Power Optimization in Clustering and Routing for Wireless Sensor Networks Using Particle Swarm Optimization

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Abstract: **Wireless Sensor Networks (WSNs) are key for various applications that involve long-term and low-cost monitoring and actuating. In these applications, sensor nodes use batteries as the sole energy source. Therefore, energy efficiency becomes critical. The Wireless Sensor Network is a collection of sensor nodes organized into a cooperative network. Wireless Sensor Networks are emerging because of the development in the wireless communication technology. The PSO algorithm is used for clustering and routing in WSN. The proposed approach is able to present energy efficient clustering and routing in WSN. By using clustering in a sensor network it can increase the lifetime of network. PSO prolong the network lifetime. Cluster head nodes, makes routing more easily and the rest of the sensor nodes turn off their radios to save energy. In PSO algorithms to demonstrate their superiority in terms of network life, energy consumption, dead sensor nodes and delivery of total data packets to the base station.**

Index Terms: WSN-Wireless Sensor Networks, Cluster Head, PSO-Particle Swarm Optimization

I. INTRODUCTION

Recent developments in processor, memory and radio technology have enabled Wireless Sensor Networks (WSNs) which are deployed to collect useful information from an area of interest. Wireless sensor networks are expected to be used in a wide range of applications, such as military surveillance, environmental monitoring, target tracking, etc . A WSN consist of a large of tiny and low power sensor nodes, which are randomly or manually deployed across an unattended target area. WSNs have potential application in environment monitoring, disaster warning systems, health care, defense reconnaissance and surveillance system (Akyildiz et al., 2002). One of the most important constraints on sensor nodes is the low power consumption requirement.

Sensor nodes carry limited, generally irreplaceable, power sources. Therefore, while traditional networks aim to achieve high quality of service (QoS) provisions, sensor network protocols must focus primarily on power conservation. They must have inbuilt trade-off mechanisms that give the end user the option of prolonging network lifetime at the cost of lower throughput or higher transmission delay.

In WSN, sensor nodes are divided into several groups called clusters. Each cluster has a leader know as cluster head (CH). All the sensor nodes sense local data and send it to their corresponding cluster head. Then the CHs aggregate the local data and finally send it to the base station (BS) directly or via other CHs. Clustering is one of the most challenging issues and it can be mainly focused on improving scalability and to enlarge the lifetime of the network. Clustering sensor nodes has the following advantages: (1) It enables data aggregation at cluster head to eliminate the redundant and uncorrelated data; thereby it saves energy of the senor nodes.(2) Routing can be more easily managed because only CHs and thus require small routing information; this in turn improves the scalability of the network significantly.(3) It also conserves communication bandwidth as the sensor nodes communicate with their CHs only and thus avoid exchange of redundant messages among themselves.

However, CHs bear some extra work load contributed by their member sensor nodes as they receive the sensed data from their member sensor nodes, aggregate them and communicate it to the BS. Moreover, in many WSNs, the CHs are usually selected amongst the normal sensor nodes which can die quickly for this extra work load. In this context, many researches (Gupta and Younis, 2003; Low et al.., 2008; Ataul et al., 2009;Kuila and jana, 2012a; Kuila et al., 2013) have proposed the use of some special nodes called gateways, Which are provisioned with extra energy. These gateways act like cluster heads and responsible for the same functionality of the CHs. Therefore, gateways and

CHs are used interchangeably in the remainder of the paper.

Unfortunately, the gateways are also battery-operated and hence power constrained. Lifetime of the gateways is very essential for the long run operation of the network. The main objective of this paper is to develop an efficient PSO-based clustering and routing algorithm for WSNs with the consideration of energy consumption of the sensor nodes for prolonging network life time.

II. RELATED WORKS

The sensor nodes in a sensor network are resource constrained. The power consumption must therefore be as low as possible, because replacing the battery of every node even once in a month would be a big problem. Thus the power management becomes an important issue to increase the lifetime of sensor node. So it is very essential to identify the energy efficient shortest path. For identify PSO the following papers are illustrates various descriptions given by various authors which are related to this project.

