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An Improved LEACH with Location Based Cluster Head (LBCH-LEACH) using Two-Hop Communication

Mitra Bhushan
Department of Information Technology, Rajkiya Engineering College, Azamgarh (U.P.), India

Abstract— Wireless sensor networks are energy restraint networks. Energy efficiency, to extend the network for a longer time is critical issue for wireless sensor network protocols. Clustering is an effective technique to optimize the energy of sensor nodes in wireless sensor networks. LEACH is a fully distributed clustering method that picks cluster head randomly from the nodes. In LEACH, though node death is random but it is perceived that border area nodes die first. But critical field surveillance application needs border nodes to function for much longer time period. In this paper, we focused on cluster head selection and implemented with LEACH. Proposed approach makes some nodes cluster head which have more residual energy and minimum distance from base station (as there is no certainty in LEACH about the location of CHs) in next round and they use two-hop communication.

Simulation results show that LBCH-LEACH implement the above discussed improvements effectively and efficiently and prolongs the network lifespan over LEACH.

Keywords— Wireless Sensor Network, LEACH, Network Lifetime, LBCH-LEACH.

I. INTRODUCTION

A Wireless Sensor Network (WSN) contains a large number of small nodes with sensing, computation, and wireless communications capabilities [1]. The sensors attached to the nodes measure ambient conditions related to the environment in which they are deployed, process the data and transmit them to the base station. Besides, sensor nodes are equipped with a radio transceiver or other wireless communications device, a small microcontroller and an energy source. Since in most WSN applications the energy source is a battery and energy plays an important role in such applications because sensor nodes are generally constrained with limited energy. Therefore, preserving the consumed energy of each node is an important goal that must be considered when developing a routing protocol for WSN. In general, routing in WSNs [3] can be divided into flat, hierarchical, and location based routing depending on the network structure. Hierarchical routing is also known as cluster based routing because in this type of routing sensor nodes are grouped together and form clusters. In each cluster, a higher energy node is
assigned as a head-node and known as cluster-head (CH). The CH acts as the leader of their own cluster having the responsibilities like collection and aggregation the data from their respective clusters and transmitting the aggregated data to the Base station (BS) [5] [18]..

The most used hierarchical routing protocols in WSN are LEACH, PEGASIS, TEEN, EECS, HEED etc [13]. LEACH is the simplest routing protocol among them in WSN whose primary objective is to share the energy load equally among all sensor nodes in the network and prolong network life time. In this paper we propose an improved version of LEACH protocol which is more energy efficient by taking less radio communication distance than original LEACH.

LEACH (Lower Energy Adaptive Clustering Hierarchy) protocol is a grade routing protocol. Paper [4] introduces LEACH protocols in detail. Paper [6] presents a modified protocol, but it is still faulty and the performance matrixes are complex.

II. LEACH PROTOCOL

A. Low Energy Adaptive Clustering Hierarchy (LEACH)

LEACH is one of the most common clustering algorithms [3] for WSNs[4]. 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 accumulation are local to the cluster. LEACH forms clusters by using a distributed algorithm, where nodes make independent 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 regulates its cluster

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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.

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

where p is the desired percentage of cluster heads, r the current round and G is the set of nodes which have not LEACH consists of two phases: Set up phase (cluster formation phase) and the steady-state phase.

