International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 – 5161

Available at http://inpressco.com/category/ijcet

Research Article

Energy Efficient and Delay based on PSO with LST Algorithm for Wireless Sensor Network

Pooja Singh* **and Raghav Yadav**

Department of Computer Science & Information Technology, SSET, SHIATS, Allahabad, India

Accepted 25 Nov 2016, Available online 29 Nov 2016, **Vol.6, No.6 (Dec 2016)**

Abstract

Wireless sensor networks can provide low cost solution to verity of real-world problems. Sensors are low cost tiny devices with limited storage, computational capability and power. In wireless sensor network's sensors are randomly deployed in the sensor field which brings the coverage problem and limited energy resources. Hence energy and coverage problem are very scarce resources for such sensor systems. This research focuses on the maximization of network lifetime which has become a critical issue in sensor networks and also tackles with the problem of time delay in the transmission of the information. This research work gives the combination of PSO based algorithm (gives better performance in the term of energy efficiency and data security) and cluster based Least Spanning Tree algorithm (gives good energy efficiency and very less time delay), which are very effective alone for WSN, and also obtain life of sensor node and data transmission by LST based PSO algorithm. These techniques effectively overcome the problems of low energy and coverage of sensor range. For the observation of the analysis of the energy data of the sensors and the mathematical calculation of the data transmission and input-output energy, MATLB-2013 tool was used. After the observation of the results analysed by the MATLAB tools, it found that the combination of the LST based PSO algorithm was better performed than PSO algorithm and cluster based Least Spanning Tree algorithm alone and it was also performed better than other types of advanced energy efficient algorithm.

Keywords: *Wireless Sensor Network, coverage optimization; discrete PSO; non-convex region, grid.*

1. Introduction

Wireless sensor network is a class of wireless ad hoc networks in which sensor nodes collect, process and communicate data acquired from the physical environment to an external base station (BS), thus allowing for monitoring and control of various physical parameters. Recent advances in micro sensor technologies have made these sensors available in large numbers, at low-cost, small in size and able to be employed in a wide range of applications such as in the military and environmental monitoring fields, as well as many others. When studying the overall network design problem in wireless sensor networks there are many important aspects that need to be taken into consideration, such as the small size of the sensor node, its hardware complexity and ultra-low energy consumption. Among them, energy efficiency should be considered as the key design objective, since a sensor node can only be equipped with a limited energy supply. Clustering is one of the design methods used to manage the network energy consumption efficiently, by minimizing the number of nodes that take part in long-distance communication with the base station and distributing the energy consumption evenly among the nodes in the network. In this approach, each group of sensors has a cluster head node that aggregates data from its respective cluster and sends it towards the base station as a representative sample of its cluster.

Therefore, the application of the clustering-based approach has the advantage of reducing the amount of information that needs to be transmitted, as well as enhancing resource allocation and bandwidth reusability. In WSNs, communication takes place with the help of spatially distributed autonomous sensor nodes equipped to sense specific information. WSNs, especially the ones that have gained much popularity in the recent years, are typically, ad hoc in nature and they inherit many characteristics or features of wireless ad hoc networks such as the ability for infrastructure less setup, minimal or no reliance on network planning, and the ability of the nodes to self organize and self-configure without the involvement of a centralized network manager, router, access point, or a switch. These features help to setup WSNs fast in situations where there is no existing network setup or in times when setting up a mixed infrastructure network is considered infeasible, for example, in times of emergency or during relief operations. WSNs have

*Corresponding author: **Pooja Singh; Dr. Raghav Yadav** is working as Associate Professor

variety of applications in both the military and the civilian population worldwide such as in cases of enemy intrusion in the battlefield, object tracking, habitat monitoring, patient monitoring, fire detection, and so on.

