# Performance Evaluation of PEGASIS and LEACH Protocol Using MATLAB Based Simulation Platform

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**Abstract**

Wireless sensor network (WSN) is widely considered as one of the most important technologies for the twenty-first century. In the past decades, it has received tremendous attention from both academia and industry all over the world. In WSNs, topology plays an essential part in minimizing different imperatives, for example, latency, restricted vitality, computational asset emergency and nature of the correspondence. There are many types of routing protocols in WSN such as hierarchical protocols consist of LEACH and PEGASIS routing protocol. This study aims to evaluate the performance of PEGASIS and LEACH protocol using MATLAB based simulation platform. Simulation results showed better performance for PEGASIS even both protocols fall under hierarchical category. In this project describe PEGASIS a greedy chain protocol that is near optimal for a data-gathering problem in sensor networks. PEGASIS outperforms LEACH by minimizing the distance non leaders-nodes must transmit, limiting the number of transmission and receives among all nodes, and using only one transmission to the BS per round. PEGASIS protocol achieves an increases of 2 times higher than LEACH protocol in term of energy consumption. For the system lifetime PEGASIS perform 30% better than LEACH and in terms of delay LEACH introduces less delay than PEGASIS.

**Keywords:** LEACH, Matlab, PEGASIS

## 1.0 Project background

Wireless Sensor Network (WSN) consist of a great amount of small nodes which have sensing, computing and communication abilities. Owing to characteristics like convenient deployment, easy self-organizing, and real-time monitoring, WSN are extremely popular in a variety of applications such as healthcare, green agriculture and environmental surveillance (Hau, Zhenjiang, Yi, Manna, 2015) (Bing, Wenzhong, Naixue, Guolong, Athanasios, Hong, 2016). However, most of the sensor nodes are battery-driven, to change or recharge their batteries is a tremendous challenge. Therefore, it is critical to design an energy-efficient routing protocol to wisely use the limited energy of WSN. (Jinyu, Shubin, Chen, Yanhong, Jingtao, 2018) (Haifeng, Wenzhong, Naixue, 2017).

There are very large array of diverse sensor nodes that are interconnected by a communication network in WSN. The elementary components of a sensor node are sensing unit, a processing unit, a transceiver unit and a power unit. The sensor node senses the physical quantity being measured and coverts it into an electrical signal. Then, the signal is fed to an A/D converter and is ready to be used by the processor (Parminder, K. et al, 2012). The processor will convert the signal into data depending on how it is programmed and it sends the information to the network by using a transceiver. The sensing data are shared between the sensor nodes and are used as input for a distributed estimation system (Akkaya & Younis, 2004) (Heinzelman, Chandrakasan & Balakrishnan, 2000).

The fundamental characteristics of WSN are reliability, accuracy, flexibility, cost effectiveness, and ease of deployment (Akkaya & Younis, 2004). As we know that wireless sensor network mainly consists of tiny sensor node which is equipped with a limited power source. The lifespan of an energy-constrained sensor is determined by how fast the sensor consumes energy. A node in the network is no longer useful when its battery dies. Researchers are now developing new routing mechanisms for sensor networks to save energy and pro-long the sensor lifespan. The dynamic clustering protocol allows us to space out the lifespan of the nodes, allowing it to do only the minimum work it needs to transmit data (Akyildiz, Su, Sankarasubramaniam & Cayirci, 2002). The WSN can be applied to a wide range of applications, such as environment management, environmental monitoring, industrial sensing, infrastructure protection, battlefield awareness and temperature sensing. So, it is essential to improve the energy efficiency to enhance the quality of application service (Akyildiz, Su, Sankarasubramaniam & Cayirci, 2002) (Sabarish, Moorthy, Dhivya & Sakthi, 2012).

## 1.1 Problem statement

There are various problems in Wireless sensor network. Coverage problem, which reflects how well a sensor network is monitored or tracked by sensors. Position estimation problem, which relates to the distance measured between sensor positions. In addition, one of the fundamental issues is energy conservation of sensors, system lifetime and throughput. Incidentally, the energy consumption can be correlated to the quantity of packets sent and received. In Wireless sensor networks, most of the energy is consumed in transmission and receiving of data as compared to sensing and processing of data (Rahman & Anwar (2013). Sensor nodes are severely constrained by the amount of battery power available, limiting the lifetime and quality of the network.

