DEVELOPMENT OF SOM NEURAL NETWORK BASED ENERGY EFFICIENT CLUSTERING HIERARCHICAL PROTOCOL FOR WIRELESS SENSOR NETWORK

Md. Tofael Ahmed[1], Bipasa Sharmin Setu[1],
Maqsudur Rahman[2] and A. Z. M. Touhidul Islam[3]

[1]Department of Information and Communication Technology,
Comilla University, Bangladesh
[2]Department of Computer Science and Engineering,
Port City International University, Bangladesh
[3]Department of Electrical and Electronic Engineering,
University of Rajshahi, Bangladesh

ABSTRACT

Cluster-Based Routing Protocols is a renowned scheme to extend the lifetime and energy consumption simultaneously for the Wireless Sensor Network (WSN). Every sensor node work homogenously or heterogeneously which is energy constrained when energy and memory capacity is limited. Congregating information resourcefully in perilous situations in the sensor network for a large-scale area and huge time is required an effectual protocol. In this paper, we proposed a cluster-based hierarchical routing path protocol, namely SOM-PEG protocol, which is a modified PEGASIS protocol based on traditional PEGASIS with the employment of Self Organizing Map (SOM) neural network (NN). The simulation is performed on MATLAB simulation tool as well as NN GUI. The performance comparison shows that the proposed protocol provides better network lifetime and ensures less energy consumption compared with traditional PEGASIS protocol.

KEYWORDS

WSN, PEGASIS, SOM-PEG, NN GUI, SOM, Energy consumption, Lifetime

1. INTRODUCTION

Wireless Sensor Network (WSN)is formed with a huge amount of tiny sensor nodes in a sensor field, which are non-deterministically installed over the region where human intervention is a bulky task. At first, wireless sensor networks were developed dedicatedly for the military applications specially for battlefield surveillance. Nowadays, it enhances its application in industrial and civilian area where industrial process control and monitoring, machine monitoring, environment control, and inhabitant monitoring, patient monitoring, smart home and smart traffic control are performed by the WSN [1]. A typical view of the WSN has shown in Fig.1 using some internetworking devices. Neural networks are used to solve hardware and software problems of WSN applications which are also known as Artificial Neural Networks (ANN) [2]. Parallelization, speed, and flexibility are the strength of it. The main focus of these technologies is solving pattern recognition problems, clustering network, dynamic time series, etc. To investigate the energy-efficient cluster-based hierarchical WSN protocols a neural network protocol is used and aimed to enlighten the network lifetime and decrease the energy consumption.

DOI:10.5121/ijassn.2020.10301

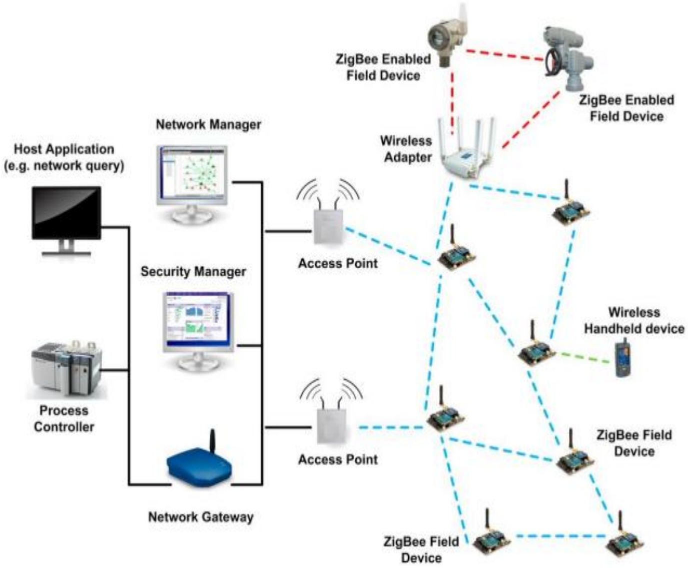

Figure 1. A typical view of WSN with central monitoring [7].

To support the data accretion in the network these nodes moves in the small groups called clusters. Clustering is used to enhance the networks lifetime, which is a primary metric that evaluates the performance of a sensor network [2]. Figure 2 shown below describes the basic hierarchy of clustering where a user can receive data from remote sensor through the internet.

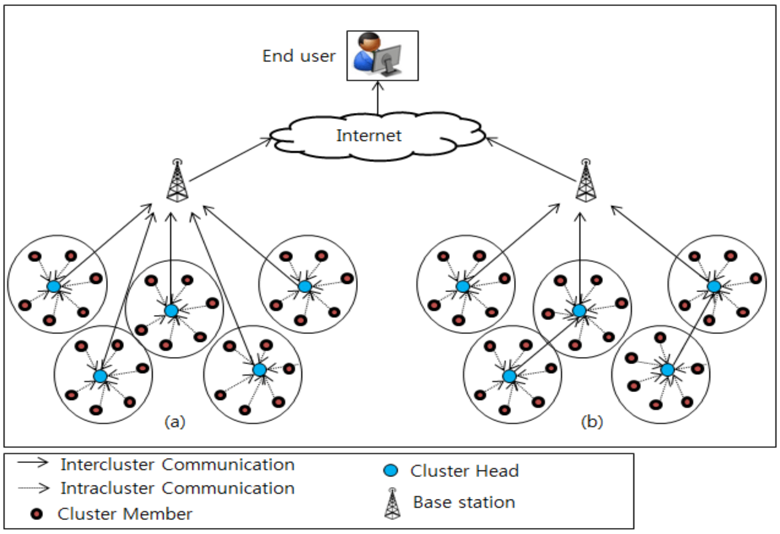

Figure 2. Basic Clustering hierarchy.