Even though sensor networks have emerged to be attractive and they hold great promises for our future, there are several challenges that need to be addressed. Some of the well-known challenges are attributed to issues relating to coverage and deployment, scalability, quality -of-service (QoS), size, computational power, energy efficiency, and security. With the rapid development in miniaturization, low power wireless communication, micro sensor, and microprocessor hardware, it have become a reality to deploy small, inexpensive, low-power, distributed devices, which are capable of monitoring physical environment by local processing and wireless communication.

2. Background

All There are various algorithms which are used for the energy efficiency of wireless sensor network which are improved time to time by different authors; some important and useful algorithms are shown in figure 1.1.

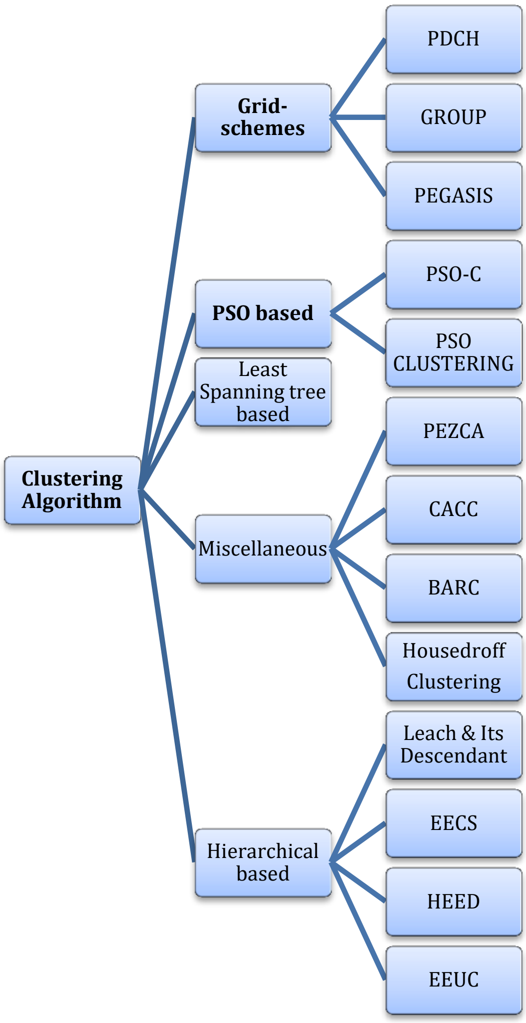

Fig.1 Different types of algorithm

3. Related Work

For making of an effective system we make a model which contains all prospects of the system and also it executable. So the system model of an energy and delay efficient wireless sensor network is given bellow:

A. Radio Power Model and Characteristic Distance

For a simplified power model of radio communication, the energy consumed per second in Transmission is:

$$E_t = (e_t + e_d r^n)B \quad (1)$$

Where e_t is the energy/bit consumed by the transmitter electronics (including energy costs of imperfect duty cycling due to finite startup time), and e_d accounts for energy dissipated in the transmit op-amp (including op-amp inefficiencies). Both e_t and e_d are properties of the transceiver used by the nodes, r is the transmission range used. The parameter n is the power index for the channel path loss of the antenna. This factor depends on the RF environment and is generally between 2 and 4. B is the bit rate of the radio and is a fixed parameter in our study.
On the receiving side, a fixed amount of power is required to capture the incoming radio signal

$$E_r = e_r B \quad (2)$$

For currently available radio transceivers are e_t=50x10-9 J/bit, e_r=50x10-9 J/bit, e_d=100x10-12 J/bit/m2 (for n=2) and B=1Mbit/s. Since the path loss of radio transmission scales with distance in a greater-than-linear fashion, the transmission energy can be reduced by dividing a long path into several shorter ones. However, if the number of intermediate nodes is very large then the energy consumption per node is dominated by the term e_t in equation (1) and the receiving energy consumption hence an optimum exists. Intermediate nodes between a data source and destination can serve as relays that receive and rebroadcast data. Let us consider multi-hop communication in a finite one dimensional network from the source to the base station across a distance d using k hops. The source at $x=d$ will generate traffic of A Erlang, so that each intermediate node receives and transmits the same traffic, A. The routing nodes are assumed to be regularly spaced and to consume no energy while idle. The power consumed by this communication is then simply the sum of the transmit and receive energies multiplied by the effective bit rate, BA, and is given by

$$P = \sum_{i=1}^{k}(e_t + e_d r_i^n + e_r)BA \quad (3)$$
$$d = \sum_{i=1}^{k} r_i \quad (4)$$