Since wireless network communications consume significant amount of battery power, sensor nodes should spend as little energy as possible receiving and transmitting data. Therefore, it is desirable that the network protocol should take care of issues like energy-efficiency, system lifetime and delay. Thus, this project is to investigate the suitable network protocol used such as low-energy adaptive clustering hierarchical (LEACH) and power-efficient gathering in sensor information systems (PEGASIS) (Shreshtha, Rakesh, 2018) that will give the best performance in the wireless sensor network. In this research, both protocols are compared to distinguish the performance of those networks in terms of energy consumption of randomly deployed node, network lifetime pattern and time requirement comparison for completing a round.

## 1.2 Objectives

The objectives of this project are:

i. To study about LEACH and PEGASIS protocol in wireless sensor networks.

ii. To investigate and analyze the performance of LEACH and PEGASIS protocol in wireless sensor network.
iii. To compare the performance of LEACH and PEGASIS protocol.

## 2.0 Methodology

### 2.1 Project flowchart

The system planning for this project is to understand the LEACH and PEGASIS routing protocol in Wireless Sensor Networks. In order to compare the performances between LEACH and PEGASIS, we simulated both of them using MATLAB. MATLAB is used in order to understand the necessity of routing protocols and their benefits we briefly describe the power consumption model for WSN devices. The project flowchart as shown in figure 1.

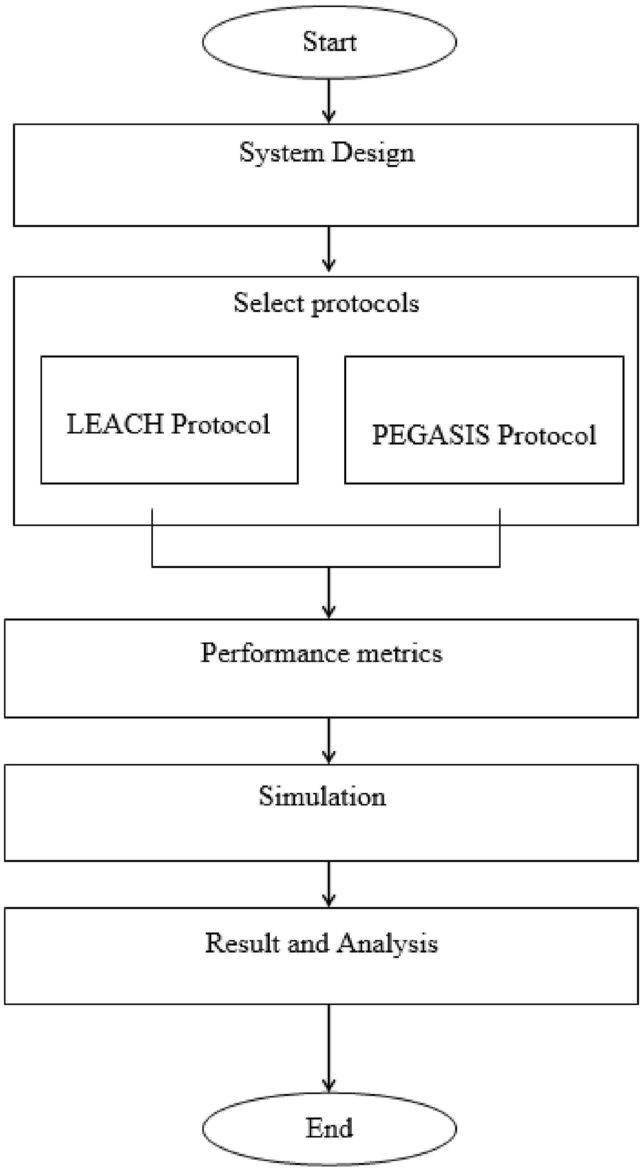


**Figure 1**: Project flowchart

## 2.2 System design

All the simulation is using MATLAB R2013a. MATLAB is very useful for making scientific and engineering plots, offers a variety of data plotting function plus a set of GUI tools to create and modify graphic displays. The following steps can be used in constructing the system model for LEACH and PEGASIS protocol:

i. Creating a New script. At the HOME function, click New and choose Script
ii. Write codes in the editor area
iii. After writing the code, save the script and run the simulation to get the result signal by pressing the Run icon.
iv. If there are problems in the coding, it will mention in command windows.

## 2.3 Implementation of LEACH algorithm

Basically, the development of LEACH protocol is referring of the flowchart shown in Figure 2.

