P-LEACH: Energy Efficient Routing Protocol for Wireless Sensor Networks

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***Abstract*- Wireless Sensor Network (WSN) are of paramount significance since they are responsible for maintaining the routes in the network, data forwarding, and ensuring reliable multi-hop communication. The main requirement of a wireless sensor network is to prolong network energy efficiency and lifetime. Researchers have developed protocols Low Energy Adaptive Clustering Hierarchy (LEACH) and Power-Efficient Gathering in Sensor Information Systems (PEGASIS) for reducing energy consumption in the network. However, the existing routing protocols experience many shortcomings with respect to energy and power consumption. LEACH features the dynamicity but has limitations due to its cluster-based architecture, while PEGASIS overcomes the limitations of LEACH but lacks dynamicity. In this paper, we introduce PEGASIS-LEACH (P-LEACH), a near optimal cluster-based chain protocol that is an improvement over PEGASIS and LEACH both. This protocol uses an energy-efficient routing algorithm to transfer the data in WSN. To validate the energy effectiveness of P-LEACH, we simulate the performance using Network Simulator (NS2) and MATLAB.**

***Keywords* – Wireless Sensor Networks, LEACH Protocol, PEGASIS Protocol, P-LEACH Protocol**

I. INTRODUCTION

Wireless sensor networks (WSNs) are widely considered one of the most important technologies for the twenty-first century. In the past decades, they have received tremendous attention from both academia and industry all over the world. A WSN consists of hundreds to thousands of sensor nodes that have the ability to communicate among themselves using radio [1]. Nodes collaborate to accomplish a common task. For example, environment monitoring, military surveillance, and industrial process control. The basic philosophy behind WSNs is that, while the capability of each individual sensor node is limited, the aggregate power of the entire network is sufficient for the required mission [2]. The most important factor for WSN is the efficient energy usage and long lifetime. A higher lifetime can be accomplished through optimized applications, operating systems, and communication protocols [3].
Researchers have developed some protocols like LEACH and PEGASIS that have energy efficiency as the most vital goal. The LEACH protocol is based on cluster formation, where all nodes in a network organize themselves in a local cluster and select a cluster head, which collects information from non-head node and transmit it to the base station. LEACH protocol effectively increases the network lifetime but greatly reduces total energy consumption, since they consume more energy in the cluster head node and once head node dies all other nodes associated with it becomes isolated[4].In [5], an enhancement over the LEACH protocol was proposed. The protocol, called Power-Efficient Gathering in Sensor Information Systems (PEGASIS), is a near optimal chain-based protocol.
In [6], the PEGASIS protocol, a chain of sensor nodes is formed and leader node is selected for each round randomly. Leader of a particular round collects the data, fuses the data, and sends the data to the base station. Although clustering overhead is avoided, PEGASIS still requires dynamic topology adjustment since a sensor node needs to know about the energy status of its neighbors in order to know where to route its data. Such topology adjustment can introduce significant overhead, especially for highly utilized networks.
Hence, in this paper we propose the protocol P-LEACH, which overcome the shortcomings of LEACH and PEGASIS both. In P-LEACH, we use the cluster formation technique of LEACH in the chain based architecture of PEGASIS. As a result, the system will have higher lifetime, low energy consumption, and unlike PEGASIS, can also deal with a dynamic system. This protocol uses an energy efficient routing algorithm to achieve the proposed results. The remainder of the paper is organized as follows: Section II briefs the progress in the field of WSNs; Section III presents the design and functional components of the protocol and explains the algorithm. Section IV shows the simulation result of P-LEACH routing protocol; Section V concludes the entire paper.

II. RELATED WORK

Many energy efficient techniques were employed. In [7], Handy *et al.* focus on reduction in power consumption of wireless sensor networks with the help of the LEACH protocol. LEACH's stochastic cluster head selects an algorithm by a deterministic component to define the lifetime of a sensor network. It presents the three metrics – First Node Dies (FND), half of the Nodes Alive (HNA), and the Last Node Dies (LND) that determines the lifetime of a sensor network. However, it is assumed that all nodes in the network are homogenous and energy-constrained and are able to reach the base station, nodes have no location information, and cluster heads perform data compression. In [8], multi-hop routing with the LEACH protocol to prolong lifetime of WSN is implemented based on Received Signal Strength Indicator (RSSI). It introduces the concept of equal clustering in which any node reaches the BS in an equal number of hops. This reduces energy consumption. But using direct communication protocol, it requires large amount of transmission power and thus drains the battery. This results in reduction in network lifetime.

