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Evaluation and Improvement of Pegasis Using Ant Colony Optimization

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Abstract— In the last few years many research work have been conducted by the researchers in the field of routing protocols in wireless sensor networks. Nowadays their main area of concern is based on routing protocols utilizing the concept of Swarm Intelligence. This dissertation deals with reducing the usage of energy in wireless sensor networks by ants traversing different paths. Ant colony algorithm is generally an optimization technique which is used to optimize the performance of ants by providing them easy way to find the shortest path as we can say nodes in real environment. The main attention of this research work is to understand the working of ant colony algorithm by using Stigmery operation in such a way that it increases the efficiency of the Pegasis protocol. The proposed work has been simulated based on the simulator MATLAB in which simulation will be performed and various parameters are used in regard of wireless sensor networks.

Keywords— Sensor Network, Swarm intelligence, LEACH, PEGASIS, ACO, Stigmery, Greedy Algorithm.

I. INTRODUCTION

A wireless sensor network is a wireless network composed of a large number of nodes that are spatially distributed with limited power, processing and communication capabilities. These sensors work with each other to sense some physical phenomenon and then the information gathered is processed to get relevant results. Sensor nodes have two main functionalities: monitoring the environment and sending the sensed data to a special node called sink. The monitored data can either be send periodically or when a particular event occurs. Wireless sensor networks are highly distributed networks of small lightweight nodes that are arranged over large area. Sensor node has capability of sensing, first it sense the data and process that data. After processing it route that data to base station through a communication medium. Ad hoc networks are also like wireless networks. A comparison with ad hoc network lead to some differences. Such as, sensor network has a large number of nodes. Due to more prone to failure, energy drains rapidly. They have no unique global IDs. Maintaining the lifetime of wireless sensor network is most important goal in sensor network research. Sensor networks are to deal with sensitive data, so they also need some security consideration. There are some architectures overviewed and routing protocols which are suitable for Wireless sensor network.

A. Routing protocols

Routing is a very important aspect in terms of wireless sensor networks. Routing stands for the sending the required data to the destination in such a manner that it reaches efficiently with high throughput and accuracy. Two basic routing protocols are studied and implemented.

1) LEACH

It is the first network protocol that uses hierarchical routing for wireless sensor networks to increase the life time of network. All the nodes in a network organize themselves into local clusters, with one node acting as the cluster-head. All non-cluster-head nodes transmit their data to the cluster-head, while the cluster-head node receive data from all the cluster members, perform signal processing functions on the data (e.g., data aggregation), and transmit data to the remote base station. Therefore, being a cluster-head node is much more energy-intensive than being a non-cluster-head node.

2) PEGASIS

It is Power Efficient Gathering in Sensor Information System. The key idea in PEGASIS is to form a chain among the sensor nodes so that each node will receive from and transmit to a close neighbor. The protocol, which is called Power-Efficient Gathering in Sensor Information Systems (PEGASIS), is an optimal chain-based protocol. In this algorithm, it decreases the energy consumption by creating a chain structure which comprises of all nodes and continually data is aggregated across the chain. The algorithm presents an idea that if nodes form a chain between source and sink, only one node in the given transmission time-frame will be transmitting to the base station. Data-fusion occurs at each and every node in the sensor network allowing for all relevant information to permeate beyond the network. Cluster formation is mostly avoided and only one node in a chain is used to transmit to the BS instead of using multiple nodes. So as to increase the network life time, nodes need to communicate only with their closest neighbors and they take turns in communicating with the Base Station. When the communication of all nodes with the base-station ends, a new round will start and this process will go on.

B. Ant Colony Optimization

Ant colony optimization (ACO) was introduced by the Italian scholar, M. Dorigo [1]. It is a novel meta-heuristic technique that has been successfully applied in solving various problems in combinatorial optimization. To create the shortest path from food sources to nests, ACO algorithm helps in modelling the behaviour of real ants. The ants assemble pheromone trail while walking and all other ants prefer to follow a path where the amount of pheromone is rich. When an ant searches a food source, it carries it back to the nest and starts depositing the chemical. Other ants will begin to choose a shorter path between food source and their nest, where there is higher quantity of pheromone. This ant foraging behaviour can solve ACO problems.

