A Lifetime Improvement Approach Using Load Distribution in LEACH Protocol

Deepika Tayal, Deepshikha Varshney, Rohit Kumar Gupta

***Abstract*— Wireless Sensor Networks (WSN) have gained researcher's attention in recent years due to its technological advancements such as environmental monitoring, target tracking, battlefield surveillance etc. In wireless sensor networks, energy efficiency is an important factor should be considered when the protocols are designing. It is built of sensor nodes that are powered by batteries. Sensors are equipped with wireless interfaces with which they can communicate with one another to form a network. Each sensor network node can monitor physical or environmental conditions like temperature, pressure, sound etc and pass this data to a main location. Due to its energy constraints, the deployments of WSNs will require enhancements to maintain the network's lifetime. A clustering based routing algorithm called low-energy adaptive clustering hierarchy (LEACH) that is one of the most popular hierarchical routing algorithms for sensor networks. The current cluster based routing techniques may result in increased network workload, energy consumption and re-transmissions. To overcome these problems, we propose an energy efficient secondary cluster head selection algorithm for wireless sensor network. In this technique, secondary cluster head are selected based on the parameters such as residual energy, minimum average distance from the member. Thus, an energy efficient routing protocol which is proposed in this paper distribute the load over the cluster head in the cluster, that enhances the network lifetime and reduces the network overload.**

***Index Terms*—Clustering, Cluster head Energy Efficient, WSN**

I. INTRODUCTION

A. Wireless sensor networks

Wireless sensor network consisting of many sensor nodes that communicate over a wireless media. Wireless sensor network has its own design and resource constraints [1]. Resource constraints include a limited amount of energy, short communication range, low bandwidth, and limited processing and storage in each node. Design constraints are application dependent and are based on the monitored environment. The environment plays a key role in determining the size of the network, the deployment scheme, and the network topology. The size of the network varies with the monitored environment. A WSN typically has little or no infrastructure. It consists of a number of sensor nodes working together to monitor a region to obtain data about the environment. A sensor node [3,9] is equipped with a sensor module, a processor, a radio module and a battery. These sensors are small, with limited processing and computing resources, and they are inexpensive compared to traditional sensors. These sensor nodes can sense, measure, and gather information from the environment and, based on some local decision process, they can transmit the sensed data to the user.Since the battery limits the lifetime of the sensor nodes it also limits the lifetime of the sensor network, thus energy efficiency is a major issue for sensor networks. An important target in many sensor networks is to monitor an area as long time as possible. Hence, it is important to distribute energy consumption evenly across the network. When the energy consumption is evenly distributed, the major part of the sensor nodes will stay alive approximately equally long time. A wireless sensor network (WSN) has important applications such as remote environmental monitoring and target tracking natural disaster relief, biomedical health monitoring etc.

Figure 1 show the basic structure of the wireless sensor network [2] in which sensor node deployed in the wireless sensor network and they communicate with each other for collect the information from the environment, or directly send to the sink node.

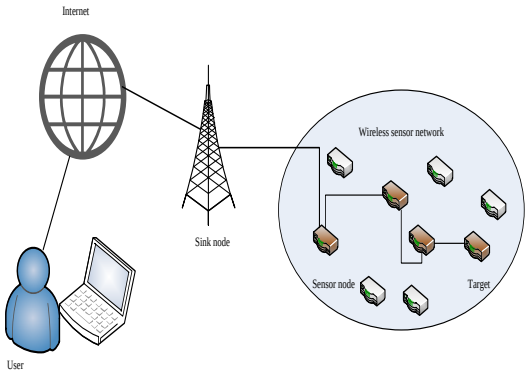

Figure 1: Structure of Wireless Sensor network

B. Routing protocols in WSN

Routing [4] is main challenge faced by wireless sensor network. Routing is complex in wireless sensor network due to dynamic nature of WSN, limited battery life, computational overhead, self-organization and limited transmission range of sensor nodes. Number of energy aware routing algorithms or protocols have been proposed for WSNs in recently years. Routing in WSNs can be divided into flat-based routing, hierarchical-based routing, and location-based routing depending on the network structure. In flat-based routing, all

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nodes are typically assigned equal roles or functionality. In hierarchical based routing, designed to reduce energy consumption by localizing communication within the cluster and aggregate data to reduce transmissions to the BS. In location-based routing, sensor nodes' positions are exploited to route data in the network. Quality of routing protocols depends upon the amount of data successfully received by Base station from sensors nodes deployed in the network region.

