Improvement of LEACH Routing Protocol in Wireless Sensor Networks

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Abstract—Wireless Sensor Networks consist of small, low-power, low-energy nodes used for monitoring environmental parameters such as temperature, humidity and motion. The sensor nodes run on batteries that are not recharged during the network's lifetime. Therefore, increasing WSN lifetime is a significant problem. In this article, We propose an improvement on the LEACH routing protocol to decrease energy consumption and increase network lifetime. Modified LEACH selects the cluster head node not only by considering residual energy of the node greater than the average residual energy level of nodes in network, but also on the basis of the distance between the candidate sensor node to the BS as a key parameter. The results of simulation show our proposed algorithm outperforms Basic LEACH protocol in terms of throughput and network lifetime

Keywords:- Wireless Sensor Networks(WSN), LEACH, Cluster Head(CH), Routing Protocols.

I. INTRODUCTION

Wireless Sensor Network (WSN) is used for many applications like environmental monitoring and habitat study, over a battle field for military surveillance and reconnaissance, in emergent environments for search and rescue, in factories for condition based maintenance, in buildings for infrastructure health monitoring, in homes to realize smart homes, or even in bodies for patient monitoring. It is one of the most growing fields and it will become the part of human life like mobile phones in a near future due to its growing application. Nodes in WSN sense the physical phenomena like temperature, pressure, humidity or location of objects and transfer the sensed data to the Base Station. In the WSNs, each node has limited energy because they operate on a battery power and this battery power is limited. Lifetime of the wireless sensor network depends upon its battery power and maximizing the lifetime of wireless sensor network is one of the major research areas currently.

A sensor node is made up of four basic components: a sensing unit, a processing unit, a transceiver unit and a power unit [15]. They may also have application dependent additional components such as a location finding system, a power generator and a mobilizer.

LEACH is a cluster-based protocol. LEACH is one of the most popular cluster-based routing protocols for WSNs. LEACH randomly selects a sensor node as Cluster Head (CH) and rotates this role to evenly distribute the energy load among the sensors in the network. In LEACH, the Cluster Head (CH) nodes compress data arriving from nodes that belong to the respective cluster and send an aggregated packet to the Base Station (BS). Cluster Head Selection method can be useful to increase throughput as well as network lifetime.

The rest of the paper is organized as follows. In section 2 we give an analysis of the LEACH protocol. Section 3 introduces our proposed method for cluster head selection method. Section 4 describes simulation results and discussions. Finally section 5 describes the conclusion and future work of our research work.

II. RELATED WORK

This section briefly describes the operation of cluster-based LEACH routing protocols:

A. Leach Protocol:

LEACH is one of the widely used cluster-based routing protocols for Wireless Sensor Networks. LEACH is a self-organizing, adaptive clustering protocol that uses randomization to distribute the energy load evenly among the sensors in the network. In LEACH, the nodes organize themselves into local clusters, with one node acting as the Cluster Head (CH).

In LEACH, the Cluster Head (CH) nodes compress data arriving from nodes that belong to the respective cluster and send an aggregated packet to the Base Station (BS). The CH node's energy is rapidly exhausted because it has to process more work than other nodes. The data aggregation can exclude a lot of redundant data to decrease the communication load on the CH node. The member nodes in a cluster communicate with their CH node by single-hop, and only the CH can forward aggregative data to the BS directly.

The operation of LEACH protocol is divided into rounds. Each round consists of two phases:

– Setup Phase
– Steady-State Phase as described below.

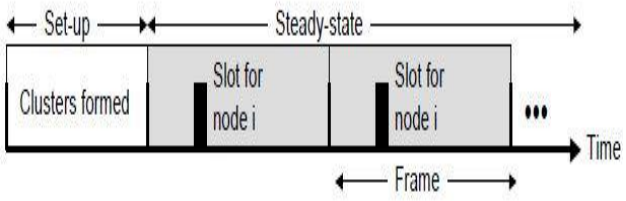

Fig. 1: Phases of LEACH protocol [8]

1) Setup Phase: Setup Phase consists of Cluster-head Selection, Cluster Formation, TDMA Schedule Creation.

a) Cluster-head selection:

During this step, each candidate node selects a random number between 0 and 1 (e.g. 0.05) and compares it with a calculation threshold value T(n). If the random number is lower than the threshold value T(n), then that candidate node will become the CH in the current round.

$$T(n) = \frac{p}{1 - p * \left(r \bmod \frac{1}{p}\right)}, if\ n \in G$$

Where, p is desired percentage of CH (e.g. 0.05),
r indicates the current round in the network;
And G is set of nodes that have not been CH in the last 1/p rounds.

b) Cluster Formation:

Each node that has elected itself a cluster-head for the current round broadcasts an advertisement message to the rest of the nodes. The non-cluster-head nodes must keep their receivers on during this phase of set-up to hear the advertisements of all the cluster-head nodes. After this phase is complete, each non-cluster-head node decides the cluster to which it will belong for this round. This decision is based on the received signal strength of the advertisement.

c) Tdma Schedule Creation:

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.