There are a number of routing protocols used in WSN to make the network user accessible. They are briefly explained in the following section.

i. LEACH: Low Energy Adaptive Clustering Hierarchy protocol are the special types of WSN protocol where each sensor node doesn't send the data to sink or base station to take decision for the further hop.

ii. PEGASIS: Power-efficient gathering in sensor information systems which doesn't have any clustering overhead but manages topology dynamically for the cluster. PEGASIS form a chain among all the sensor nodes to form a intercommunication among the closest neighbor [3].

iii. APTEEN: Adaptive periodic Threshold-Sensitive Energy-Efficient Sensor Network follow he TDMA technologies so that their signals transmission remains turned off when they arein inactive mode.

iv. ECHERP: Equalized Cluster Head Election Routing Protocolis follows energy conservation over balanced clustering [4] which have less network lifetime and higher energy consumption compared with PEGASIS.

Despite tremendous development, there are still limitations that WSNs suffer. Some challenges like designing a low power network, data security, and architecture of network have taken the most attention of researchers in the last years [5]. As it is an one time installation network, predict the expected lifetime of each sensor nodes before the network installation is very important to install a network in a remote area.

There is lots of study in several clustering protocols of WSN. The objective of this work is to propose an algorithm (called SOM-PEG) applied for large number of sensor nodes in a large distance area, which will provide less energy consumption and improved network lifetime.

This paper is organized as follows. In section I, we have discussed an introduction and objectives of the work and Section 2 presents literature review. In Section 3, the most important protocol PEGASIS protocol has been analyzed. Section 4 described SOM neural Networks. Section 5 describes the proposed SOM-PEG protocol and the simulations procedure is presented in Section 6. Section 7 gives simulation results and discussion. Finally, conclusions of the work are presented in section 8.

2. RELATED WORKS

There are so many researches went through Wireless Sensor Network (WSN). Therefore, the main goals of all research are to develop WSN routing protocols that extend the network lifetime and facing the challenging issues of WSN. Yong-Chang et al. [6] proposed a method where a chain is deducing by adopting a threshold distance in order to decrease the foundation of a long link. Their model able to prove that the proposed method has better performance than PEGASIS.

Ref. [7] proposed a routing protocol that works hierarchically with stationary wireless sensor networks and they claimed that their scheme can solved the core problems in PEGASIS which helps to improve the lifetime of the wireless sensor network. Authors in [8], they proposed a protocol named EEPB which has improved PEGASIS from two perspectives, firstly, it adopts the threshold distance to evade PEGASIS in order to forming a long chain. Secondly, the early death problem of chain nodes can be solved by this protocol.

In [4], the authors have developed a double cluster heads in one chain and to avoid the existing long chain they prepared a hierarchical structure in the new algorithm. Their simulation result shows that, this algorithm is able to increase the productivity of energy-using the load balancer, which help to extend the lifetime of the whole network. A clustering protocol where the Kohonen SOM concept are used for clustering has proposed in [9].The unpredictable behaviors of network parameters estimation and corresponding applications presentation was the major focus of their works. A LEACH protocol is proposed where SOM neural networks select cluster Heads to infer further decision in [10]. In case of cluster heads estimation, all the SOM inputs are used as parameters of cluster heads. There are lots of the SOM based clustering protocols was developed for the purpose of lilfe time maximization and less energy consumption of wireless sensor network [10-14].

3. PEGASIS PROTOCOL

The chain building process of PEGASIS is to lessen the total length during processing which is as similar as the traveling salesman problem. In PEGASIS each node intercommunicates to close neighbors to send control to the base station as it is the clustering head of this particular network. The energy allocation process among the sensor nodes follow the clustering heads estimation method consistently [15]. Primarily the nodes has place casually in the playfield and that is why all the nodes are organized as at a random location. Using a greedy algorithm the sensor nodes proficiently organized the chain starting from some high energy nodes [16].The base station also able to form this chain and can broadcast it to all the nodes in the network. The PEGASIS protocol can save the huge amount of energy during the configuration of cluster and sensing data delivery method for the purpose of network lifetime maximization [15].

Instead of cluster information in LEACH, the PEGASIS protocol constructs a chain efficiently for the head of the cluster which is responsible to carry data to the base station. The energy consumption consistently depends on the head nodes in the networks [15]. In that case PEGASIS protocol performs twice better than LEACH. The hierarchical routing protocol architecture of PEGASIS works in three steps as shown in the Fig. 3.

