are carried out using NS-2. The NS-2 written in C++ and a script language called Object Tool Command Language (OTCL). A traffic generator named *cbrgen* is developed to simulate constant bit rate (CBR) sources. A mobility generator named *setdest* is developed to simulate node movement. Event type: s send, r receive, d drop, f forward. The network configuration for the rest of simulation is given in table I.

Table I: Network configuration parameters

Parameter	Value
Routing protocol	LEACH and DW-LEACH WCB DST
Field size	1000m x 1000m
Number of total nodes (n)	500
Number of advance nodes (m)	0.1 x n
Number of normal nodes	n - m
BS Location	500m ,500m
Energy per node (normal)	0.5 J
Energy per node (advance)	1 J
Election probability for advance node to become the cluster-head	0.10
Packet size	4000 bits
Number of rounds (Max)	2000
$E_{tx} = E_{rx}$	50 nJ /bit
Efs	10 pJ/bits/m ²
EDA	5nJ
Emp	0.0013pJ/bits/m2

IV. Results and Discussion

A. NETWORK SETUP

Figure-1 shows the initial nodes distribution of the network where DW-LEACH protocol is implemented. A 1000m*1000m field is taken and nodes are randomly placed in it. The sink/base station (BS), which is denoted by x, is placed at the center of the field (500, 500). Placing the base station at the center is convenient so that no node founds it out of its transmission range. Here, the advanced nodes are shown by a plus symbol (+) and the normal nodes by a circle (o). In Figure-1, all the nodes are alive in the network.

After a few rounds, a few of the nodes drains out all their energy. Such dead nodes are shown by the red dot symbol (•). Such scenario is shown in Figure-2. The reason why some of the nodes drained out their energy before the others is because these nodes would have become the cluster-heads in the initial rounds of the data transmission. Since the cluster heads have to aggregate the data and send it to the base station, which might be located far from the base-station, the cluster heads use up their energy faster as compared to the non-cluster head nodes.

Figure 1: Initial Nodes Distribution in WSN with 500 Nodes

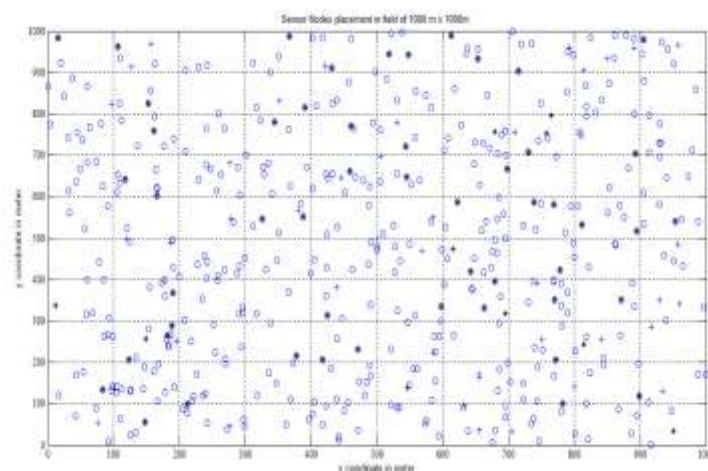


Figure 2: Nodes Distribution in WSN with 500 Nodes after 1200 rounds

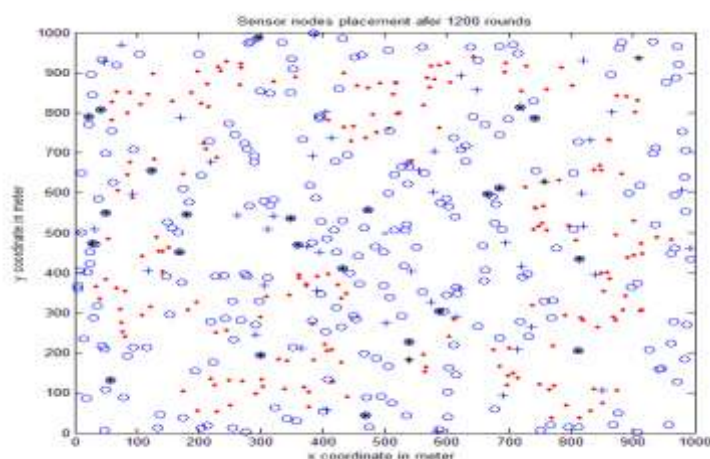


Figure-3 shows when almost all the nodes in the network die. The network ceases to work. No data is being transmitted or received either by the cluster-heads or the base-station. A snapshot of different parameter values of the four types of nodes the normal node, the advanced node, the cluster-head and the base station, as shown. Normal nodes died early as compared to advance nodes those does not become cluster head because advance node having higher residual energy. But those advance node become cluster head died early as they uses their energy faster as compared to non cluster head either they normal or advance nodes.

