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Efficient Load Balanced Routing Algorithm Based On Genetic And Particle Swarm Optimization

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ABSTRACT: Wireless sensor network (WSN) is a group of spatially dispersed and dedicated sensors for monitoring and recording the physical conditions of the environment and organizing the collected data at a central location. Sensor networks pose a number of new conceptual and optimization problems such as location, deployment and tracking in that many applications rely on them for needed information. Unbalanced Clustering Architecture and unbalanced energy consumption are inherent problem in WSNs. This uneven energy dissipation can significantly reduce network lifetime. In existing system, the cluster was balanced using Balanced Clustering Algorithm with Distributed Self Organization (DSBCA) and then the network lifetime was improved by creating efficient path from source to destination using A-star. The proposed system is based on the optimal path for routing with better network lifetime and lesser energy consumption using Modified Particle Swarm Optimization (MPSO) and Artificial Bee Colony (ABC).

KEYWORDS: Load balancing, Wireless sensor network, Clustering, Genetic algorithm

I. INTRODUCTION

Wireless Sensor Network consists of a large number of wireless nodes called sensor nodes and one or more base stations called the sink. These sensor nodes collect information from the environment based on their sensing mechanism [1]. The nodes deployed in large numbers collaborate to form an ad hoc network capable of reporting to data collection sink (base station). Wireless sensor network have various applications like habitat monitoring, building monitoring, health monitoring and target tracking.

The main responsibility of the sensor nodes in each application is to sense the target area and transmit their collected information to the sink node for further operations. Sensor nodes in the large-scale data-gathering networks are generally powered by small and inexpensive batteries unexpected in surviving for a long period [2]. Each sensor node makes its decisions based on its mission, the information it currently has, knowledge of its computing, communication, and energy resources. The node must have capability to collect and route data either to other nodes or back to an external base station or stations that may be a fixed or a mobile node capable of connecting the sensor network to an existing communication infrastructure or to the internet [3].

Resource limitations of the sensor nodes and unreliability of low-power wireless links [4], in combination with various performance demands of different applications impose many challenges in designing efficient communication protocols for wireless sensor networks [5]. Meanwhile, designing suitable routing protocols to fulfill different performance demands of various applications is considered as an important issue in wireless sensor networking. In this context, researchers have proposed numerous routing protocols to improve performance demands of different applications through the network layer of wireless sensor networks protocol stack.

The main constraint in designing a routing protocol in WSNs is limited power of sensor nodes that mandates the design of energy-efficient communication protocol. There are many protocols proposed for other wireless networks like mobile or ad-hoc. How-ever, these protocols cannot be used directly due to resource constraints of sensor nodes like limited battery

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power, computational speed, and human interface of node device and density of nodes in network. Compared to flat and multi hop communication cluster based architecture provides long life time, hence it is preferred [6].The clustering method is used for communication between nodes and sink, since it is energy efficient when compare to single and multi hop routing. In clustering, one of the sensor nodes in the cluster will be elected as Cluster Head (CH) and which is responsible for relaying data from each sensor to the remote receiver. In clustering few CH nodes are heavily loaded, then energy depletion will occur. To get uniform energy depletion, load balancing (equal number of nodes to each cluster) is introduced over clusters.

As sensor networks scale up in size, effectively managing the distribution of the networking load will be of great concern. By spreading the workload across the cluster in sensor network, load balancing averages the energy consumption. Load balancing is also useful for reducing congestion hot spots, thereby reducing wireless collisions.

Therefore, the method proposed is seeks to investigate the problems of balancing energy consumption and maximization of network lifetime for WSNs. A novel approach is proposed a new approach by combining clustering approach for load balanced and swarm intelligence for selecting the optimal routing path from the source to the destination by favoring the highest remaining battery power.

II. RELATED WORKS

Wireless sensor networks have gained increasing attention from both the research community and actual users. Many clustering algorithms in various contexts have also been proposed in the past by [7, 8, 9]. Many of these algorithms aim at minimizing the energy spent in the homogeneous system.