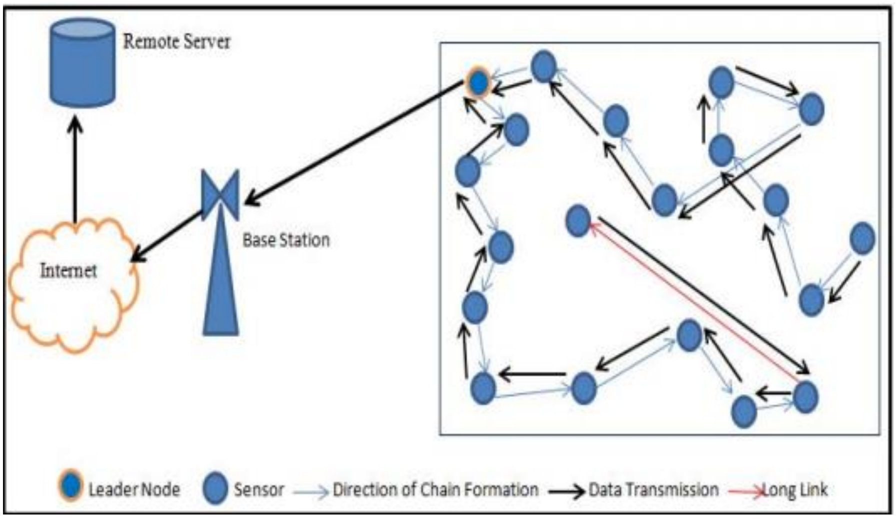

Figure 3. WSN with PEGASIS Protocol Architecture.

There formed a PEGASIS chain under each cluster nodes through the greedy approach. Each sensor nodes collects, process, and defuse data to its neighbor and finally to its Cluster Head through the chain by token passing approach.

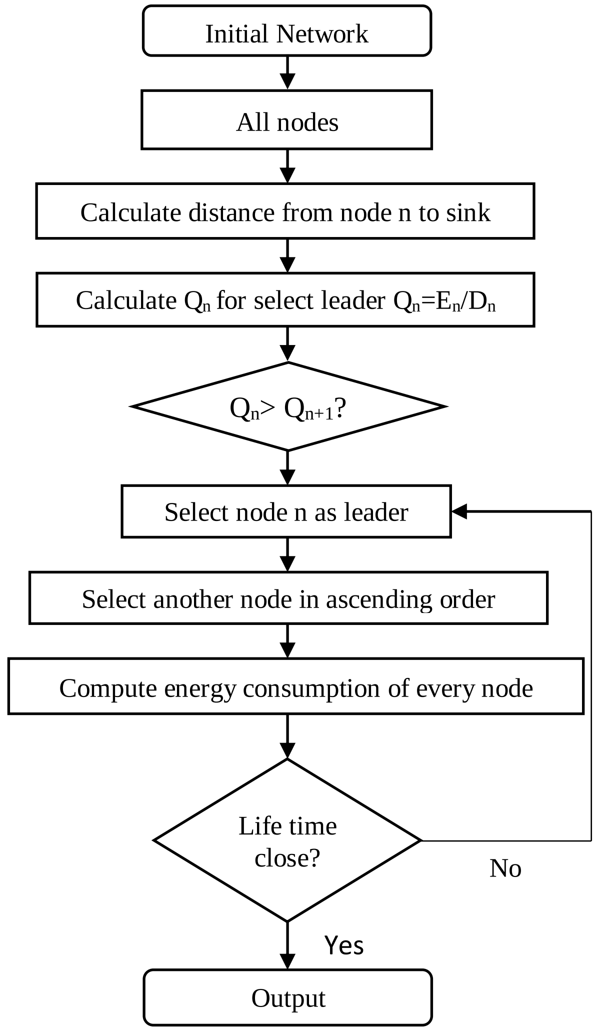

Figure 4. Process of leader selection in PEGASIS and Chain Formation.

4. SELF-ORGANIZING MAP (MOP) NEURAL NETWORK

The weight of the winner and its surrounding neurons in the SOM topology is updated regardless of the input vector [17]. During the weight update, the distant and nearest neurons to the 1-vicinity of the winning neuron and the winning frequency of each neuron are found and taken into consideration [17]. The learning performance is estimated using three standard measurements in new SOM and it also used in input data sets for the further steps. Using the SOM protocol cluster, the whole sensing area can efficiently covered. The base station transmits and receives data with the interconnected SOM clustered head nodes.