C. *Clustering*

Clustering [5] is used in WSN's to provide network scalability, resource sharing and efficient use of constrained resources that provides network topology stability and energy saving attributes. Cluster schemes will decrease the overall energy consumption and reducing the interferences among sensor nodes. Cluster will reduce the communication overheads. Clustering is a very effective way to reduce energy consumption in the wireless sensor networks. In WSN, the sensor nodes are grouped into self disjoint sets called a cluster. The total network is subdivided into smaller groups called cluster and each cluster would has a head and that is called as cluster-head (CH).
In clustering schemes [6], there are two types of nodes in one cluster, one cluster head (CH) and several other cluster members (CMs). Cluster members gather data from the environment periodically and send the data to cluster heads. As shown in Figure 2, Cluster heads aggregate the data from their cluster members, and send the aggregated data to the base station (BS). There are two kinds of communications between cluster heads and the BS, single-hop communication and multi-hop communication. In multi-hop communication clustering algorithms, the energy consumption of cluster heads consists of the energy for receiving, aggregating and sending the data from their cluster members, known as intra-cluster energy consumption and the energy for forwarding data for their neighbor cluster heads known as inter- cluster energy consumption. The main goal of cluster-based routing protocol [5] is to efficiently maintain the energy consumption of sensor nodes by involving them in multi-hop communication within a cluster.

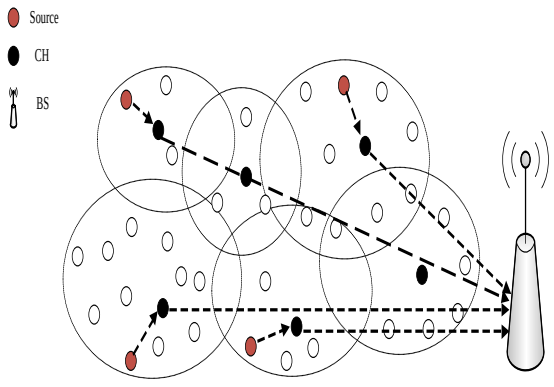

Figure 2 : Clustering based routing in WSN

Clustering has many advantages like it reduces the size of the routing table ,conserve communication bandwidth, prolong network lifetime, decrease the redundancy of data packets, reduces the rate of energy consumption etc.

D. *Clustering Based Protocol*

LEACH [4,5] (LOW-ENERGY ADAPTIVE CLUSTERING HIERARCHY) is a cluster-based energy efficient hierarchical routing protocol, which reduce the number of transmissions towards to the BS. LEACH randomly selects a few sensor nodes as cluster-heads and rotates this role to evenly distribute the energy load among the sensors in the network. In LEACH, the cluster-heads compress data arriving from nodes that belong to the respective cluster, and send an aggregated packet to the BS in order to reduce the amount of information that must be transmitted to the BS. LEACH protocol [7] uses round as unit, each round is made up of cluster set-up stage and steady-state stage, for the purpose of reducing unnecessary energy costs, the steady state stage must be much longer than the set-up stage. In other words, it reduces network traffic and the contention for the channel. LEACH has motivated the design of several other protocols which try to improve upon the CH selection process.

II. Related Work

LEACH (Low Energy Adaptive Clustering Hierarchy) [8,10] is a self-organizing, adaptive clustering-based protocol that uses randomized rotation of cluster-heads to evenly distribute the energy load among the sensor nodes in the network. LEACH based on two basic assumptions: (a) base station is fixed and located far away from the sensors, and (b) all nodes in the network are homogeneous and energy constrained. The idea behind LEACH is to form clusters of the sensor nodes depending on the received signal strength and use local cluster heads as routers to route data to the base station. The key features of LEACH are:

- Localized coordination and control for cluster set-up and operation.
- Randomized rotation of the cluster "base stations" or "cluster-heads" and the corresponding clusters.
- Local compression to reduce global communication.

In LEACH, the operation is separated into fixed-length rounds, where each round starts with a setup phase followed by a steady-state phase. The duration of a round is determined priori. LEACH algorithm works as follows:

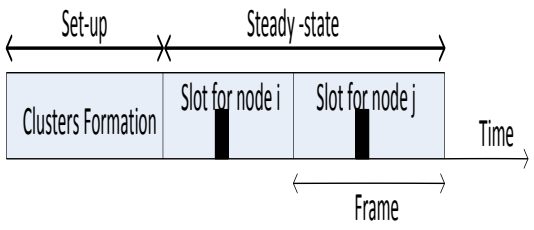

Figure 3: Phases of LEACH

1. Advertisement phase: In this phase, nodes elect themselves to be a cluster-heads for the current round (r) through a cluster-head advertisement message. For this cluster-head advertisement, the cluster heads use CSMA MAC protocol. After the completion of this phase, and depending on the received advertisement signal strength; the non cluster-head nodes (their receivers must be kept on during this phase to hear the advertisements of all cluster-heads) determine the cluster to which they will belong to for this current round (r). At each round, a node n selects a random number k that is between 0 and 1. If k is less than a threshold T(n), then the node becomes a cluster-head for the current round (r).

$$T(n) = \begin{cases} \frac{P}{1-P(r \bmod (1/p))}, & \text{if } n \in G, \\ 0, & \text{otherwise.} \end{cases}$$

Where P is the desired percentage of cluster-heads, r is the current round, and G is the set of nodes that have not been cluster heads in the last $1=P$ rounds. Since k is randomly selected, then the number of cluster heads may not be fixed.

2. Cluster set-up phase: After each non-cluster-head node will has decided to which cluster it belongs, it informs the cluster-head node that it will be a member of the cluster. So, each node transmits this information back to the cluster head using CSMA MAC protocol.

