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AN AD HOC LEACH PROTOCOL WITH COMPACT DATA REDUNDANCY FOR WIRELESS SENSOR NETWORKS

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ABSTRACT

WSN is a set of connected tiny devices (sensor nodes) with limited energy resource. WSNs have ability to extract the information from the harsh and hostile environment without human interaction. Once, WSN is deployed, it is impossible to recharge or replace the energy resource due to inaccessibility of nodes. So, network lifetime and fault tolerance are critical parameters. It’s become very important to handle energy resource carefully as it plays vital role in prolonging the network lifetime.

To achieve the fault tolerance, redundancy has been created in terms of number of nodes. The nodes close to each other send most correlated data to the sink. Transmitting and processing of correlated data results in wasting the energy that shortens the lifetime of WSNs. Since WSN is energy constrained, energy must be utilized in an efficient way so that most of the energy is dissipated in doing useful work.

In this work, we propose LEACH- CDR (Low Energy Adaptive Clustering Hierarchy-compact data redundancy) protocol. It is improvised LEACH protocol. The key idea is to group two closest nodes (termed as neighbour nodes), allowing only one to transmit to the cluster head (CH) within the network. The proposed method is useful when sensor nodes are deployed closer and density is high. Comparison with the classical LEACH shows that the proposed method improves the network lifetime and energy efficiency. The scheme reduces the redundant data to be sent from nodes to cluster head.

KEYWORDS: Analog to Digital Converter, Automatic Repeat Request, Carrier sense multiple access, WSN.

INTRODUCTION

Wireless sensor networks are the set of tiny nodes (Sensor nodes or Mote) that are capable to map the physical quantity from the environment into the measurable quantity **(Heinzelman, 2000).** Sensors are the devices that produce a measurable response to a change in a physical phenomenon like temperature, humidity, pressure, motion etc. It is a sensing technology where compact devices called sensor nodes or motes deployed in a remote area that detect and capable to capture the physical parameters easily, process data and transmit sensed information to the base station (BS). These devices can simply be represented by an equation: Sensing + Processing Unit + Radio = Support for thousands of applications (**Hill, 2003**). These small sized sensor nodes or motes in WSNs are capable of sensing, gathering, processing data and share the collected information with other neighbor nodes in the network, via wireless medium e.g. low radio frequency (RF) channel. WSN nodes are equipped with limited battery power which is deployed to perform the sensing task in a remote area. Due to the inaccessibility of nodes in some cases, the lifetime of WSNs are expected for a long period, even years.
The extremely important issues in WSNs are the network lifetime and data availability due to their deployment in hard-to-reach environment. It is very difficult to recharge or replace the battery of sensor nodes due to their deployment in harsh or hidden environment. It is also not possible to fit a large battery into a sensor node, since nodes are too small in size. As sensor nodes cannot accommodate a large battery, this make sensor node extremely energy constraint. For instance total energy stored in a smart dust mote is only 1J (**Pottie and Kaiser, 2000**). Having only such a small amount of energy is the only power supply to a sensor node, it is only a vital factor in determining lifetime of the sensor networks. Due to energy constraint, most of the research works

therefore have a common concern of minimizing energy consumption in WSN. The network should be energy efficient, fault tolerant, and provide the real-time communication as well as automatic and effective action in crisis situations.

PROBLEM FORMULATION & OBJECTIVE

In WSNs, the most critical issues are data availability and energy consumption. It is required to deploy the redundant nodes to monitor the specific field so that we get the data regularly even if some of the nodes get failed. Due to this redundancy of nodes, data sent to the particular cluster head (CH) by the member nodes is highly co-related. After receiving data from all the member nodes, CH aggregates and sends the information to the base station. Most of the redundant data is eliminated within clusters. In WSNs, each node is provided with limited range and covers limited physical area. It has established that most of the energy is consumed in data reception and transmission **(Tiago *et al.*, 2006). Heinzelman *et al.* (2000)** proposed a hierarchical routing protocol known as Low Energy Adaptive Clustering Hierarchy (LEACH) protocol, that optimizes energy cost and improve reliable transmission on a WSN. LEACH protocol present an elegant solution to the data collection problem, and LEACH achieves a factor of 8% improvement compared to direct transmissions (**Lindsey et al., 2002a).** The principle concept in LEACH was arranging nodes into clusters from which one cluster head per cluster transmit data to the base station on behalf of others. The proposed work attempt to further optimize energy cost from a sensor network during data gathering.

