An Energy Efficient Approach Using Load Distribution through LEACH-TLCH Protocol

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Abstract – Wireless networking is an emerging technology that allows users to be able to access a broad range of information and services. Commonly monitored parameters are temperature, humidity, pressure, wind direction etc. Energy is the scarcest resource of WSN nodes, and it determines the lifetime of WSNs. Minimizing energy dissipation and maximizing network lifetime are important issues in the design of applications and protocols for sensor networks. A clustering based routing algorithm called Low-Energy Adaptive Clustering Hierarchy (LEACH) is one of the most popular hierarchical routing algorithms for sensor networks. But this cluster based routing technique results in increased network workload, energy consumption and re-transmissions. To overcome these problems, this paper proposes an Energy efficient secondary cluster head selection algorithm for wireless sensor network (WSN). By controlling the distances among the cluster heads, the uniform distribution of cluster heads is satisfied. And then using two-level mode, the data are transmitted to the base station. LEACH is compared with the improved LEACH-TLCH method with the help of simulation. Simulation results show that the improved method can reduce the network consumption energy greatly and lengthens the network lifetime efficiently.

Index Terms – Clustering, Cluster head, Energy Efficient, WSN.

1. INTRODUCTION

Wireless sensor networks (WSNs) generated an increasing interest from industrial and research perspectives. Wireless networks are getting popular due to their ease of use. Consumer/user is no more dependent on wires. User is free to move and enjoy being connected to the network. So, one of the great features of wireless network that makes it fascinating and distinguishable amongst the traditional wired networks is its mobility.

1.1. Wireless Sensor Networks

Wireless sensor network consist of many sensor nodes that communicate over a wireless media. Wireless networks are the networks in which computer devices communicate with each other without the use of any wire. Users in wireless networks transmit and receive data using electromagnetic waves, but the condition is that the source and destination devices must lie within the radio range of each other. Thus, wireless networks are getting more and more popular because of their mobility, simplicity and very affordable and lesser cost of installation.

A WSN typically has little or no infrastructure. A sensor node is equipped with a sensor module, a radio module, a processor 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. Due to this, energy efficiency is a major issue for sensor networks.

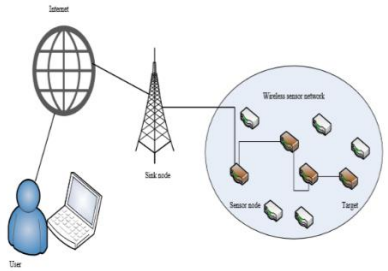

Figure 1: Structure of the wireless sensor network

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

1.2. Clustering in WSN(Wireless Sensor Network)

The use of wireless sensor networks (WSNs) has grown enormously in the last decade, but there is crucial need of scalable and energy-efficient protocols in corresponding large-scale environments. Hierarchical clustering is very much useful in such directions. Moreover, they provide advantages like system scalability, lifetime, and energy efficiency.

By grouping sensor nodes into clusters, we can achieve high energy efficiency and prolong network lifetime in large-scale WSN environments. The corresponding hierarchical routing and data gathering protocols imply cluster-based organization

of the sensor nodes in order that data fusion and aggregation are possible, thus leading to significant energy savings. In the hierarchical network structure, each cluster has a leader, called cluster head (CH), which performs the fusion and aggregation task, and the other common sensor nodes (SN) act as members. The cluster formation process eventually leads to a two-level hierarchy where the CH nodes form the higher level and the cluster-member nodes form the lower level. The sensor nodes periodically transmit their data to the corresponding CH nodes. The CH nodes aggregate the data (thus decreasing the total number of relayed packets) and transmit them to the base station (BS) either directly or through the intermediate communication with other CH nodes. However, because the CH nodes send all the time data to higher distances than the common (member) nodes, they naturally spend energy at higher rates. As shown in Figure 2, Cluster heads aggregate the data from their cluster members, and send the aggregated data to the base station (BS).

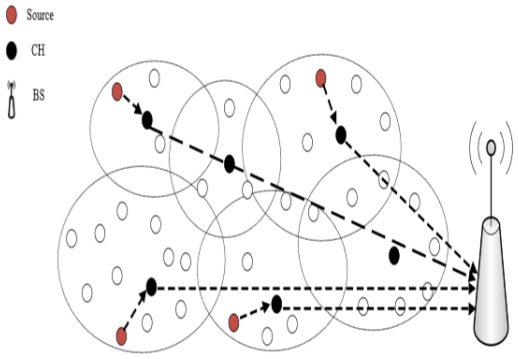

Figure 2: Cluster Based Routing in WSN

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.

1.3. Classification of Clustering Protocols

There have been several different ways to distinguish and further classify the algorithms used for WSNs clustering:

Clustering algorithms for homogeneous or heterogeneous networks:

This type of classification is based on characteristics and functionality of sensors in the cluster. In heterogeneous sensor networks, there are generally two types of sensors, sensors with higher processing capabilities and complex hardware, and common sensors, with lower capabilities. High capable sensors are generally used to create some sort of backbone inside the WSN—being preset as the CH nodes—and also serve as data collectors and processing centers for data gathered by other sensor nodes. Less capable sensors are used to actually sense desired attributes in the field. In homogeneous networks, all nodes have the same characteristics, hardware and processing capabilities. In this case, every sensor can become a CH. Moreover, the CH role can be periodically rotated among the nodes in order achieve better load balancing and more uniform energy consumption.

