An improved modified LEACH-C algorithm for energy efficient routing in Wireless Sensor Networks

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***Abstract*—Wireless Sensor Network (WSN) is mainly characterized by its limited power supply. Hence, protocols designed for WSNs should be energy efficient. Cluster based routing helps to improve the network lifetime. Centralized Low-Energy Adaptive Clustering Hierarchy (LEACH-C) is an energy efficient cluster based routing protocol that has shown improvement over Low Energy Adaptive Clustering Heirarchy (LEACH) protocol. A modified LEACH-C (LEACH-CM) protocol is proposed in this paper that considers the distance between the selected cluster head (CH) and a member node; and the distance between the member node and Base Station (BS) to transmit data by a member node to CH or BS. The proposed approach selects number of CHs on the basis of alive nodes in the network, rather than considering total nodes in the network. Simulation results show that LEACH-CM outperforms to LEACH-C, and improves the network lifetime.**

***Index Terms*—Wireless Sensor Network (WSN), Energy efficient clustering, Centralized LEACH (LEACH-C), LEACH-CM**

I. Introduction

WIRELESS Sensor Network (WSN) consists of a large number of sensor nodes, wherein each node has a limited processing capability, a small amount of memory, a transceiver for wireless communication and a power source to provide required energy to various components of a sensor node for their proper functioning. Numerous difficulties have been acquainted to implement protocol stack for WSNs as each WSN node has size, energy, computational and storage constraints. WSN should function properly for a longer duration to provide required services as per the need of the underlying application, and for that the protocol designed for WSN should be energy efficient because it is difficult to replace or recharge batteries of a WSN node [1]. Many techniques are developed to enhance the network lifetime of WSN such as sleep scheduling, MAC protocols, routing protocols, etc.[2].

This paper focuses on cluster based routing schemes as it helps to enhance the lifetime of WSNs. In this technique, nodes are elected as CHs from a subset of nodes which are eligible to become CH. The remaining nodes act as member nodes for the elected CHs. Each member node selects nearest CH to save own's energy, and transmits its data to the selected CH. CH performs data aggregation on the data received from its member nodes. This method of data transmission is energy efficient as the energy required for communication is high compared to the energy required for computation [3], [4], [5]. The role of CH should be on rotational basis to avoid premature death of CHs. This is required because many activities are performed by each CH, including cluster head announcement, an announcement of data transmission schedule to the member nodes, reception of data from member nodes, data aggregation, transmission of aggregated data to BS etc.

Each clustering protocol can be classified as distributed protocol, semi-centralized protocol or centralized protocol. This classification is based on the cluster head election method used by a particular protocol. There are different techniques to classify routing protocols, and detail discussion of such techniques can be found in [6], [7], [8].

Low Energy Adaptive Clustering Hierarchy (LEACH) [9] is pioneer protocol for cluster based routing technique. It is distributed energy efficient clustered routing protocol. However, due to stochastic nature, it fails to maintain the desired number of CHs during each round. It is likely possible that during a particular round more than one CH may sit nearby [10], which lowers the improvement in the network lifetime. CVLEACH [10] overcomes the problem of LEACH by creating non-overlapping cluster regions as far as possible. However, due to stochastic nature of both protocols, LEACH and CVLEACH, strong candidates may not be selected as CHs during each round. This can be overcome by using centralized clustering scheme, and it is discussed in section II.

The rest of the paper is organized as follows: Centralized clustering schemes are discussed in section II; Modified LEACH-C (LEACH-CM) is described in section III; Simulation parameters and result discussions are given in section IV; and concluding remarks are given in section V.

II. Related Work

LEACH-Centralized (LEACH-C) [11] is a centralized clustering algorithm. In this protocol, each node sends its energy information after every round. After getting energy information from all nodes, BS calculates the average energy of the network. A node works as a member node if its energy is lower than the average energy of the network. BS finds the desired number of CHs using simulated annealing algorithm

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from the set of nodes whose energy is higher than the average energy of the network. BS announces CHs for the current round. Each recipient node compares its node ID with the node IDs received from BS, and works as a CH for the current round if a match is found, otherwise works as a member node.