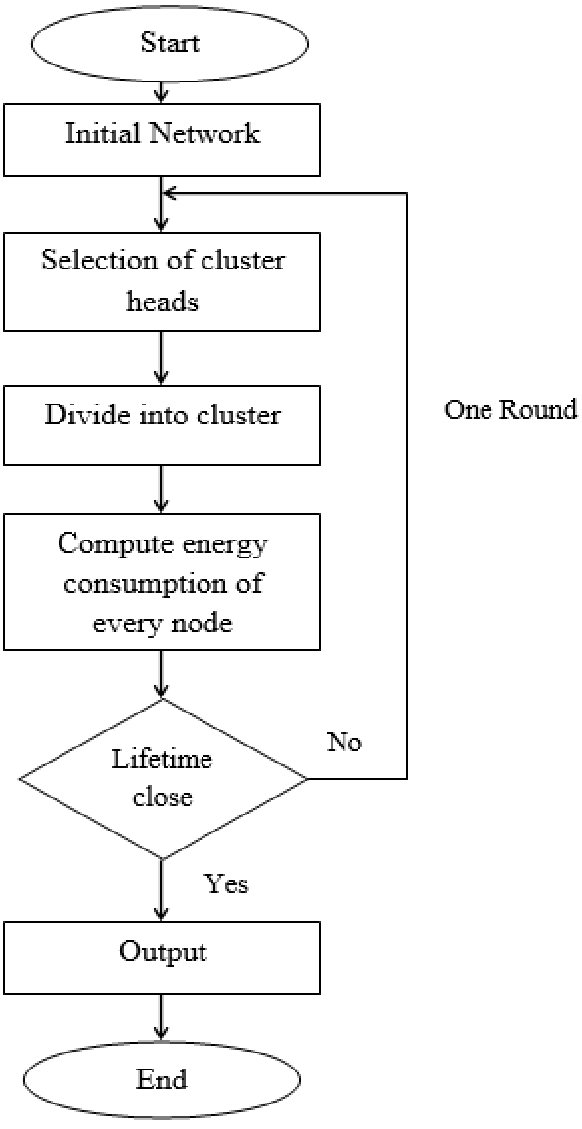


**Figure 2**: Flowchart of LEACH protocol

The cluster formation and the cluster head selection algorithm are given below:

- Step 1: Initialization
- Step 2: If node *i* is CH processed from step 3 to step 7. If not returns to step 1.
- Step 3: CH broadcasts an advertisement message (ADV) using the CSMA MAC protocol. ADV = node's ID + distinguishable header.
- Step 4: Based on the received signal strength of ADV message, each non-Cluster Head node determines it's Cluster Head for this round.
- Step 5: Each non-Cluster Head transmits a join-request message (Join-REQ) back to its chosen Cluster Head using CSMA MAC protocol. Join-REQ = node's ID + cluster-head ID + header.
- Step 6: Cluster Head node sets up a TDMA schedule for data transmission coordination within the cluster.
- Step 7: TDMA schedule (1. Prevents collision among data messages. 2. Energy conservation in non-cluster head nodes)
- Step 8: end

### 2.4 Implementation of PEGASIS algorithm

The main idea in PEGASIS is for each node to receive from and transmit to close neighbors and take turns being the leader for transmission to the BS. This approach will distribute the energy load evenly among the sensor nodes in the network.

- Initially place the nodes randomly in the play field
- *i*- th node is at a random location
- The nodes will be organized to form a chain, which can either be accomplished by the sensor nodes themselves using a greedy algorithm starting from some node. Alternatively, the BS can compute this chain and broadcast it to all the sensor nodes.
- For constructing the chain, assume that all nodes have global knowledge of the network and employ the greedy algorithm.
- The greedy approach to constructing the chain works well and this is done before the first round of communication.
- To construct the chain, we start with the furthest node from the BS. We begin with this node in order to make sure that nodes farther from the BS have close neighbors, as in the greedy algorithm the neighbor distances will increase gradually since nodes already on the chain cannot be revisited.
- For gathering data in each round, each node receives data from one neighbor, fuses with its own data, and transmits to the other neighbor on the chain.
- Node $i$ will be in some random position $j$ on the chain. Nodes take turns transmitting to the BS, and we will use node number $i$ mod N (N represents the number of nodes) to transmit to the BS in round $i$.
- The leader in each round of communication will be at random places are to make the sensor network robust to failures.

