Development of energy efficient routing protocol using Hop PEGASIS in Wireless Sensor Networks

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Abstract: In a Wireless sensor network (WSN), communication of the gathered data in the network from the nodes to the base station is a prominent activity and this communication of data consumes the maximum amount of energy. When there is a constant flow of information from the nodes to the base station in a wireless sensor network, the energy of the nodes gets drained due to limited battery resources of a sensor node. This directly affects the lifetime of the entire network. So our aim is to devise a routing protocol which will minimize the energy consumption and hence result in achieving extended lifetime of the entire sensor network. In this paper, we propose the Hop PEGASIS approach. The proposed Hop PEGASIS approach is more efficient than the LEACH, PEGASIS and Hierarchical PEGASIS protocols. Therefore, we focus on the concept of energy conservation which is a important factor and a major challenge in the design of Wireless sensor networks. We have used MATLAB environment for simulation.

Keywords: Wireless sensor network (WSN), Sensor node, LEACH, PEGASIS, Chaining**,** Clustering.

I. INTRODUCTION

Wireless sensor network (WSN) consists of a collection of sensing devices. These sensing devices are known as sensor nodes. The sensor nodes are scattered in the sensor field which is situated far away from the user [1]. These sensors have gained greater importance due to the advancement of Micro-Electro-Mechanical Systems (MEMS) [2]. The four main building blocks of a sensor node are: sensing unit, communication unit, processing unit and power unit i.e. .the battery. These sensor nodes observe an event or gather some physical data from its area of interest and then processes the gathered data by the processing unit embedded in it and sends processed data via a short range radio transmitter i.e. the communication unit to a central data collector called the base station [3].

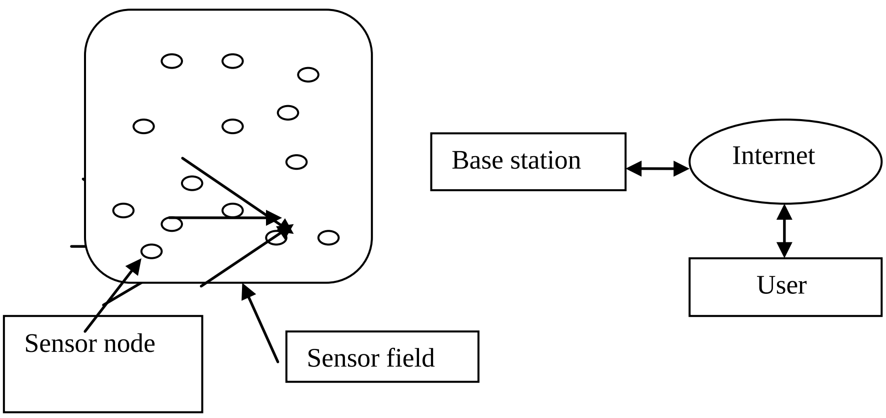

Figure 1: An example of Wireless Sensor Network

The main aim of Wireless sensor network routing approaches is to find routes that result in prolonged lifetime of the entire network. The key applications of WSN include military applications like battlefield, environmental applications, health applications, home applications, other commercial applications [4]. Smart sensors are used extensively in tele-monitoring, tracking moving objects, home automation, telemedicine and industrial applications [5]. The WSN consists of nodes which are resource constrained and these nodes are deployed for collecting information from the sensor field.

Lifetime of a Wireless Sensor Network can be defined as the time from the inception to the time when network becomes non-functional. A network may become non-functional when a single node dies or when a particular percentage of nodes die depending on application.

One of the most efficient ways to reduce energy consumption is the use of routing protocol [6]. The network protocols [7] are of great importance and are different from conventional protocols. These network protocols results in the enhancement of the network lifetime.