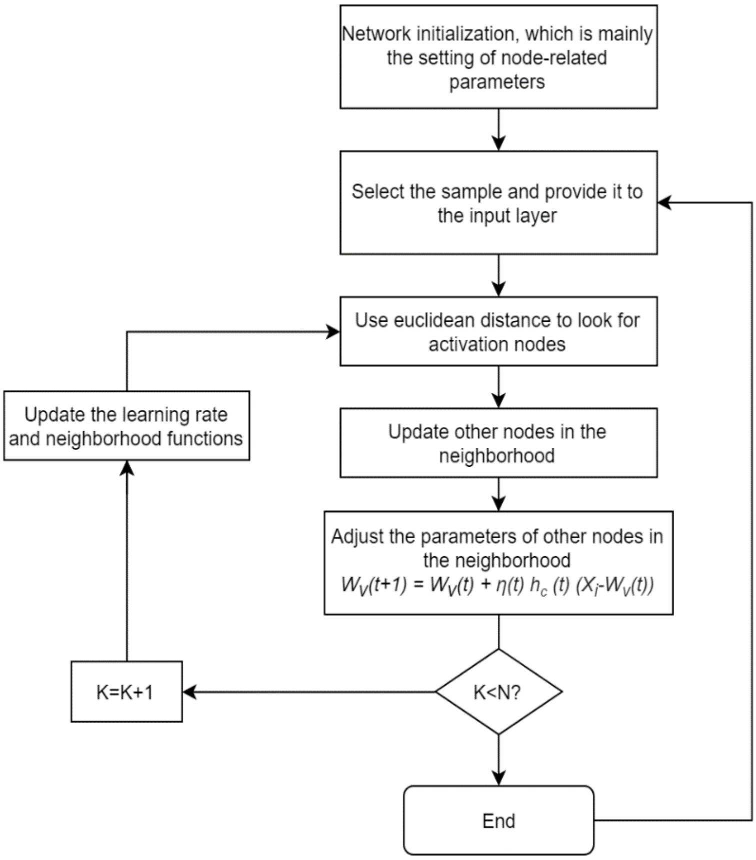

Figure 5. Flowchart of Cluster-Based SOM Neural Network.

The flowchart of cluster-based SOM neural network represents the overall process of SOM formation. To calculate the nearest distance, it uses the SOM algorithm in which Euclidean distance is used to look for activation of nodes.

5. Proposed SOM-PEG Protocol

Motivated by original PEGASIS protocol, other hierarchical architecture and cluster-based SOM protocol of Neural Network, we have proposed a modification to the process of chain formation and cluster-based network selection. Our main goal is to minimize the energy consumption and maximize the network alive time. For a wireless sensor network, we assume the following conditions as constraints.

- Fixed base station with long distance between sensor nodes.
- Heterogeneous sensor nodes with limited-energy.
- The energy consumption depends on the distance.
- No mobility of sensor nodes.
- Nodistributed sensor nodes.
- One time installation.
- Equal competences.
- Power control capabilities.

5.1. Algorithm

The Algorithm is mainly complete in two steps which are given below.

(1) Cluster Head (CH) Selection by SOM-NN

i. Each node weights are randomly initialized from a sensor field. Each node has a topological position (x,y coordinates), weight vector w.

ii. Choose an input vector node and find the node whose weight vector is neighboring to the selected point node. The distance is calculated by the Euclidean distance.

iii. For *i=1 to n*
j = 1 to m

$$D(j) = \sum_{i=1}^{n} p \sum_{j=1}^{m} (x_i - w_j)^2 \qquad (1)$$

Where D(j) is the minimum winning unit index,

x_i is the position of each node vector,
w_j is the weight vector of each node

iv. Calculate the Best Matching Unit (BMU) from shortest distance nodes.

v. The neighborhood of BMU is defined as all the nodes lying within its radius of influence.

vi. The weight vector is associated with a neighbor node. Also BMU is updated by means of the following calculation

vii.

$$iw(q) = iw(q-1) + \alpha p(q) - iw(q-1) \quad (2)$$

Where *p(q)* is the input vector chosen,*iw(q-1)* is the weight vector associated with node *i* and *iw(q)* is the updated value of the weight vector.

viii. Repeat from step ii until the iteration limit has been reached.

(2) PEGASIS Chain Formation in Each Cluster

i. **Chain formation phase:** Each cluster creates a chain. The first node is selected from the clustered nodes located farthest from CH.

ii. **Leader selection:** A node is selected as a leader considering the residual energy.

iii. **Transmission phase:** Data transmission occurs in.

a) Each node in the chain contracts with two messages; one it receives and another it transmits.
b) The sensor nodes collect and forward the data until it reaches to the base station.
c) The leader node receives the collected information, it forwards it to the base station.

Equation:

Chain leader selection of each cluster is random and determined by

$$Q_n = \frac{E_n}{D_n} \tag{3}$$

Where E_n = Residual energy of nth node, D_n = distance between base station and nth node, Q_n = deterministic weight of the nth node.