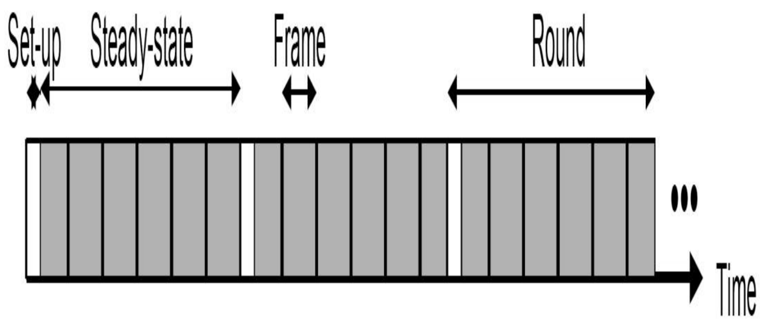

Figure 1: Timeline of Phases

1) *Set-up Phase:* First step is cluster head selection. At the first of each round, each node selects a random number between 0 and 1 and compares it to the threshold *T* shown in formula. If the selected random number is less than the threshold *T*, the node would be selected as a cluster head for the current round. Assuming there are *N* nodes in the field with *k* number of cluster heads, LEACH ensures that all the nodes become cluster heads only once in every (*N/k*) round.
2) *Steady State Phase:* The steady state phase is the data transmission step. During this phase, nodes in each cluster send their data based on the allocated transmission time to their local cluster heads. To reduce the energy dissipation, the receiver of all non-cluster head nodes would be turned off until the nodes' defined allocated time. After receiving all the data from the nodes, the cluster head aggregates all the data sent from the member nodes into a single signal and transfers it to the base station.

B. *LEACH* is the simplest hierarchical protocol which holds clustering approach and if employed properly, can lead to energy efficient networking in WSNs [8]. But still these substantial energy savings, there raises some issues as described below:

1) LEACH offers time slots for every node in the network to transmit data to CHs even though some nodes might not have data to transmit [3][4].
2) LEACH is appropriate for small size network because in LEACH it adopts that all nodes can communicate with each other and are able to touch sink which is not true all the time for large size network [1].
3) In LEACH periodic dynamic clustering follows after the completion of each round that moves significant overhead which may balance energy gain derived by the clustering option [3].
4) In LEACH there is no method to guarantee that the elected CHs will be evenly distributed over the network. So all cluster-heads might be concentrate only in one segment of the network .
5) LEACH involves that all nodes are constantly listening which is not convincing in a arbitrary distribution of the sensor nodes [3] .

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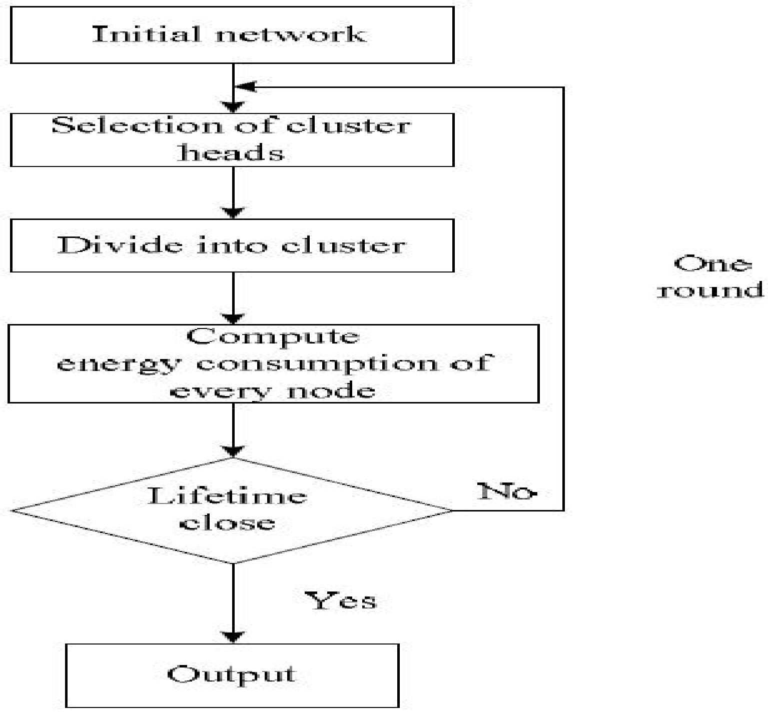

Figure 2: Flow Chart of LEACH Protocol

Meanwhile, LEACH has many disadvantages, many researchers have been done to make this protocol executes better. Some of these improvements are briefly described in the following points

III. RELATED WORK AND LITERATURE REVIEW

A. LEACH-C

W. B. Heinzelman et al. proposed application oriented protocol design for WSN which is known as LEACH Centralized (LEACH-C) [8]. It is advancement over the LEACH protocol. LEACH-C, uses a integrated clustering algorithm and the similar steady-state phase as LEACH. LEACH-C is more efficient than LEACH because LEACH-C delivers about 40% more data per unit energy than LEACH.

