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Improved LEACH Routing Communication Protocol for Wireless Sensor Network

Mankita, Er. Paramjeet Singh, Er. Shaveta Rani
(Computer Science and Engineering (CSE)
Giani Zail Singh Campus College of Engineering and Technology, Bathinda, Punjab, India)

***ABSTRACT*-A WSN (wireless sensor network) consists of thousands of sensor nodes which have limited energy, memory, and computation capability. In some of extreme environment, it becomes difficult to replace the sensor nodes once they used up the resources. Therefore, many researchers in this field focus on how to design an efficient routing protocol to prolong the life span of the network. The hierarchical protocols such as LEACH and LEACH-C have better performance in saving the energy consumption. However, neglecting the choosing formula of CHs and non-CHs makes the consumption of too much energy. In order to reduce the energy consumption, we improve the tradition method used for selecting cluster heads. Meanwhile, we establish a vice cluster head for each cluster to reduce the energy consumption and prolong the lifetime. Hence, simulations show that our improved protocol performs better than the LEACH and the LEACH-C.**

Keywords- Wireless Sensor Network, Energy Efficient Routing, Network Lifetime, Balanced Cluster.

I. INTRODUCTION

WSN (wireless sensor network) consists of several number of small sensor nodes with limited power, memory, and computational capabilities. The various applications of the WSN involve many fields, such as the military battlefield, forest fire detection, Weather Monitoring and other extreme environments.
Sometimes, it becomes difficult to replace the dead nodes with new ones to supply energy for the system. Hence, making sensor nodes working as long as possible is the main method to maximize the lifetime of the system. The reason of energy consumption of sensor nodes

generates from the long distance transmission of data. An efficient cluster head selection method by the routing protocol will have a great impact on the consumption of energy and network lifetime. So how to design an energy efficient routing protocol becomes the main goal for the wireless sensor network. The traditional routing protocol cannot adapt to the wireless sensor network due to the inherent property of WSN.

Hence, many protocols have been developed to satisfy the need of WSN. The cluster idea present in has a significant role in the research of WSN routing protocols. It deploys the sensor nodes into different clusters, with a cluster head in each cluster. The hierarchical routing protocols is divided the whole network into two or more levels called rounds. Here, each level will perform different tasks. LEACH (low energy adaptive clustering hierarchy) is a classical version in the hierarchical routing protocol family in which the communication process divides into rounds, where each round starts with a set-up phase and followed by a steady-state phase.
In the setup phase, some of the sensor nodes are selected as cluster heads (CHs) and rest of nodes join in the clusters as member nodes. In the steady-state phase, the CHs aggregate the data from their own cluster members and then transmit them to a base station (BS).
In contrast to LEACH, LEACH-C uses a central algorithm for selecting the CHs in each round, but it requires all the sensor nodes to send their information to remote BS regarding residual node energy and node position in network. In each routing protocol, the existence of cluster head (CH) in a cluster avoids the long transmission distance to BS in a communication process for each sensor node. High frequency of reclustering among sensor nodes will cause the energy distribution and waste a certain amount of energy in the whole network. Based on the ideology of traditional LEACH, we modify the choosing formula for reducing the consumption of sensor nodes' energy and change the process of selecting CHs to reduce the frequency of re-cluttering.

II. LEACH and LEACH-C Protocols

LEACH is a most popular clustering based routing protocol for a wireless sensor network. In LEACH, the nodes are organized into cluster in the geographical area and the communication process is divided into rounds, where each round includes set-up and steady-state phases. A TDMA(time division multiple access) schedule table is created and manipulated by a cluster head(CH) which is used by its member nodes to get when to transmit data packets in order to avoid collision during any communication process. Whenever emergency affairs happen in the monitor area, the sensor nodes are triggered to send data to their cluster head instead of the remote BS by themselves. The cluster head mainly aggregates the data coming from different member nodes and then transmits them to BS. In the whole process, the cluster head just works as a relay node to shorten the transmission distance so as to save energy. As for the set-up and steady-state phases in a round, they can be described as follows.