2) *Steady-State Phase*: The sensor nodes begin sensing in their areas and send data to their CH within the TDMA time slot allocated. Steady phase can be considered as data transmission phase. Every sensor node transmits their data while their turn comes. In Steady Phase, every Non-CH node waits for their turn to transmit the data. They may turn-off their radio until their turn comes. At the same time, CH's can't turn off their radio. They have to collect data from every non-CH nodes and aggregate them. After aggregating them CH's have to send this aggregated data to sink node.

The duration of this phase is longer than setup phase. Dividing the sensor nodes into small manageable units is called as clustering.

Cluster Head (CH) aggregates the data coming from different nodes & communicates with Base Station.

III. Cluster Head Selection In Leach Protocol

Although the LEACH routing protocol obviously has many advantages for WSNs in cluster organization, it does not consider residual energy of candidate nodes. Therefore, it is possible for a candidate node that has low residual energy to be selected as a CH. On the other hand, LEACH does not examine the distance between candidate sensor nodes and the BS. Consequently, if the distance of the CH is far from the BS, it will consume a lot of energy for data communication.

A. Proposed Method To Counter This Issue:

The aim of LEACH protocol is to minimize energy consumption or in other words, to maximize the network lifetime. To make this happen several ideas are proposed for CH selection but they were based on mainly the node's (to be selected as CH) energy level. The node having greater energy level will be selected as CH most of the times. But here in the new proposed scheme not only the node's energy level is considered but also it's location or position both within the CH & from the Base Station are considered.

1) *Steps Of Proposed Method:*Here the proposed method for selecting cluster head is based on Residual energy and distance:

- Step 1: Calculate the factor of minimum Residual energy and initial amount of energy will be taken.
  En = (Residual Energy / Initial energy)
- Step 2: Calculate the distance of one node to all other nodes.
  dij = distance from Ni to Nj
- Step 3: Calculate the average distance from all other nodes in the cluster.
- Step 4: Calculate distance from Base Station to each node in cluster for all nodes.
  Dbsi= Distance from BS to Ni
- Step 5: Calculate the average distance from the node to the Base Station.

The proposed method will select CH node with a residual energy higher than the average energy of the nodes in the current round, and that is nearer to the BS.

So the data sent in one second by a node will be high. So throughput will increase & also it will require less transmission time to send the data to Cluster Head because the distance between nodes is less. So here some modification to Cluster Head Selection algorithm can be done by proposed method so that transmission time & Network Lifetime will be increased.

IV. Simulation And Performance Evaluation

This section shows the simulation results with different performance measures like Lifetime of sensor network, Throughput, Cluster Head formation & scope. The simulations are conducted using MATLAB (R2008a) to run topology & get precise plots. MATLAB is a high-level language and interactive environment for numerical computation, visualization, and programming. Here, Modified LEACH is implementation of our proposed method. The simulation parameters are shown in table 1.

Table. 1: Simulation Parameters

Parameters	**Value**
Simulator	MATLAB (R2008a)
Routing Protocols	LEACH
Network Size	100 × 100
Number of nodes	100
Packet Size	2000 bits
Election Probability value of CHs (p)	10%
Number of rounds	500
Initial energy per node (E0)	0.5 J
E_{DA}	5 nJ / bit
E_{TX} & E_{RX}	50 nJ / bit

A. Simulation Results:

Following section shows the simulation results with different performance measures like throughput, network lifetime & optimized cluster head formation of network w.r.t LEACH.

1) Lifetime Of Sensor Network: Fig. 2 shows the lifetime of sensor network in case of Basic LEACH, LEACH with Energy & modified LEACH protocol. It clearly shows that Modified LEACH is improving the lifetime of sensor network than Basic LEACH & LEACH with Energy.

Here, Modified LEACH gives Higher network life time than basic LEACH protocol.

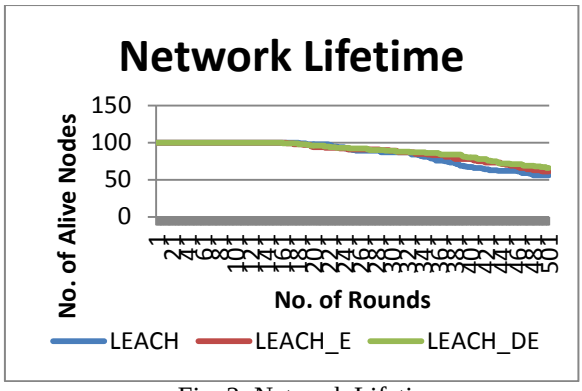

Fig. 2: Network Lifetime

Fig. 2 shows the lifetime of sensor network in case of LEACH, LEACH with Energy and modified LEACH protocol. It is clear that Number of Alive nodes in LEACH=56, LEACH with Energy=61 & Modified LEACH=66 after 500 rounds. So lifetime of network will increase with Modified LEACH.