B. LEACH-F

It is the improved version of LEACH protocol with stable clusters and revolving cluster heads [7]. Here clusters are designed once and fixed, and the cluster-head’s position rotates among the nodes within the cluster. As clusters are formed only once so there is no set-up overhead at the beginning of each round. LEACH-F does not allow new nodes to be added to the system and do not adjust their behavior based on nodes dying.

C. E-LEACH

Energy-LEACH (E-LEACH) [9] improves the CH selection procedure in LEACH. It makes residual energy of node as the main metric which decides whether the nodes turn into CH or not after the first round. The operation of E-LEACH is divided into rounds, in the first round, every node has the same probability to turn into CH, that mean nodes are randomly selected as CHs, in the next rounds, the residual energy of each node is different after one round communication and taken into account for the selection of the CHs. That mean nodes have more energy will become a CHs rather than nodes with less energy.

D. V-LEACH

V-LEACH [10] is a new version of LEACH Protocol which aims to reduce energy consumption within the wireless network. The main concept behind V-LEACH is that besides having a CH in the cluster, there is a vice-CH that takes the role of the CH when the CH dies. By doing this, cluster nodes data will always reach the BS; no need to elect a new CH each time the CH dies which will extend the overall network life time.

E. H-LEACH

Hierarchical LEACH (H-LEACH) [3] is proposed by Wairagu G. Richard considering the concept by minimizing the communication distance between nodes to conserve energy. It employs the same clustering approach as LEACH during initial phases and later it extends LEACH by further clustering the cluster heads and nominates one of the cluster head, which then acts as the Master Cluster Head (MCH), to forward data to the base station. In H-LEACH finally only one MCH is involved to transmit all compressed data to base station, so central point of failure situation may occur when the MCH will be dead.

F. Multi-hop LEACH

When network's diameter is increased outside a certain level, distance between CH and BS is increased enormously. This scenario is not fit for LEACH routing protocol [9], in which BS is at single-hop to CH. In this case, energy dissipation of CH is not reasonable. To address this problem, Multi-hop LEACH is proposed in [10]. Multi-hop LEACH is another addition of LEACH routing protocol to increase energy efficiency of SN [11][12][13]. It is also complete distributed clustering based routing protocol. Like LEACH, in Multi-Hop LEACH some nodes elect themselves as CHs and other nodes associate themselves with elected CH to complete cluster formation in setup phase. In steady state phase CH collects data from all nodes of its cluster and transmits data directly or through other CH to BS after aggregation. Multi-Hop LEACH allows two types of communication operations; inter-cluster and intra-cluster. In former type of communication, when whole network is divided into multiple clusters, then each cluster possesses one CH. This CH is responsible for communication for all nodes in the cluster. CH receives data from all nodes at single-hop, aggregates and transmits directly it to sink or through intermediate CH. In later type of communication, when distance between CH and BS is large then CH uses intermediate CH to communicate with BS.

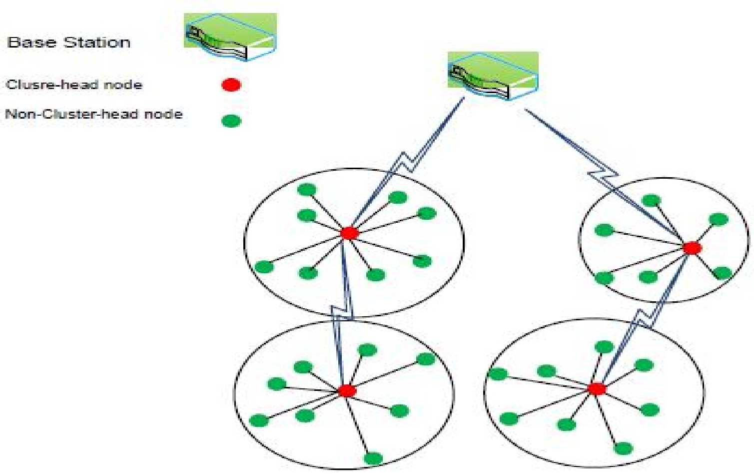

Figure 3: Multi Hop LEACH

Multi-Hop LEACH communication architecture is portrayed in Figure 3. Randomized rotation of CH is similar to LEACH. Multi-Hop LEACH selects best path with minimum hop-count between first CH and BS.