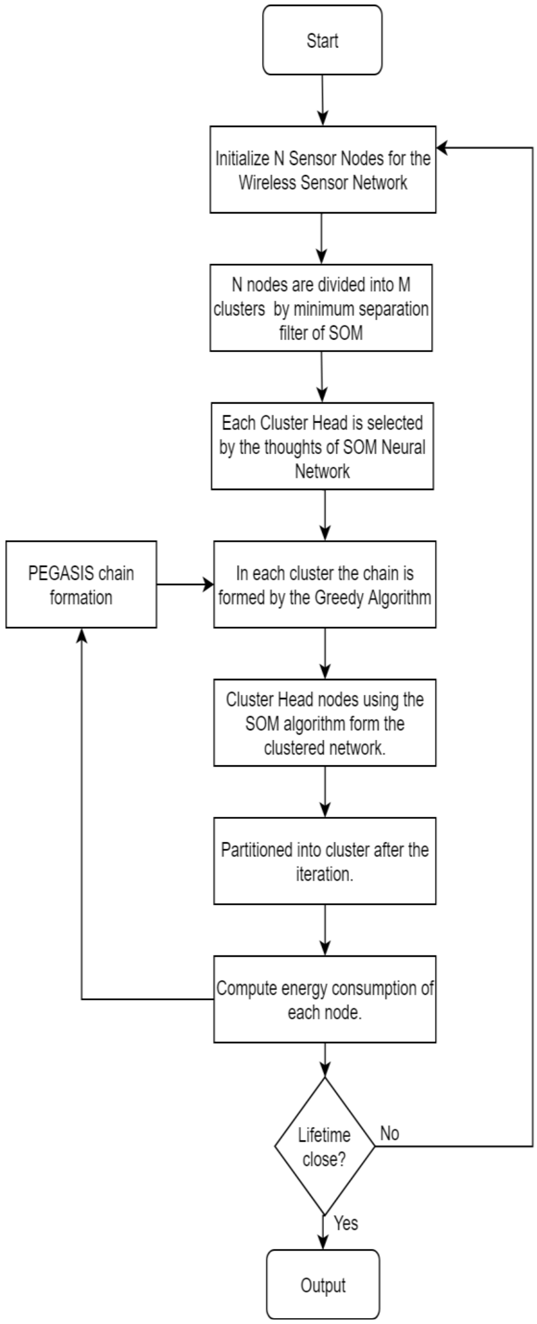

Figure 6. Flowchart of Proposed SOM-PEG Cluster Formation.

And for the leader selection,

$$\text{CH} = Q_n > Q_{n+1} \quad (4)$$

Where Q_n is the leader node.

Other nodes are selected in descending order of their weight which is called the Greedy approach.

5.2. Flow Chart

Flow chart of proposed SOM-PEG is given in Figs.6 and 7.

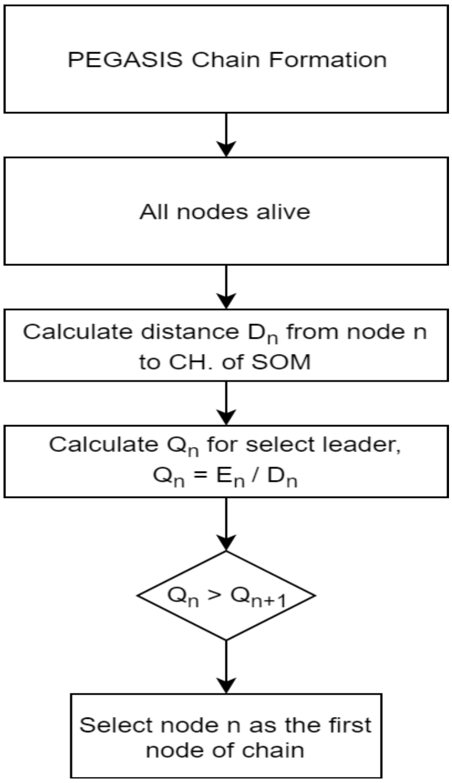

Figure7. Flowchart of PEGASIS Chain Formation of Each Cluster.

6. Simulation Procedures

6.1. Environment Setup

A variety of tools has been used for the simulation of WSN routing protocol, such as OPNET, MATLAB, OMNET++, and NS, etc. In order to fully simulate the protocol here, we use the popular network simulation platform MATLAB and Neural Network Graphical User Interface (NN GUI) for the experiment.

In WSN there are a lot of parameters to evaluate a clustering algorithm. The parameters used for simulation are shown in TABLE I. Extensive simulation is carried out by varying the node density and initial energy.

6.2. Simulation Matrices

6.2.1. Network Lifetime

Network lifetime is usually measured using three matrices [2].

i) FND - First Node Dies means 10% die of total nodes.
ii) HND - Half of the Nodes Die revels 50% die of total nodes.

iii) LND - Last Node Dies represents 90% die of total nodes.

When last nodes are going to die the network, lifetime turns to failure that requires re-synchronization.

Table 1. Simulation Parameters.

Parameter Name	**Value**
Area	100 X 100
Number of Nodes	I. 50 II. 100 III. 200 IV. 500 V. 1000
Initial Energy /Node	I. 0.25 J II. 0.50 J III. 2 J
Relative Position of BS	(50,60)
Number of Dead Nodes in the beginning	0
Energy Required for Transmission	50*10^ (-9) J/b
Energy Required for Receiver	50*10^ (-9) J/b
Amplifying Energy Required by the Transmitter	100*10^ (-12) J/b/m^2
Energy required to run circuitry (both for transmitter and receiver)	50*10^ (-9); units in Joules/bit
Packet Size	4000 bits

6.2.2. Energy Consumption

Besides network lifetime, another metric to check the efficiency of a routing protocol is its energy consumption per transmission. The energy consumption of the network totally depends on the lifetime of the network. The number of dead nodes revels the balance of energy consumption, as much as less the nodes die means as much as higher efficiency of energy usage. When a node's contains less than zero energy, this node's treat as a dead node [5].