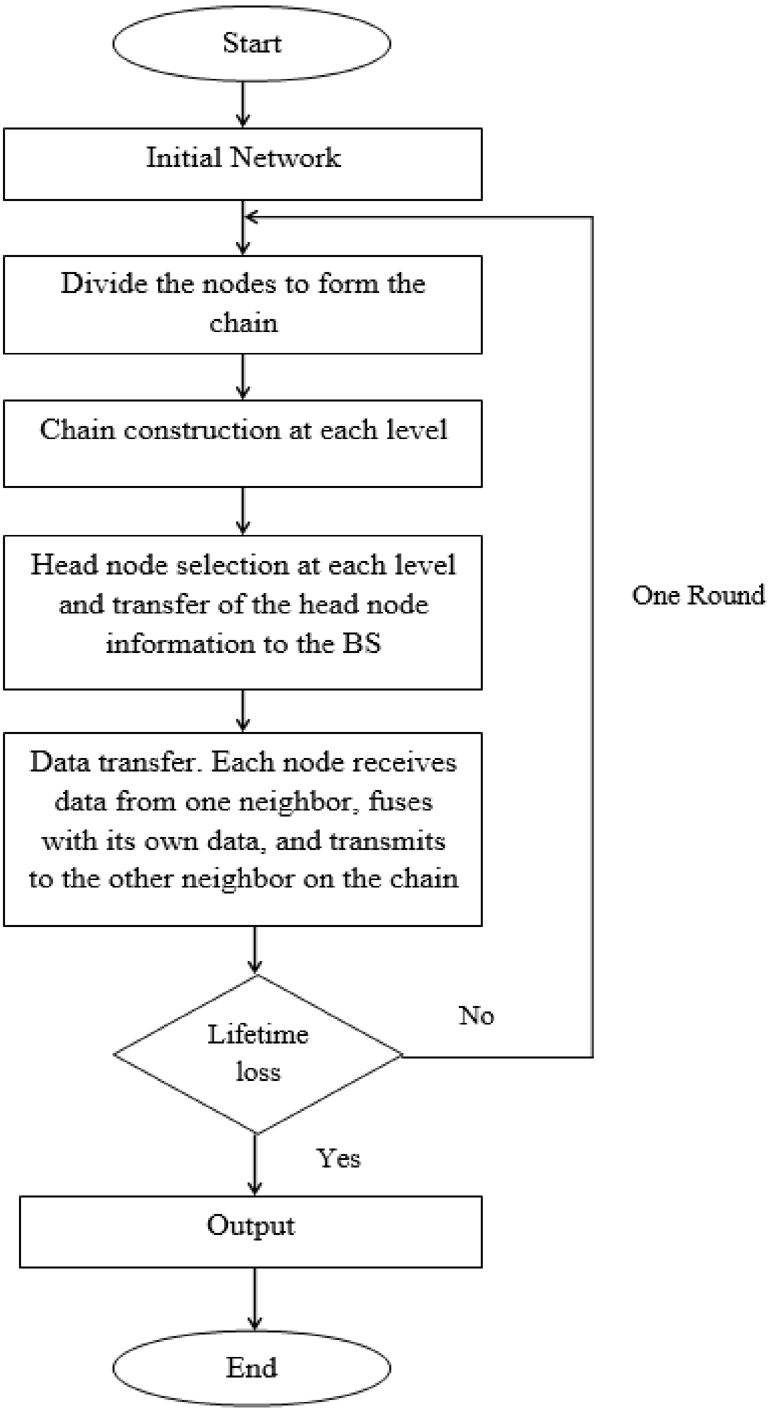


**Figure 3**: Flowchart of PEGASIS protocol

## 3.0 Evaluation of results

### 3.1 Simulation on the MATLAB (LEACH Protocol)

For this project, a 100-node network with randomly distributed nodes in a 100 x 100meter area. The base station (BS), is located at (x=50, y=50). The length of each signal is 2000 bits and the energy required for data aggregation is 5nJ/bit/signal. Data processing time per node is taken as 5-10 milliseconds. The radio speed is considered as 1Mbps. The communication model used the first order radio model concept.