The main objective is to extend LEACH routing algorithm to improve the energy efficiency by reducing data redundancy. We will follow the objectives listed below to reach our goal.

I. To study hierarchical routing protocols, and analyze LEACH in particular.
II. To implement modified LEACH protocol on MATLAB.
III. To compare and validate the effectiveness of proposed improvement.

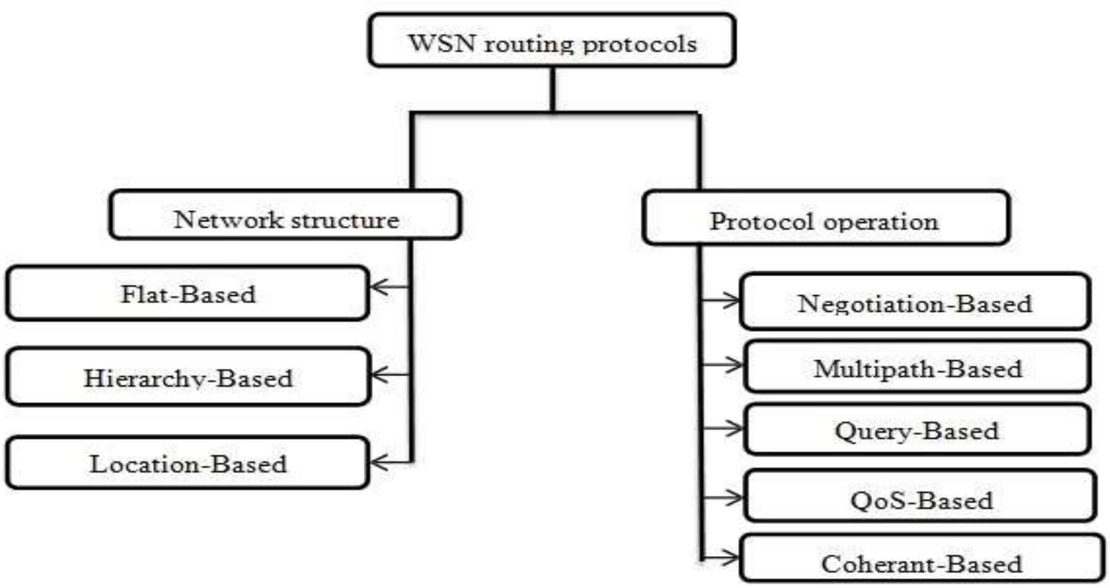

***Fig. 1.1 Classification of WSN routing protocols** (**Acs and Buttyan, 2007**).*

LEACH DESCRIPTION

The LEACH (Low-energy Adaptive Clustering Hierarchy) protocol presented by **(Heinzelman et al., 2000), (Heinzelman et al., 2002)** is the first hierarchical routing protocol which based on clustering. It is a distributed protocol as there is no central authority for cluster formation. LEACH organizes the network into clusters and selects one node as a cluster head in each cluster. Other nodes in a cluster are called member nodes. These member nodes have to send their sensed data to the respective cluster head (CH) rather to send to BS directly.

- It generates the TDMA slot for each member nodes.
- Once, it collects data from all the member nodes. It performs data aggregation on the collected data.
- Finally, it sends the aggregated data to the CH on behalf of other nodes.

Authors made some assumption during this work as given below:

- Base station is immobile and situated far from the sensor network.
- Network is homogeneous means all nodes in the network have the same initial energy.
- Nodes are energy constrained.
- All member nodes are expected to have data all the time.
- All nodes are synchronized.

The key features of LEACH protocol is as follows:

- Distributed and localized coordination and control for cluster set-up and operation.
- Randomized rotation of cluster heads in each round.
- Local processing of data to reduce global communication.

