Analysis on Energy-Efficient Protocols for Wireless Sensor Networks

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Abstract

Wireless Sensor Network (WSN) is a Wireless Network in which a sensor or a group of sensors communicate with each other as well as the surroundings to gather information about it and transmit it to the receiver of the Base Station (BS). The operations in a WSN is usually carried out with the help of finite sources of energy such as battery. Therefore, these networks constantly need the replacement of batteries. But the replacement of the batteries is quite a complicated task because of the complexity of the structure. So it is quite a critical issue while designing such Networks. In order to solve this issue, the wireless networks must be energy-efficient and durable to sustain for longer durations. Here, two types of Wireless Networks Protocols have been introduced and explained – LEACH (Low-Energy Adaptive Clustering Hierarchy) Protocol and EAMMH (Energy Aware Multi-Hop Multi-Path Hierarchical) Protocol. They are explained in both Homogeneous as well as Heterogeneous Systems and are simulated using MATLAB.

Key Words: Wireless sensor network, base station, low-energy adaptive clustering hierarchy, energy-aware multi-hop multi-path hierarchical,
1. Introduction

Wireless Sensor Networks

WSN consists of numerous sensor nodes which sense their nearby space and gather data. This collected data is then transmitted to the nearest BS. They are generally operated in harsh environments and weather conditions for various purposes such as for detecting enemy units and targets, guiding the warheads to their designated targets, curing various diseases such as Alzheimer’s, weather monitoring etc. The replacement of batteries in WSN becomes difficult because of the presence of millions of nodes arranged in a very large network size [1-3]. Moreover, it is extremely difficult to recharge a used battery while the setup is in working mode. Therefore, it was decided to make the WSN energy-efficient so as to tackle these problems. For this, many proposals have been made for solving the complexity of constructing an energy-efficient WSN. These proposed WSN protocols substantially reduce the liabilities and drawbacks of a WSN system [4-7]. LEACH makes an apt example for a routing protocol (RP) which follows a system based on hierarchy. It incorporates the fabrication of a cluster of nodes, which considers the quality of the signal as its pivotal need and the native Cluster Head (CH). Hence we can achieve a decrease in the power consumption while transmitting the data because the CH transmits data to the receiver of its nearest BS instead of single sensory nodes. As we know, a WSN follows the process of Single-Hop (SH) or Multi-Hop (MH) while communicating [8-10]. In SH, there is a direct communication between the CH and the sensory nodes whereas in MH, the data is transmitted to the nearest CH of the BS. Hence there is no need of communicating directly to BS from the nodes. Therefore, MH process of communication is more energy-efficient than the SH process of communication because the distance between the nodes and the CH results in dissipation of energy. Here, both the LEACH protocol as well as the EAMMH protocol are presented and are analyzed in both Homogenous system and Heterogeneous system using MATLAB simulation.

Low-Energy Adaptive Clustering Hierarchy (Leach)

LEACH protocol works on the basis of “Cluster Theory” in which CH is selected from a group of nodes in a random way. CH plays a vital role in the collection of information from a group of sensory nodes and transmission of signals to its nearest BS. For every cluster of nodes, time slots are assigned using essential schedule created by CH. Here, the process of transmission is classified into time periods, where each time-period includes set-up(SU) phase and steady-state (SS)phase. In SU phase, the CH is selected among the cluster of nodes whereas in SS phase, the information is collected and transmitted to BS.

A cluster head is selected by each sensory node, based on the strength of the received signal [11-15]. In this phase, more than one broadcast message may be
received by a node from different cluster heads, but the node has the ability to calculate the space between the node and the group by analyzing the signal which was broadcasted. Here, the distance of the node from the group of nodes determines the strength of the signal as the strength of the signal increases with the decrease in distance. This is how it calculates its distance from the cluster. These sensory nodes detect their nearby spaces during the SS phase. Then they collect the information and transmit it to their nearest CHs. These CHs cumulate the data after receiving all data, and transmit it to their nearest BS. After some time, the whole process returns to the SU phase again and then enters another round of selecting a new CH.