In [9], sensor webs consisting of nodes with limited battery power and wireless communications are deployed to collect information from the field. Gathering information in an energy efficient manner is critical to operating the sensor network for a long period of time. Each sensor node has to send that packet to the distant base station. The LEACH protocol forms clusters to fuse the data before transmitting it to the base station. The PEGASIS protocol is put forth to reduce the amount of energy sent per round, to overcome the drawback of the LEACH protocol. PEGASIS eliminates the overhead dynamic cluster formation, minimizes the transmission distance for non-leader nodes, and limits the number of transmissions and receptions among all nodes.

In [10], the existing PEGASIS protocol has a chain of sensor nodes that is formed, and for the data gathering round leader for each round is selected at random. The head of each cluster collects the data, fuses it, and sends to the base station. Here, the first node is selected for a particular number of rounds from those nodes in the network. Another approach is to pick the node with highest energy as the head of the data gathering process. The protocol is implemented in square, circular and rectangular topologies successfully. However, the PEGASIS is based on assumption that sensor nodes are static in behavior, and all nodes have global knowledge of the network. General Self-Organized Tree Based Energy Balance Routing Protocol (GSTEB) has been put forth in [4] as a substitute to LEACH, PEGASIS and HEED Protocols. This protocol uses a routing tree technique, where the roots of a routing tree technique have been selected by the base station, which then broadcasts this information to all nodes in the network. GSTEB requires less energy to change the topology in each round, has short transmission delay, and prolongs the network lifetime. The only shortcomings with this protocol are its transmission distance and power consumption.

Al-Karaki *et al.* posted the advantages and disadvantages of routing, power management, and data dissemination protocols that are energy efficient in [5]. Based on network structure the routing techniques are classified as hierarchical, location-based, or cluster based routings. These are evaluated for design, energy and communication overhead savings, and drawbacks. Based on this analysis the challenges and pinpoint future research guidelines are posed. Our paper gives highlights a few of the issues posed in [5]: energy and power efficiency, and dynamicity.

III. DESIGN AND FUNCTIONAL COMPONENTS OF P-LEACH

LEACH and PEGASIS are the most well-known energy efficient protocols for wireless sensor networks. LEACH considers a dynamic cluster approach and energy efficiency during wireless transmission, while PEGASIS considers the power consumption, reduced traffic overload, increased network lifetime and cost efficiency, but doesn't take into account a dynamicity. The combination of the two protocols is to design an ideal routing protocol for wireless transmission and networking. The cluster head set is responsible for data forwarding in LEACH, while in PEGASIS, hierarchical chain formation is implemented through an energy efficient algorithm for the same. We propose the new protocol P-LEACH that combines the chain formation technique within the clusters for data forwarding.

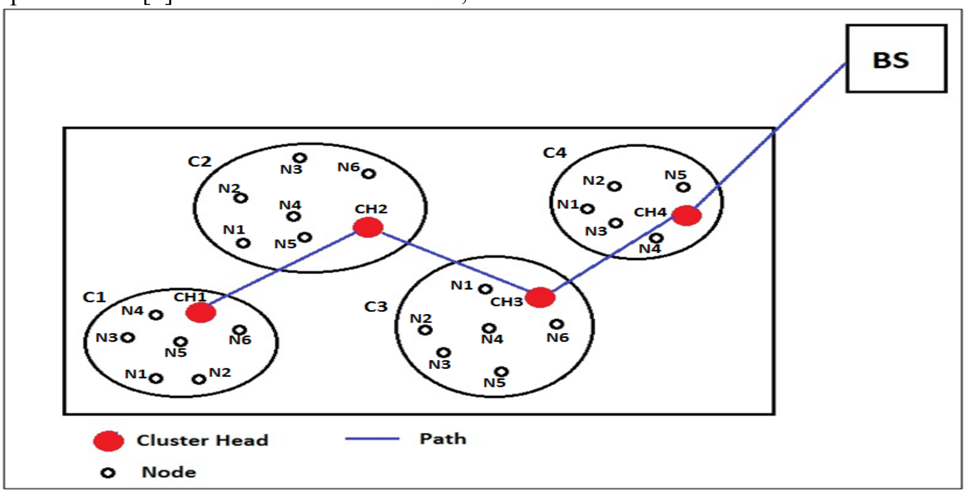

Fig. 1: Architecture of P-LEACH

In Fig.1, the hollow circles represent the nodes, and the black spots represent the cluster heads. The line represents the optimized path from nodes (cluster-heads) to the Base Station. The nodes in a cluster select an active cluster head having the highest energy amongst them. Each cluster head communicates with other cluster heads in the network and thus form a chain to the base station. The cluster head having the nearest distance to the base station is selected as a leader of the chains, who is responsible for sending the data to the base station directly. The proposed protocol is explained in algorithm-1.