II. RELATED WORK

One of the efficient routing protocols is the hierarchical routing protocol [8]. In hierarchical routing protocol the whole WSN is divided into some clusters. Every cluster has a cluster head or head node that performs the data aggregation or fusion before forwarding the data to the base station. The special feature of this protocol is that it allows self-organization capabilities that result in large scale network deployment. Two of the main routing protocols of the hierarchical routing are:

A. LEACH

LEACH stands for Low Energy Adaptive Clustering Hierarchy. In LEACH [9], the entire network is divided into several clusters. In LEACH the concept of distributed clustering comes into picture. Each cluster has a special node and this node is known as the cluster head. The sensor nodes collect the data and transmit them to cluster head, cluster head then transmits the gathered data to the base station or the sink. LEACH operates in two phases: set up phase and the steady state phase. In the set up phase clusters in the network and the cluster heads are formed. In order to balance the energy dissipation of nodes the cluster heads change randomly. The data transfer to the base station takes place during the next stage i.e. the steady state phase. In this phase the sensor nodes in the network can begin sensing and transmitting data to the cluster heads. Once the cluster head gathers all the data from the nodes then it transmits the information to the base station. After this whole process, the network again enters into the set up phase and again a new cluster head is selected. LEACH enables self organizing of sensor nodes and the energy is evenly distributed because of the rotating cluster heads. LEACH achieves considerable amount of reduction in energy dissipation compared to direct communication and minimum transmission energy routing protocol.

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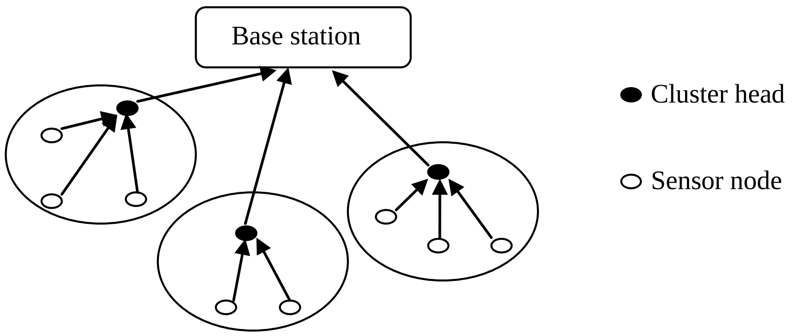

Figure 2: Cluster formation in LEACH

B. PEGASIS

PEGASIS [10] stands for Power efficient gathering in Sensor Information Systems. It is considered to be an extension of LEACH protocol. In this protocol the concept of chaining comes into picture. The sensor nodes which are closest to each other will be considered to form the chain and this chain is responsible for communicating with the base station. Only one node will be considered from this chain to transmit to the base station instead of multiple nodes. Each node will fuse its own information with the information of the neighbouring node and this will form a single packet. This single packet will be of the same length and transmit the fused information to the next sensor node. Greedy approach is used in forming the chain. In PEGASIS, signal strength is considered to measure the distance to all the neighbouring nodes. This signal strength is adjusted so that only one node can be heard. A new chain is constructed using the same process when a sensor node in the chain dies due to limited battery power. The problem with the chaining approach of PEGASIS protocol is that whenever a single node dies the whole chain has to be constructed as it becomes non-functional.