II. Related Work

Parminder Kaur, Mrs. Mamta Katiyar, (2012) [16] paper tells that a WSN is a specialized wireless network made up of a large number of sensors and at least one base station. The main difference between the WSN and the traditional wireless networks is that sensors are extremely sensitive to energy consumption. Saving the energy is a crucial issue in designing the wireless sensor networks. Since the radio transmission and reception consumes a lot of energy, one of the important issues in wireless sensor network is to inherent limited battery power within network sensor nodes. In order to increase the lifetime of sensor nodes, it is preferred to distribute the energy dissipated throughout the wireless sensor network. So it is essential to design effective and energy aware protocols in order to enhance the network lifetime. In this paper, a review on network structure based routing protocol in WSNs is carried out. Energy consumption and network life time has been considered as the major issues.

Stephanie Lindsey and Cauligi S.Raghavendra, (2002) [7] The wireless Sensor nodes consist of restricted battery power and wireless communications is done systematically to gather useful information from the field and capturing the sensed and measured information in an energy efficient manner is critical to operate the sensor network for a very long time. In collecting a data, problem is defined in a round of communications where each and every sensor node has a data to be passed over to the base station. If the transmission of data takes directly to the base station by each sensor node then it will consume the power quickly. The LEACH protocol give an elegant solution where all clusters before transmitting the data to the base station , fuse the data and by randomizing approach the cluster heads are appointed, to pass over the data to the base station. LEACH protocol achieves an improvement over direct transmissions and in this paper, we use a protocol name: PEGASIS (Power-Efficient Gathering in Sensor Information Systems), a chain-based routing protocol that is an improvement over the LEACH protocol. In PEGASIS, each and every sensor node communicates only with a close neighbor and takes turns while transmitting the sensed data to the base Station, thus reduce a large amount of energy spent per round and the simulation results show that LEACH is far behind than PEGASIS in performance.

W. Heinzelman, A. Chandrakasan, H. Balakrishnan (2000) [8], proposed about the Energy Efficient communication protocols for wireless sensor networks. Wireless distributed micro-sensor systems will enable the reliable monitoring of a variety of environments for both civil and military applications. In this paper, we look at communication protocols, which can have significant impact on the overall energy dissipation of these networks. Based on our findings that the conventional protocols of direct transmission, minimum-transmission-energy, multi-hop routing, and static clustering may not be optimal for sensor networks.

Komal Chadha, Najme Zehra Naqvi, Harmeen Kaur Matheru (2011) [18] Ant colony optimization (ACO) is a meta-heuristic approach to tackle hard combinatorial optimization problems. The basic element of ACO is a solution construction mechanism, which affect the decision-making processes of ant colonies as they forage for food and find the most efficient routes from their nests to food sources. This paper is a review report on ant colony optimization with its algorithms in chronological order and Vehicle routing problem (one of the application of ACO).Following this, there is a brief introduction of Estimation-based ACO.

Ant colony optimization is an iterative distributed algorithm. On every iteration, a set of artificial ants (cooperating agents) are considered. At each step of the construction of solution, an ant selects the following node to be visited according to a stochastic mechanism that is biased by the pheromone: when in node 'i', the following vertex is selected stochastically among the previously unvisited ones. In particular, if node j has not been previously visited, it could be selected with a probability that is proportional to the pheromone associated with edge (i, j). At the end of an iteration process, on the basis of the quality of the solutions constructed by the ants, the pheromone values in order to bias ants are modified in future iterations to construct solutions similar to the best ones previously constructed. The ACO system contains two rules:

1. Local pheromone update rule, which is applied whilst constructing solutions.
2. Global pheromone updating rule, which is applied after all ants construct a solution.

