Balanced LEACH and Balanced 2-Tier LEACH Protocol for Wireless Sensor Networks

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ABSTRACT: *Wireless sensor networks are appearing as an emerging need for mankind. Its growth is expeditiously increasing and hence there a need of immense research in this field. Sensor node depends mainly on the battery power, which cannot be revitalized or substituted. Therefore, conservation of energy and energy efficient routing must be taken into account to realize a dynamic and adaptive networking concept for wireless sensor networks. LEACH protocol was proposed in order to balance the energy consumption and improve the network lifetime by forming clusters. However, LEACH protocol suffers by demerits such as improper distribution of clusters, latency caused by unclustered nodes and direct transmission of aggregated data at the cluster head to the base station. This paper, proposes a new balanced LEACH (B-LEACH) algorithm which is intended to extend the lifetime of the network by balancing the energy consumption of the entire network. B-LEACH algorithm provides even distribution of clusters in the topology but the cluster heads have to transmit aggregated data to longer distance to reach base station where cluster heads dissipate more energy for this trait. Further, balanced 2-tier LEACH algorithm have been implemented to enhance the life time of the network by routing the aggregated data through an intermediate node which reduces the energy dissipation at the cluster head.*

Key Words: *Wireless sensor networks, LEACH, Cluster head, sensor nodes.*

I. INTRODUCTION

Wireless sensor networks (WSN) are generally considered as a standout amongst the most paramount technologies for the twenty first century. The application of the WSN involves many fields [2], such as the military battlefield, forest fire detection and other extreme environments. In these situations, it is difficult to replace the dead nodes with new sensor nodes to supply energy for the network. So conservation of the energy of the sensor nodes is the main method to maximize the lifetime of the network. LEACH is considered as the most popular Hierarchical routing protocol that use cluster based routing in order to minimize energy consumption. In LEACH, the network is divided in to clusters where each cluster has cluster-head (CH). These CHs have the responsibilities of collecting and aggregating the data from their respective clusters and transmitting them to the Base Station (BS). The aggregation [5, 6] of the data at CHs greatly reduces the energy consumption in the network by minimizing the total data messages transmitted to the BS. Also, the CHs act as local sink for the data, so that the data is transmitted relatively over a short distance.
The reaming of the paper is organized as follows. Section 2 discusses the LEACH protocol in detail. Proposed protocols to the conventional LEACH protocol are presented in Section 3. Results and discussion in presented section 4 and section 5 conclude the paper.

II. LEACH PROTOCOL

LEACH (Low Energy Adaptive Clustering Hierarchy) [8] is the first hierarchical cluster-based routing protocol for wireless sensor network. In LEACH, the nodes organize themselves into local clusters. A dedicated node selected as cluster-head is responsible for creating and manipulating a TDMA (Time Division Multiple Access) schedule and aggregating the data coming from different nodes and sending it to the BS. The process of LEACH is divided into rounds. Each round consists of two phases: Set-up Phase and Steady-state Phase.

2.1Set-up phase

Each node in the monitor field decides independently of other nodes whether it will become a cluster-head in the current round. During the choosing phase [9], each node generates a random number between 0 and 1, and then compares the value with the below threshold.

$$T_n = \begin{cases} \frac{p}{1-p\left(r \bmod \frac{1}{p}\right)} & if\ n\ in\ G \\ 0 & otherwise \end{cases} \quad (1)$$

Where p is the percentage of cluster heads over all nodes in the network, r is the number of rounds of selection, and G is the set of nodes that haven't been selected as cluster heads in round 1/p. The node whose number is bigger than the threshold will select itself as the cluster-head. Then the CH will broadcast an advertisement message to inform their neighbourhood that it is the new cluster-head. The noncluster nodes send the message containing their IDs by using CSMA to join a cluster with strongest signal strength. After that, each CH knows its own member nodes' information including the numbers and IDs. Based on the message, the CH creates TDMA schedule table and broadcasts it to the cluster members. So all the member nodes know their idle slots, and then the Steady-state Phase starts.