Figure 3: Nodes Distribution in WSN with 500 Nodes after 1500 rounds (mostly nodes are red dot i.e. dead)

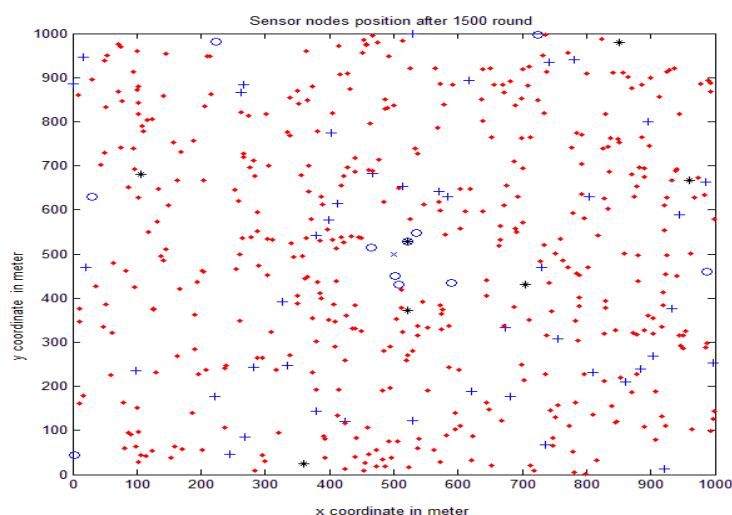
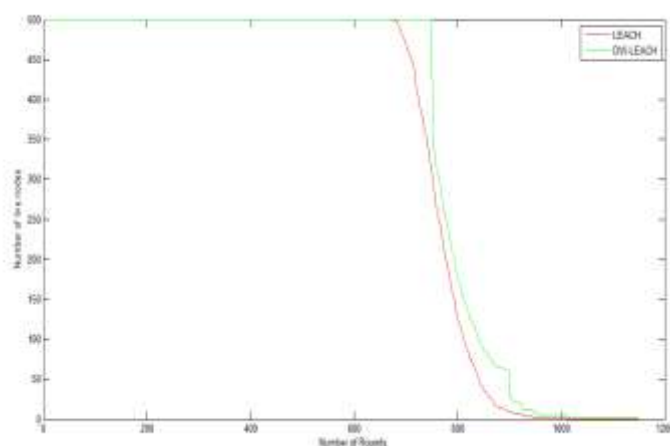


Figure 4: Number of Rounds vs. Number of Alive nodes



B. Number of Alive Nodes

It can be seen that nodes remain alive for a longer time (rounds) in proposed DW-Leach than Leach. Figure 4 describes the comparison between the Leach and DW Leach protocols in terms of number of alive nodes. Initially all nodes have energy, thus each node participates in the network. After some time (800 rounds) Leach protocol nodes die due to empty energy, but DW Leach protocol remains energy rich due to its weight calculation. The node having higher energy remains cluster head until it reaches its threshold value.

C. Network Lifetime

The network lifetime is directly proportional to the number of nodes in the network. Initially figure 5 shows the increase in the network lifetime as the number of nodes increases. But after 300 nodes (in 100m x 100m) both protocols' network lifetime (number of rounds) decreases. DW Leach performs better in terms of number of rounds. It has 10 to 20% higher lifetime as compared to Leach.

Figure 5: Network Lifetime vs. Number of nodes

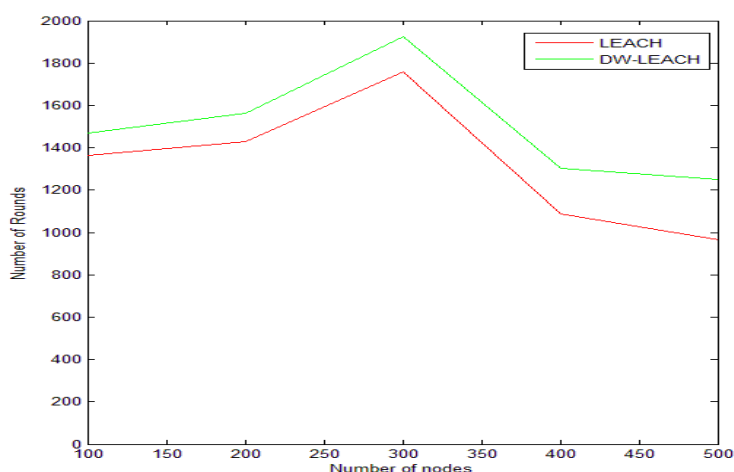
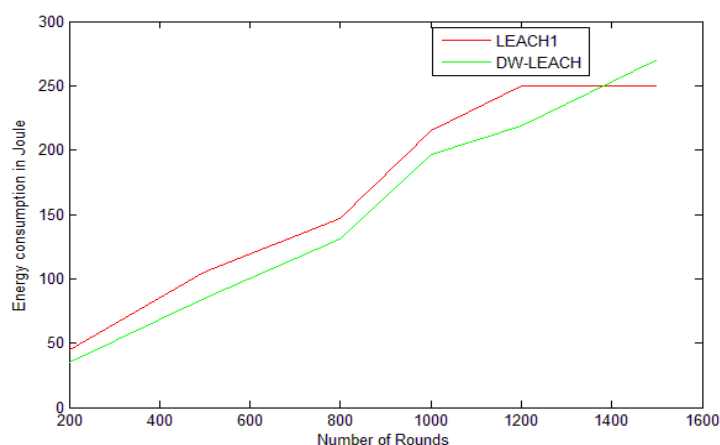


Figure 6: Number of rounds vs. total network energy consumption



D. Energy Consumption

In the proposed algorithm DW Leach the energy consumed is reduced since only activated nodes in the network are involved in network and rest of nodes remain in standby mode. Figure 6 shows the graph comparing the energy consumption between Leach and DW Leach.

V. Conclusions

Simulation results show that Distributed Weighted Leach performs well over Leach protocol. This routing management guaranteed network connectivity, efficient routing and maintains network performance in WSN with low energy consumption. The DW Leach suffers initial setup delay but after that it outperforms over many hierarchy routing schemes for WSN.

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