In order to minimize P we note that it is strictly convex and use Jensen's inequality. Given d and k then P is minimized when all the hop distances r_i are made equal to d/k. The minimum energy consumption for a given distance d has either no intervening hops or k_{opt} equidistant hops where k_{opt} is always of,

$$k_{opt} = \left(\frac{d}{d_{char}}\right) \quad (5)$$

The distanced_{char}, called the characteristic distance, is independent of d and is given by,

$$d_{char} = \sqrt[n]{\frac{e_t+e_r}{e_d(n-1)}} \quad (6)$$

The characteristic distance depends only on the energy consumption of the hardware and the path loss coefficient (i.e. it is independent of the traffic); d_{char} alone determines the optimal number of hops. For typical COTS (commercial, off-the-shelf)-based sensor nodes, d_{char} is about 35 meters. The introductions of relay nodes are clearly a balancing act between reduced transmission energy and increased receive energy. Hops that are too short lead to excessive receive energy. Hops that are too long lead to excessive path loss. In between these extremes is an optimum transmission distance that is the characteristic distance.

In the above section I have introduced a simple energy model in which no energy was consumed while the node was idle. This led to a characteristic distance that was independent of traffic. We now include the idle state energy and show how the characteristic distance is modified. On one hand a short range is preferred for energy efficient data transmission as a result of the nonlinear path loss ratio. On the other hand more redundant nodes can be put into the sleep state to prolong the network lifetime if a long range is used in the topology management of sensor networks. If the transmission route is divided into k grids and only one node wakes up in each grid as relay node, as in the GAF protocol, the total energy consumption per second by k hops is

$$P = k(e_rBA + e_tBA + e_d\left(2\frac{d}{k}\right)^n BA + ce_r(1-2A)B \quad (7)$$

The last term $ce_r(1-2A)B$ in the equation (7) represents the energy consumption when the radio neither receives nor transmits, i.e. it is in the idle state. The energy consumption in the idle state is approximately equal to that in the receiving state, so that the parameter c is close to 1. Note that we are currently assuming that nodes in the sleep state consume no energy. Also, we assume that the routing node in each grid can be located anywhere within that section and so the radio range is now twice the grid size. The energy efficient optimum size of the virtual grid can now be derived from equation (1.7) and is given by

$$R_{opt} = {r_{opt}}/{2} = \sqrt[n]{\frac{(e_t+e_r)A+ce_r(1-2A)}{2^nA(n-1)e_d}} \quad (8)$$

We know the energy consumed at the cluster head is much larger than that at individual sensing node. The reason is as follows: (1) the cluster-head needs to relay all the traffic of the cluster; (2) for each data unit, the cluster-head needs to transmit longer distance due to transmission between clusters, while the sensing nodes just transmit data inside the cluster. In view of this, let E_p and E_c be, respectively, the current energy and clustering energy (E_c is fixed), after a period of time, the i^{th} cluster-head has transmits information n_1 times and has receives information n2 times before T_1(suppose the energy of the i^{th} cluster-head is not lower than the threshold and the information unit is A Erlang) .the remainder energy of the i^{th} cluster-head at T_1 is then simply as the equation (9).

$$E_p(i) = E_p(i) - \sum_{k=1}^{n_1} E_r(i,k) - \sum_{i=1}^{n_2} E_r(i,l) - E_c \times n_i \quad (9)$$

Where i, j, k respectively denote cluster-head, n_i is the clustering time in cluster i before T_1.