Furthermore, an ACO algorithm includes two more mechanisms: trail evaporation and, optionally can use, daemon actions. Trail evaporation decreases over time all trail values, in order to avoid unlimited accumulation of trails over some component. Daemon actions used to implement centralized actions which cannot be performed by single ant, such as the invocation of a local optimization procedure, or the updating of global information to be used to decide whether to bias the search process from a non-local perspective. Although each ant of the colony is complex enough to find a feasible solution to the problem under observation, good quality solutions can only emerge as the result of the collective interaction among the ants. Each ant makes use only of private information and of information local to the node it is visiting.

Manoj Ahlawat, (2013) [13] A Wireless Sensor Network (WSN) is a type of network which consists of collection of small device called sensors nodes. A Sensor node has a various resource constraint (i.e., storage, communication capability and battery power). To form a network, these sensor nodes are set with interface through which they can communicate with one another. The ongoing improvement in sensor technology has made possible WSN that have wide and varied application. While choosing the right sensor for an application a number of characteristics are important.

III. PROBLEM STATEMENT

Wireless Sensor Networks gather and process the packets from its sensor nodes and pass it to the base station (BS). Primary routing goals of WSN systems are to extend network life and prevent connection errors that emerged from the use of intensive energy management techniques. As such, these routing approaches emerged as swarm intelligence based schemes.The aim of my research work is to study an artificial intelligence technique which is Ant Colony Optimization. Here swarm intelligence is used in the form of ACO for wireless sensor network and improve the routing protocol.

IV. PROPOSED METHOD

In this section we discuss the Ant Colony optimization algorithm used for chain construction. ACO makes sure that none of the inter-nodal distances becomes extremely large during chain construction i.e. they never exceed a threshold value. Ant Colony Optimization [13] is inspired by the behavior of real ants searching for food. The main objective of ACO is to utilize both local information (visibility) as well as information about good solutions obtained in the past (pheromone), when constructing new solutions. To apply ant algorithm in our problem, we place ants arbitrarily on the nodes. Each ant is a simple agent with certain memory attributed. According to a probability, an ant chooses the next node into which it has to move into. This probability is a function of inter-nodal distance and pheromone deposited upon the link. Every ant has a taboo table recording nodes which the ant has already accessed. The Taboo table forbids the ant to move into previously visited nodes. At the end of travelling an ant deposits pheromone on the paths it has travelled through. Based on the information collected an ant determines an ant's choice of anode from its neighborhood. The mathematical formulations are omitted here due to the lack of space. In this way the entire chain is constructed. The chain is reconstructed using ACO when a node dies, but by bypassing it and by following all the above mentioned facts.

Steps are given below:

1) Initialize all the network parameters which are the number of nodes, initial energy of the nodes, random BS location.
2) Sink sends hello packet to all the nodes to get information of all the nodes.
3) Sink finds the farthest node by comparing the distances of all the nodes from itself in first region.
4) The chain formation starts from the farthest node *i* also known as end nodes. The end node finds the nearest node from itself. ACO makes sure that none of the inter-nodal distances becomes extremely large during chain construction i.e. they never exceed a threshold value.
5) Each node finds the distance between itself and the nearest node not connected in chain, and then connects with it following the same approach.
6) In the chain, each node *i* receiving data from the node j, acts as a parent to node *j*, whereas node *j* acts as a child to node *i*.
7) Number of nodes= number of ants= number of cities (M)
8) Starting from the base station, using node selection procedure an active ant will be selected to select the best tour.
9) Initialize c = 0 (chain counter).
10) c=c+1
11) The selected node will act as a source ant for others.
12) Repeat steps 10 and 11 while (c ≤ M).
13) The equations used to calculate transmission costs and receiving costs for a k-bit message and a distance d

ETx (k, d) = ETx– elec (k) + ETx–amp (k, d)
ETx (k, d) = Eelec*k + Îamp * k* d2

14) When a node dies then again using the above node selection procedure a new node is selected and a new tour is created.

