Optimized Clustered Chain Based Power Aware Routing (CCPAR) Scheme for Wireless Sensor Networks

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Abstract
Wireless sensor networks (WSN) are used in different environments to perform various monitoring tasks. The routing protocols of WSN have always been an area of research to avail the best possible routing with better energy efficiency. Efficient swarm intelligence based routing protocols that can be used to obtain the application specific service guarantee are the key design issues in designing a WSN model. In this thesis a new hierarchical, chain based and with optimized routing path protocol - Clustered Chain based Power Aware Routing (CCPAR) using the Ant Colony Optimization (ACO) & Particle Swarm Optimization (PSO) algorithms has been proposed, that utilizes the periodic assignments of the cluster head role to different nodes based on the highest residual battery capacity for ensuring the even dissipation of power by all the nodes. Chaining the nodes in each cluster and the use of a separate chain for the cluster heads (CH), CCPAR provides the advantage of small transmit distances for most of the nodes which results the nodes to be operational for a longer period of time by saving their limited energy. With the help of ACO and PSO algorithm the result have been be improved from previous work. For the implementation of this proposed work MATLAB Software has been used.

Keywords
Wireless sensor network (WSN), Clustered Chain based Power Aware Routing (CCPAR), Ant Colony Optimization (ACO), Particle Swarm Optimization (PSO), cluster heads (CH)

I. Introduction

Wireless sensor networks (WSN) are helpful for sensing the environment for monitoring different tasks. Research area for the new routing protocols in WSN is always open as the better and better routing protocol is the requirement of WSN. Different techniques have been implemented to find out best routing path for routing protocols. In this thesis a new power-aware, adaptive, and hierarchical and chain based protocol - Clustered Chain based Power Aware Routing (CCPAR) using the Ant Colony Optimization (ACO) & Particle Swarm Optimization (PSO) algorithms are proposed for static nodes only. Battery consumption due to the optimization algorithms of the proposed work is overcome by the periodic assignment of CHs. With the help of ACO and PSO algorithm the result has been improved from previous work. The thesis focus is on optimized path, static sensor nodes can avail rechargeable battery technique like in case of solar system embedded nodes on street cameras, air particles node and fixed environment for research areas. The proposed thesis best suits the environment with energy supply and need of better optimized path.

A. Clustered Chain based Power Aware Routing (CCPAR) [1]

In this scheme the base station has global knowledge about the location of all the nodes in the network and, therefore, at the very first round it divides the whole area into a number of clusters in an attempt to uniformly distribute the nodes across all the clusters and to ensure the coverage of the whole of the deployed region. One node from each cluster is selected by BS as the cluster head depending upon the energy level of different nodes. In the first round the initial selection is done depending on the assumption that at start-up every node has the same energy level. After the selection of the cluster heads, the base station computes the chain among cluster heads and broadcasts this chain to the cluster head nodes. Now each CHs broadcast “cluster-head declaration” message. After receiving these messages from different CHs, depending on signal strength every non-CH node selects its CH. Finally a full chain is ready a) chain among CHs, b) BS to one of CH among the chain of CHs and c) chain among non-cluster head nodes with its CH.

Once the chain is setup, data is transferred from nodes to their nearest neighbor. In this sequence data is collected at different CHs. Now via the chain of CHs, each CH transmits data to their nearest chain-in CH, and thus the aggregated data reaches to the CH which is in connection with BS. Finally BS uses the collected data for external purpose.

At the end of each round or a certain periodic interval, every node sends the information about its remaining energy level to the next node in the chain, in this way the energy information reaches to the corresponding CHs. And via CHs chain the aggregated information reaches to BS. Using this information the BS can select the cluster heads for the next round based on the maximum remaining energy level of the nodes. Once the cluster heads are selected by BS, the base station creates the new chain of CHs and selects the leader in that chain for the next round depending on the remaining energy level so that the CH with the duty of transmitting aggregated data to the BS is the one with the highest remaining energy level. Finally BS broadcasts this chain to the cluster heads and then the further steps are repeated for the next round as per above.

B. Particle swarm optimization (PSO) [2]

PSO algorithm is capable of optimizing a non-linear and multidimensional problem, which gives good solutions efficiently while requiring minimal parameterization. The basic concept of the algorithm is to create a swarm of particles which move in the space (the problem space) in search of their goal or the place which best suits their needs to be fulfilled. Particle swarm optimization mimics human or insects social behavior. Individuals interact with one another while learning from their own experience, and gradually move towards the goal. In the free space while a particle in search of its need moves towards goal, then it keep track of its best position called personal best (p-best) and also the global best position (g-best) for reaching the goal. Depending on its g-best every particle in the problem space updates its p-best. And thus via best possible optimal path each particle reaches the goal.