B. Particle Swarm Optimization Algorithm for Cluster Setup

The operation of our protocol is based on a centralized control algorithm that is implemented at the base station, which is a node with a large amount of energy supply. The proposed protocol operates in rounds, where each round begins with a setup phase at which clusters are formed. This is followed by a steady state phase in which we used a similar approach as in. At the starting of each setup phase, all nodes send information about their current energy status and locations to the base station. Based on this information, the base station computes the average energy level of all nodes. To ensure that only nodes with a sufficient energy are selected as cluster heads, the nodes with an energy level above the average are eligible to be a cluster head candidate for this round.

C. Least spanning tree

The minimum spanning tree is a tree of a planar graph. Each edge is labelled with its weight, which here is roughly proportional to its length. Given a connected, undirected graph, a spanning tree of that graph is a sub graph that is a tree and connects all the vertices together. A single graph can have many different spanning trees. A least spanning tree (LST) or minimum weight spanning tree is then a spanning tree with weight less than or equal to the weight of every other spanning tree. More generally, any undirected graph (not necessarily connected) has a minimum spanning forest, which is a union of minimum spanning trees for its connected components. A spanning tree for that graph would be a subset of those paths that has no cycles but still connects to every house. There might be several spanning trees possible. A minimum spanning tree would be one with the lowest total cost

a. Constructing least spanning tree

By Eq(9),we can compute the remainder energy, if E_p(i) is lower than E_v, then modify the information table of the i^{th} cluster-head: set flag=0; broadcast information to its children, also inform the neighbour j^{th} cluster-head doesn't transmits information to it, and let i^{th} cluster-head i is in the sleeping state; else the i^{th} cluster-head may go along the next clustering or transmitting or receiving. According to Prim algorithm, suppose undirected graph G (V, E, D), where V is the set of cluster-heads and the number is N, E is the set of connections of cluster-head, and D is the distance of cluster-heads, the process of constructing least spanning tree as illustrated below:

• Initialization: V_1=Sink, E′=null, and V_2=V-V_1.
• Select a edge: which has minimum distance from Sink to one cluster-head (suppose is V_i), where V_i is directly connected with Sink, then set, V_1= {Sink, V_i}, E ′= {(Sink, V_i)}, V_2=V_2-V_1.
• For each cluster-head V_k in V_1 do :select a minimum distance d(k,j),which V_k ЄV_1,V_j Є V_2 and E′=(V_k, V_j) Є E , but V_k is not Є E′, then V_1=V_1 Є V_j, E′={(V_k, V_j)} Є E′, V_2=V_2-V_j.
• If V_2 is empty then end, else go to above.

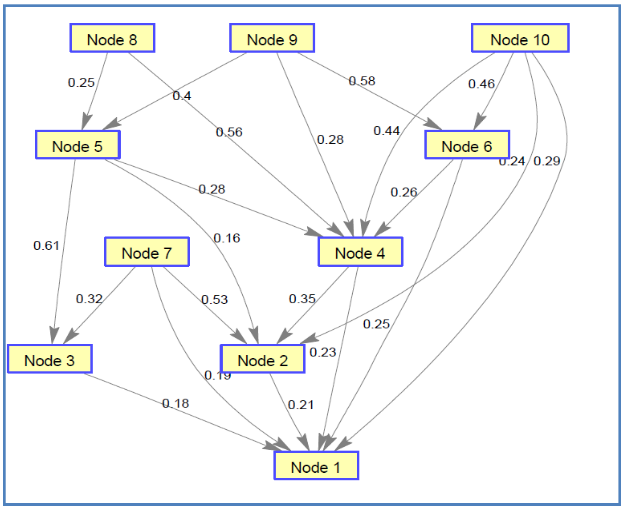

Figure 2 (a) deployment of sensor node

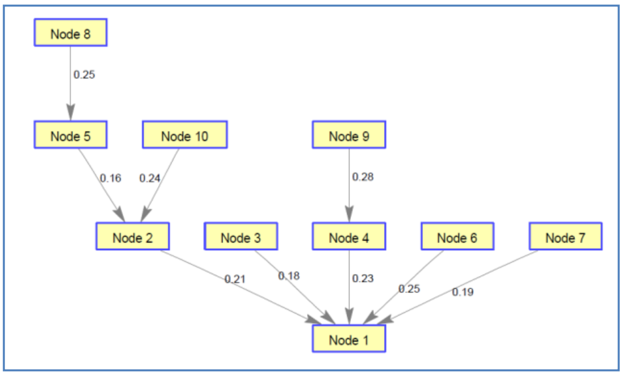

Figure 2 (b) Least spanning tree graph.