6.2.3. Convergence Indicator

Convergence Indicator (CI) is used to estimate network conjunction. It is assumed that the higher value of CI is better than the fixed energy consumption of the network.

$$CI=\frac{LND-HND}{HND-FND} \quad (5)$$

7. RESULTS AND DISCUSSIONS

Here we measured the performance of both the PEGASIS and SOM-PEG protocols and tried to compare them. We put number of nodes 50, 100, 200, 500, and 1000 respectively with initial energy 2J by MATLAB simulator. The simulation results are presented in Figures 8 to 12.

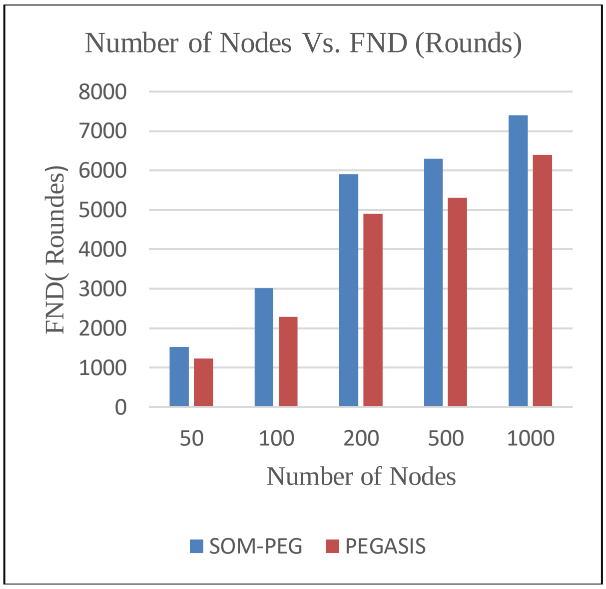

Figure 8. Number of Nodes vs FND (Rounds).

The number of rounds for first 10 % nodes dies (FND) increses with the increse of total nodes for the simulation. In every step SOM-PEG gets more rounds to dies its first nodes (Fig. 8) compare with PEGASIS protocol. From Fig. 9, we see that SOM-PEG perform better results compare with traditional PEGASIS protocols in every class of simulations with incresing the total number of nodes in case of half number of nodes (HND) destroyed.

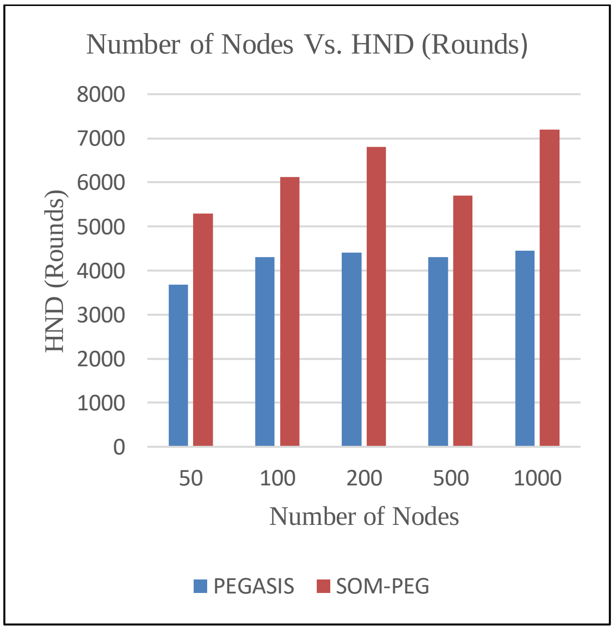

Figure 9. Number of Nodes Vs HND (Rounds).

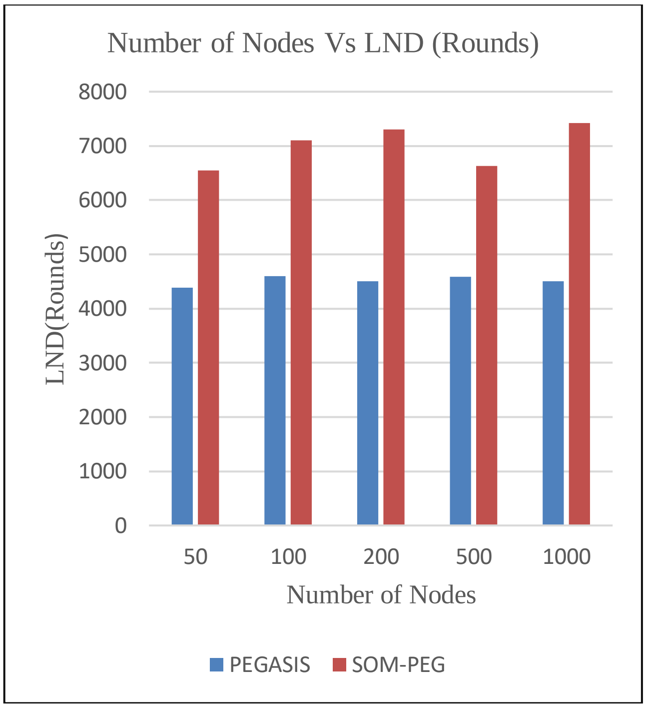

Figure 10. Number of Nodes Vs LND (Rounds).