2.2 Steady-state phase

During the Steady-state Phase, each node can turn off its radio until it senses the necessary data. The member nodes can send their data to CH during their allocated schedule table created during the Set-up Phase. As for the CHs, they have to keep up their communication status at all times so as to receive the data from their member nodes. When the CH receives all the data sent by their members, it will aggregate them at first and then send the aggregating data packets to BS in order to save energy.

III. PROPOSED PROTOCOLS

LEACH (Low Energy Adaptive Clustering Hierarchy) utilizes randomized rotation of cluster heads to evenly distribute the energy load among the sensors in the network. But, LEACH cannot select the cluster-heads uniformly throughout the network, where some nodes may remain non-clustered (Non-members). Non-member nodes in the network have to transmit their data directly to the Base station (BS), resulting in more energy depletion in these nodes which in turn reduces the overall network lifetime. To address this problem, a balanced LEACH (B-LEACH) algorithm is been discussed.

3.1 Balance LEACH

In B-LEACH, initially all nodes are assumed to be homogeneous. A node is randomly elected has a cluster head (CH) and advertises itself as the first CH and issues lock range such that no other node in that particular area can advertise itself as CH. After that, another CH is selected from rest of the network. In this way the whole network is divided into some predefined areas. Each area contains one CH and all the nodes in that area forms a cluster, if a node receives advertisement from two or more cluster heads it chooses a nearest cluster head and sends join request to it. Then no single node in the network has to transmit their data very far to reach the CHs. Thus the CHs are uniformly distributed throughout the network.

3.1.1 *Cluster Formation Algorithm*:

- A node is randomly elected itself as a CH
- Cluster Head broadcast an advertisement message (ADV) using CSMA/CA ADV = node's ID + distinguishable header.
- All the nodes in free space loss range around cluster head blocks itself from cluster head process.
- Step one repeats for desired number of clusters.
- Each non-Cluster Head node determines its nearest CH for this
- Each non-Cluster Head transmits a join-request message (Join-REQ) back to its nearest CH using CSMA/CA Join-REQ = node's ID + cluster-head ID + header.
- Cluster Head node sets up a TDMA schedule for data transmission coordination within the cluster.

In both LEACH and Balanced-LEACH protocols, CHs route the aggregated data directly to BS, which consumes more energy in CH, which is observed to be inefficient routing. To allow the system to cope with balanced clustering and to be able to cover optimum area without degrading the service, balanced 2-tier LEACH protocol has been implimented.

3.2Balance 2-tier LEACH

The network topology is divided into inner forwarding nodes and outer clustering nodes to maintain free space loss model over the network, outer clustering nodes are allowed to form non-overlapping clusters and cluster head (CH) compresses aggregated data from member nodes and routes it to forwarding node. Inner forwarding nodes routes its generated data to base station(BS), while outer clustering nodes are in setup phase, once data from inner nodes is routed to base station, forwarding nodes are free to access as routers for the outer CHs.

3.2.1 Energy consumption model for 2-tier LEACH

Assume that CH is situated at 160 meters from BS having a data packet of length 100 bits. If a CH transmits data packet directly to BS. Since 160 meters is greater than threshold distance (87.7 meters), using radio model from section 1.3 and table 1.1, energy consumption by CH is given by below equation.

$$ETx = Eelec*L + Emp * L * (d)^4 \qquad (2)$$

Energy consumption by CH to transmit 100 bits to a distance of 160 meters is found to be 9.01968*10-5 j.

Again if CH routes data through an intermediate node situated at a distance of 80 meters from both CH and BS, here data from CH is received by forwarding node and it retransmits the collected data to BS, so in this model the energy is consumed by both transmission and reception, however distance is less than threshold distance and losses is brought down to free space model by intermediate hop, energy consumption for data transmission is given by

$$ETx = Eelec*L + Emp * L * (d)^2 \qquad (3)$$

Energy consumption to receive data from node is given by

$$ERx = Eelec*L \qquad (4)$$

Therefore total energy consumption for 1 hop is given by

$$ETotal = ETx(d1) + ERx + ETx(d^2) \qquad (5)$$

$$ETotal= \{Eelec*L+Efs*L*(d1)^2\}+\{Eelec*L\} + \{Eelec*L+Efs*L*(d2)^2\} \qquad (6)$$

Comparing energy consumption for both direct and indirect transmission, it can be concluded that indirect transmission conserves energy. This implies the need to maintain more free space loss model over the network to conserve energy in the network.