Mhatre and Rosenberg (2004) [10] give guidelines about the modes of propagation, clustering and battery energy of normal and CH nodes. Cheng and Shi (2009) [11] analyzed the heterogeneity with new clustering algorithm which decides the cluster head according to the node energy. CH selection algorithm was needed as LEACH. Hur and Kim (2008) [12] explains about adaptive clustering and power control for homogeneous sensor networks. A survey on energy efficient scheduling mechanisms for WSN is given by [13] (Wang and Xiao, 2005).

So there is no centralized cluster formation mechanism in PEGASIS [14], [15] thus each node has to spend additional energy for performing data aggregation to achieve hierarchical distribution of energy. Sh. Lee et al. proposed a clustering algorithm CODA [16] in order to relieve the imbalance of energy depletion caused by different distances from the sink. CODA differentiates the number of clusters in terms of the distance to the base station. The farther the distance to the base station, the more clusters are formed in case of single hop with clustering. In HEED, author introduces a variable known as cluster radius which defines the transmission power to be used for intra-cluster broadcast [17]. HEED terminates within a constant number of iterations, and achieves fairly uniform distribution of cluster heads across the network. The authors in [18] determine the optimal cluster size in network for analyzing the problem of prolonging network lifetime. According this result, they propose a location aware hybrid transmission scheme that can further prolong network lifetime. In [19] proposed an unequal clustering size model for network organization, which can lead to more uniform energy dissipation among cluster head nodes, thus increasing network lifetime. The work in [20] proposed to minimize the hop stretch of a routing path (defined as the ratio of the hop distance of a given path to that of the shortest path) in order to reduce the energy cost of end-to-end transmission.

The work in [21] exploited two natural advantages of opportunistic routing, i.e. path diversity and the improvement of transmission reliability, to develop a distributed routing scheme for prolonging the network lifetime of a WSN. Lu et al. in [22] proposed an Energy-Efficient Multi-path Routing Protocol (EEMRP). It has the capability of searching multiple node-disjoint paths and utilizes a load balancing method to assign the traffic over each selected path. Both the residual energy level of nodes and the number of hops are considered to be incorporated into the link cost function. It uses a fairness index to evaluate the level of load balancing over different multi-paths. Furthermore, since EEMRP only takes care of data transfer delay, the reliability of successful paths sometimes is limited.

III. METHODOLOGY

In wireless sensor network Energy utilization is a very critical issue in WSN. To overcome these problem efficient cluster head are selected through cluster head selection algorithm to select CH periodically, which in turn increases the overhead. But in cluster head selection are fixed. If few CH nodes are heavily loaded, will consume their energy soon. To get uniform energy utilization, load balancing (equal number of nodes to each cluster) is introduced over clusters. After the completion of the cluster formation with load balancing result, finding the optimal route path for above results becomes also important to reduce the time and find the best result. Routing the best path using optimization techniques reduce the time complexity and makes the best routing path in WSN.

A. Load balanced cluster formation

Cluster head selection

Determining the number and place of cluster heads has always been a challenge. The dynamic nature of issue, due to the frequent changes in cluster heads in each round of network's activity, makes the issue more complex and as result modeling is not possible through math classic methods. Common clustering algorithms in other studies have benefited from heuristic methods. On the other hand, genetic algorithm [23] is so flexible in solving dynamic issues. In this paper, genetic algorithm is used to determine the cluster heads in a way that the minimal amount of energy is consumed.

Fitness Criterion is based on the minimal consumed energy from network nodes in each generation. In base station, the number of nodes that have introduced themselves as cluster head candidates determines the chromosome's length in genetic optimizing method. Each of this chromosome's genes recognizes some of the sensor network nodes. Chromosome's structure is defined as: $chrom = \{g_i \mid i = 1,2,3,\ldots,l\}$, where l is the chromosome's length and g_i is the i-th gene.