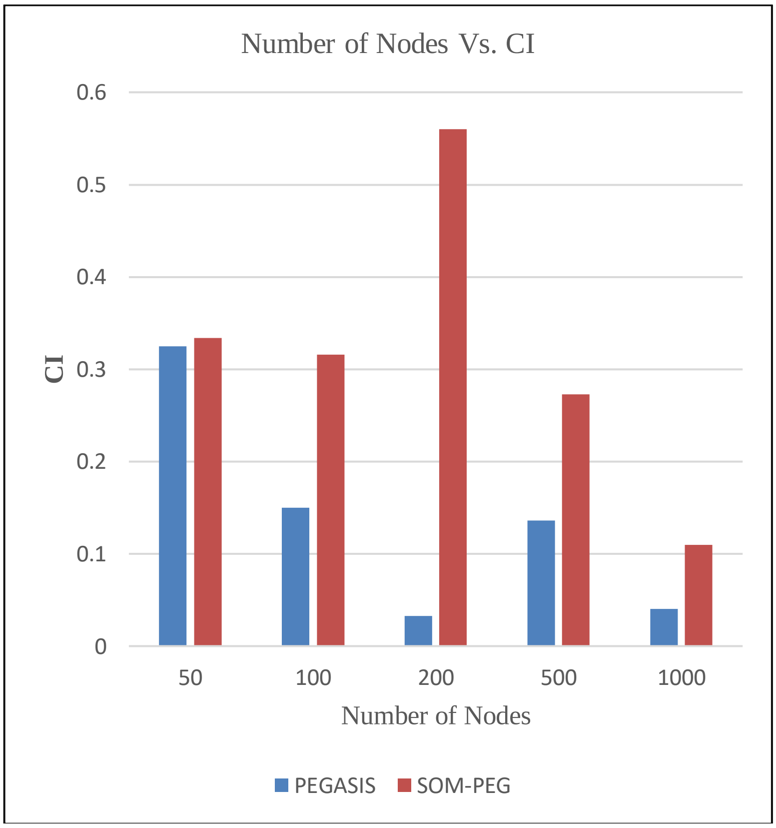

Figure 11. Number of Nodes Vs Convergence Indicator (CI).

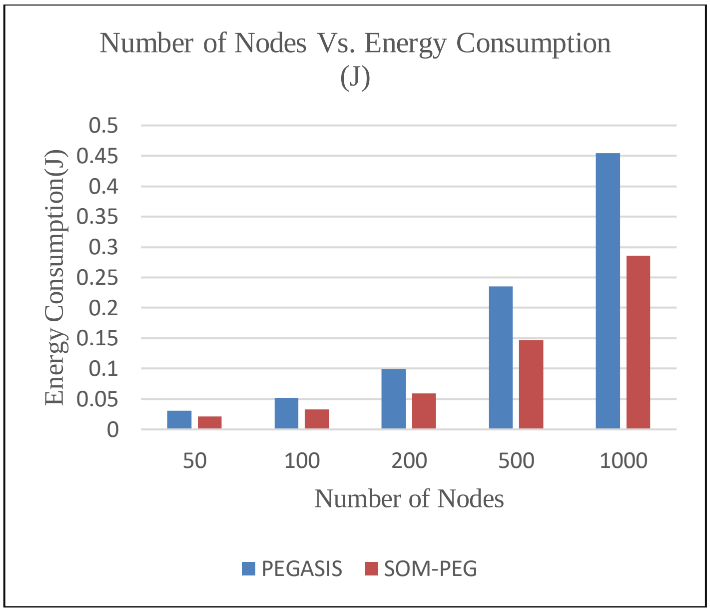

Figure 12. Number of Nodes Vs Energy Consumption (J).

Figure 10 shows the best result for the SOM-PEG protocol and PEGASIS protocol in case of last nodew dies (LND). The total number of roundes for last nodes dies takes more rounds for SOM-PEG protocol than PEGASIS. SOM-PEG protocols perform extra rounds for last nodes dies means it can survive more time than PEGASIS protocol.

Generally, highest convergence indicator is the sign of maximum lifetime. In the Fig. 11, the proposed protocol shows that it perform high convergence of indicator with the increase of total number of nodes per simulation. The convergence of indicator shows the high performance up to 200 nodes and after that its value gradually decreases. In every case SOM-PEG shows best results compared with PEGASIS protocol.

In case of energy consumption, the proposed SOM-PEG protocol shows better results in every step of simulations. The traditional PEGASIS protocol consume high energy with the increase of total number of nodes and it takes extra high energy if the total number of nodes increase more than 500, whereas the proposed SOM-PEG protocol shows stable energy consumption with high number of nodes (Fig. 12).

From all of the above graphical results (Figs. 8 to 12), we can say that the proposed SOM-PEG protocol provides better outcomes than traditional PEGASIS protocol in every performance metrics with less energy consumption and improved network lifetime.