IV. PROPOSED APPROACH

In this proposed approach, we improved the LEACH protocol and proposed an improved LEACH with location based CH and two hop communication (LBCH-LEACH) for WSNs. We take into consideration the location of each node while clusters are forming. The simulation result proves that our proposed scheme noticeably increases the life time of the network. We also take advantage of clustering infrastructure and data aggregation as used in LEACH. At first we explain the system and radio model in our proposed algorithm. Apart from assumptions iv. and viii., the following assumptions are drawn directly from the LEACH.

A. System Model

1) The initial energy of all the nodes is the same.

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2) The communication environment is error free.
3) All the nodes are able to send data and receive data from the base station.
4) Sensor nodes are uniformly distributed in a two dimensional field.
5) The base station has no energy limitation.
6) All the messages that are being sent have the same number of bits.
7) All sensor nodes are the same in terms of size and performance.
8) The location of the base station is fixed during data transmission.

B. Radio Model

We have taken the identical radio model as proposed by W.R.Heinzelman [4] which is the first order radio model. In this model, a radio dissipates E_{elec} = 50 nJ/bit to run the transmitter or receiver circuitry and P_{amp} = 100 pJ/bit/m2 for the transmitter amplifier. The radios can control their power to enhance the least power required to reach the anticipated recipients. The radios can also be turned off to avoid receiving undesired transmissions.

C. Proposed Method

In our proposed algorithm the network is distributed in equal size of five clusters (number of clusters based upon the value p). As result each cluster contains a CH and the selection procedure based upon the concept of maximum residual energy after cluster formation. Data transmission from CH to BS follows two hop communication accordingly. We used the following techniques to improve the original LEACH:

1) *Maximum Residual Energy:* In our proposed algorithm, we make residual energy of node as the main matrix which decides whether these nodes turn into cluster head or not in the next round. In first round communication, every node has the same probability to turn into cluster head. n (n=p×N) nodes are randomly selected as cluster heads, and then, the residual energy of each node is different after one round communication. We select n nodes with more residual energy as cluster heads in next round communication, and so on until all nodes are dead.