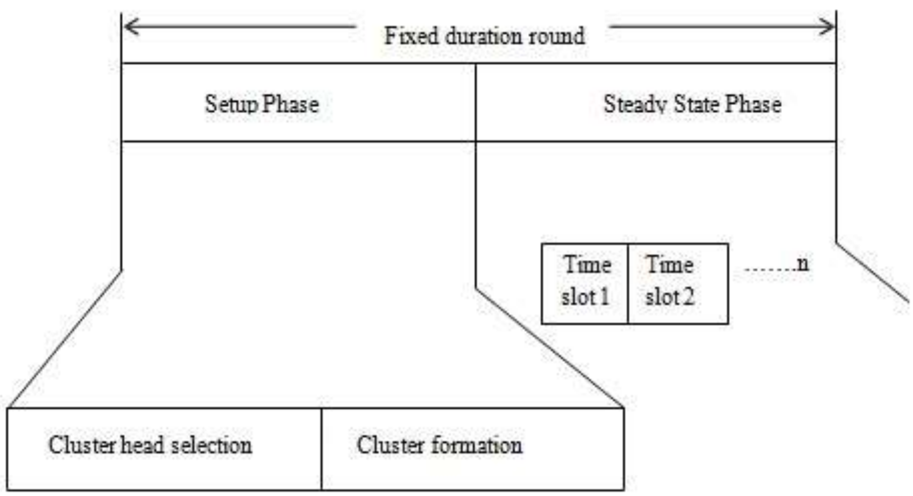

Fig. 1.2: Working of LEACH Protocol.

PROPOSED METHODOLOGY

During data transmission, each member node has data to send to the CH in their allotted TDMA slot. In classical LEACH protocol during this transmission, non-cluster head nodes send their data to the CH irrespective to the other nodes close to each other in the cluster. Sensor nodes which are situated very close sense the same phenomenon and send it to the CH. It wastes the energy of member nodes in terms of sending same data and energy of CHs to receive and perform aggregation on the data. We proposed a method to reduce some data redundancy during data transmission within cluster. To maintain the monitoring quality which is measured by the number of data packets send to the sink, we assume that only two nodes can be the neighbour of each other so that at least one data packets must be sent to the CH from the area of neighbour nodes. It does not allow much reduction in data packets send to the CH. Our algorithm reduces the number of data messages received at the CH. Once the CHs broadcast the ADV messages, member nodes choose one of

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the CH based on signal strength and send the join-REQ message which is a short message containing the node ID and CH's ID back to the CH. In our approach we add a new field in join-REQ message that indicate node position. Fig. 1.3 and Fig 1.4 show the join-REQ messages in LEACH and proposed method respectively.

Node's ID	CH's ID

Fig. 1.3: join-REQ message format in LEACH.

Node's	ID Node's position	CH's ID

Fig. 1.4: join-REQ message format in proposed method.

After receiving message from all the member nodes, CH finds the closest nodes based on (x, y) position and prepares the single TDMA schedule for each pair of neighbour nodes transmit the schedule to member nodes containing CH's ID and neighbour nodes ID. Nodes which have no neighbour, sends their data in the same manner as in LEACH. Fig. 1.5 describes the formation of pair of neighbour nodes.

In Fig. 3.8, we consider only two clusters, first cluster having one C1 as CH node, and M1-M5 as the member nodes, second cluster having C2 as CH node and M6-M12 as member nodes.

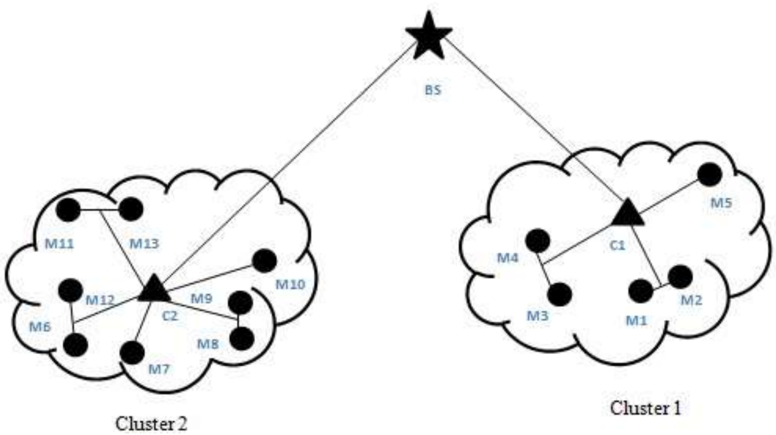

Fig. 1.5: Neighbour node formations.