Pratyay Kuila and **Prasanta K. Jana** propose a cluster based routing algorithm called CEBCRA (Cost-based Energy Balanced Clustering and Routing Algorithm) CEBCRA is a distributed algorithm which consists of three phases namely selection of CHs, cluster setup and data routing. The algorithm is fully based on the local information of a sensor node such as residual energy, number of neighbours and their distances. CEBCRA selects CHs amongst the normal sensor node using a weight function of the residual energy and the number of neighbours of a sensor node. Then all non-CH sensor nodes join a CH. In their proposed work, the best neighbour relay node is selected by measuring the cost of each path towards base station. We test the proposed algorithm through simulation and compare the results with LEACH and DEBR. Results show that our proposed method is far better than the DEBR as well as LEACH with respect to energy consumption and number of live sensor nodes.

Buddha Singh and **D. K. Lobiyal** apply the swarm optimization to find optimized position of cluster head (CH) in order to reduce the overall energy consumption during packet transmission to sink. Particle Swarm Optimization (PSO) is a technique which is known for its easy implementation and fast convergence. Further, we analyze the effect of link failure probability on transmission of packets and derive expected number of retransmission over a path in the sensor network. The PSO ultimately reduces the communication distance by locating optimal position of the cluster head nodes in the cluster. Our proposed technique is implemented within the cluster rather than base station, which makes it a semi-distributed approach. Our proposed technique show better performance in terms of network lifetime, average number of packets sent and energy consumption, than the LEACH-C and PSO-C protocols respectively. Further, our future work includes the implementation of sensor mobility in higher dimension region of interest and distributed PSO-application in heterogeneous wireless sensor networks.

Qing Cao, **Tarek Abdelzaher**, **Tian He**, **John Stankovic** proposes a protocol for node sleep scheduling that guarantees a bounded-delay sensing coverage while maximizing network lifetime. Our sleep scheduling ensures that coverage rotates such that each point in the environment is sensed within some finite interval of time, called the detection delay. The framework is optimized for rare event detection and allows favourable compromises to be achieved between event detection delay and lifetime without sacrificing (eventual) coverage for each point. We compare different sleep scheduling policies in terms of average detection delay, and show that ours is closest to the detection delay lower bound for stationary event surveillance. We also explain the inherent relationship between detection delay, which applies to persistent events, and detection probability, which applies to temporary events. Finally, a connectivity maintenance protocol is proposed to minimize the delay of multi-hop delivery to a base-station. The resulting sleep schedule achieves the lowest overall target surveillance delay given constraints on energy consumption.

N. M. Abdul Latiff, C. C. Tsimenidis and **B. S. Sharif** present an energy-aware clustering for wireless sensor networks using Particle Swarm Optimization (PSO) algorithm which is implemented at the base station. We define a new cost function, with the objective of simultaneously minimizing the intra-cluster distance and optimizing the energy consumption of the network. The performance of our protocol is compared with the well known cluster-based protocol developed for WSNs, LEACH (Low-Energy Adaptive Clustering Hierarchy) and LEACH-C, the later being an improved version of LEACH. 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 this paper, we develop a centralized, energy aware cluster-based protocol to extend the sensor network lifetime by using PSO algorithm. Our proposed protocol makes use of a high-energy node as a cluster head and produces clusters that are evenly positioned throughout the whole sensor field. The main idea in the proposed protocol is the selection of a cluster head that can minimize the intra cluster distance between itself and the cluster member, and the optimization of energy management of the network. Simulation results demonstrate that our proposed protocol can achieve better network lifetime and data delivery at the base station over its comparatives.