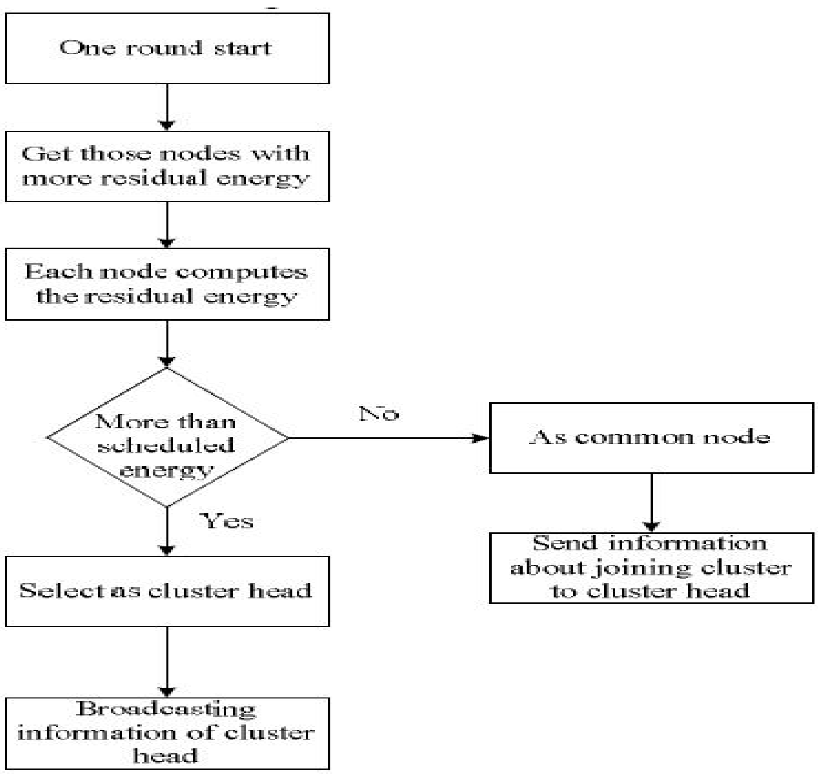

Figure 4: Selection Procedure of Cluster Head

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2) *Location of Cluster Head:* In LEACH, There isn't any certainty about the location of CHs whether they are uniformly distributed through the network. So there is possibility that elected CHs will be concentrated in one part of network; hence some nodes will not have any CHs in their neighborhood. To resolve this problem, we divide the network in equal size of clusters as each cluster must have a CH, number of clusters decided by the value of p. Here, we use p=0.05 describes that there should be five CH among all nodes in each round. Therefore the network is divided into five clusters by the coordinates of x-axis (the network size is 100*100) means the first cluster exists from 0 to 20 and second is 20 to 40 and so on.
3) *Two-Hop Communication:* During the data transmission phase, the common nodes in one cluster send data by the TDMA schedule to the cluster head which is similar in LEACH. The transmission between cluster heads and the BS has two types: one-hop transmission and two-hop transmission. When the near cluster is alive, the far area's cluster heads may transmit their aggregated data to the BS via the near cluster head. Otherwise, they directly communicate with the BS. The flow chart of two-hop transmission between the cluster heads and BS is shown in Figure 6.

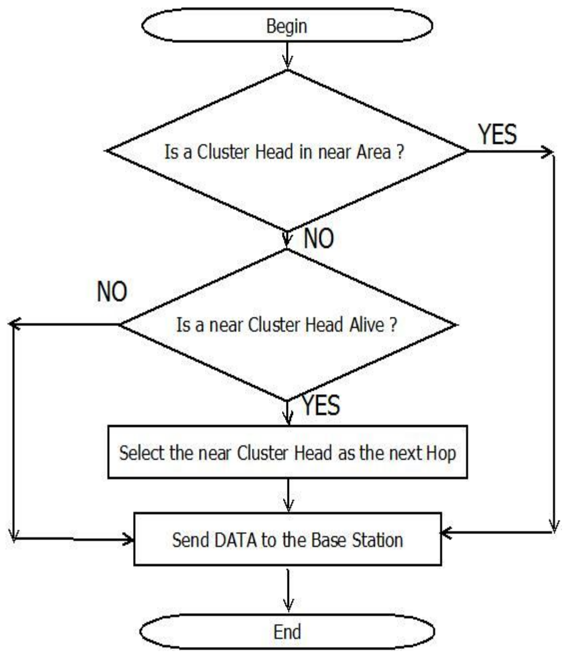

Figure 5: Two-Hop Communication

D. Proposed Algorithm

1) Create a random sensor network
2) Divide the network into segments
3) For each segments do:
4) For first round CH selection is same as LEACH, in which a node chooses a random number between 0 and 1.
5) Each Non-CH nodes of that segments form a cluster.
6) Now CH receives data from Non-CH nodes and aggregates them.
7) Follow Two-Hop communication. Calculate energy dissipation and subtracted from the remaining energy of every node.
8) If Energy of a node ==Null, then those nodes are deleted from the network and the lifetime close and we get the out.
9) Else choose the node with maximum residual energy as a CH and repeat step 5 to 9.