Deployment of node by least spanning tree is shown in the figure 2 (a & b).In this deployment we take one cluster which is nearer to the sink. Now by MAC protocol we find out the weightege of different edge (path distance). And make an incident matrix which shows the direction of data flow from node to node.

Now we apply least spanning tree algorithm and we get shortest path from each node to the node 'A', which is the nearest cluster head of the network from the sink. The least spanning tree graph is shown in the figure 2 (b).

4. Proposed Methodology

PSO cluster based least spanning tree algorithm is explained in the Figure 3. Proposed methodology has following steps:

- Thousands of sensor nodes are deployed in the environment.
- Select a node as sink near the base station.
- Now apply particle swarm optimization algorithm for the clustering of the network and Identify a sensor node which is closest to sink then choose the best sensor node as cluster head (best sensor means, the sensor which has maximum energy).
- Calculate the distance between neighbour cluster head (d) (Apply LST).
- Compare the distance from other active node of the same cluster to the neighbouring cluster head, (d_j).if d_j is less than d, then select jth node as cluster head.
- Calculate the energy of cluster head (E_i)
- If energy of cluster head is greater than threshold energy (E^{th}) then it is working as cluster head, but if E_i<E^{th} then apply PSO algorithm again.
- This process will be continuing till last sensor node.

5. Results

The performance of the proposed protocol is evaluated using Matlab. In this proposed model, first evaluate the total power consumed by a node during transmission and reception of the data per hop. After simulating for 100 nodes in a 100m x 100m network area with unequal initial energy of nodes to show the effect of the different nodes' energy in the network.

A. Power Loss of Node with Traffic

Now it calculated the power consumed by a node to transmit a data to sink which is r meter far from the sensor node. This power consumption or energy loss is calculated when a node transmit signal to sink directly which is very large and node is dead very soon, power loss is shown in the Figure 4.

After applying normal clustering to the network and calculating characteristic distance d_{chr} with respect to number of hop, bit rate and traffic. In the proposed simulation, 1 MBPS data rate, maximum 100 hops for reaching to the sink and network traffic is vary from 0.0 Erlang to 1.0 Erlang. Zero Er means no traffic.