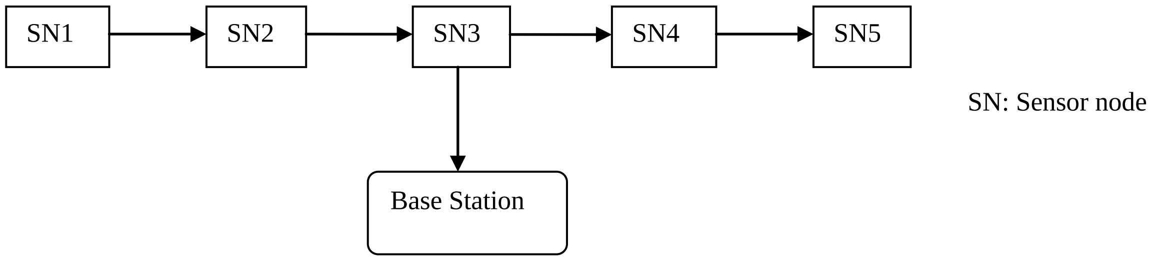

Figure 3: Chaining in PEGASIS

C. Hierarchical PEGASIS

Hierarchical PEGASIS [11] is an extension of the PEGASIS protocol. The main aim of hierarchical PEGASIS is the reduction of transmission delays of packets to the base station. In Hierarchical PEGASIS, energy X delay metric is taken into consideration to solve the data gathering problem. Simultaneous transmission of messages takes place in order to reduce the delay in PEGASIS. In hierarchical PEGASIS, two approaches are considered to avoid collision and signal interference among the sensor nodes. They are CDMA, which incorporates signal coding and in the second approach only spatially separated nodes are transmitted at the same time. A chain is formed as a hierarchical tree by all the sensor nodes. A node is chosen at a particular level and this node transmits data to the nodes in the upper level of the hierarchy until it reaches the base station.

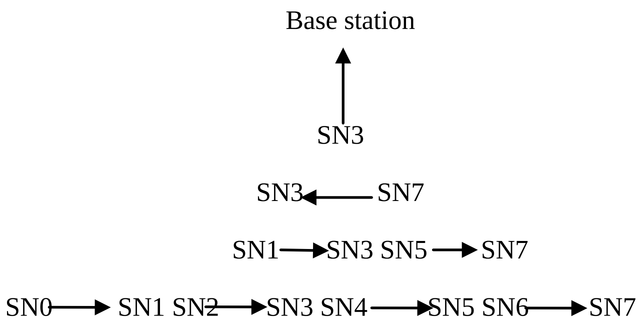

Figure 4: Hierarchical PEGASIS hierarchy example

III. RADIO MODEL FOR TRANSMITTING AND RECEIVING

In our proposed work, we assume the standard basic model [12] where the radio dissipates $E_{elec} = 50\ nJ/bit$ to run the transmitter or receiver circuitry. An energy loss of r^2 is assumed due to channel transmission. In the radio model to transmit a k-bit message a distance d, the radio expends:

$$E_{Tx}(k,d) = E_{Tx-elec}(k) + E_{Tx-amp}(k,d)$$
$$E_{Tx}(k,d) = E_{elec} * k + \varepsilon_{amp} * k * d^2 \qquad (1)$$

To receive this message, the radio expends

$$E_{Rx}(k) = E_{Rx-elec}(k)$$
$$E_{Rx}(k) = E_{elec} * k \qquad (2)$$

The radio channel is assumed to be symmetric. This means energy required to tran[illegible]ssage from node X to node Y is the same as the energy required to transmit a message from node Y to X.

IV. PROPOSED HOP PEGASIS APPROACH

When there is a direct transmission between the cluster heads and the base station, the cluster head that is situated far away from the base station uses strong signals while transmission to the base station. This leads to more consumption of energy thus reducing the network lifetime. Our main aim is to improve the PEGASIS protocol so as to enhance the network lifetime. The concept of hop routing which leads to the base station is applied to the sensor nodes. Inter clusters are formed in the network. We divide the sensor nodes into clusters and we assume that there are 5 levels in the network.