*2) Throughput:*The definition of Throughput in sensor network varies from application to application. In continuous-monitoring applications, each sensor node transmits its sensed data to the BS periodically. For target localization problem, all the data generated in network must reach to BS for accurate target location estimation.

Comparing Modified LEACH with Basic LEACH & LEACH with Energy, Modified LEACH gives better throughput.

As Number of Packets sent to Base Station:

- In Basic LEACH=4453
- In LEACH with Energy=5379
- In Modified LEACH= 12704

Table. 2: Analytical Comparison Results (Throughput)

No.	Basic LEACH	LEACH with Energy	LEACH with Energy & Distance
1	4439	5256	13708
2	4362	5104	12198
3	4310	5019	11967
4	4478	5190	13119
5	4249	5487	12876

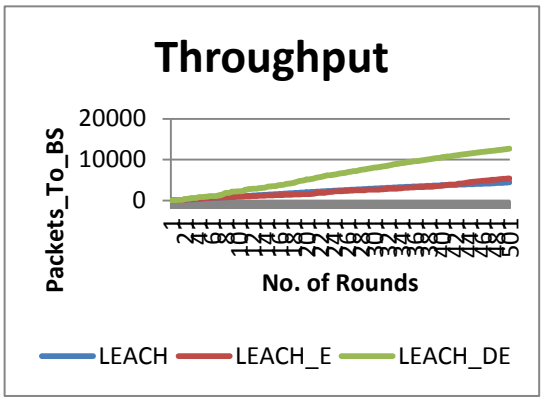

Fig. 3: Throughput

Fig. 3 shows the Throughput of sensor network in case of Basic LEACH, LEACH with Energy and modified LEACH protocol. It is clear that Total number of Packets sent to Base Station in LEACH=4331, LEACH with Energy=5338 & Modified LEACH=12820 after 500 rounds. So overall throughput of network will increase with Modified LEACH protocol.

*3) Cluster Head Formation & Scope:*Modified LEACH differs from LEACH in a sense that initially its number of Cluster Heads remain stable. But as the Number of Rounds is increasing, the number of nodes that become Cluster Head is less. So total energy consumed by these cluster heads will become less & sensor network can work for long period of time.

Modified LEACH executes same Cluster Heads for next round if they have energy greater than defined threshold.

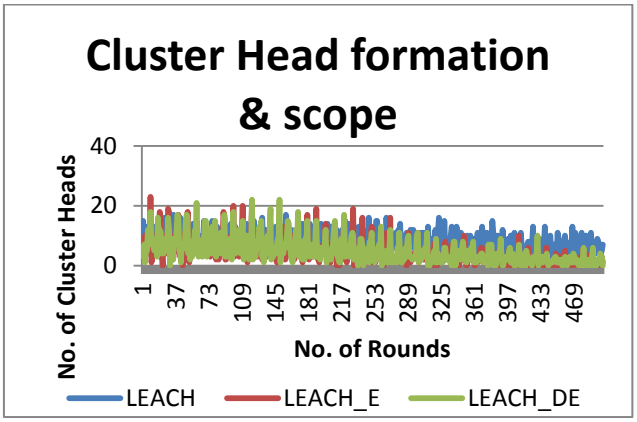

Fig. 4: Cluster Head formation & scope

Fig. 4 shows the Number of Cluster Head in each rounds of sensor network in case of Basic LEACH, LEACH with Energy and modified LEACH protocol.

Here in Basic LEACH Number of Cluster Head in each round is higher, so they consume more energy. In LEACH with energy Number of Cluster Head in each round is comparatively less. But in case of Modified LEACH, Number of Cluster Head in each round is very less. So that they will consume less energy & this network will work for longer period of time. So we can say that Network Lifetime will increase.

Simulation results show that Modified LEACH performs better considering parameters of throughput, network life time & optimized cluster head formation of network with respect to Basic LEACH.

V. Conclusion & Future Work

Clustering is essential for sensor network applications where a large number of sensors are deployed for sensing purposes. Cluster Head selection and Cluster formation part plays very important role in LEACH protocol. The algorithm for Cluster Head Selection has been found to increase Quality of Service. In this research paper, we propose an improvement to the cluster-based LEACH routing protocol for better network lifetime in a WSN. The proposed method will select cluster head using LEACH not only concerns about the current energy level but also takes into account the position or location of that node to be selected as cluster head. It is clear that the CH node closer to the BS will consume less energy than other nodes because communication of data consumes the most energy in WSNs.

Further improvement of LEACH protocol by choosing CH selection criteria based on Bacterial foraging optimization, fuzzy logic, etc & combination of them with residual energy can also be implemented.

As a part of future work, Researchers can implement

better Clustering techniques to make cluster formation uniform.

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