After crossover operator, mutation happens in a way that a mutation may be created in a bit of one or some chromosomes. Finally, after crossover and mutation, base station selects the chromosome which has the networks least energy difference in proportion to the previous round and introduces the available nodes to network as cluster head and other nodes join to the nearest cluster head. Network's current energy in k-th round is shown with $E^{k}_{Network}$ .Fitness function is computed through equation that should become minimum.

$$fitness = \left|E^{k}_{Network} - E^{k-1}_{Network}\right| \quad (1)$$

The following algorithm shows the stages of the proposed algorithm.

Step 1: Initial network;

Step 2: each node sends the position of itself in the network to its Neighbors.

While (all of node are alive) do

Step 3: each node calculates its chance parameter using Adaptive neuro fuzzy logic based on the parameters of residual energy and expected residual energy.

Step 4: each node that has more chance than its Neighbors, introduce itself as cluster Head candidate to the Base Station(BS);

Step 5: in BS using Genetic algorithm based on chaotic, main cluster heads are determined;

Step 6: main cluster heads are introduced to all nodes in network;

Clusters Building Phase

Load balanced cluster algorithm sets the threshold of cluster size. The number of cluster nodes cannot exceed the threshold to avoid forming large clusters, which will cause extra overhead and thus reduce network lifetime. When the cluster head node receives $Join_{message}$ sent by the ordinary node, it will compare the size of cluster with threshold to accept new member and update the count of cluster nodes if the size is smaller than threshold, or reject the request. If the rejected node has cluster head already, the clustering process ceases. Otherwise, it finds another appropriate cluster to join.

Load balanced cluster algorithm avoids the fixed cluster head scheme (cluster head manages cluster and forwards data, so it consumes energy faster than other nodes), with periodic replacement to balance the node energy consumption.

B. Swarm intelligence based optimal path selection

Optimal path selection using Modified Particle swarm optimization

PSO is a bio-inspired [24] (Kennedy and Eberhart, 1995) computational method, which is a population based optimization technique which performs a parallel search on a solution space. Optimum solution is obtained from the set of randomly generated initial solutions by moving particles around in the search space, which finds the optimum solution by swarms following the best particle. Each particle has particular velocity and position, at each iteration a new velocity value is calculated and it is used to update the particle's position. The process iterates until reaching a stopping condition (optimum one).

In standard PSO, because the particle has the ability to know the best position of the group particles have been searched, one particle is required to find the global best position rather than all particles to find it, and other particles should search more domains to make sure the best position is global best position not the local one. Based on these ideas, some modifications are used in traditional PSO algorithm. Firstly, the modified algorithm chooses the particle with maximum fitness when it is iterating, initializes its position randomly for increasing the chaos ability of particles. By this means, the particle can search more domains. Secondly, by referring to ideas of the simulated annealing algorithm and using neighborhoods to achieve the guaranteed convergence PSO in [25], it is hoped that the fitness of the particle which has the best value in last iteration would be smaller than last times, and it is acceptable the fitness is worse in a limited extent α . The change of fitness value of two positions is calculated using Δf , d accept the new position if Δf is smaller than α . Otherwise, a new position is assigned to the particle randomly from its neighborhood with radius r.

Algorithm for optimal path selection using MPSO

Initialize the node as a particle, position, velocity
do
For each node n with position x_n
Calculate fitness function Δf of each node based on velocity and position
Evaluate the node with smallest fitness function for new position
If new position is acceptable then
Update its position

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Else
Randomly assign the new position for node
Renew the position and velocity of the other nodes based on the new position
For each node
If fitness value > fitness value of $pbest_n$ then
$pbest_n \leftarrow fitness\ function\ of\ node$
Calculate the fitness value of $gbest$
If fitness value > fitness value of $gbest$
$gbest \leftarrow fitness\ with\ position$
If (stop criteria is satisfied)
Optimal path is selected
Else return to fitness calculation

Optimal path selection using artificial bee colony optimization

Artificial Bee Colony (ABC) is a novel optimization algorithm that comes under Swarm Intelligence. ABC algorithm is inspired by social behavior of natural bees. It was introduced by Karaboga in 2005 [26]. In ABC algorithm, the colony of artificial bees is formed of three been groups: employed bees, onlooker bees and scout bees.