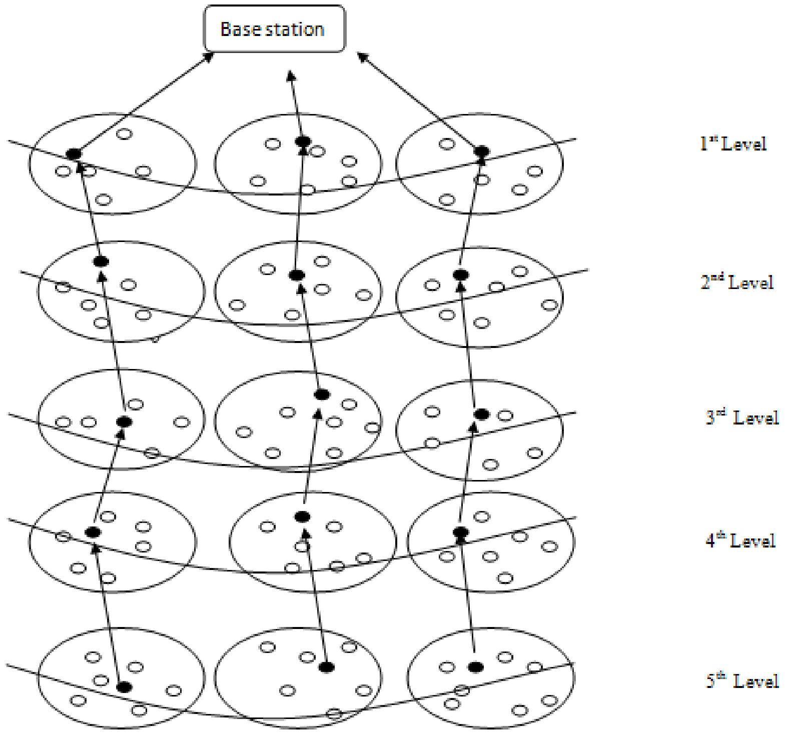

Figure 5: Proposed Hop PEGASIS

The concept of hierarchical PEGASIS routing protocol is applied in our proposed protocol. In hierarchical PEGASIS there are three main phases i.e. announcement phase, cluster formation phase and data communication phase. In our proposed protocol of Hop PEGASIS, there in an initialization phase and data transmission phase. The last sub phase can be determined by

```
    If (cluster_head) then
       Det_niv ()
           If (hnID pertains to niveau5_) then
           Find next_hopID in “niveau4_”
  Else if (hnID pertains to niveau4_) then
           Find next_hopID in “niveau3_”
  Else if (hnID pertains to niveau3_) then
            Find next_hopID in “niveau2_”
  Else if (hnID pertains to niveau2_) then
            Find next_hopID in “niveau1_”;
 Else the “next_hopID” is baseID”
End if
Senddata_nexthop ()
  If (next_hopID!=baseID) then
       Add hnID to its list
End if
           End if
```

Det_niv determines the level of cluster head as a function of its distance to the Base station. In our proposed Hop PEGASIS approach there 5 circles. The center is the base station. The first circle is the level 1 which is denoted as a-ray and this is closest to the base station. Level 2 is the second circle (radius b>a). Similarly, Level 3 is the third circle (radius c>b), Level 4 is the fourth circle (radius d>c) and finally Level 5 is the fifth circle (radius e>d). Therefore the sensor nodes whose distance from the base station is less than or equal to “a” belongs to the Level 1 and so on.

V. SIMULATION DETAILS

Simulation is carried out in the MATLAB simulator.

Table I
Simulation parameters

PARAMETER	VALUE
Number of rounds	3000
Data packet	2000
Number of nodes	100
Initial energy of node	0.50J
E_{elec}	50 nJ/bit

VI. RESULTS

A. Creation of random sensor network

A random sensor network of 100 nodes is created. We have taken MATLAB as a tool for simulation. Our sensor network consists of 100 nodes in a 100x100 sensor field.

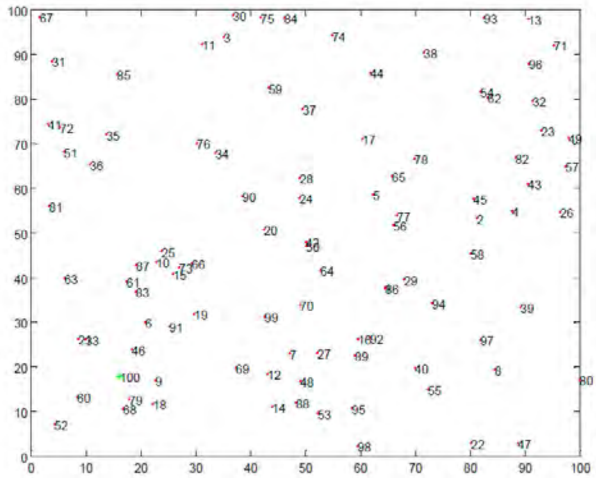

Figure 6: Random sensor network

B. Graph between dead nodes and the total number of rounds in LEACH

The graph between dead nodes and the total number of rounds in LEACH shows that the first sensor node dies around 100 rounds and the last sensor node dies at around 1100 rounds. For simulation in MATLAB, we have taken the total number of sensor nodes as 100 and the total number of rounds as 3000.