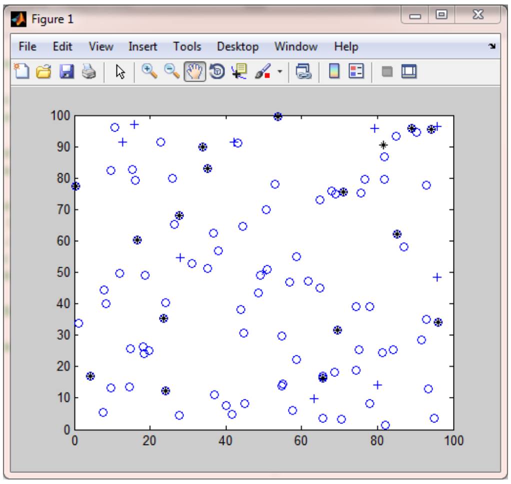


**Figure 4**: Network Topology

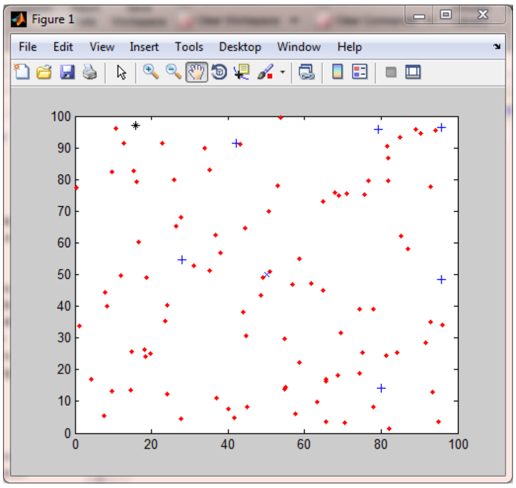


**Figure 5**: Dead node

Figure 4 shows that the network topology for LEACH Protocol. 100 nodes taken by providing each node with energy of 0.5 J, indicated with the bubble shape random network and advanced node with twice the energy of normal node indicated with + sign. Figure 5 shows the simulation results, comprising of dead nodes indicated with red dots and the live nodes indicated by + and bubble symbol. The nodes with higher energy always prefer to stay alive to enhance system life time.

### 3.2 Simulation on the MATLAB (PEGASIS Protocol)

The parameters used for this simulation are shown in Table 1:

**Table 1**: System parameter value for PEGASIS

| Parameter | Value |
|---|---|
| Number of nodes | 100 |
| Probability of selection | 0.1 |
| Energy | 0.5 |
| Transmission Energy | 50*0.000000001 |
| Receiving Energy | 50*0.000000001 |
| Forwarding Energy | 100*0.000000000001 |

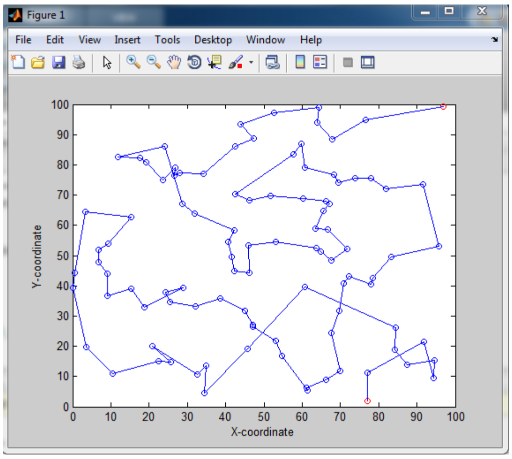


**Figure 6**: Chain construction in PEGASIS protocol

Chain construction in PEGASIS protocol is shown in Figure 6. The algorithm uses the following steps to form a chain. Firstly, initialize the network parameters. Determine the number of nodes, initial energy and BS location information. Gathered data moves from node to node, get fused, and eventually a designated node transmits to the BS. Nodes take turns transmitting to the BS so that the average energy spent by each node per round is reduced.

## 4.0 Performance evaluation

### 4.1 Energy consumption

To evaluate the performance of the protocol it has been simulated in 100 node network and the nodes are randomly distributed in a 100m x 100m. For the purpose of simulation, the simple radio energy model was used that proposed by Heinzelman.et.al. The explanation about this radio model is described in the chapter 3. We use the same radio model for LEACH and PEGASIS. The model assume, a radio dissipates $E_{elec}$= 50 nJ/bit to run the transmitter or receiver circuitry and $E_{amp}$=100 pJ/bit/$m^2$ for the transmitter amplifier to achieve an acceptable $E_b$. To do the comparison, the protocol is simulating to determine the Sum of Remaining Energy of nodes per round in LEACH and PEGASIS protocol.