Employed bees visit the food source and gather information about food source location and the quality. Employed bees have memory, so they know the places they have visited before and the quality of food there. Employed bees performs the local search and try to exploit the neighboring locations of the food source and search the best places of foods in the surrounding areas of the present value. Onlooker bees are bees that are waiting on the dance area to decide which food source is better. This decision is made on the basis of information provided by employed bees. Onlooker bees perform the global search for discovering the global optimum. Scout bees do a random search for the food. Scout bees discovers the new area which are uncovered by the employed bees, these bees are completely random in nature and their operation of search. Scout bees avoid the search process to get trapped in local minima. The position of a food source represents a possible solution to the optimization problem and the nectar amount of a food source corresponds to the quality (fitness) of the associated solution [27].

In the ABC algorithm, the first half of the colony consists of employed bees and the second half consists of onlooker bees. The first positions of food sources randomly generated where each employed bee is nominated to a food source. Then, each employed bee determines a new neighboring food source of its currently associated food source by (1) and computes the nectar amount of the new food source for each iteration. If the nectar amount of the new food source is higher than the previous one, then employed bee moves to the new food source, otherwise it continues with the old one.

$$v_{ij} = x_{ij} + \theta_{ij}(x_{ij} - x_{kj}) \tag{2}$$

Where θi is a random number between [-1…1], vi is a candidate solution, xi is the current solution and xk is a neighbor solution and j∈ {1, 2…D} is randomly chosen index where D is the dimension of the solution vector.

The employed bees share the information about their food sources with onlooker bees after all of them complete the search process. An onlooker bee evaluates the nectar information taken from all employed bees and chooses a food source with a probability related to its nectar amount by (2), known as roulette wheel selection method which provides better candidates to have a greater chance of being selected.

$$P_i = \frac{fit_i}{\sum_{n=1}^{SN} fit_n} \quad (3)$$

Where fiti is the fitness value of the solution i proportional to the nectar amount of the food source in the position i and SN is the number of food sources equal to the number of employed bees. Once all onlookers have selected their food sources, each of them determines a new neighboring food source of its selected food source and computes its nectar amount. The bee memorizes the new position and forgets the old one whether its nectar is higher than that of the previous one; otherwise it keeps that.

The employed bee becomes a scout when a food source is exhausted by the employed and onlooker bees. Any position cannot be improved further through a predetermined number of cycles which is called limit parameter, the food source is assigned as abandoned and employed bee of that source becomes scout. In that position, a new solution is randomly generated by the scout is given by:

$$\max^{j} - x^{j}_{\min}) \quad (4)$$

Where abandoned source is represented by x_i, θ_i is a random number between [-1…1] and j∈ {1, 2… D}.

Algorithm for optimal path selection using ABC

Initialize the population as nodes , fitness value, cycle
Assume the sensor nodes as $z_i = 1, \ldots, SN$
Evaluate the fitness function (f_i) for the nodes
Set cycle to 1
Repeat
For each employed bee {
Selection of new nodes v_i by using (2)
Calculate the value of f_i for each node
Apply the greedy selection process}
Calculate the probability values p_i for the selected nodes (z_i) by (3)
For each onlooker bee {
Select a node z_i depending on p_i
New nodes v_i are selected
Calculate the value of f_i for each node
Apply the greedy selection process}
If there is an abandoned solution for scout then replace it with a new solution which will be randomly produced by (4)
Memorize the best solution so far
Cycle=cycle+1

IV. EXPERIMENTAL RESULTS

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In the simulation experiments, WSNs nodes are randomly distributed in the 50 m × 50 m area. The PSO based optimal path selection, ABC based optimal path selection and optimal path selection using A* are compared with each other and best path is selected for optimal communication between the cluster head and base station. The effectiveness of three optimal routing algorithms is validated through simulation. This section describes simulation environment performance metrics, and experimental results.