V. RESULTS

For results 100m x 100m network area has been considered and 100 nodes and energy level of 0.5J has been implemented at the basic level. Simulations show that proposed algorithm A-PEGASIS performs better. The results focus on number of sensor nodes alive, lifetime of network and energy efficiency which are important indicators to measure the performance. ACO improves the efficiency of network. In this chapter performance of A-PEGASIS is compared with same metrics. Performance is compared with

1. Low Energy Efficient Clustering Hierarchy (LEACH)
2. Power Efficient Gathering in Sensor Information System (PEGASIS)

Various simulations are performed to check the efficiency of the new algorithm A-PEGASIS:

Simulation 1:

Here the network area deployed is in 100m x 100m with number of nodes is 100 and the energy level of the nodes is 0.5J. First of all the basic PEGASIS is been implemented.

Fig. 6.1 shows the graph between the total number of live nodes and the total number of rounds implemented using basic PEGASIS. It can be seen here that 100 nodes are live till 1228 rounds. Then the live nodes decreases rapidly as the number of rounds increases. On reaching 1400th round numbers of live nodes are almost 20 and they reduce to 0 at 2250th round. So the stability period of PEGASIS protocol is 1228 rounds which will be compared to the other protocols further. This implementation is of the basic PEGASIS and is quietly the same as the Original PEGASIS

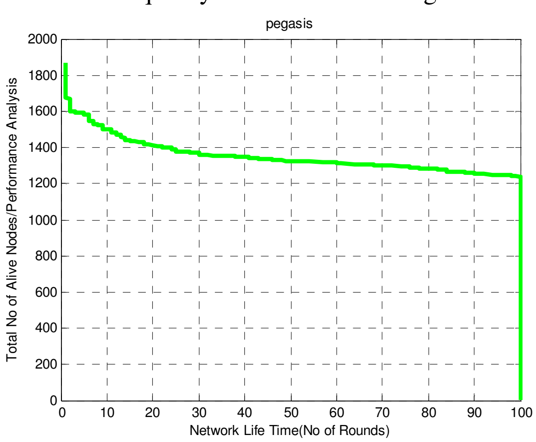

Fig 6.1 Applying Pegasis on 100 Nodes

Simulation 2:

In this simulation basic LEACH with the same network deployments' of 100m x 100m network area having 100 nodes and energy level of 0.5J.

Fig. 6.2 is the implementation of the basic LEACH and is been verified with the Original one. The graph shows the comparison of number of live nodes to the number of rounds. Initially the numbers of live nodes are 100 till 350 rounds. After this round, the number of live nodes starts decreasing linearly. On reaching 1200th round we are left with 20 live nodes. At the end all the live nodes are dead by 1900th round. Here, the stability period is 350 which are far more less than PEGASIS stability period.

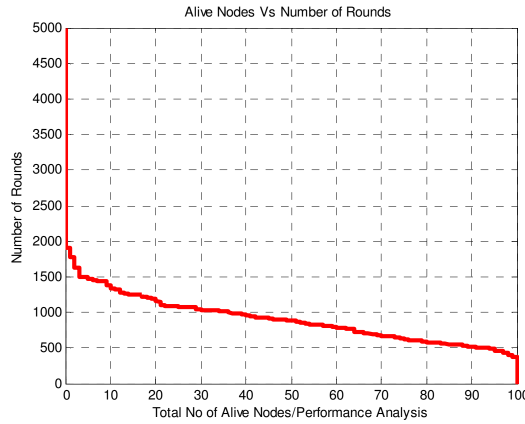

Fig. 6.2 Applying Leach on 100 Nodes

Simulation 3:

Here in the third simulation the new proposed algorithm has been implemented with the same area, number of nodes and the energy level.

Fig. 6.3 is the implementation of the proposed A-PEGASIS. The graph shows the comparison of number of live nodes to the number of rounds. Initially the numbers of live nodes are 100 till 1350 rounds. After this round, the number of live nodes starts decreasing and on reaching 1760th round we are left with 20 live nodes. At the end we have no live nodes by 2500th round. As we discussed that the first node die at 1350 round this is better than the stability period of LEACH and PEGASIS. So, in the proposed scenario the network lifetime is improved than the others.