Base Station Controlled Dynamic Clustering Protocol (BCDCP) [12] is a centralized clustering technique that improves the network lifetime by balancing load on the CHs i.e., each CH serves approximately equal number of member nodes. Authors have proposed partition-based LEACH (pLEACH) in [13]. Like LEACH-C, it is a centralized clustering scheme, in which BS partitions entire network into the required number of sectors, and the highest energy node from each sector is elected as CH. A centralized cluster formation and distributed CH selection based algorithm is proposed in [14] that divides network into energy balanced clusters and selects optimal number of CHs to enhance the network lifetime.

A genetic algorithm based LEACH-C routing protocol is proposed in [15], wherein a method is proposed for representation of chromosomes. In this protocol, fitness function is derived using features, which is based on energy information of nodes. Low Energy Adaptive Clustering Hierarchy protocol with K-means and MTE (LEACH-CKM) [16] is an extension of LEACH-C protocol. It uses K-means classification algorithm for grouping nodes into clusters and Minimum Transmission Energy (MTE) algorithm to transmit data from remote nodes. Authors in [17] have proposed an algorithm to estimate energy of the nodes to reduce overhead of transmission of nodes' energy level to BS during each round, and thus improves the network lifetime. All these protocols have shown network lifetime improvement over LEACH-C. However, the modifications proposed in the paper by extending LEACH-C protocol, which is termed as LEACH-CM, is yet not proposed by any one till date to the best of our knowledge.

III. Modified LEACH-C Algorithm (LEACH-CM)

In LEACH-C, each node sends its coordinate values and energy information to the BS. The BS uses this information to calculate the average energy of the network. A set of nodes having higher energy than the average energy of the network, is eligible to become CH for the current round. LEACH-C finds the desired number of CHs from the set of eligible nodes using simulated annealing algorithm.

In the proposed approach, LEACH-CM, the CH selection and cluster formation methods are same as LEACH-C with two modifications, discussed later in this section. The BS collects information about the coordinates and energy information from all nodes, and calculates the average energy of the network. The set of nodes having energy higher than the average network energy are eligible to become CHs for the current round. The desired number of CHs are identified by BS using simulated annealing algorithm. In the proposed approach, each sensor node calculates Euclidean distance between itself and BS while sending its coordinate values and the current energy information to the BS. This information is saved in the sensor node's memory as BS_{dist}.

The first modification in the proposed approach, LEACH-CM is as follows: Once the CHs are identified by BS, each CH announces that it is a CH for the current round to the other nodes in the network which are in communication range of the CHs. A set of recipient nodes which are non-CH nodes for the current round, i.e. member nodes for the current round calculate their Euclidean distances from the CH(s) from which they have received CH announcement message(s). This distance is called as CH_{dist}. A member node transmits its data to the BS if BS_{dist} is less than the CH_{dist}, otherwise it transmits its data to the selected CH. It is possible in topology, where BS is located in the center of the node deployment area, and during a particular round a node is nearer to the BS compared to CH. The same is also possible even if BS is outside and closer to the node deployment area. This proposed modification is an extension of LEACH-C protocol, and it is also used in LEACH [9].

The second modification which is proposed in LEACH-CM is as follows: LEACH-C gives optimal performance when the desired percentage of CHs (p) is set to 5% of the total nodes (N). In LEACH-C, BS always selects 5% of the total nodes as CHs during each round. However, nodes die over a period of time. Hence, LEACH-CM selects 5% of alive nodes ($AN = N - Dead$) as CH. Also, LEACH-CM takes the ceil value of the total number of CHs ($CH_n = AN * p$) if CH_n is less than one, otherwise it takes the floor value of CH_n. Apart from these two modifications, LEACH-CM follows the same assumptions that of LEACH-C [11].

IV. Simulation parameters and result discussions

A. Simulation parameters

Simulations are carried out using Network Simulator [18]. To test the performance of the proposed approach LEACH-CM against LEACH-C, a network is created with a random node deployment of varying node density between 50 to 200 nodes. These nodes are deployed in an area of 100m x 100m. Each node has 2J of initial energy. CH re-selection interval is set to 20 seconds. Each simulation is carried out for 3600 seconds. Simulation parameters are given in Table I.