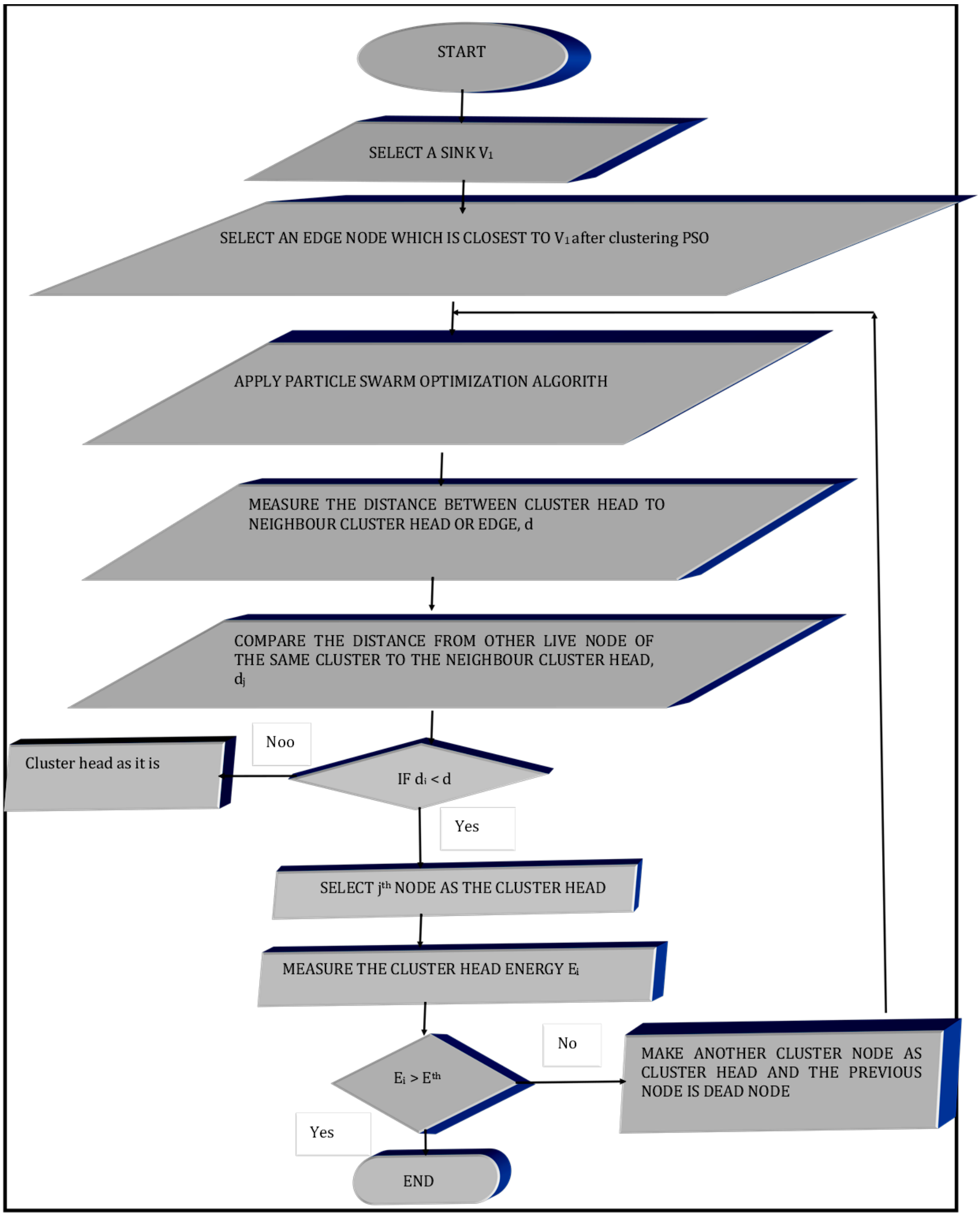

Figure 3: Flowchart of the proposed algorithm for cluster setup

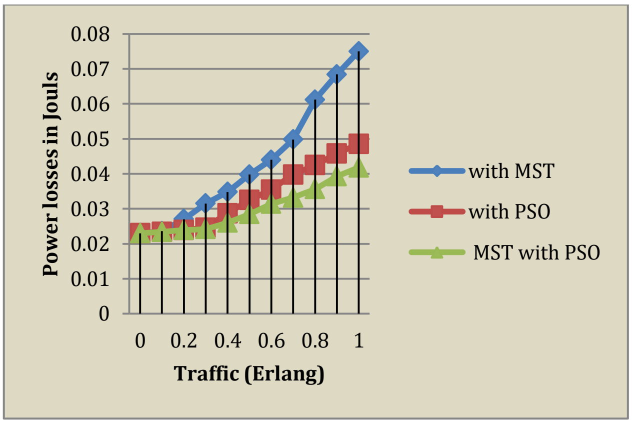

Figure 4: Power loss of node with traffic

B. Analysis of Power Losses per Node per Hop With Respect To Range

Now by using d_{chr} weightage of the path is calculated from different cluster head to the sink. Now again the power consumption of the node is calculated while sending signal to the sink with clustering and find out the consumption of power reduced when traffic increases with compare to without clustering. Figure 5 shows the calculated value of energy consumed by per node per hop over the distance from the node. Now applying Prim algorithm for least spanning tree it has found that the energy loss by per node per hop is reduced and my network is more energy efficient and delay efficient also due to use of least spanning tree as shown in the graph. Subsequently, after applying PSO algorithm for the clustering of the network the performance of the network is improved by the best selection of the cluster head and best least path of the tree. It has been found that with PSO clustering and least spanning tree algorithm the power consumption is very less as shown in the table and graph.