RESULT AND DISCUSSIONS

The observation and findings of various simulations conducted in MATLAB. The experimental observations recorded, analyzed and discussed systematically in the subsequent sections for different combinations of variables.

To evaluate performance of LEACH and proposed method, we have used the following perfrmance metrics.

Energy consumption: This is the amount of energy consumed by sensor nodes during the period of network lifetime in transmitting, receiving, idle and sleep. The unit of energy consumption used in the simulations is Joule. We further analyze the energy consumption in two aspects: *Energy consumption by CH* is the amount of energy consumed by the CHs during data gathering within the respective clusters. *Energy consumption by member nodes* is the amount of energy dissipated by the member nodes in order to transmit the sensed data to respective CH.

Packet received at CH: It is the number of data packets successfully received at the destination nodes (CH) sent by source nodes.

Network lifetime: This is defined as the minimum time at which maximum number of sensor nodes will be dead or shut down during a long run of simulation.

Table 1.1 Simulation parameters used.

Parameters	Value
Number of nodes	100
Network size	100 × 100
BS location	(50, 175)
E_{Tx}	50 nJ/bit
E_{Rx}	50 nJ/bit
$€_{fs}$	10 pJ/b/m^2
$€_{mp}$	0.0013 pJ/b/m^4
E_{DA}	5 nJ/b/signal
Data packet size	500 bytes

CONCLUSION

In this study, we focus on extending the wireless sensor networks lifetime. To achieve our goal, we study various design issues in WSNs followed by the examination of routing protocols, specifically hierarchical routing protocols and analyze LEACH in particular. Routing protocols have great impact in determining the network lifetime since most of the energy is consumed in sending and receiving of data.

This work is carried out with the objectives to study the Low Energy Adaptive Clustering hierarchy (LEACH) protocol and extending the LEACH protocol to utilize the energy of sensor nodes efficiently that leads to longer lifetime of WSNs. During this work, MATLAB is used for simulation purpose. We propose an improvised LEACH protocol with reduced data redundancy (LEACH-RDR) and for that simulation results are obtained. To validate our proposed method, obtained results are compared with classical LEACH protocol in MATLAB. The proposed approach is also applicable for other LEACH based variants. On the basis of results obtained, following conclusions are made:

1. ***Network lifetime of system is improved.*** It is measured by the total number of rounds that a network completes successfully. The proposed approach extends the lifetime by 20%, 19%, 22% , 23%, 26% , 21% , 26% , 25% , 33% , 25% and 26% in terms of FND, 10% nodes die, 20% nodes die, 30% nodes die, 40% nodes die, HNA, 60% nodes die, 70% nodes die, 80% nodes die, 90% nodes die, and LND respectively; each having 0.25 j of energy per node. In a nutshell, proposed approach extends the network lifetime by 24% at an average. The same results were also obtained for 0.5 j and 1.0 j energy per node.

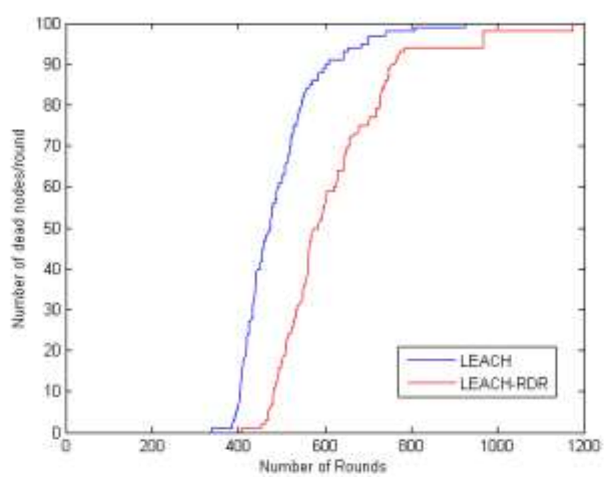

Fig. 1.6: No. of dead nodes per round on 0.25 j/node energy.