TABLE I
Parameters used for Simulation Runs

Parameter Name	Value
Node Deployment Area	100m X 100m
Number of Nodes (Excluding BS)	1) 50 2) 100 3) 200
Initial Energy/Node	2 J
Round duration	20 seconds
Simulation Stopping Criteria	3600 seconds
Packet Size	4000 bits
Percentage of Cluster Heads	5% [11]
Proposed Approach Compared with	LEACH-C [11]

B. Simulation metrics and result discussions

- **Network Lifetime:** Network lifetime is measured using three metrics: First Node Dies (FND), Half of the Nodes Alive (HNA) or Half of the Nodes Die (HND) and Last

Node Dies (LND) [19], [20]. FND is also referred as stable period [21]. The result for FND, HND and LND is shown in the Figures 1–3 respectively. It can be seen from the figures that the proposed approach improves the network lifetime, including stability period. Alive nodes

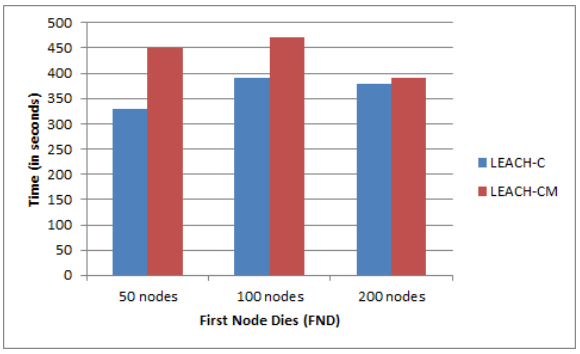

Fig. 1. First Node Dies (FND)

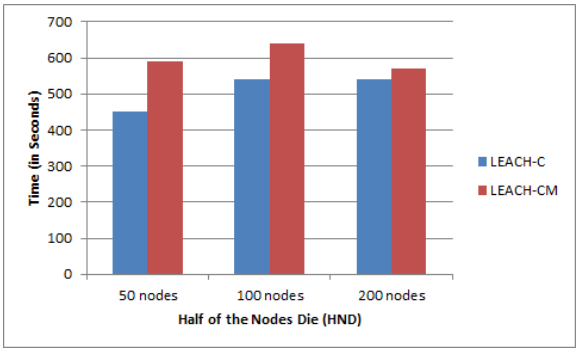

Fig. 2. Half of the Nodes Die (HND)

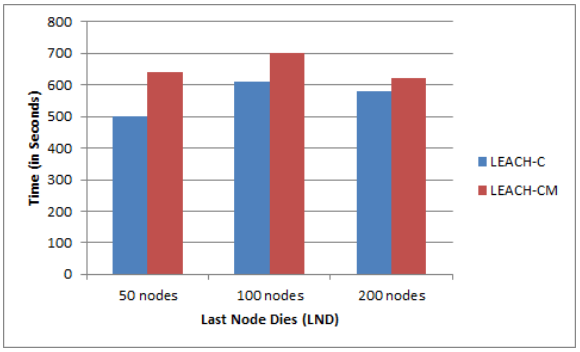

Fig. 3. Last Node Dies (LND)

over a period of time for a network with different node densities is shown in the Figures 4–6. These figures confirm that the proposed approach LEACH-CM outperforms to LEACH-C protocol, and at any point of time LEACH-CM has higher number of alive nodes as compared to LEACH-C. Energy consumption over a period of time for a network with different node densities is shown in the Figures 7–9. These figures confirm that at any point of time, the proposed approach LEACH-CM has lower energy consumption as compared to LEACH-C.