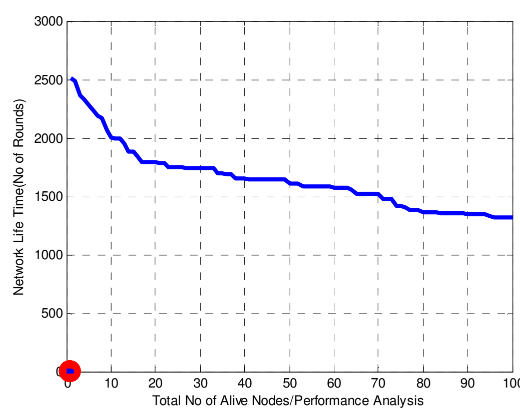

Fig 6.3 Implementation of Proposed ACO

Simulation 4:

Now the three protocols which are implemented are compared in one graph to see and compare their performances.

Fig. 6.4 shows the graph of comparison of LEACH, PEGASIS and A-PEGASIS. This graph clearly shows that the proposed method is more efficient than the other two protocols. ACO uses the energy of the nodes efficiently which makes the node in the plot lasting longer than the other protocols. A-PEGASIS gives 10% better network lifetime than PEGASIS technique and 81% better than LEACH due to efficient energy utilization.

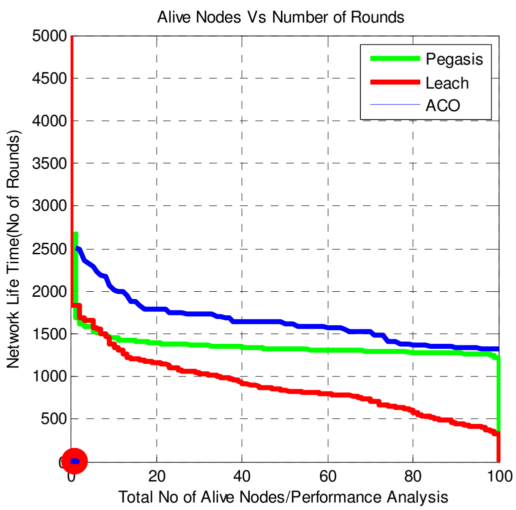

Fig 6.4 Comparison of the three protocols.

Number of Alive Nodes	Number of Rounds		
	LEACH	*PEGASIS*	*A-PEGASIS*
100	350	1225	1350
90	500	1275	1375
80	600	1290	1400
70	700	1300	1500
60	750	1320	1600
50	800	1350	1650
40	900	1370	1700
30	1050	1385	1750
20	1200	1400	1800
10	1500	1425	2000
0	2100	1825	2500

Table 6.1: Comparison between live nodes in three protocols

Table 6.1 shows the tabular representation of the live nodes and the number of rounds in the LEACH, PEGASIS and in A-PEGASIS. All the 100 nodes are alive for 350 rounds in LEACH and 1225 in PEGASIS whereas lifetimes of all the 100 nodes increases till 1350 rounds in A-PEGASIS. With increase in number of rounds the live nodes die out gradually. Covering 2250 rounds, all the nodes die out in PEGASIS where in the case of LEACH it takes 1900 rounds for all the 100 nodes to die and it go to 2500 rounds in A-PEGASIS.

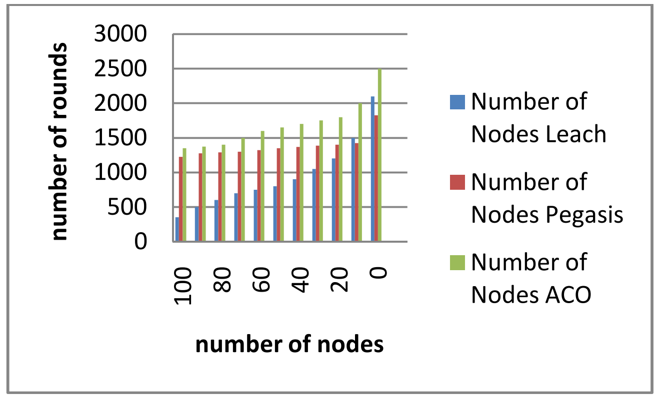

Fig. 6.5 Comparison of the lifetime of network in terms of percentage of number of live nodes

Fig. 6.5 gives a more clear view to the comparison of the three protocols we have been studying. It is authenticated that the proposed A-PEGASIS has better lifetime than the other two protocols.