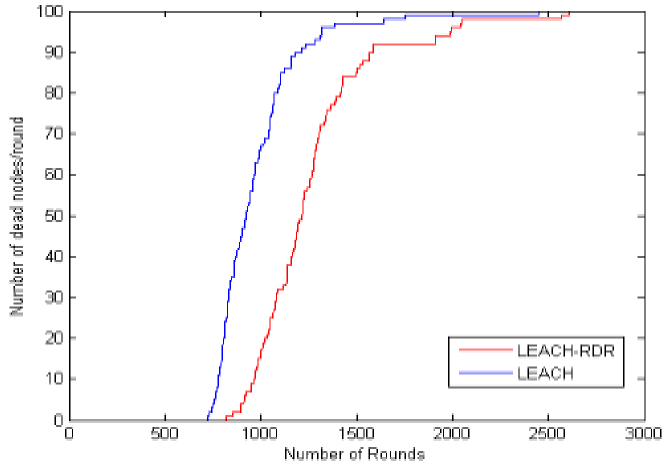

Fig. 1.7: No. of dead nodes for 0.5 j/node energy.

2. ***Energy dissipation is decreased at member nodes and CH***. Energy is consumed by CH node in doing the cluster operations such as receiving & aggregating the data and by member nodes in transmitting the sensed data to the CH. After half-life of the network, energy dissipation within the clusters in proposed method is more than traditional LEACH. It is due to the early death of nodes in traditional LEACH. Where as in the proposed method nodes remain alive and functional after half-life of the network.

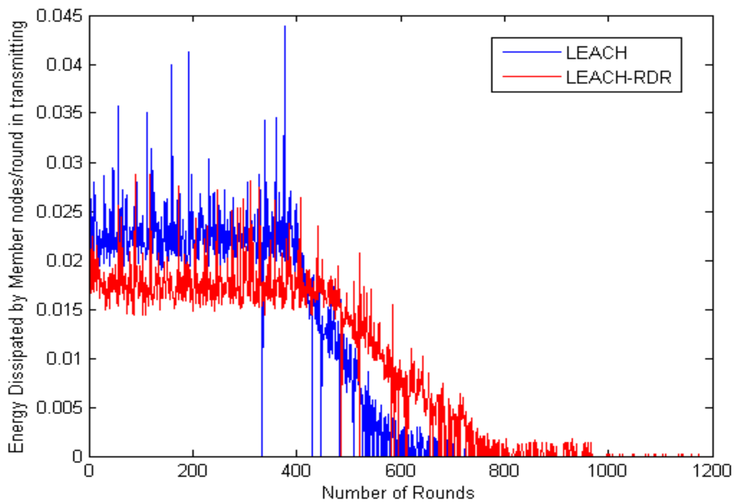

Fig. 1.8: Energy dissipation by member nodes on 0.25 j/node energy.

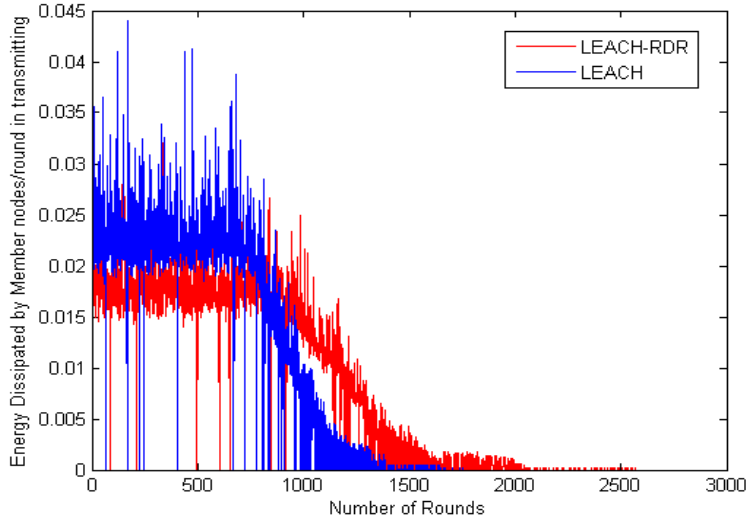

Fig. 1.9: Energy dissipation by member nodes on 0.5 j/node energy.

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