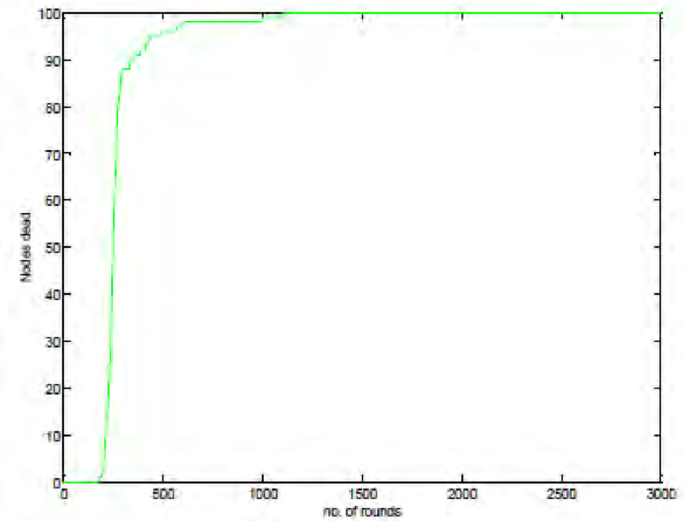

Figure 7: Graph between nodes dead vs. no of rounds in LEACH

C. Graph between dead nodes and the total number of rounds in PEGASIS

The graph between dead nodes and the total no of rounds in PEGASIS shows that the first sensor node dies at around 1700 rounds and the last node dies at around 2500 rounds for the given simulation of 3000 rounds.

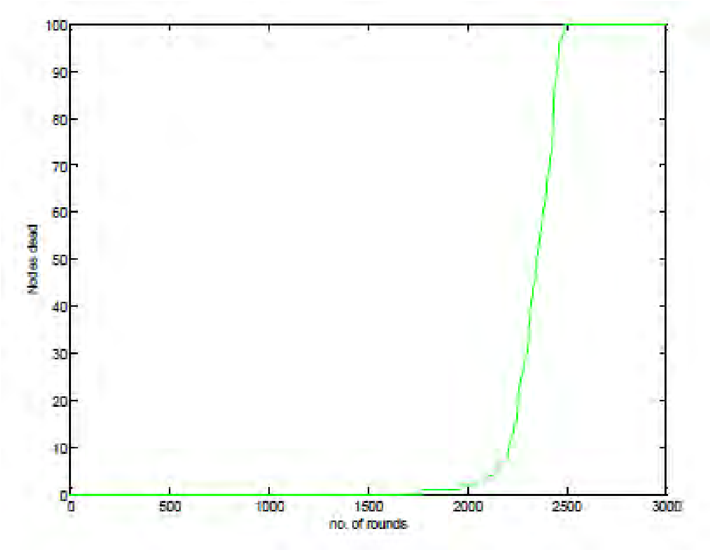

Figure 8: Graph between nodes dead vs. no of rounds in PEGASIS

Therefore, we see that PEGASIS performs better than LEACH because in LEACH the last sensor node dies around 1100 rounds and for PEGASIS, the last node dies at around 2500 when we simulate for 3000 rounds in MATLAB.

So we can infer that PEGASIS is more energy efficient than the LEACH protocol in terms of the total no of nodes dead within the given amount of rounds.