8. Conclusions

The main purpose of designing a routing protocol for wireless sensor networks is to make it as energy-efficient as possible that will keep the network runs for a longer period. Here, we proposed a cluster-based hierarchical routing path protocol, called SOM-PEG protocol, which is a modified PEGASIS protocol based on traditional PEGASIS with the employment of SOM neural network. The SOM-PEG protocol consider the location of the sensor nodes, residual energy of each nodes, distance between nodes and helps to ignore the unwanted process of the data which can save the energy of nodes as well as extend network lifetime. Based on the comparative performance analysis of the two protocols, we may conclude that the proposed SOM-PEG protocol is more energy efficient and provides improved network lifetime than the traditional PEGASIS protocol.

REFERENCES

[1] Deepak Goyal and Malay Ranjan Tripath, "Routing Protocols in Wireless Sensor Networks: A Survey", Second International Conference on Advanced Computing & Communication Technologies, INSPEC Accession Number: 12616438, Publisher IEEE (2012).

[2] Umesh M. Kulkarni, Deepti V Kulkarni, Harish H. Kenchannavar, "Neural network-based energy conservation for wireless sensor network ", International Conference On Smart Technologies For Smart Nation (SmartTechCon), INSPEC Accession Number: 17754733, Publisher: IEEE (2017).|

[3] R. Sittalatchoumy, L. Sivakumar, "Performance Enhancement of Energy Efficient Protocols for application in WSN", Journal of Theoretical and Applied Information Technology, vol. 60, no. 1, pp. 112-118 (2014).

[4] Stefanos A. Nikolidakis, Dionisis Kandris, Dimitrios D. Vergados, and Christos Douligeris, Algorithms volume, "Energy Efficient Routing in Wireless Sensor Networks Through Balanced Clustering", vol. 6, issue 1, pp. 29-42 (2013).

[5] Alaa Eisa, Hazem M. El-Bakry, Samir M. Abd Elrazik, Sajjad Q. Hasan, Asaad Q. Hasan, Samir Zaid, "Challenges in Wireless Sensor Networks", International Journal of Advanced Research in Computer Science & Technology, Vol. 4, Issue 4, pp. 22-27 (2016)

[6] Y. Yong-chang, G. Wei, "An improved PEGASIS in Wireless Sensor Network", Electronic Journal, (2008).

[7] Hasan Al-Hasan, Mohammad Qatawneh, Azzam Sleit, Wesam Almobaideen, "EAPHRN: Energy Aware PEGASIS-Based Hierarchal Routing Protocol for Wireless Sensor Networks," Journal of American Science, vol. 7, no. 8, 753-758 (2011).

[8] Abdelbari Ben Yagouta, Maher Jabberi, Bechir Ben Gouissem "Impact of Sink Mobility on Quality of Service Performance and Energy Consumption in Wireless Sensor Network with Cluster-Based Routing Protocols", 14th International Conference on Computer Systems and Applications (AICCSA), pp. 1125-1132, Publisher: IEEE (2017).

[9] P.J. Chandra, M.P. Kumar, and C. Goutam, "Development of Laguerre Neural-Network-Based Intelligent Sensors for Wireless Sensor Networks", IEEE Transactions on Instrumentation and Measurement, vol. 60, no. 3, (2011).

[10] Tao Li1, Feng Ruan1, Zhiyong Fan1, Jin Wang2 and Jeong-Uk Kim3 "An Improved PEGASIS Routing Protocol Based on Neural Network and Ant Colony Algorithm" International Journal of Future Generation Communication and Networking, Vol. 8, No. 6, pp. 149-160 (2015)

[11] Gail A. Carpenter and Stephen Grossberg, " A self-organizing neural network for supervised learning, recognition, and prediction", IEEE Communication Magazine, Volume: 30 , Issue: 9, pp. 38-49 (1992).

[12] Mario Cordina and Carl J. Debono "Increasing wireless sensor network lifetime through the application of SOM neural networks", 3rd International Symposium on Communications, Control and Signal Processing, Publisher: IEEE, INSPEC Accession Number: 10044621 (2008).

[13] Nauman Ahad, Junaid Qadir, and Nasir Ahsan "Neural network in the wireless network: Techniques, applications, and guidelines", Journal of Network and Computer Application, vol. 68, Issue: C, pp. 1-27 (2016).

[14] Vesanto J, Alhoniemi E. "Clustering of Self Organizing Map", IEEE Transactions on Neural Networks, Vol. 11, No. 3, pp. 586-600 (2000)

[15] T. Liu and F. Li, "Power-efficient clustering routing protocol based on applications in wireless sensor network", Proceedings of 5th international conference on Wireless Communications, Networking and Mobile Computing, WiCOM, (2009).

[16] S. Lindsey and C.S. Raghavendra, "Pegasis: Power-efficient Gathering in Sensor Information Systems", Proc. of IEEE International Conference on Computer Systems, San Francisco, USA (2002).

[17] H. Shahbazi, M.A. Araghizadeh and M. Dalvi, "Minimum Power Intelligent Routing In Wireless Sensors Networks Using Self Organizing Neural Networks", IEEE International Symposium on Telecommunications, pp. 354–358 (2008).