3.2.2 Network division

The randomly distributed nodes are location aware and homogenous, Base station (BS) is placed in the center of the topology, topology is divided into inner forwarding nodes and outer clustering nodes which is as shown in Fig 1.

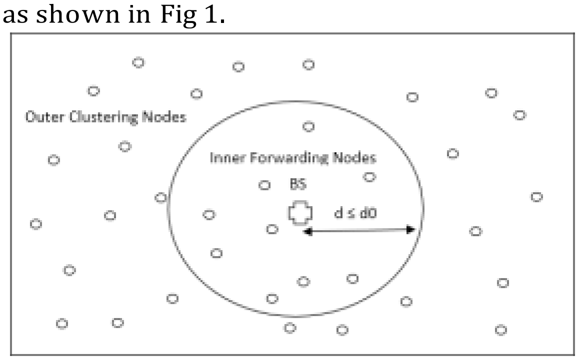

Fig.1 Network division of Balanced 2-tier LEACH protocol

Inner Forwarding Nodes are nodes which are located within the radius of threshold distance (d0) from the Base-station.When a round is initiated by base-station the outer clustering nodes are busy in cluster formation and these forwarding nodes act as independent nodes not involving in Cluster formation and communicate with base station directly. By this mechanism, possible latency is avoided by intelligent management of time. The communication between the forwarding nodes and base-station is achieved by CSMA/CA. Once the data is aggregated by cluster-head (CH), Cluster-head routes their data through the nearest forwarding node.

Outer Clustering Nodes are nodes other than the inner forwarding nodes (i.e. d > d0), they involve in cluster head selection, cluster formation. The selected cluster heads issues time-frames to member nodes and aggregates data from them, then aggregated data is fused (compressed) for efficient communication, cluster heads find the nearest forwarding node to route data to base station.

3.2.3 Balanced 2-tier LEACH algorithm

- Round is initiated by Base station advertisement

- All nodes are awaken by Base station advertisement message.
- Network topology is divided into inner forwarding nodes and outer clustering nodes
- Cluster Heads are chosen randomly in outer clustering nodes
- Cluster formation
- Concurrently during cluster formation in outer clustering nodes, inner forwarding nodes transmits its generated data to base station using CSMA/CA.
- Cluster Heads aggregate data from its member nodes using TDMA.
- Cluster members are active only during their time slot and enter sleep mode during rest of time.

Cluster Heads compress the aggregated data and finds a nearest free node in inner forwarding range to route compressed data to BS.

IV. RESULT AND DISCUSSION

The performance of LEACH, balanced LEACH and two-tire LEACH is evaluated using MATLAB simulator by considering Energy and total packets as performance metrics. Some assumptions were made concerning the node features are as follows

- All nodes are homogeneous in nature.
- The base station is situated at the center of the topology
- Clusters and nodes are static in nature.

Scenario 1

In the scenario 1, 100 nodes are randomly deployed within the area of 350m x 350m. The parameters used in the simulation are listed in Table 3.1.

Table 3.1

Nodes	100
Network size	350 m X 350 m
Base station location	(175,175)
Radio propagation speed	3×10^8 m/s
Processing delay per bit	0.0000125 s/b
Radio speed	40 kbps
Initial energy in each node	0.0025j
Simulation Rounds	400

Scenario 2

In this scenario, 100 nodes are randomly deployed within the area of 350m x 350m. The parameters used in the simulationsare listed in Table1.