C. Ant Colony Optimization (ACO) [3]

ACO is a probabilistic technique for solving computational problems which can be reduced to finding good paths through graphs. ACO algorithm mimics the ant's behavior for finding food and informing other ants about food and the best possible shortest path. On the basis of natural ant's behave the artificial way of finding the shortest path natural ant's technique can be concluded as follows:

- After having information about the destination, the artificial ants start travelling along any present path.
- While moving, the information about the time length, the congestion status, and the node identifiers of the followed path are gathered by artificial ants and stored as it's memory
- At each intermediate node, the next node to move to is selected by making decision using these parameters:

(1) node-local artificial pheromones,
(2) node-local problem-dependent heuristic information, and
(3) The ant's memory.

- Once they have arrived at the destination, the artificial ants go back to their source nodes by moving along the same path they came.
- During this backward travel, node-local models of the network status and the pheromones stored on each visited node are modified by the artificial ants if it has better result than previously stored.
- By this process the best possible shortest path is stored at different nodes, which could be used by all artificial ants to travel along shortest path.

II. Related Work

Ali Z. et al. [4] proposed various bio inspired and evolutionary approaches including genetic programming (GP), Neural Network, Evolutionary programming (EP), Particle Swarm Optimization (PSO) and Ant Colony Optimization (ACO) used for the routing protocols in ad hoc and sensor wireless networks. K. Majumder et al. [1] proposed a new power-aware, adaptive, hierarchical and chain based protocol -CCPAR (Clustered Chain based Power Aware Routing) that utilizes the periodic assignments of the cluster head role to different nodes based on the highest residual battery capacity for ensuring the even dissipation of power by all the nodes. Transmission from a single cluster head to the base station in each round and the distribution of the data aggregation workload among all the nodes, save the cluster heads from early exhaustion. The use of data aggregation also reduces the amount of information to be transmitted to the base station. By chaining the nodes in each cluster and using a separate chain for the cluster heads, CCPAR offers the advantage of small transmit distances for most of the nodes and thus helps them to be operational for a longer period of time by conserving their limited energy. Duc Chinh Hoang et al. [5] proposed a framework that enables practical development of centralized cluster-based protocols supported by optimization methods for the WSNs. Based on this framework, a protocol using harmony search algorithm (HSA), a music-based meta-heuristic optimization method, was designed and implemented in real time for the WSNs. Ali-Asghar Salehpour et al. [6] proposed an efficient routing algorithm for large scale cluster-based wireless sensor networks. The technique uses two routing levels. In the first level (intra-cluster), cluster members send data directly to their cluster head. In the second level (inter-cluster), the cluster heads use ant colony optimization (ACO) algorithm, which is a biologically inspired paradigm for optimization approach, to find a route to the base station. As only cluster heads participate in the inter-cluster routing operation, the method can provide a smooth operation more effectively. The delay of the algorithm is minimized by using the ant colony optimization algorithm along with clustering.

III. Optimized CCPAR

The proposed routing protocol is self-organizing, adaptive, hierarchical and chain based routing protocol with optimization. In WSN scenario the BS is fixed far away from the other nodes. BS communicates with external users and transmits the collected data sensed by the sensor nodes. The BS has constant source of power supply. So it has no problem of energy dispense and can transmit with high power to all the nodes. It has been assumed that the BS has global knowledge about the entire network and all nodes possess the same amount of initial energy.

A. CCPAR with ACO and PSO Optimization- Algorithm

The total process for this protocol will have a number of rounds. After each round, integrated data is sent to the BS. And then the BS transmits the required data to the users through external networks. Each round of the algorithm consists of the following phases.

Cluster Chain Setup [1]

In this phase the chain among CHs in connection with BS and another chain of non-CH nodes are established. In the proposed scheme the BS has global knowledge about the location of all the nodes in the network and, therefore, at the very first round it divides the whole area into a number of clusters in an attempt to uniformly distribute the nodes across all the clusters and to ensure the coverage of the whole of the deployed region. One node from each cluster is selected by BS as the cluster head depending upon the energy level of different nodes. In the first round the initial selection is done depending on the assumption that at startup every node has the same energy level. After the selection of the cluster heads, the base station computes the chain among cluster heads and broadcasts this chain to the cluster head nodes. Now each CHs broadcast "cluster-head declaration" message. After receiving these messages from different CHs, depending on signal strength every non-CH node selects its CH and a separate chain of non-CH nodes with their CH is formed. Finally, chain among CHS, non-CH and BS is established.