D. Comparison between LEACH and PEGASIS

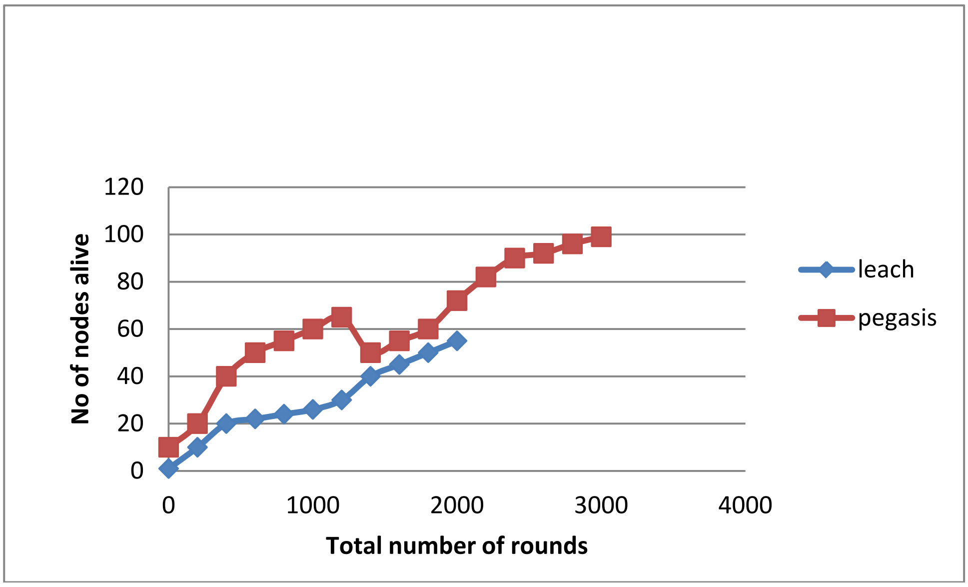

Figure 9: Comparison between LEACH and PEGASIS.

Simulation is done taking the total number of rounds as 3000 and the total number of sensor nodes as 100. The comparison between LEACH and PEGASIS shows that PEGASIS performs better than LEACH in terms of the total number of nodes that remains alive after 3000 rounds. Therefore energy efficiency in PEGASIS is more than that of LEACH protocol.

E. Comparison between Hierarchical PEGASIS and hop PEGASIS

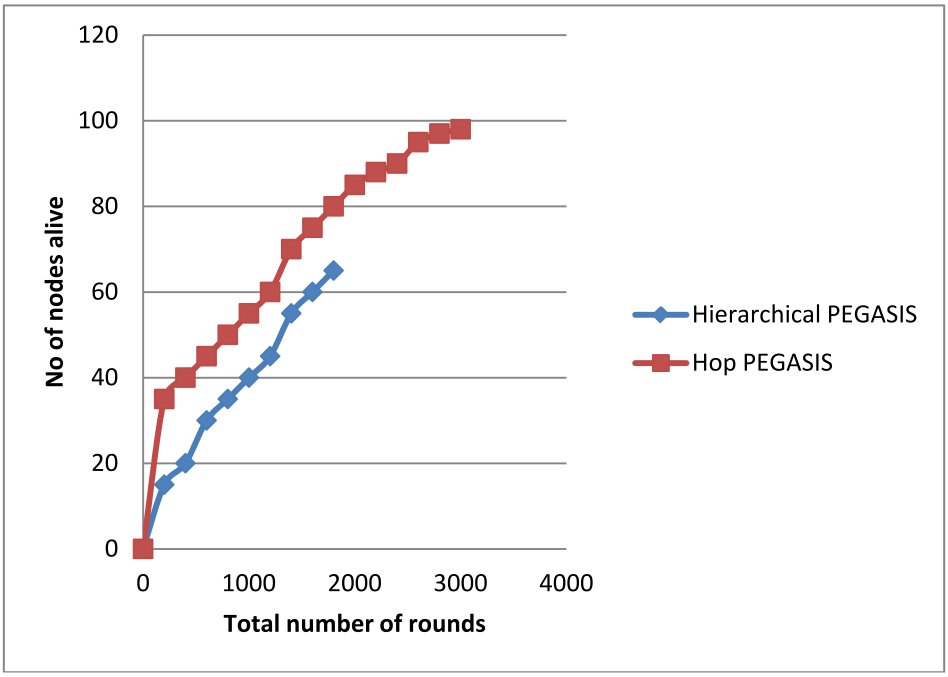

Figure 10: Comparison between Hierarchical PEGASIS and Hop PEGASIS

The above graph shows that our proposed Hop PEGASIS approach performs better than the Hierarchical PEGASIS routing protocol. This is because in hierarchical PEGASIS there is no mechanism of multiple hops routing as our proposed Hop PEGASIS. The information from the distant cluster heads can be routed efficiently.