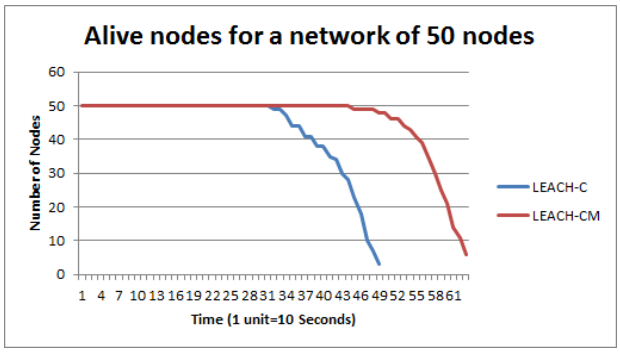

Fig. 4. Alive nodes over a period of time for a network of 50 nodes

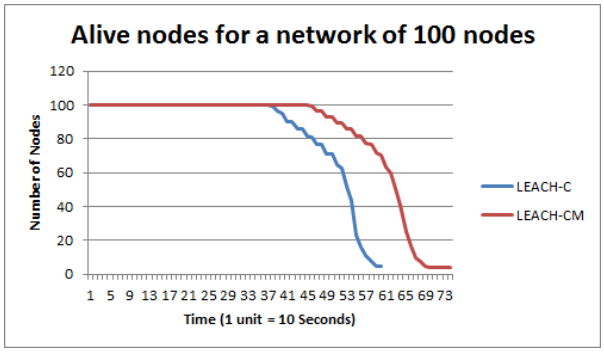

Fig. 5. Alive nodes over a period of time for a network of 100 nodes

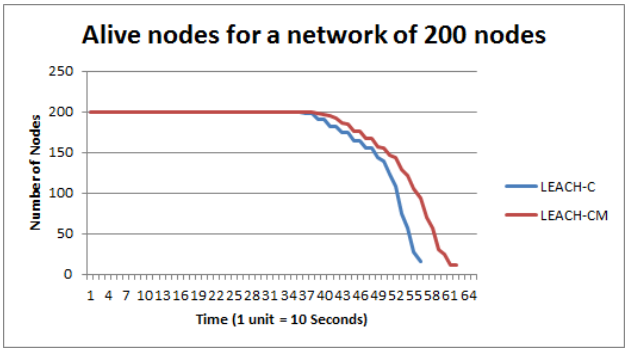

Fig. 6. Alive nodes over a period of time for a network of 200 nodes

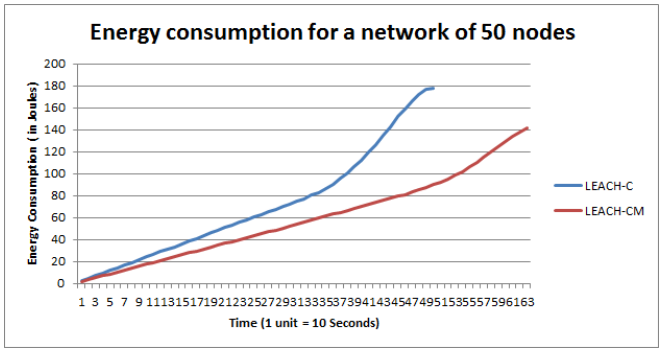

Fig. 7. Energy consumption over a period of time for a network of 50 nodes

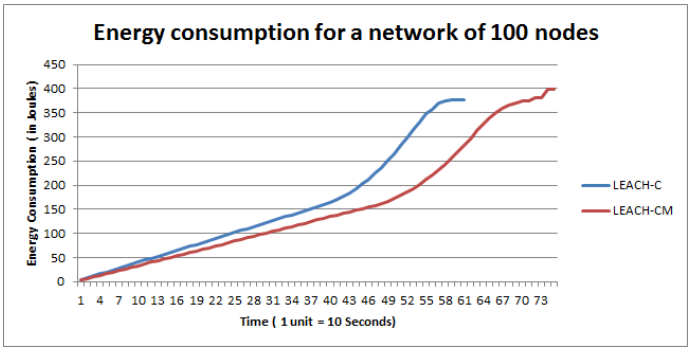

Fig. 8. Energy consumption over a period of time for a network of 100 nodes

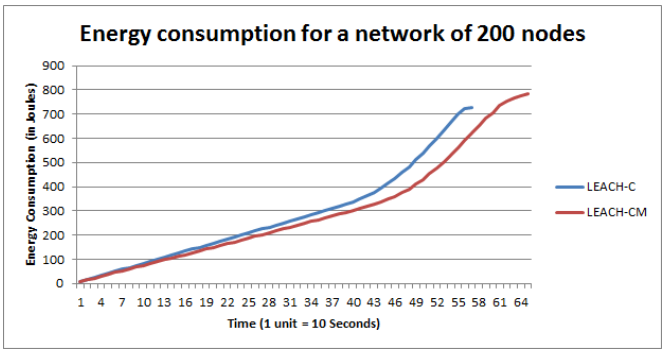

Fig. 9. Energy consumption over a period of time for a network of 200 nodes

- **Number of Packets:** It indicates number of packets received by BS from the network. Number of packets received by the BS from the network is shown in the Figures 10–12. It confirms that higher number of packets are received by the BS for LEACH-CM protocol as compared to LEACH-C protocol for varying node densities. Higher the number of packets received indicate lower die rate of the nodes and consumption of energy [22]. Hence, Figures 10–12 are inline with the Figures 4–6.