Simulation 5:

In this simulation the three protocols are compared with different levels. Network area considered is 100m x 100m with 100 numbers of nodes.

Table 6.2 shows the observations made for different energy levels starting from 0.1J to 0.5J. It can be seen that when the energy levels are differed the proposed algorithm remains the efficient one in comparison with the others. As the energy of a node is increased the efficiency of the algorithm also increases.

Energy Level (in Joules)	LEACH (at round number)		PEGASIS (at round number)		A-PEGASIS (at round number)	
	First node dead	*Last node dead*	*First node dead*	*Last node dead*	*First node dead*	*Last node dead*
0.1	110	340	240	350	310	1230
0.2	250	790	490	730	630	1670
0.3	340	1300	720	950	980	2100
0.4	360	1650	970	1320	1330	2450
0.5	390	1900	1225	1825	1350	2500

Table 6.2 Comparison at different energy levels

Simulation 6:

In this next simulation we consider the same network area as 100m x100m and a static energy level of 0.5J but with different number of nodes starting from 50, then 100, 150 and finally 200.

Table 6.3 shows the observations made using different number of nodes. Considering a total of 50 nodes initially, increasing them by 50 nodes repeatedly till the total number of nodes are 200, shows that with the increase in number of nodes the number of rounds increases which results in enhancement of the network lifetime. In the case of 50 nodes in the area of 100mx100m long chains are formed so nodes are dead earlier as compared to the network of 100 nodes. As we increase the nodes the chains become short and so less the energy loss.

ENERGY 0.5J					
Number of Nodes = 50	***Nodes***	50	30	15	0
	Rounds	780	875	1080	1300
Number of Nodes = 100	***Nodes***	100	75	50	0
	Rounds	1350	1525	1650	2500
Number of Nodes = 150	***Nodes***	150	100	50	0
	Rounds	1780	2000	2600	3700
Number of Nodes = 200	***Nodes***	200	150	100	0
	Rounds	2150	2480	2800	4650

Table 6.3 Observations with different number of nodes

VI. CONCLUSION

It is concluded from the analytical simulation results that improved ACO is energy efficient protocol by having longer stability period, high network efficiency and low energy consumption. This shows that Ant Colony Optimization performed on the chain based formation can give better results than that of the basic LEACH and PEGASIS.

In this thesis an improved PEGASIS using Ant Colony Optimization has been proposed. It has been concluded that:

- As the number of live nodes gets used and exhausted, the number of rounds keeps on increasing. This shows lifetime of ACO used PEGASIS is better than original PEGASIS and LEACH.
- Also by increasing the nodes from 50 to 200 in the rounds of 50, the number of rounds significantly increases.
- Also with the change in the energy level from 0.1J to 0.5J the proposed algorithm remains its network efficiency.

In this research work PEGASIS chain construction has been improved by using Ant Colony Optimization and it has been concluded that improved method is efficient than basic PEGASIS and LEACH. But a difficult situation which arises in this is the black hole problem in which the surrounding nodes of the sink dies eventually and causes a energy less hole which causes long chains and hence leads to energy loss. Also in near future the other swarm intelligence technologies can be used (for eg. Artificial Bee Colony or Particle Swarm Optimization) on PEGASIS as well as LEACH and improve their network lifetime and energy consumption.

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AUTHOR PROFILE

Sakshi Verma received B.Tech degree in Computer Engineering from Giani Zail Singh, PTU Campus, Bathinda in 2012, respectively. During 2012-2015, i stayed in networking lab, to do a research on Routing Protocols in WSN and to improve its performance using Ant colony algorithm.