Algorithm 1: Energy efficient algorithm for p-leach routing protocol.

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Step 1: Initializing the Network (Nodes (N), Base Station
(BS), Location L (x,y), Energy(E))
Ni =  1 to 16
            Ei = E1 to E16
            Ni – sends Ei info to BS
            Ni -- sends L(x,y) to BS
Step 2: Cluster Head Selection
 For (i=0; i<=16; i++)
          {
            If
              Ei = Emax
             Then
               Ni = Chi
          }
            End if
       End for
Step 3: Giving and receiving messages internally
        BS → CH(M) to Ni
        Ni  → ack to BS
Step 4: Chain Formation and selecting a leader
             Leader -- Chi (min L(x,y) & Emax)
             Path    -- CH1 – CH2 – CH3- CH4- BS

Step 5: Transferring the Data
         Ni of respective CHi → D(Ni) to CHi
         CHi ←D(Ni)
         CH1→CH2→CH3→CH4(L)→BS

Step 6: Change of Cluster Head
    For (i=0; i<=16; i++)
         {
         If
            Emax(CHi)<= Eeff
         Then
             Ni(Emax2) = CHi
         }
         End if
    End for
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In Algorithm-1, all the nodes (N) send their location L(x,y) and energy (E) information to Base Station (BS) in step-1. BS receives location (L) and energy (E) from nodes N1, N2, N3, N4, N5, N6 and so on, of each cluster. For Cluster Head Selection in step2, BS selects a node Ni with the maximum remaining energy $'E_{max}'$ as the Cluster Head CH for each Cluster. In Step 3, once the BS selects the Cluster Head, it informs every node in the network about the selection of the CH. Nodes send an acknowledgement message back to the BS informing the BS that it has successfully received the information.

In step 4, a CH with maximum energy and minimum distance from the base station is selected as the Leader, so as to contact the BS directly. Hence, the minimum path from source to destination is drawn. In step 5, the data is transferred through the path drawn. First, the data of each node is sent to the CH of the cluster. Now the CH gathers the data from all the nodes and forwards it to the next CH in the chain. In step 6, IF loop is implied if the energy of the cluster head goes below the expected energy level. If CH fails to maintain the same maximum energy, then the node with the second highest maximum energy is selected and declared as the CH as per step 2. This ensures successful working of the Cluster Head in the Cluster-Chain-based architecture of the P-LEACH routing protocol.

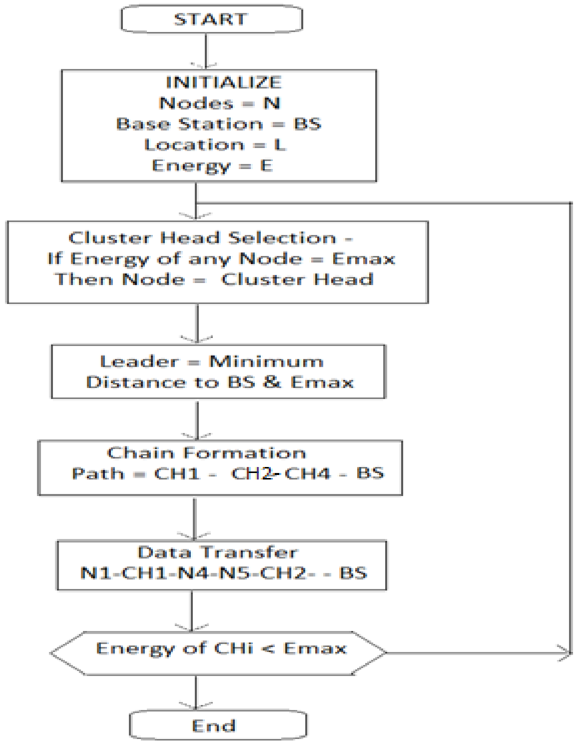

Fig. 2: Flow Chart P-LEACH Algorithm

Fig. 2 shows the flowchart of the Energy Efficient Algorithm. At Initialization stage, the REQ messages are sent by the Base Station to every Node. The Nodes then are equally divided into Clusters depending on sensing range, and form the Cluster ID and table. The node with maximum energy is selected as the Cluster Head. The next selected cluster head node is with the higher energy. The leader with lease distance from the base station is selected based on its location. The chain formation is based on distance and energy of every node. Then the data transfer takes place.