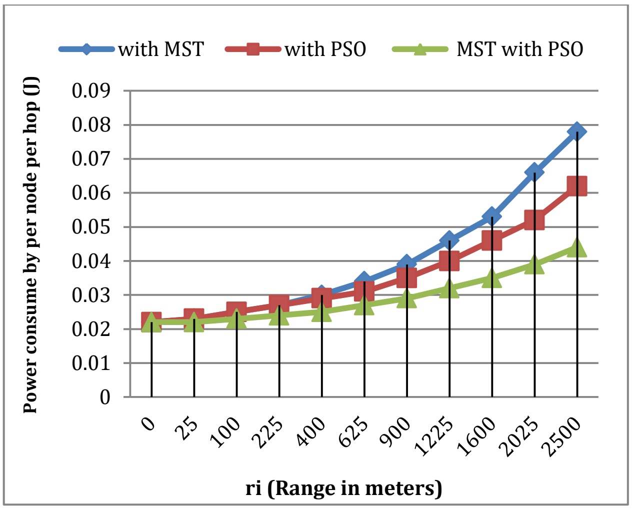

Figure 5: Analysis of Power losses per node per hop with respect to Range

C. Analysis of Life of Node Vs Traffic

In figure 4 the lifetime of the node over high traffic is high in the PSO algorithm with comparison to other condition. This proposed model gives approximately 4000 seconds per node over full traffic.

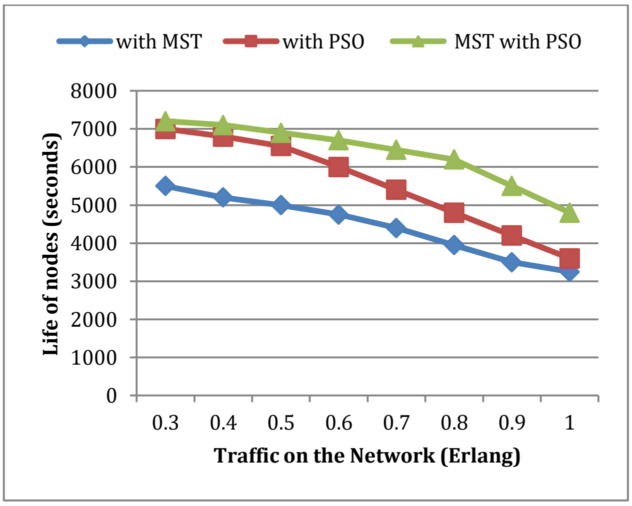

Figure 6: Analysis of Life of node Vs Traffic

D. Life of Nodes over Full Traffic

While taking full traffic in the network and distributing whole power of the nodes of the network it is observed that with PSO clustering and least spanning tree more numbers of nodes are found to be live or active as compared to conventional method and cluster based least spanning tree algorithm. In the proposed model 36 nodes live in 600 seconds while without clustering network dead in 300 seconds, with clustering network dead in 400 seconds and cluster based least spanning tree algorithm has only 6 nodes active as shown in the Figure 6 Due to this the lifetime of the network will be more and network can work for long time without connection loss.

E. Average Energy Consumption in the Network

Figure 7 illustrates the amount of energy consumed by the sensors over a simulation period of 900 seconds. The graph clearly establishes the effectiveness of my proposed PSO-LST in delivering maximum sensor operations in an energy-efficient way. The rate at which the residual energy of the sensors is replenished with PSO-LST is apparently lower than the other protocols respectively.