III. PROPOSED WORK

A wireless sensor network consisting of a large number of small sensors with low-power transceivers can be an effective tool for gathering data in a variety of environments. The data collected by each sensor is communicated through the network to a single processing centre that uses all reported data to determine characteristics of the environment or detect an event. The communication or message passing process must be designed to conserve the limited energy resources of the sensors.

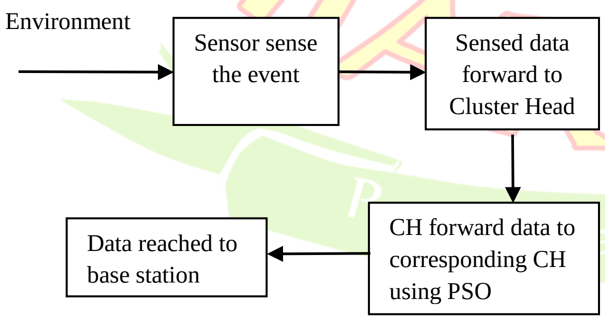

Fig 1.Block Diagram of proposed system.

The main constraint of the WSN is limited power sources of the sensor nodes. Therefore, energy conservation of the sensor nodes is the most challenging issue to prolong the network lifetime. Our main objective is to maximize the network lifetime. Clustering in WSNs can greatly contribute to overall system scalability, lifetime, and energy efficiency. Hierarchical routing is an efficient way to lower energy consumption within a cluster, performing data aggregation and fusion in order decrease the number of transmitted messages to the BS. In WSN sensor nodes are divided into several groups called clusters. Each cluster has a leader know as cluster head (CH). The sensor node sense local data and send it to their corresponding CH. Then the CH aggregates the local data and finally sends it to base station (BS) directly or via other CHs.Cluster heads are nodes that are vested with the responsibility of routing messages for all the nodes within their cluster. A cluster head may also be one of the nodes or one specifically richer in resources.

The proposed PSO-based clustering takes care of energy consumption of the normal sensor nodes as well as the gateways. For clustering, particles are cleverly encoded to produce complete clustering solution. A different fitness function is also used by taking care of those gateways which inevitably consumes more energy by acting as relay node in packet forwarding. We perform extensive simulation on the proposed methods and evaluate them with several performance metrics including network life-time, number of active sensor nodes, energy consumption, total number of packets delivery and so on. The PSO-based routing builds a trade-off between energy consumption of the CHs and delay in forwarding the data packets. It finds out a route form all the gateways to the base station which has comparably lower overall distance with less number of data forwards.

IV. PSO OVERVIEW

Particle swarm optimization (PSO) is a population based stochastic optimization technique developed by Dr. Eberhart and Dr. Kennedy in 1995, inspired by social behavior of bird flocking or fish schooling. Particle Swarm Optimization is inspired by natural life, like bird flocking, fish schooling and random search methods of evolutionary algorithm. It can be observed from the nature that animals, especially birds, fishes, etc. always travel in a group without colliding. This is because each member follows the group by adjusting its position and velocity using the group information. Thus it reduces individual's effort for searching of food, shelter etc.

Each particle is evaluated by a fitness function to judge the quality of the solution to the problem. PSO is initialized with a group of random particles(solutions) and then searches for optima by updating generations. In every iteration, each particle is updated by following two "best" values. The first one is the best solution (fitness) it has achieved so far. (The fitness value is also stored.)This value is called pbest. Another "best" value that is tracked by the particle swarm optimizer is the best value, obtained so far by any particle in the population. This best value is a global best and called gbest. In each iteration, its velocity V_{id} and position X_{id} in the dth dimension is updated using the following equations respectively.

$$V_{id}(t) = w \times V_{id}(t-1) + c1 \times r1\times(Xpbest_{i,d} - X_{i,d}(t-1)) + c2 \times r2 \times(Xgbest_{d} - X_{i,d}(t-1))$$

$$X_{i,d}(t) = X_{i,d}(t-1) + V_{i,d}(t)$$

Where w is the inertial weight c1 and c2 are two non-negative constants called acceleration factor and r1 and r2 are two different uniformly distributes random numbers in the range [0,1]. The updated process is iteratively repeated until either an acceptable Gbest is achieved or a fixed number of iteration t_{max} is reached.