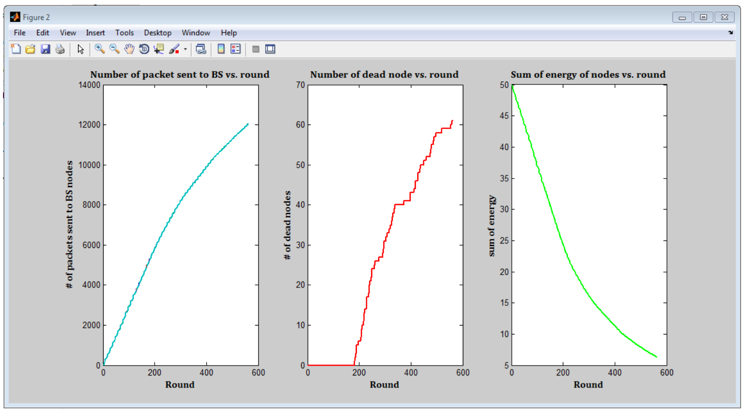


**Figure 7:** Number of packet sent to BS, Number of dead node and Sum of energy of nodes with area size m x m (LEACH protocol)

The result shown in Figure 7 shows the number of packet sent to BS compare to round, number of dead node to know the system lifetime and sum of remaining energy of nodes per round to know the energy consumption of LEACH protocol. For this simulation is set to 600 rounds.

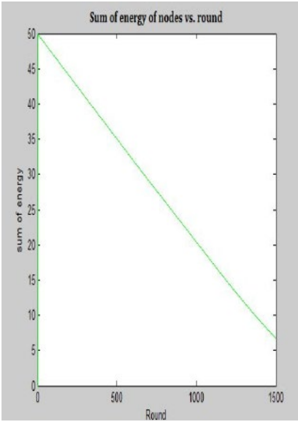


**Figure 8**: Sum of energy of nodes vs. number of rounds in LEACH protocol

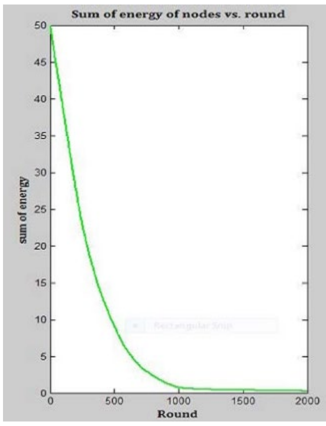


**Figure 9**: Sum of energy vs. Number of Rounds in PEGASIS protocol

Figure 8 show the result for LEACH protocol to determine the sum of remaining energy of nodes per round. Initially, sum of energy of all nodes are 50J, as rounds are increased energy is consumed. We can see when the simulation up to 480 rounds residual energy are about 15J, 20J residual energy are remain left until 310 round, 25J about 240 rounds and for 30J energy up to 200 rounds. From the Figure 9, we can see that, for PEGASIS protocol residual energy are 15J at 1195 rounds, 20J residual energy up to 1007 rounds, 25J residual energy remain left until 830 rounds and 30J up to 664 rounds.

## 4.2 System lifetime

By using several random 100 node networks, the simulation is done for using different total initial energy and network size. Firstly, as shown in table 2 is the performance result for the network size 50m x 50m field. The BS is located at (25, 150) in a 50m x 50m field. Secondly, table 4.2 shows the simulation result for network size 100m x 100m when the BS is located at (50, 300). To measure system lifetime when the 1%, 20%, 50% and 100% of the nodes death during simulation are run. Once a node dies it is considered dead for the rest of the simulation.

**Table 2**: Performance result for a 50m x 50m network

| Energy J/Node | Protocol | Percentage of node death | | | |
|---|---|---|---|---|---|
| | | 1 % | 20% | 50% | 100% |
| | | Number of rounds | | | |
| 0.25 | LEACH | 400 | 478 | 520 | 630 |
| | PEGASIS | 785 | 1000 | 1040 | 1096 |
| 0.5 | LEACH | 800 | 960 | 1035 | 1200 |
| | PEGASIS | 1578 | 2010 | 2080 | 2190 |

**Table 3**: Performance result for a 100m x 100m network

| Energy J/Node | Protocol | Percentage of node death | | | |
|---|---|---|---|---|---|
| | | 1 % | 20% | 50% | 100% |
| | | Number of rounds | | | |
| 0.25 | LEACH | 165 | 204 | 232 | 310 |
| | PEGASIS | 330 | 620 | 684 | 775 |
| 0.5 | LEACH | 335 | 405 | 460 | 576 |
| | PEGASIS | 675 | 1250 | 1362 | 1540 |

### 4.3 Performance comparison for LEACH and PEGASIS protocol

As measurement tools, for this research considered the liveliness of the sensors, energy consumed by the sensors and the time requirement to complete several hundred rounds. This is the result get when using several random 100-node networks with each node having 0.5 Joules of initial energy and 100m x 100m network size.