IV. SIMULATION AND RESULTS

Our performance evaluations are based on the simulation of 100 wireless sensor nodes that form a wireless sensor network over a rectangular (600 m X 600 m) flat space. All network nodes start the simulation by an initial energy that is equal to 5 Joules and an unlimited amount of data to be transmitted to the base station. In addition, the energy of the base station is considered unlimited. Each node uses its limited reserves of energy during the simulation, which causes the depletion. Any node which has exhausted its energy reserve is considered dead.

We simulated P-LEACH protocol with MATLAB and parameters are given in Table II. The expected outcomes for the data transfer – energy, failure and lifetime are evaluated and compared with the existing protocols. The values are compared and plotted in Microsoft Excel. The simulation parameters are provided in Table 1.

TABLE I: Simulation Parameters for MATLAB

Parameters	Value
Simulation Area	600 X 600
Number of Nodes	200
Number of Rounds	180
Base Station Location	(150,50)
Channel Type	Wireless Channel
Energy of Node	5J
Transmission Energy, ETx Receiving Energy, ERX	50 50
Simulation Time	5 Minutes
Sensing range	30 meters
Packet size	256 tes

Fig. 3 shows a comparison of the number of dead nodes in P-LEACH, PEGASIS, and LEACH. The results show that for 180 rounds, P-LEACH has the minimum number of dead nodes: approximately 82. For PEGASIS and LEACH, the numbers of dead nodes are 132 and 175 respectively. Thus, P-LEACH is more sustainable and conserves energy. The reason for fewer dead nodes in our approach is that we integrated the best features of both LEACH and PEGASIS.

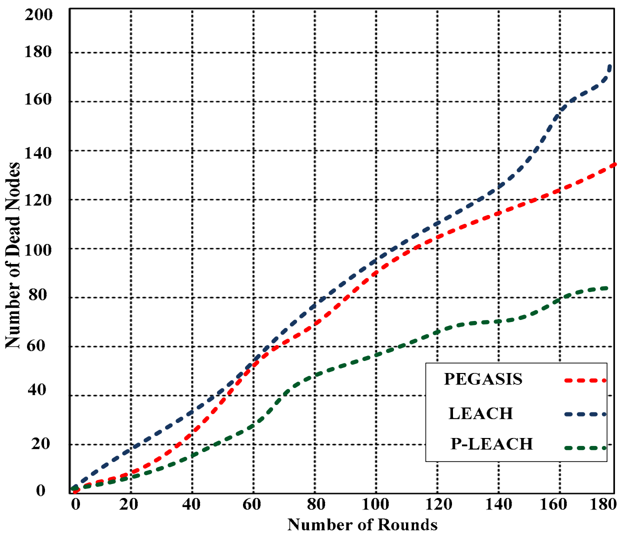

Fig. 3: Number Dead Nodes

Fig. 4 shows the comparison of the average energy of the nodes in P-LEACH, PEGASIS, and LEACH. The average energy of the nodes in P-LEACH is more than the other two. This leads to the conclusion that P-LEACH is an energy efficient routing protocol.

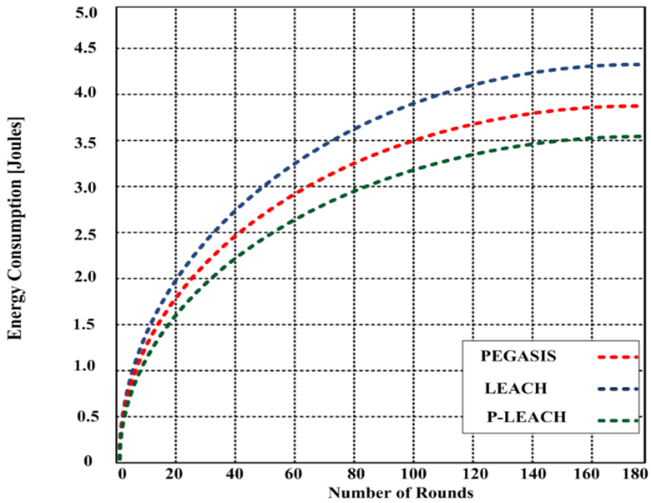

Fig. 4: Average Energy of nodes

V. CONCLUSIONS

In this paper, we proposed the P-LEACH Routing Protocol for improving energy efficiency in wireless sensor networks. The performance of P-LEACH is compared with the LEACH and PEGASIS protocols. With simulation we observed that P-LEACH performs much better than LEACH, and PEGASIS in terms of network lifetime, number of dead nodes and energy consumption. MATLAB is used for evaluating the performance of the protocol. Based on the simulation results, we determined that P-LEACH performs better than LEACH and PEGAIS in terms of energy and lifetime of the network. The simulation results validate that our proposed approach could extend the network for WSNs applications.

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