A. Set-Up Phase

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After the deployment of sensor nodes, each node in the monitor field is independent to be a cluster head in the current round. During the setup phase, each node generates a random number between 0 and 1 and then compares with the predefined threshold value

$$T(n)=\begin{cases}\dfrac{p}{p*[r \bmod (1/p)]}, & n \in G,\\ 0, & n \notin G,\end{cases}$$

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 have not been selected as cluster heads in round $1/p$. The figure.1 shows the working process of LEACH protocol [12].

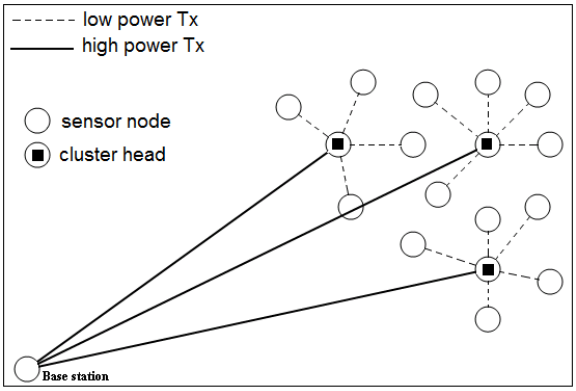

Fig1. Clustering structure of LEACH

The sensor node whose number is larger than the predefined threshold will select itself as a cluster head and then broadcasts the message to its surrounded sensor nodes to the status of them. In this phase, a member node may receive more than one message from different cluster heads, but the member node can judge its distance to a cluster head from the received signal strength; the stronger the signal, the closer to a cluster head. So the node which has the strongest signal strength will send message containing its ID to the closest cluster head (CH) for saving energy spent on the transmitting distance. After receiving request message from one node, cluster head records the node's ID and proclaims it as its member node. After exchanging of the messages between cluster heads and non-cluster heads, each CH gets its own member nodes' information about IDs and each member node gets which cluster it belongs to. Based on the message it records, the cluster head creates a TDMA schedule table and broadcasts it to its member nodes. Hence, all the member nodes get their idle slots for data transmission, and then the steady-state phase starts.

B. Steady-State Phase

The cluster head in each cluster provides a guarantee for the data transmission in a steady-state phase. If sensor nodes sense environment data, they will send the data to their cluster heads during the idle slots recorded in the TDMA schedule table. Otherwise, member nodes can turn off their radio until they sense the necessary environmental conditions. After receiving all the data sent by their members, CHs will aggregate them firstly and then send them to BS. Since some sensor nodes may sense similar environmental conditions, the aggregation on the cluster head can reduce communication traffic and unnecessary bandwidth cost, which has a positive reflection to the energy's consumption and data transmission distance, becomes shorter as compared to transmitting to BS. However, the heavy tasks executing on CH can lead to too much energy consumption. To avoid making the CHs die early and cause the cascade effect in the network, a new cluster will be rebuilt in the whole network.

C. LEACH-C Protocol

Like LEACH, LEACH-C also organizes the sensor nodes into clusters with each cluster a cluster head and divides a round into set-up and steady state phases. The steady phase in LEACH-C is similar to LEACH. It differs from LEACH only in that it uses a high-energy base station to choose the cluster heads.

In the set-up phase of each round, every sensor node sends its information about residual energy and node location to remote BS. Then the BS selects the cluster heads based on the information and broadcasts the IDs of cluster heads to other member nodes. This method makes the nodes with more energy and more chance to become the cluster head in the current round or level. But, every sensor node needs to send its ID and energy information to remote BS to compete for the role of cluster heads. But it causes energy consumption on the long distance transition and minimizes lifecycle of network. Here, we can assume that there will be a certain amount of energy needed to be consumed on the transition of energy information for each sensor node during every round, which cannot be neglected in communication.

Although LEACH and LEACH-C protocols act in a good manner but they also suffer from many drawbacks like the following.

(i) CHs' selection is random. No need to consider the residual energy of every node.

(ii) These protocols cannot cover a large area.

(iii)The high frequency of building clusters wastes a certain amount of energy.

(iv)CHs are not uniformly distributed in the deployed area, where CHs can be located at the edge of the cluster.

III. The Improvement to the Cluster-Based Leach Protocol

Based on LEACH, LEACH-C and other improvement protocols, we propose a modification to the cluster head selection process to reduce energy consumption. For a sensor network, we first make the following assumptions.