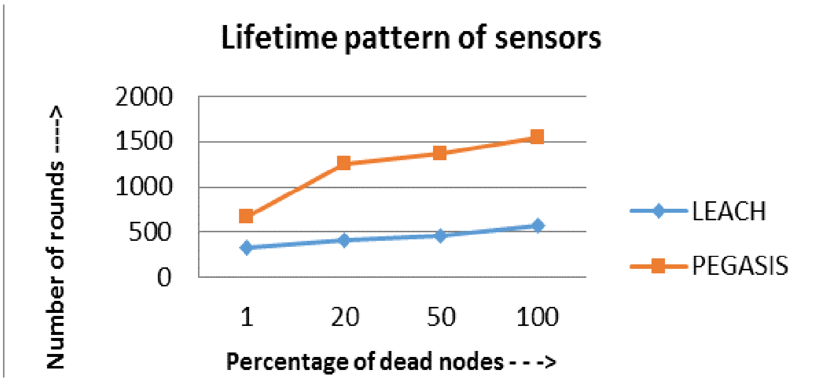


**Figure 10**: Lifetime pattern of a randomly deployed 100 node sensor network

Figure 10 shows the lifetime pattern of a randomly deployed 100 node sensor network. X-axis is percentages of dead nodes and y-axis is number of rounds. A node is considered to be dead when its energy becomes zero and excluded for the consecutive rounds. As shown in the Figure 10 round numbers achieved are determined when 1%, 20%, 50% and 100% of nodes are died. When LEACH protocol run the simulation at about 335 round the percentage of dead nodes is 1% while the PEGASIS protocol achieve more round at 675 rounds when 1% of dead node. 20% of dead nodes happened when LEACH has run the simulation 405 rounds, while PEGASIS is run up to 1250 rounds and 20% of dead nodes. When then number of rounds is increased, the percentage of dead node also increase but different achievement for both protocol. The graph shown that PEGASIS perform 30% better than LEACH in term of system lifetime. The number of rounds for PEGASIS protocol to do the simulation is higher compare to LEACH. PEGASIS protocol outperforms LEACH by eliminating the overhead of the dynamic cluster formation, minimizing the distance non leaders must transmit, limiting the number of transmissions and receives among all node, and using only one transmission to the BS per round. Distributing the energy load among the nodes increases the lifetime and quality of the network.

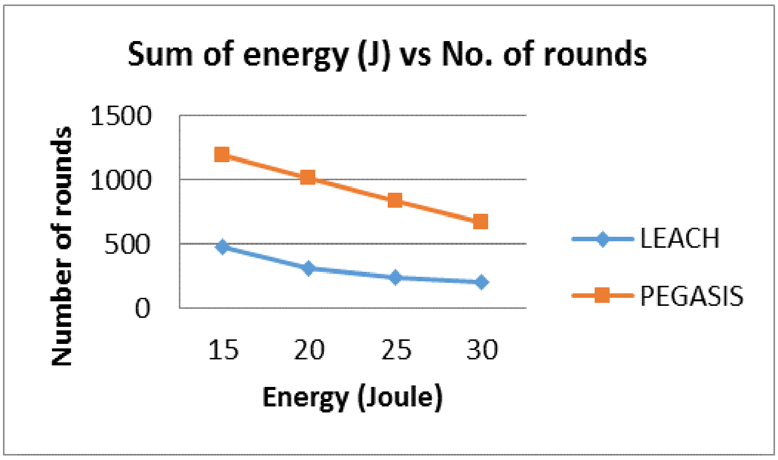


**Figure 11**: Comparative analysis of sum of remaining energy in Nodes vs Number of rounds

Form the analysis of sum of remaining energy of nodes per round as shown of Figure 11 shows energy consumption of randomly deployed 100 node network. X-axis is sum of remaining energy in node and y-axis is the number or round taken for the dissipation energy. Initially, sum of energy of all nodes are 50J, as rounds are increased energy is consumed. For LEACH protocol, we can see when the simulation up to 480 rounds residual energy are about 15J while for PEGASIS protocol at the same residual energy the simulation is at 1195 rounds. Then, for LEACH protocol 20J residual energy are remain left until 310 round and for PEGASIS protocol for 20J residual energy up to 1007 rounds. From the simulation shows that PEGASIS protocol consumes less energy compare to LEACH protocol. It gives about 30% better performance than LEACH.