3. Schedule Creation phase: The cluster-head node receives all the messages for nodes that would like to be included in the cluster. Based on the number of nodes in the cluster, the cluster-head node creates a TDMA schedule telling each node when it can transmit. This schedule is broadcast back to the nodes in the cluster.

4. Data Transmission phase: After the creation of both the clusters and the TDMA schedule (TDMA is fixed), nodes in the cluster start transmitting the data they already have during their allocated transmission time to the cluster-head (cluster-head node keeps its receiver on all the time to receive the sent data). Once all the data (sent by nodes in the cluster) have been received by the cluster-head node, it will perform signal processing function to compress the data into a single signal.

III. Problem Definition

In LEACH protocol, due to the randomness of clusters forming, the energy of cluster head is very different, so do the distances between cluster heads and base station. Cluster heads are responsible not only for sending data to the base station but also for collecting and fusing the data from common nodes in their own clusters. In the process of data collection and transmission, the energy consumed by data transmission is greater than that of data fusion . If the current energy of a cluster head is less or the distance to base station is much far, then the cluster head will be died quickly because of a heavy energy burden. To address these issues, this article proposes a new improved algorithm on how to balance the energy loads of these cluster heads.

In LEACH protocol, cluster heads are responsible not only for sending data to the base station but also for collecting and aggregate the data from non cluster head node in their own clusters. Due to this, the cluster head having more load so the survival time of the cluster head is reduced, arise the cause of cluster head failure. This is the noticeable problem in LEACH protocol that affect the network lifetime.

IV. Improved Algorithm

LEACH Protocol with Two Levels Cluster Head is an improved one based on LEACH Protocol, the methods of cluster-head selection and clusters forming are same as LEACH protocol. If a cluster head's current energy is less than the average energy, or the distance between the cluster head and base station is longer than the average distance, then the common node with maximum energy in this cluster will be selected as the secondary cluster head. If a cluster head's current energy is greater than the average energy or the distance between the cluster head and base station is shorter than the average distance , it is unnecessary to select a secondary cluster head.

In a cluster which has secondary cluster head, the secondary cluster head is responsible for receiving and fusing data collected from the member nodes and sending them to its cluster head, the cluster head is only responsible for transporting data to base station. In a cluster without secondary cluster head, the cluster head is responsible for collecting data from the member node and sending them to base station after the data was fused.

Description of improved algorithm:-

A. The stage of cluster forming

First, a node choose a number between 0 to 1, if the number is less than $T(n)$, then the node becomes cluster head, else, normal nodes it becomes. Cluster heads broadcast their own information to other nodes, the other nodes will listen to the broadcasting messages. All normal nodes determine which cluster they should join in this round based on the strength of the signal they received. After determining which cluster they should belong, CSMA Protocol will be used to send a confirmation message to their cluster heads. At this point, the clusters forming stage is finished.

B. The selecting of secondary cluster head

Each cluster head decides whether to set a secondary cluster head according to the current energy itself and the distance to the base station, if $E(i) < E_{ave}$ or $d(i) > d_{ave}$, then these kinds of cluster heads should choose the node with maximum energy as secondary cluster head in its cluster, otherwise, the secondary cluster head is not required.

C. To create a transport schedule

The secondary cluster head broadcasts message of being secondary cluster head to the other ordinary nodes and builds a schedule (uses TDMA, a time slot is assigned to each node), informs the schedule to the other nodes. In clusters without secondary cluster head, the cluster heads distribute sending time slot to the others after get the join information of normal nodes. The stable stage begins when each node have gotten its sending time slot.

D. Data transferring

When clusters have formed and the TDMA schedule is determined, the nodes start to transfer the monitoring data. The secondary cluster heads receive data from the other nodes and fuse these data, these fused data was sent to the cluster heads, then cluster heads send these data to base station by single-hop method. In those clusters without secondary cluster head, the cluster heads receive the information from other nodes, fuse them and send them to base station.

E. Steps of improved algorithm:-

1. Firstly, we have a network of sensor nodes.
2. Selection of cluster head according to the random no generator.
3. Divison of sensor nodes into clusters.
4. If the energy of the node in the particular cluster is less than the avg energy or the distance is greater the avg distance then secondary cluster head is choosen
5. TDMA schedule creation by the secondary cluster heads if exists otherwise done with the CH.
6. Local data aggregation by secondary cluster head
7. Data is sent to the SCH to CH
8. Data transmission by cluster heads to BS.
9. Stop

V. Conclusion

In this paper, we have proposed an energy efficient secondary cluster head selection algorithm for wireless sensor network. In LEACH protocol, heavy energy burden over the cluster head in the cluster are affected the survival time of the cluster head .So that the lifetime of the network is reduced. That why we take an assumption to introduce the concept of secondary-cluster head selection in the cluster. In this technique, secondary cluster heads are selected based on the parameters such as residual energy, minimum average distance from the member.This assumption are used to maximize the life time of the network which is the main factor of the LEACH protocol.

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