a) Algorithm: pso-routing

Input: (1) Set of cluster heads $\xi=\{g1,g2.......,g_M\}$.
(2) PnextHops(g_i) and HopCount(g_i), $\forall$ i, $1\leq i \leq M$.
(3) Predefined swarm size N_p.
Output: Route R: $\xi \rightarrow \{\xi + g\ M+1\}$.
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Step 1: Initialize particle P_i, $\forall$ I, $1\leq i \leq N_p$.
Step 2: for i=1 to Np **do**
2.1: Calculate Fitness (P_i)
2.2: $Pbest_i = P_i$
end
Step 3: Gbest = {$Pbest_k$ | Fitness($Pbest_k$) = min(Fitness($Pbest_i$)), $\forall$ i, $1\leq i \leq N_p$)}
Step 4: While (!(Terminate))
for i=1 to N_p **do**
4.1: Update velocity and position of P_i
4.2: Calculate Fitness(P_i)
4.3: If Fitness(P_i) < Fitness($Pbest_i$) **then**
Pbesti = P^i
end
4.4: If Fitness($Pbest_i$) < Fitness(Gbest) **the**
end
end
Step 5: Calculate Next Hop(g_i), $\forall$ i, $1\leq i \leq M$,(i.e., route R) using Gbest
Step 6: Stop

Our algorithm should generate the positions of the particles in such a way that is can satisfy the range. This can be made if we choose the position as follows:

- If new position is negative or zero, then replace the position value by a newly generated random number which tends to zero.
- If new position is greater than one, then replace the position value by one.

V. SYSTEM IMPLEMENTATION

A. Module 1: network design

We simulate the wireless sensor network using NS2 simulator version 2.35having following parameters. Simulation process and results analysis first of all, to set the topology and the configuration of nodes properties, and also properties of MAC layer for some address type, protocol type, channel type, simulation time and transmission way of wireless. In our simulation, we used topography size 500 m x400 m, number of wireless nodes 41 nodes with maximum moving speed 8 m/s. We did the Simulation for 1000 sec. with maximum 6 connections at a time allowing TCP traffic. The network simulation parameters we have used for our simulation purpose shown in the following table I.

We analyzes the simulation result of AODV protocol in sensor network. A Tcl script is written in NS2 for simulation of network model. When this Tcl script is executed it creates two files trace file and Nam file. The Nam file is used to visualize simulated network, whereas trace file store different events statistics such as each individual packets arrival time, departs or is dropped, information about protocol agent,traffic agent, source and destination nodes address etc., which can be used to measure a protocol performance.

Table I: Simulation Parameters

Network parameters	Values
No. of nodes	41
Topography area	500 m X 400m
Source Traffic	FTP
Connection Type	TCP
Routing protocol	AODV
Simulation Time	1000 Sec
Network Simulator	NS2- 2.35

Different tools are available for the extracting and analysis of required data from trace file such as grep, Awk, sed, Perl. We wrote AWK script to extract the required statistical data of trace file.

B. Module 2: formation of cluster and cluster head

The main aim of hierarchical routing is to efficiently maintain the energy consumption of sensor nodes by involving them in multi-hop communication within a particular cluster and by performing data aggregation and fusion in order to decrease the number of transmitted messages to the base station. The CHs are usually selected amongst the normal sensor nodes which can die quickly for this extra work load. There are some special nodes called gateways, which are provisioned with extra energy.

These gateways act like cluster heads and responsible for the same functionality of the CHs. In our approaches, when CHs are just regular sensors nodes and time efficiency is a primary design criterion, clustering is being performed in a distributed manner without coordination. In our approaches, when CHs are just regular sensors nodes and time efficiency is a primary design criterion, clustering is being performed in a distributed manner without coordination.