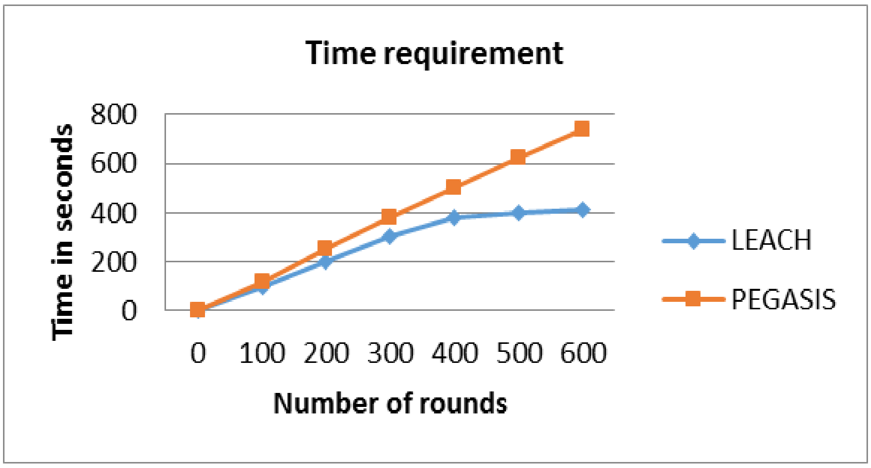


**Figure 12**: Time requirement comparison for completing rounds

For the Figure 12, x-axis is number of rounds and y-axis is the time in seconds. It is the time requirement comparison for completing rounds. Since PEGASIS forms a single chain among the nodes it introduces excessive delay. But LEACH introduces less delay than PEGASIS. It is clearly shows that LEACH performs better than PEGASIS in terms of delay.

## 5.0 Conclusion

The research was carried out based on the implementation of WSNs architecture by using LEACH and PEGASIS routing protocols. The most challenges in WSNs are energy consumption of nodes and to increase the system lifetime of sensor network. In this project, the objective to achieve is to investigate and analyze the performance of routing protocols for LEACH and PEGASIS. After that, the data get from the simulation will be compared to know the better performance between two protocols. To validate the algorithm, simulations had been carried out using MATLAB.

Simulation results showed better performance for PEGASIS even both protocols fall under hierarchical category. In this project describe PEGASIS a greedy chain protocol that is near optimal for a data-gathering problem in sensor networks. PEGASIS outperforms LEACH by minimizing the distance non leaders-nodes must transmit, limiting the number of transmission and receives among all nodes, and using only one transmission to the BS per round. Nodes take turns to transmit the fused data to the BS to balance the energy depletion in the network. In LEACH, local data processing occurs at specified nodes called cluster-heads and finally aggregated data is transmitted to the BS.

By distributing the energy load among the nodes increases the lifetime of the network. LEACH is cluster-based hierarchy while PEGASIS is a chain-based approach. For the network lifetime, PEGASIS offers 30% better than LEACH in extended lifetime of the network as there is a balance in energy distribution. The number of node deaths in PEGASIS is lesser as compared to LEACH. From the analysis of sum of remaining energy of nodes per round shows that PEGASIS protocol consumes less energy compare to LEACH protocol. It gives about 30% better performance than LEACH. Since PEGASIS forms a single chain among the nodes it introduces excessive delay. But LEACH introduces less delay than PEGASIS. It is clearly shows that LEACH performs better than PEGASIS in terms of delay.

The improvement of routing algorithm for WSNs is very important to achieve a goal for energy consumption and network lifetime. The suggestion for future works as the following:

i. To develop a new hierarchical routing protocol that compensates the demerits of both LEACH and PEGASIS.
ii. Study the same protocols that presented in this project by using different network simulator.

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