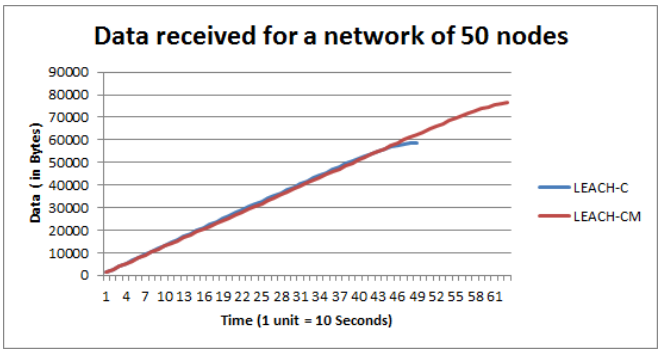

Fig. 10. Data received by BS over a period of time for a network of 50 nodes

- **Average energy consumption/node:** It indicates the average energy consumption per node. Lower the value of average energy consumption per node, better is the network lifetime. It is a very important parameter to prolong the network lifetime [23]. Average energy consumption per node is shown in the Figure 13. It can be concluded from the figure that the proposed approach LEACH-CM helps to minimize the average energy consumption per node as compared to LEACH-C, and thus improves the network lifetime.

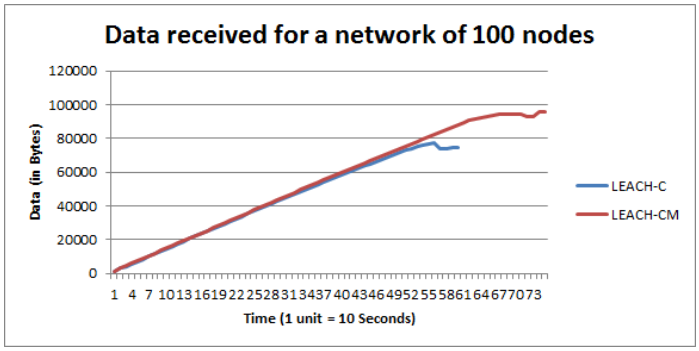

Fig. 11. Data received by BS over a period of time for a network of 100 nodes

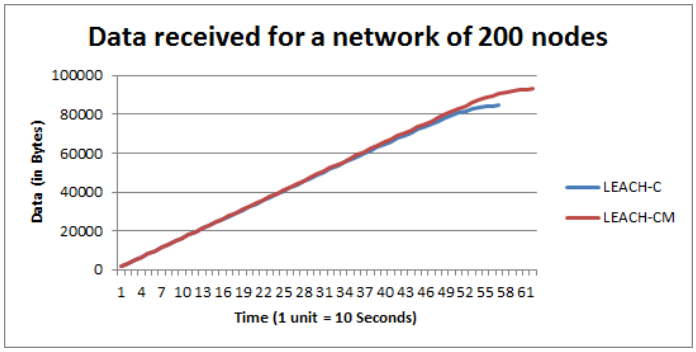

Fig. 12. Data received by BS over a period of time for a network of 200 nodes

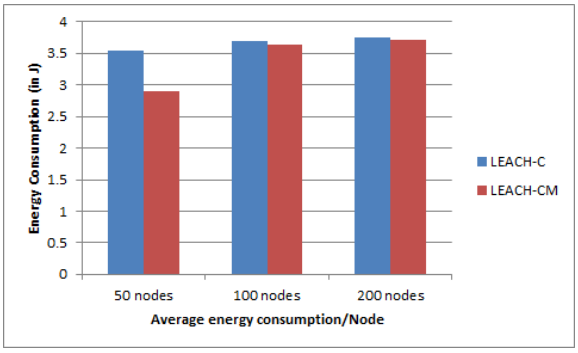

Fig. 13. Average energy consumption/Node

V. Concluding Remarks

LEACH-CM protocol is proposed in the paper by extending LEACH-C protocol with two modifications. The first modification is that non-CH nodes decide to transmit their data directly to BS or through CH whichever is energy efficient, and the second one is to select number of CHs on the basis of alive nodes in the network, rather than considering total nodes in the network. The first approach allows individual member node to save its energy by transmitting to either BS or CH whichever is nearest to it. The second approach reduces the number of CHs

over a period of time as dead nodes increase in the network. Both of these approaches help to reduce the energy expenditure of a network. It concludes that the proposed approach LEACH-CM is energy efficient and improves the network lifetime, including stability period. The effectiveness of the proposed approach has been verified through simulations. LEACH-CM also delivers higher number of packets to BS compared to LEACH-C.

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