C. Module 3: routing using pso

Routing can be more easily managed because only CHs and thus require small routing information; this in turn improves the scalability of the network significantly. The PSO-based routing builds a trade-off between energy consumption of the CHs and delay in forwarding the data packets. Its finds out a route from all the gateways to the base station which has comparably lower overall distance with less number of data forwards.

VI. PERFORMANCE RESULTS

a) Network structure

The Figure 4.4 illustrates size of the topography as 500×400 m2 and there are large number of sensor nodes and group of sensor nodes within a coverage area act as cluster one node among the cluster acts as a Cluster Head(CH). In Figure 4.4 green circle indicates Cluster Head.

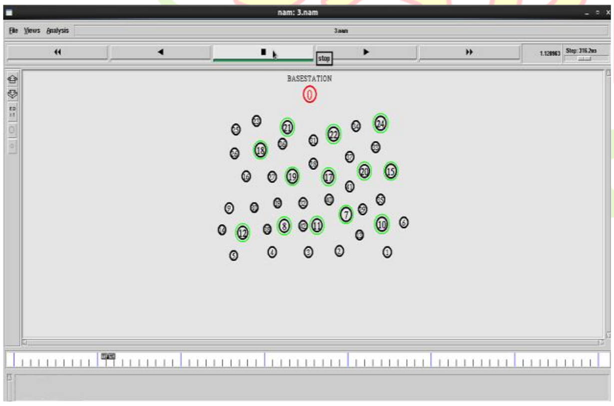

Fig 2: Network Structure

b) Data transfer through pso path

The source starts to identify the PSO path from the source to receiver. The source considers all possible paths and calculates the hop count for each path. Finally the source node selects path which has less hop count.

The section b shows the data transfer to the PSO path 5 -> 12 -> 18 -> 21-> 0.

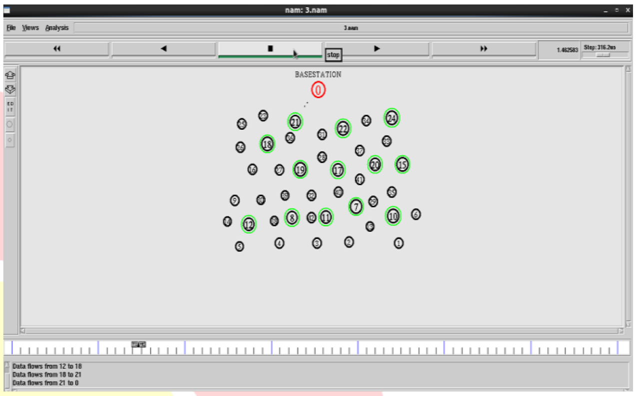

Fig 3: *Data transfer through pso path*

Finally the data reaches the receiver side through the shortest PSO path. In this stage the participating node in the routing is the only node which would be in on state. So the energy of the remaining nodes is saved. Thus the PSO path is identified using the proposed protocol and the data is sent from source to the receiver.

VII. CONCLUSIONS

In this paper, there are two important optimization problems for wireless sensor networks, i.e.., energy efficient routing and clustering respectively. Then, routing algorithm have been presented on particle swarm optimization. The routing algorithm has been developed by considering a trade-off between transmission distance and the number of hop-count. In the clustering phase, routing overhead of the CH is considered for balancing the energy consumption of the CHs. All the CHs which are heavily used as next hop relay nodes in data forwarding are assigned lesser number of sensor nodes. Thus the energy consumption of the CHs is significantly balanced and the lifetime of the network is improved. The algorithms are based on the derivation of efficient particle encoding scheme and fitness function for routing and clustering separately. The algorithms have been extensively tested with several scenarios of WSN by varying number of sensor nodes and gateways. The experimental result have shown that the proposed algorithms perform better then the existing algorithms in terms of network life, number of inactive sensor nodes and the total data packets transmission.

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