Fitness checking

After the chain setup is complete, the next phase consists of fitness checking of the available path for routing. The optimization process is carried out for fitness checking. Optimization in the proposed work is done in two phases. Firstly ACO technique is applied over nodes to calculate the path and obtained path is stored in a MATRIX. This MATRIX is further used in second phase by PSO to compute the final routing path. For the first phase the applied ACO technique on nodes (nodes are treated as artificial ants) can be illustrated as:

- At regular intervals, and concurrently with the data traffic, from each network node artificial ants are asynchronously launched toward destination nodes selected according to the traffic distribution.[3]
- Artificial ants act concurrently and independently, and

communicate in an indirect way through the pheromones they read and write locally on the nodes. [3]

- Each artificial ant searches for a minimum cost path joining its source and destination node. [3]
- Each artificial ant moves step by step toward its destination node. At each intermediate node a greedy stochastic policy is applied to choose the next node to move to. The policy makes use of (1) node-local artificial pheromones, (2) node-local problem-dependent heuristic information, and (3) the ant's memory. [3]
- While moving, the artificial ants collect information about the time length, the congestion status, and the node identifiers of the followed path. [3]
- Once they have arrived at the destination, the artificial ants go back to their source nodes by moving along the same path as before but in the opposite direction. [3]
- During this backward travel, node-local models of the network status and the pheromones stored on each visited node are modified by the artificial ants as a function of the path they followed and of its goodness. [3]
- Once they have returned to their source node, the artificial ants are deleted from the system. [3]

Applying the above technique, the obtained path is stored in a MATRIX say 'S'. Now, this MATRIX is the input for the PSO technique. Applying PSO is the second phase of the fitness checking. For initialization following setup has been done:
Number of particles be 30,
Maximum number of iterations be 50,
Dimension as 10.
Velocity vector as zero matrix of (No. of particles, Dimension),
Position vector as zero matrix of (No. of particles, Dimension),
P-Best Score as zero matrix of No. of particles
P-Best as zero matrix of (No. of particles, Dimension)
G-Best Score as infinity
G-Best as zero matrix of (1, Dimension)
Fitness as random (1, Maximum number of iterations)
The PSO technique as per above matrix 'S' input and assuming above variables as startup is illustrated as:
Caption:
i - Particle's index
d – Dimension being considered
it – Iteration number
x(i,d) – position of particle I in dimension d
v(i.d) – velocity of particle I in dimension d
c1 - acceleration constant for the cognitive component
Rnd - stochastic component of the algorithm, a random value between 0 and 1
Pb(i,d) – Particle's best position in dimension d
C2 - acceleration constant for the social component
Gb(d) – global best position in dimension d

- Initialization [2]

1: for each particle i in S do
2: for each dimension d in D do
3: //initialize all particles' position and velocity
4: x (i,d) = Rnd(x-min. x-max)
5: v (i,d) = Rnd(-v-max/3, v-max/3)
6: end for
7: //intialize particle's best position
8: pb (i) = x (i)
9: //update fitness checking- if particles best position is better than global best then update global best with particles best.
10: if f(pb (i)) < f(gb) then
11: gb = pb(i)
12: end if
13: end for

- Obtaining Final Global Best [2]

1: //initialize all particles
2: Initialize
3: repeat
4: for each particle i in S do
5: //update the particle's best position
6: if f(x(i)) < f(pb(i)) then
7: pb(i) = x(i)
8: end if
9: //update the global best position
10: if f(pb(i) < f(gb) then
11: gb = pb(i)
12: end if
13: end for
14: //update particle's velocity and position
15: for each particle i in S do
16: for each dimension d in D do
17: v(i,d) = v(i,d)+C1 *Rnd(0,1) * [pb(i,d),- x(I,d)]+C2 *Rnd(0,1) * [gb(d)- x(I,d)]
18: x (i,d) = x (i,d) + v (i,d)
19: end for
20: end for
21: //advance iteration
22: it = it + 1
23: until it < MAX ITERATIONS

After the completion of maximum iterations, a chain with global best position in each dimension is formed. This chain of global best position of different dimensions is considered as the routing path in the proposed protocol.

Data Transmission

After the chain setup and optimized path extraction, nodes can transmit data in their respective chain to their neighbors. The data is aggregated at different nodes and forwarded to the CH which is direct in connection with BS. Finally BS uses the collected data for external purpose [1].

At the end of each round or a certain periodic interval, every node sends the information about its remaining energy level to the next node in the chain, in this way the energy information reaches to the corresponding CHs. And via CHs chain the aggregated information reaches to BS. Using this information the BS can select the cluster heads for the next round based on the maximum remaining energy level of the nodes. Once the cluster heads are selected by BS, the base station creates the new chain of CHs and selects the leader in that chain for the next round depending on the remaining energy level so that the CH with the duty of transmitting aggregated data to the BS is the one with the highest remaining energy level. Finally BS broadcasts this chain to the cluster heads and then the further steps are repeated for the next round as per above phases.