F. Comparison among LEACH, PEGASIS, Hierarchical PEGASIS and Hop PEGASIS

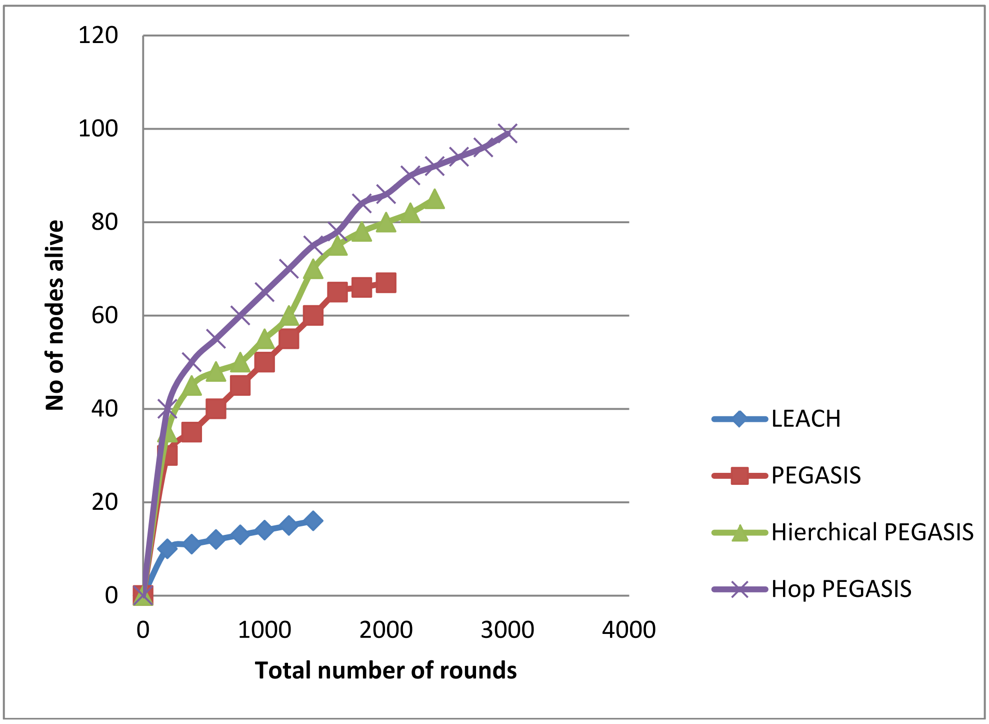

Figure 11: Comparison among LEACH, PEGASIS, Hierarchical PEGASIS and Hop PEGASIS

The above graph shows that our proposed protocol i.e. Hop PESASIS performs better than the other three approaches i.e. LEACH, PEGASIS and Hierarchical PEGASIS. The concept of hops is applied to our proposed Hop PEGASIS protocol and hence it increases the energy efficiency.

VII. CONCLUSION and FUTURE WORK

Wireless sensor networks (WSN) are one of most important area in the field of science and technology. Wireless sensor networks (WSN) have become more efficient due to the development in sensing, computation and communication. There are several constraints in WSN. One of such constraints in the low power consumption or energy efficiency. A sensor node should be energy efficient. Energy efficiency directly affects the network lifetime of the entire sensor network. The main aim of our proposed work is to develop a routing protocol which is energy efficient and it also enhance the network lifetime of the sensor network. In our work, we concentrated on the routing protocols namely LEACH, PEGASIS and Hierarchical PEGASIS. After analyzing all these protocols and gathering information about their advantages and disadvantages, we proposed the Hop PEGASIS protocol. Simulations carried out in the MATLAB simulator have shown that the proposed Hop PEGASIS protocol performs better than the other three protocols. Therefore the protocol is more energy efficient. Scalability and low latency can be taken as a framework for future work which further enhances the protocol.

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