(i) All homogenous sensor nodes have limited energy with an indentify ID.

(ii) The base station (BS) is located far from the sensors and is immobile.

(iii)Cluster heads perform data compression and aggregation.

(iv)All nodes are able to reach BS and can communicate with each other.

In the improvement, we also make use of the hierarchical cluster based routing, where improved operates into a setup phase and steady phase. We will use improved formula to select appropriate cluster heads (CHs) which are responsible for aggregating data from their member nodes and transmitting them to BS.

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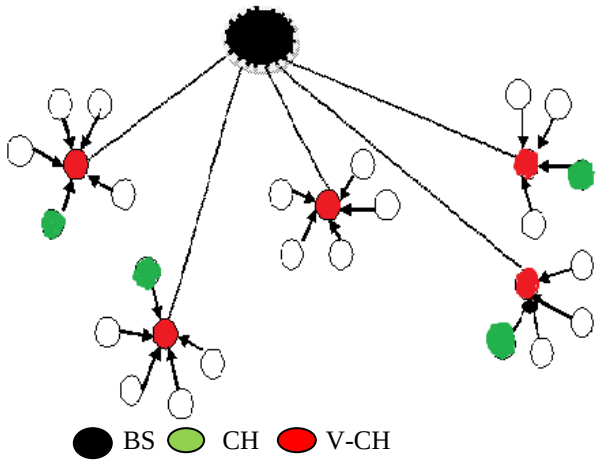

Figure 2: Improved hierarchical protocol working process.

As we know CHs will consume more energy than member nodes because of the heavy tasks. In order to avoid making the CHs die early, LEACH and LEACH-C take the measure of reclustering. However, in this paper, we will make use of the member nodes' information in the setup phase to choose the vice cluster heads (VCHs) which take over the role of as the intermediate node. Comparing with the traditional LEACH and LEACH-C, the proposed protocol will diminish the frequency of reclustering and prolong the lifecycle of the whole network.

A. Choosing Cluster Heads (CHs) in the Set-Up Phase

In LEACH-C, BS calculates the average energy of whole network. Based on the location information and energy level information send by all the sensor nodes to base station (BS), base station checks the nodes energy. If nodes energy beyond the average energy then that nodes will be selected for cluster heads (CHs) otherwise non-cluster heads in the current round.

At each round, if a node acts as CH for too much time, the energy it consumes will be larger than other sensor nodes. Using the improved equation, we can make the probability of a cluster head to consume more energy. We can observe that the improved formula adds some helpful factors in the selection of cluster heads, which is beneficial to the stabilization of clusters. In order to limit the cluster heads' number to a reasonable range, we develop the simulated annealing algorithm to establish appropriate numbers of cluster heads which is about 4%-5% of the total sensor nodes introduced in [7]. After finishing the selection of cluster heads in the set-up phase by using the simulated annealing algorithm, the steady-state phase of a round begins.

B. Vice Cluster Heads' (VCHs') Establishment during the Setup Phase

In LEACH and LEACH-C protocols, the cluster heads will deplete more energy than member nodes because they have responsibility of collecting, aggregating and relaying data to remote BS for their member nodes. To avoid making the cluster heads die early during communication time, a new round begins to reorganize the nodes into clusters and reelect the cluster heads. So, all the nodes have to rebuild the cluster heads in order to campaign for new cluster heads. As a result, it consumes some energy spent on recompleting the cluster heads. In this paper, we propose a new scheme to prolong network lifetime and diminish the frequency of reclustering. The new scheme works as follows.

After establishment of cluster heads in cluster, cluster heads starts aggregating data from their sensor member nodes. In each round, during setup phase we will check the energy of each cluster head. If the energy of each cluster head is more than the our predefined energy then we will go for the steady phase otherwise we will make the vice cluster head (VCH) which can diminish the frequency of reclustering and prolong the lifetime of network. Vice cluster head in each cluster will work as intermediate node that will aggregate sensed data from their cluster's member nodes and send aggregated data to their CHs. We can obtain that the method of establishing VCH is simple and rapid. They all have a good benefit to the saving of energy in the whole network.