Static and dynamic clustering:

A cluster formation procedure is regarded as dynamic (otherwise as static) when it includes regular (periodic or event driven) CH re-election or cluster reorganization procedures, either to effectively react to network topology changes and adjust appropriately the cluster topology, or simply aiming at the appropriate rotation of the CH role among the nodes to gain energy efficiency. Dynamic cluster architectures make a better use of the sensors in a WSN and naturally lead to improved energy consumption management and network lifetime.

Probabilistic and Non-probabilistic clustering algorithms:

In probabilistic selection clustering algorithms, a priori probability is assigned to each sensor node which is used to determine the initial CHs. The probabilities initially assigned to each node often serve as the primary criteria for nodes in order to decide their election as CHs; however other secondary criteria may also be considered either during CH election process or during the cluster formation process in order achieve better energy consumption and network lifetime. In non-probabilistic clustering algorithms, more specific (deterministic) criteria is used for CH election and cluster formation, which is mainly based on the nodes proximity (connectivity, degree, etc.) and on the information received from other closely located nodes.

2. RELATED WORK

Low Energy Adaptive Clustering Hierarchy (LEACH) is a hierarchical, probabilistic, distributed protocol with following main objectives:

- To reduce the energy consumption in the network nodes (by performing data aggregation and thus reducing the number of communication messages).
- To improve the lifetime of WSNs by evenly distributing energy consumption among all the nodes of the network.

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. LEACH forms clusters by using distributed algorithm, where nodes make their

own decisions. All nodes have a chance to become CHs to balance the energy spent per round by each sensor node. Initially, a node decides to be a CH with a probability "p" and broadcasts its decision. Specifically, after its election, each CH broadcasts an advertisement message to the other nodes. Each non-CH nodes determine a cluster to belong to, by choosing the CH that can be reached using the least communication energy (based on the signal strength of each CH message).

The role of being a CH is rotated periodically among the nodes of the cluster to balance the load. The rotation is performed by getting each node to choose a random number "T" between 0 and 1. A node becomes a CH for the current rotation round if the number is less than the following threshold:

$$T(i) = \begin{cases} p/\ (1 - p * r \bmod 1/p) & \text{if } i \in G \\ 0 & \text{otherwise} \end{cases}$$

p:desired percentage of CH nodes in the sensor population

r: the current round number

G: set of nodes that have not been CHs in the last 1/p rounds

The clusters are formed dynamically in each round and the time to perform the rounds are also selected randomly.

2.1. LEACH algorithm

LEACH algorithm works as follows:

(i) **Set-Up Stage:** During the setup phase,

- Each node becomes on the basis of threshold value.
- After selecting cluster head, other nodes select their cluster head and join the cluster based on energy.
- Each node choose nearest cluster head.

(ii) **Steady-State Stage:** During the steady-state phase,

- Cluster head fuses the data received from the cluster members and send the fused data to base station by single-hop communication.
- LEACH uses randomization to rotate cluster head for each round in order to evenly distribute the energy consumption. So, LEACH can reduce the amount of data directly transmitted to base station and to balance load in wireless sensor networks.

3. PORPOSED MODELLING

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. So, if current energy of a cluster head is less or the distance to base station is much far, then the cluster head gets died quickly because of heavy energy burden. To address these issues, new improved algorithm, LEACH-TLCH is proposed here which focusses on how to balance energy load of these cluster heads.

3.1. LEACH-TLCH

LEACH Protocol with Two Levels Cluster Head is improved version of LEACH Protocol. However, the method 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 average distance, then 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.

3.2. Description of improved algorithm
LEACH-TLCH algorithm works as follows:

(i) Cluster Formation

Firstly, every node chooses a number between 0 to 1, if this number is less than threshold value T(i) , then the node becomes cluster head, else it becomes normal node. 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, on the basis of signal strength 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.

(ii) Selection of secondary cluster head

Each cluster head decides whether to set a secondary cluster head according to its current energy and distance to base station, if $E(i) < E(avg)$ or $d(i) > d(avg)$, then such cluster heads choose node with maximum energy as secondary cluster head in its cluster, otherwise, the secondary cluster head is not required.

(iii) Creation of 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 other normal nodes after it gets join information from them. The stable stage begins when each node gets its sending time slot.

(iv) Data transfer

When clusters are formed and TDMA schedule is determined, nodes start transferring monitoring data. The secondary cluster heads receive data from the other nodes and fuse these data. This fused data is then sent to cluster heads and which is then sent by cluster head to base station using single-hop method. In clusters without secondary cluster head, the cluster heads receive information from other nodes, fuse them and send them to base station just like LEACH.

4. CONCLUSION

Energy constraint is one of the major research topics in WSN. The routing consumes the largest amount of energy in WSN, so the routing protocol used for communication should be energy efficient. In this article, we have proposed a new improved algorithm of LEACH protocol which aims at balancing energy consumption of the whole network and extending the network lifetime by balancing the energy consumption of these cluster heads. The new improved algorithm is emulated by Matlab platform, the simulation results indicate that the energy efficiency and the lifetime of network are both better than that of LEACH Protocol.

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