IV. Performance Analysis

The measurement of performance of proposed optimized CCPAR has been done in terms of computational time, phase setup duration and data delivery time.

Computational time is the time taken by the algorithm to complete its execution. It depends on the complexity of the algorithm

implemented.
Phase setup duration is estimated by calculating the time taken by different protocols for completing the setup phase.
Data delivery time is the time taken for delivering data packet from source to destination.

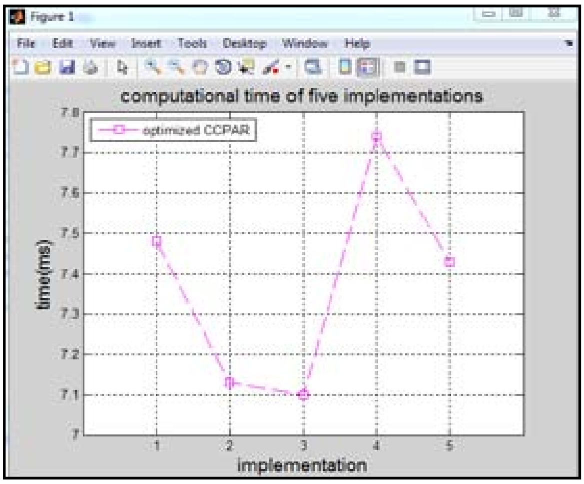

Fig 1: Computational time of proposed optimized CCPAR for five implementations.

Similarly, the different implementation results for phase setup duration and data delivery time has been shown.

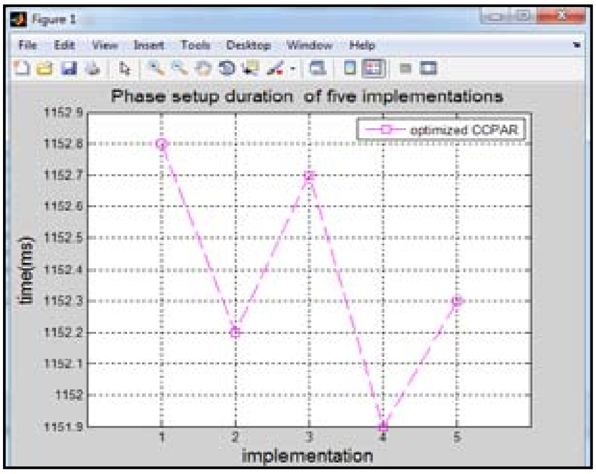

Fig. 2: Phase setup duration of proposed optimized CCPAR for five implementations.

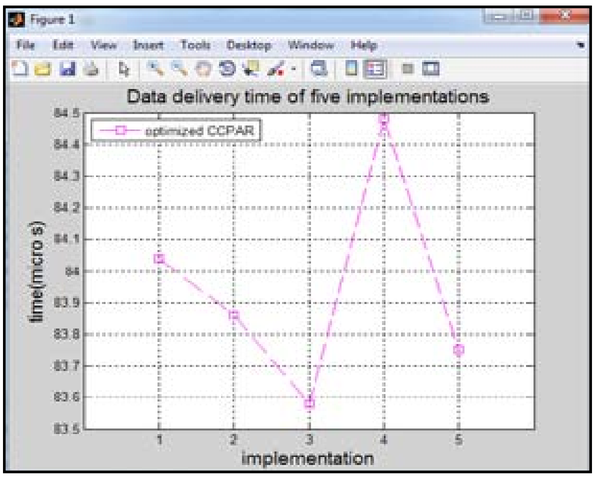

Fig 3: Data delivery time of proposed optimized CCPAR for five implementations.

Considering the five implementation results, the average of results has been calculated and thus performance of proposed routing algorithm has been evaluated. The average result has been shown in table 1.

Table 1: Data delivery time, Phase setup duration and computational time

Parameters	Optimized CCPAR
Computational time (ms)	7.37
Phase Setup duration (ms)	1152.38
Data Delivery (micro s)	83.94

V. Conclusion and Future Work

From the results of the thesis, computation time of algorithm, different protocols setup phase and data delivery time shows better results. The routing protocol has been proposed for static sensors only. The advantage of proposed work can be mainly understood as the extraction of optimized path, which is of more importance where battery is not concerned much as compared to optimized routing path. In future, the target will be to allow the mobility sensors and also increase the number of sensor nodes then proposing a routing protocol with optimization. And also improving the node life time by the battery energy consideration in case where node does not have constant energy supply.

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