IV. Simulation Result

The simulations were carried out using given parameters and the comparison of LEACH, LEACH-C with the proposed protocol has been taken up and presented below.

Table 1: Simulation Parameter

Parameter	Value
Network Size	100*100
Number of nodes	100
Packet Size	4000 bits
Initial node energy E0	0.1 j
Cluster head Probability	0.2
Amplification Energy Efs	10pJ/bit/m¹
Amplification EnergyEamp	0.0013pJ/bit/m¹

Network Lifetime

It is the time interval from the start of the network operation till the last node die. It describes the lifespan of network. The *simulation* results in figure 3 shows that proposed protocol has the longer lifetime than the LEACH and LEACH-C.

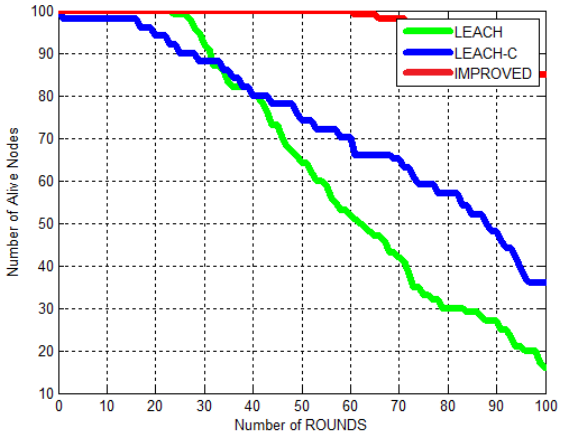

Fig3: Performance using Network Lifetime

Residual Energy

The residual battery energy of network is considered in order to analyze the energy consumption of nodes in each round. Residual energy ensures graceful degradation of network life. The average residual energy of the network is 50 joule as it is assumed that every node has 0.5 joule of initial energy. Our proposed protocol yields minimum

energy consumption than LEACH and LEACH-C as shown in figure 4.

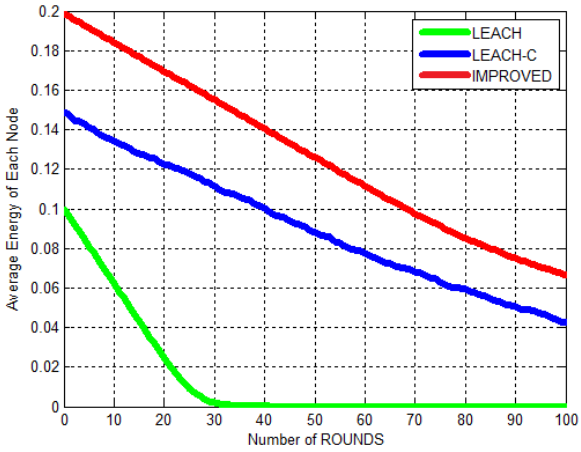

Fig4: Performance using Remaining Energy

Throughput

To evaluate the performance in terms of throughput, the numbers of packets received by BS are compared with the number of packets sent by the nodes in each round. Our proposed protocol gives better throughput due to increased network life time. Figure 5 illustrates the analysis of throughput comparison with LEACH and LEACH-C.

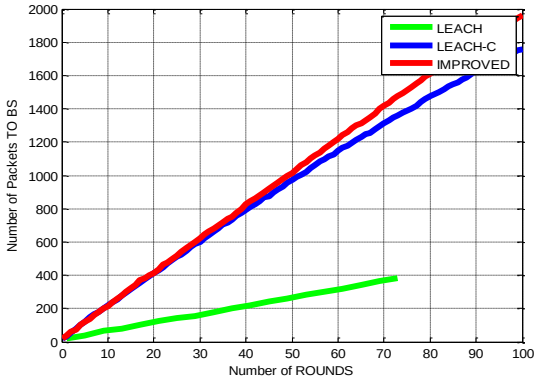

Figure5: Performance using Throughput

V. Conclusion

The improved protocol of LEACH-C compared against LEACH and LEACH-C protocols to prolong the network lifetime. In improved protocol, the intermediate nodes are created within each cluster. It reduced the energy consumption. The comparison of the three protocols is done and presented in terms of network lifetime, remaining energy and throughput.

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