TABLE 1

Nodes	**100**
Network size	**350 m X 350 m**
Base station location	**(175,175)**
Forwarding nodes	**F**
Clustering nodes	**100 – F**
Radio propagation speed	**3×10^8 m/s**
Inner forwarding range	**$d \le d_0$**
Outer clustering range	**$d > d_0$**

Processing delay per bit	**0.0000125 s/b**
Radio speed	**40 kbps**
Initial energy in each node	**0.25j**

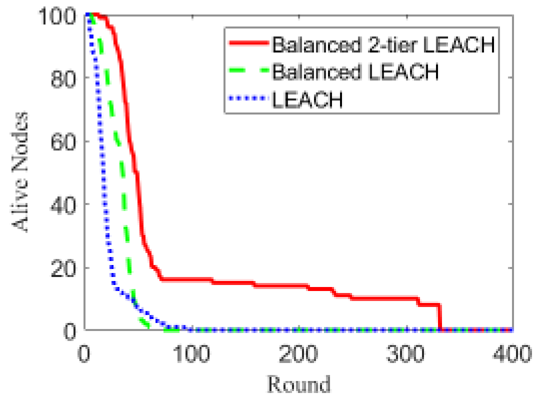

Fig.2 Round v/s residual energy

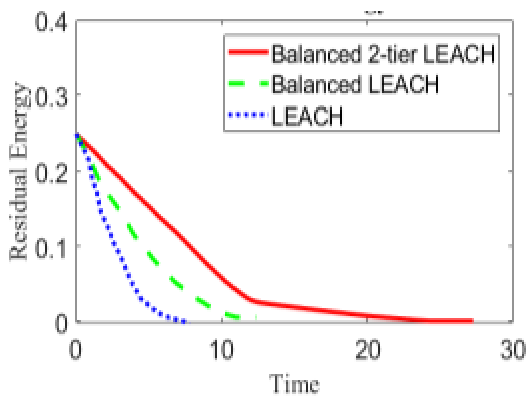

Fig.3 Time v/s residual energy

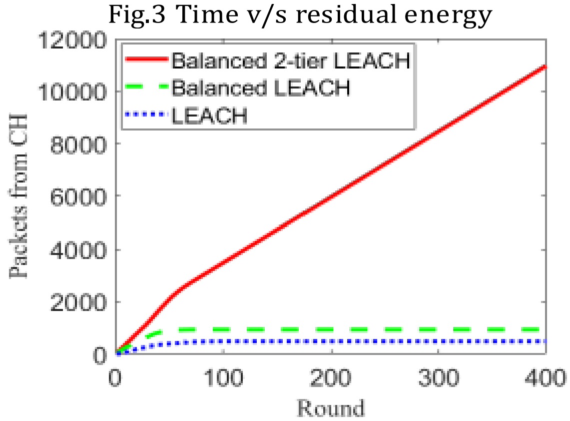

Fig. 4 Round v/s Total packets

In Balanced LEACH protocol uniform distribution of clusters in ,network topology and non-overlapping of Cluster heads is achieved, and this leads to less energy consumption Comparative to LEACH as shown in fig 3.

From fig 3, it is also observed that the energy dissipation in network is extended in Balanced 2-tier LEACH compared to Balanced LEACH, because the data from CHs takes an extra hop to reach the BS, this conserves the transmission energy in CHs. The Lifetime of nodes in the network is increased up to 2.5 times than the balanced LEACH which is as shown in fig 2.

Throughput of the network is as shown in fig 4 which shows a significant improvement of throughput compared to LEACH and Balanced LEACH, due to routing of data through an intermediate forwarding node between CH and BS, creating an effective free space loss model or less multipath loss model over the network.

V. CONCLUSIONS

Balanced LEACH algorithm has a better coverage of network topology, avoids undesired traffic caused by independent nodes and increases effective lifetime of network, allowing nodes to die approximately together.Improper death model of LEACH is addressed, efficient coverage of network topology is further more increased than Balanced LEACH.

The performance of Balanced 2-tier LEACH outlasts the balanced LEACH due to maintaining of free space loss model over the network with the help of intermediate hop between CH and BS.

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