![Flowchart of the Working of LEACH Protocol](image)

**Energy-Aware Multi-Hop Multi-Path Hierarchical (EAMMH)**

EAMMH (Energy-Aware Multi-Hop Multi-Path Hierarchical) Protocol is used for the Routing process in WSN. These protocols are majorly heuristic because execute the hop process depending on the energy of the adjacent nodes left. These Sensory nodes have a finite amount of nodal energy. In order to extend the lifetime of the Wireless Network, EAMMH Protocol avoids the selection of sensory nodes with low amount of energy while forwarding the information [16-18]. EAMMH Protocol uses numerous paths for data transmission and balances the communication load on the basis of the nodal energy remained.
EAMMH protocol aims at collecting data of the surrounding nodes and building surrounding table. This table contains all the data about the surrounding nodes, residual energy, distance of the hop, strength of the signal. This table helps for calculating the next hop using the parameters in the table which leads to the formation of Multi - Hop structure. EAMMH Protocol uses reactive protocol that generates path when essential in order to minimize the communication load. This is an improved protocol because of the induction of Routing process which is energy-aware and intra-cluster multi-hop. In EAMMH, the process of transmission is described in terms of rounds which represent the various phases of Setup transmission of Data. In the Set-up phase, the adjacent nodes discovery occurs just after deploying the nodes. This operation is carried out using several processes such as “k-of-n approach”, “beacon messaging” etc. When a cluster is created, then the CH is selected by the nodes for the present round after discovery of adjacent nodes. In SU phase, the primary objectives of operation are forming Clusters and selecting the CH for a cluster.

![Flowchart of Working of EAMMH Protocol](figure2)

**Figure 2: Flowchart of Working of EAMMH Protocol**

### 2. Mathematical Modelling

During the SU Phase, any randomly selected number between zero & one is chosen by the sensory nodes. If the number is less than T(n), the nodes becomes CH. The value of T(n) can be calculated by using the following formula:
In this formula, “p” represents the percentage of the CH present, “r” represents the present round & “G” represents the non-CH nodes in the previous $1/p$ round.

For transmission of information, every sensory node is allotted by time slots. While transmitting the information at regular intervals, it is generally assumed that transmission from the nodes takes place every time. A sensory node takes a heuristic approach for transmission of data which is given by,

$$h = K \left( \frac{E_{avg}}{h_{min} * t} \right)$$

(2)

Here, $K$ refers to any arbitrary constant. $E_{avg}$ refers to the average energy of the present path and “$h_{min}$” represent the minimum number of hops in the present path. Also, $t$ is equal to the traffic in the given path. The path in which the value of “$h$” is highest, is selected. If the $E_{min} >$ threshold for a path then, it is selected. Else, the path having the next highest “$h$” value is selected, where:

$$E_{min} = \frac{E_{avg}}{constant}$$

(3)

3. Simulation and Results

The simulation is done on the basis of two parameters:-
- Average Energy per Node Vs Number of Rounds.
- Number of Dead Nodes Vs Number of Rounds.

Following assumptions have been made on the basis of nodes before the analysis and simulation:
- The nodes should always be sending information to the CH.
- All the sensory nodes begin with equal amount of energy.
- The sensory nodes and their groups are immobile.
- It is assumed that the sensory nodes have a finite transmission range

In the Homogenous System, the LEACH Protocol is simulated on a network size of 50m x 50m with 100 sensory nodes. The location of BS is at the co-ordinates (25,50). At every 25 experiments, the sensory nodes sense the nearby spaces and transmit data to CHs. Every “o” refers to the Basic Nodes and the Blue “o” refers to the CHs. The initial energy of the nodes is set at 0.1 joules.

The simulation in the EAMMH homogenous is done using the parameters from the table 1. In the Heterogeneous System, the EAMMH Protocol is simulated on a network size of 50m x 50m with 100 sensory nodes. The location of BS is at the co-ordinates (25,50). At every 25 experiments, the sensory nodes sense the nearby spaces and transmit data to CHs. Every “o” refers to the Basic Nodes and the Blue-dotted “o” refers to the CHs. The initial energy of the nodes is set at 0.1 joules.
The simulations in both the LEACH and EAMMH are done using the following parameters:

Table 1: Simulation Set-Up Parameters for LEACH Protocol

| Parameter                                      | Value                  |
|------------------------------------------------|------------------------|
| Area of Simulation                             | 50*50                  |
| Location of BS                                 | (25,50)                |
| Type of Channel                                | Wireless Channel       |
| Type of Energy Model                           | Battery                |
| Proportion of Cluster Head                     | P=0.5                  |
| Probability of Special Nodes                   | m=0.5                  |
| Value of “α”                                   | α=1                    |
| Total number of Sensory Nodes                  | 100                    |
| Amount of Starting Energy (E₀)                 | 0.1J                   |
| Transmission Amplifier                         |                        |
| Efₛ                                             | 10*0.0000000000001 J   |
| Enₛ                                             | 0.0013*0.000000000001 J|
| Size of the Packet k                            | 5000 bits              |
| Energy of the Aggregation of Data (EₐD)        | 5*0.0000000001 J       |
| Energy of Transmission, E₉ₙ                      | 50*0.000000001 J       |
| Energy of Receiving Signal, E₉ᵣ                  | 50*0.000000001 J       |

A Heterogeneous Network is an arrangement of Sensory nodes in which some of the nodes operate with higher initial energy than the rest of the nodes. These Special nodes increases the lifespan of a network. It is assumed that there are “n” number of nodes. Among them, “m” percent of nodes have “α” times more energy than the rest. Therefore,

Basic Nodes Quantity = (1 - percent of Special Nodes) * Total number of nodes = (1-m) *n

Average energy of Basic Nodes = e₀

Special Nodes Quantity = m * n

Average energy of Special Nodes = e₀ * (1 + α)

From this, we get:

Overall energy used in the network operation = ((1-m) * n) * e₀ + (m * n) * (e₀ *(1 + α))

In the Heterogeneous System, the LEACH Protocol is simulated on a network size of 50m x 50m with 100 sensory nodes. The location of BS is at the coordinates (25,50). At every 25 experiments, the sensory nodes sense the nearby spaces and transmit data to CHs. In the Fig. 4, the Black “+” represents the Special Nodes and Blue “+” represents the Special Node CHs. Out of 100
nodes, half of the nodes have more energy than the rest of the nodes. The initial energy provided to the nodes is 0.1 joules. The value of ‘\( \alpha \)’ is 1.

In the Heterogeneous System, the EAMMH Protocol is simulated on a network size of 50m x 50m with 100 sensory nodes. The location of BS is at the coordinates (25,50). At every 25 experiments, the sensory nodes sense the nearby spaces and transmit data to CHs. In the Fig. 8, the Blue ‘+’ represents the Special Nodes and Blue-dotted Red ‘+’ represents the Special Node CHs. Out of 100 nodes, half of the nodes have more energy than the rest of the nodes. The initial energy provided to the nodes is 0.1 joules. The value of ‘\( \alpha \)’ is 1.

![Figure 3: LEACH Homogenous](image1)

![Figure 4: LEACH Heterogeneous](image2)

![Figure 5: Average Energy](image3)

![Figure 6: Average Energy](image4)

![Figure 7: EAMMH Homogenous](image5)

![Figure 8: EAMMH Heterogeneous](image6)
By comparing both the fig. 5 and fig. 6, it can be observed that the average energy per node is less than 0.1 joules in Homogenous System whereas, in Heterogeneous System, the average energy per node is nearly 0.15 joules. From this, it can be concluded that LEACH Heterogeneous Protocol performs better than LEACH Homogenous Protocol.

By comparing both the fig. 9 and fig. 10, it can be observed that the average energy per node is less than 0.1 joules in Homogenous System whereas, in Heterogeneous System, the average energy per node is nearly 0.15 joules. From this, it can be concluded that EAMMH Heterogeneous Protocol performs better than EAMMH Homogenous Protocol.

4. Conclusion

After the simulations of both the proposed protocols – LEACH and EAMMH in the Homogenous and Heterogeneous Systems, we have observed that:

- Heterogeneous Systems perform better than Homogenous Systems as their average energy per node is higher.
- Comparing both the Homogenous as well as Heterogeneous Systems of the two protocols, it was found that EAMMH performs better than LEACH in both the cases.
- Hence, from the observations, it can be concluded that EAMMH protocol is more preferable than the LEACH protocol as it is more energy-efficient.

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