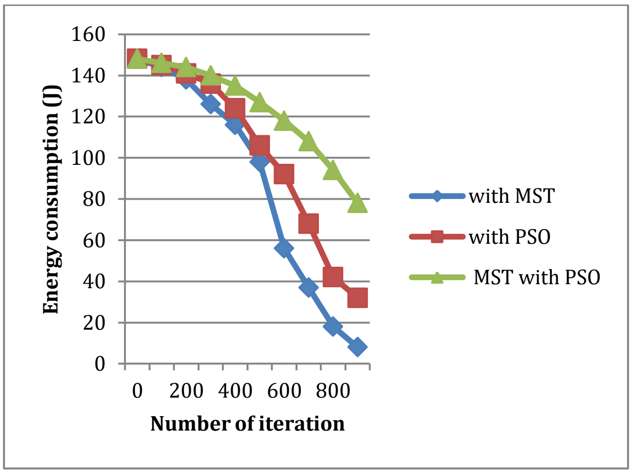

Figure 7: Average Energy Consumption in the Network

The reason behind is that the proposed PSO-based cluster scheme is semi-distributed and well-managed. However, the other protocols either lack proper cluster head control (LEACH-C) or decentralization concepts (LST), due to which the battery-based sensors run out of power rapidly

F. Number of PSO-Based Cluster Head Selection Rounds Supported By the Sensor Network

Further, in Figure.6 gives the study of the total number of cluster head selection rounds supported by the active nodes in the network. This graph assists in evaluating the overall cost of applying PSO to the cluster head selection procedure. From the large number of selection rounds (over 1000 rounds) supported by the proposed technique, it can be easily deduced that cost of the PSO operations completely outweighs the extended lifetime achieved. On the contrary, ordinary cluster based protocols degrades at a faster rate owing to its inefficient methodologies for network partitioning and head node selection.

Moreover, LST also shows gradual decrement in the plot. Such observation is expected because the member nodes remain busy most of the times in forwarding sensor information to sink rather than monitoring the environment.

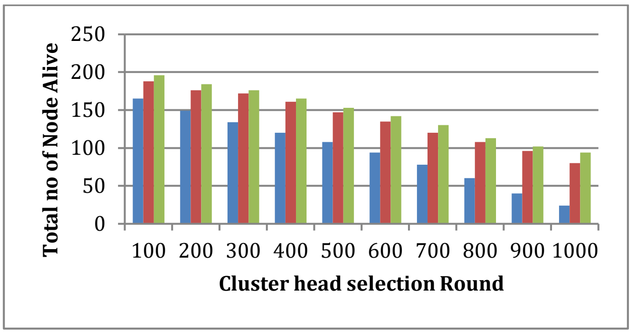

Figure 8: Number of PSO-based Cluster Head Selection Rounds Supported by the Sensor Network

Conclusion

The energy constraints in sensors pose serious challenges to the developers of sensor network. In order to improve the network performance several energy-aware cluster based techniques are designed. The issue of optimal cluster head selection is often formulated as an optimization problem. Particle Swarm Optimization (PSO) is such a method which is known for its easy implementation and fast convergence. The second major issue of time delay is improved by least spanning tree which is used for the shortest route in wireless communication.

In this dissertation, PSO has been applied for selecting the cluster heads by optimizing certain performance criteria. The cluster-based strategy enhanced the network performance as compared to certain existing techniques and in capacity the Prim' Algorithm for shortest route, the performance of the proposed model observed to be improved. The proposed PSO-LST reduces the intra cluster distance from the cluster members to the cluster head. The location of the cluster head is optimized by the proposed objective function used by PSO. A new cost function has been defined that takes into account the maximum distance between the non-cluster head node and its cluster head, and the remaining energy of cluster head candidates in the cluster head selection algorithm. Results from the simulations indicate that the proposed protocol using PSO algorithm and least spanning tree algorithm gives a higher network lifetime and delivers more data to the base station compared to cluster based protocol. Furthermore, the proposed protocol produced better clustering by evenly allocating the cluster heads throughout the sensor network area.

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