V. SIMULATION AND ANALYSIS

Extensive simulations have been conducted by using the MATLAB simulation environment to compare the performance of our proposed An Improved LEACH with Location Based Cluster Head and Two-Hop Communication (LBCH-LEACH) protocol with the Low Energy Adaptive Clustering Hierarchy (LEACH) and Modified LEACH [7]. The results show that the LBCH-LEACH extends the network lifetime, increases the overall throughput, reduces the energy consumption, and optimizes the number of cluster heads. Simulation parameters used for our experiments are given below:

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A. Simulation Parameter

The nodes are randomly deployed within the area of 100m X 100m. The base station is located at the center of the deployment area with coordinates 50m X 50m. The population of nodes for this simulation is 100 (i.e. n=100). A sample of randomly deployed nodes for our experiments is shown in Figure 5-1. The equation 2.2 can be used to determine the density of the nodes in the sensor field.

Parameter	Value
Area of Network	100 m * 100 m
Location of Base Station	50 m, 50m
Election Probability of CHs(p)	5%(0.05)
Number of Nodes	100
Initial Energy of Node	0.5
Maximum Number of Rounds	5000
Transmission Energy(E_{TX})	50*0.000000001
Receiving Energy (E_{RX})	50*0.000000001
E_{DA}	5 nJ/bit/Signal

Table 1: Parameters Used in Simulation

B. Simulation Result

MATLAB tool is used to get the simulation results. As mentioned earlier, LBCH-LEACH works in rounds. The total number of rounds used for our experiments is 5000. Simulations of LBCH-LEACH in comparison with LEACH [1] and Modified LEACH are performed to observe the frequency of dead and alive nodes per round.

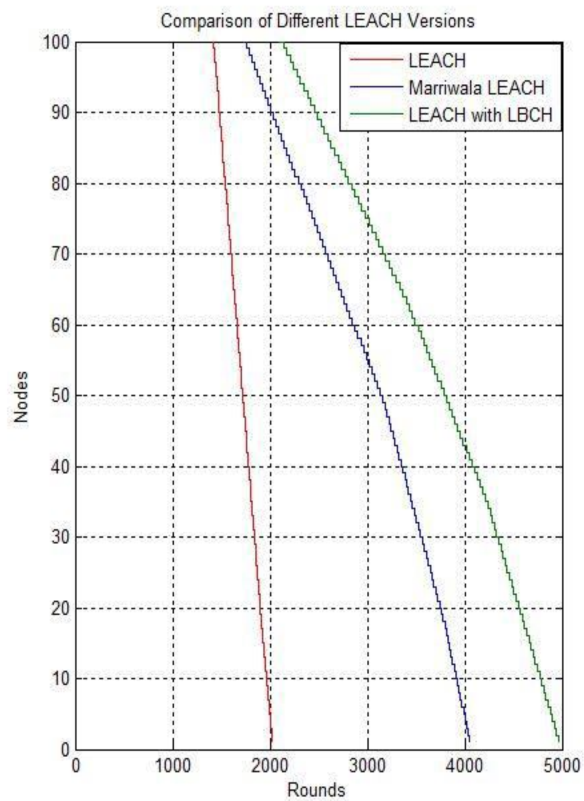

Figure 7: Comparison of total number of alive nodes in each round of all simulated versions of LEACH

The above graph represents the comparison between total numbers of alive nodes v/s each round. The simulation result represents that that the network works up to 5000 rounds in the case of LBCH-LEACH whereas in LEACH and Energy LEACH all nodes are dead at 2032 and 3982 rounds. Performance metrics is shown by the following table.

Analyzed Parameter	LEACH	ENERGY LEACH	LBCH-LEACH
First Node Dead	1418	1728	2064
Last Node Dead	2032	3982	up to 5000 rounds

Table 2: Performance Metrics

VI. CONCLUSION AND FUTURE WORK

This paper mainly concentrates on the conserving and balancing energy in a wireless sensor network. We have investigated only few of the problems. Some of the problems can be further explored are as follows. Algorithms for placing more than one base station can be explored depending on communication parameters. More accurate methods can be developed for anchor free localization in WSN. Models for identification of bottleneck nodes and resulting life time enhancement techniques. Further, we fed at the end of this study that overheads needed to implement any method should be as low as possible and low enough to make it viable. Further if random access MAC (medium access control) is used, there will be random delay and energy overhead which gets added. The impact of these need more investigations along with new methods to minimize this delay and to improve throughput per unit energy consumed.

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