In the simulation experiments, WSNs nodes are randomly distributed in the 50 m × 50 m area. The three optimal routing algorithm simulations are mainly used for observing the network lifetime. In comparison, the model in [28], and MATLAB 2009b are used as simulation tool.

In the course of simulation, the target area is set as [0, 50] × [0, 50], and the base station is in the interval[25, 100]. At the same time, the value of k is fixed as 2, 3 and4 (when k = 1, the limited communication distance of nodes may lead to low network coverage because of in sufficient neighbor nodes; when k >4, excessive big clusters or excessive nodes without cluster may reduce network life cycle), and the threshold is set as 15.

To facilitate unified comparison, the survival time is represented by the number of rounds where each round begins with a set-up phase when the clusters are organized, followed by an optimal path selection in steady-state phase when the data transfers to the base station from cluster head.

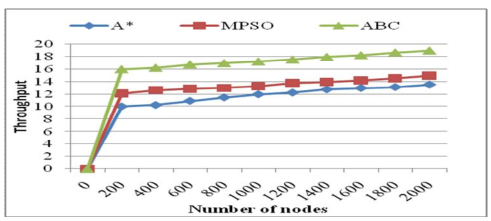

Figure 1 Compared results of Throughput with three algorithms

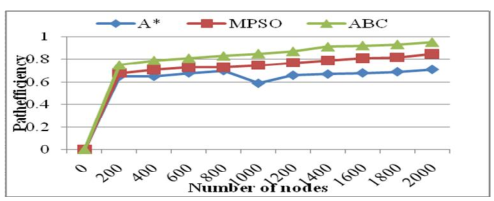

Figure 2 Compared results of Path Efficiency with three algorithms

Comparing ABC optimal routing algorithm with MPSO, A* optimization algorithm, the experimental results proves that artificial bee colony optimization algorithm for optimal path selection show better performance than the other two algorithms. The artificial bee colony algorithm selects better path and throughput for ABC is calculated using formula,

$$Throughput = \frac{number\ of\ packets\ deliverd}{total\ number\ of\ packets\ sent} \tag{5}$$

The graphical representation of the throughput comparison is shown in figure 1. The throughput of the artificial bee colony optimization is better than the other methods such as MPSO, and A*.

The figure 2 shows that the path efficiency of the proposed methodologies and the path efficiency of artificial bee colony are higher than the other existing algorithms.

$$Path\ efficiency = \frac{number\ of\ packets\ passed\ through\ shortest\ path}{total\ number\ of\ packets\ sent} \quad (6)$$

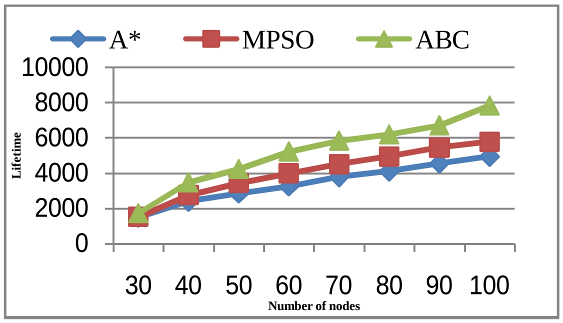

Figure 3 network lifetime comparisons

Figure 3 shows the graphical representation of network lifetime comparison. The artificial bee colony optimization algorithm performs better than the other existing algorithms such as MPSO and A*. The proposed algorithm increases the network lifetime by selecting the optimal path.

V. CONCLUSION

Sensor Networks hold a lot of promise in applications where gathering sensing information in remote locations is required. It is an evolving field, which offers scope for a lot of research. The modified particle swarm optimization and artificial bee colony optimization algorithm are used for optimal path selection from cluster head to base station data transfer. The protocol was studied by simulation for several Wireless Sensor Network scenarios and the results clearly show that it minimizes communication efficiency by selecting best path and increases the network lifetime.

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