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Energy Efficient Cluster Formation in Wireless Sensor Networks Using Particle Swarm Optimization

Amita Yadav* **and Suresh Kumar**

Department of Computer Science and Engineering, Maharaja Surajmal Institute of Technology (MSIT), C-4, Lal Sain Mandir Marg, Janak Puri – 110058, New Delhi, India; amitaay@gmail.com, suresh.fet@mriu.edu.in

Abstract

Objective: To achieve the maximum possible lifetime of a network by efficient clustering and reducing the energy expended by sensor nodes. **Methods/Analysis:** Wireless Sensor Networks are an important part in today's network infrastructure. With a great deal of importance given to minimized sensors due to the boom in Internet of Things combined with the traditional uses in military, pollution monitoring and gathering other geospatial data, WSNs are playing an ever increasing role in the technology sphere. The confinements of WSN incorporate the constrained battery life of the sensor hubs and the trouble in supplanting them on the field. Hence the most important criteria to be expand the lifetime of the system by minimising battery utilisation through efficient clustering algorithms. **Findings:** In our research, we have focused on using the Particle Swarm Optimization (PSO) algorithm for efficient clustering. The proposed model simulated through MATLAB.

Keywords: Clustering, Energy Efficiency, Particle Swarm Optimization, Wireless Sensor Networks

1. Introduction

A sensor network[1] is an infrastructure made out of sensing (measuring), computing, and conversation factors that offer an administrator the ability to tool, examine, and react to occasions and phenomena in a special environment. Standard applications include records collection, monitoring, surveillance, and medical telemetry. In addition to sensing, one is often interested in control and activation.

[2]The wireless sensor nodes are typically battery operated devices. Most of the sensor nodes are deployed remotely and it is difficult to interchange or recharge the battery. Therefore the battery lifetime posse's imposition on the lifetime of sensor elements. Alternatively, this is not always possible to use a nearby power source to power the sensor node. The three important operations responsible for power consumption in tiny node are sensing, computation and communication. Sensing is the estimation of encompassing states of environment like temperature, stickiness, acoustic, seismographic information of nature or might be movement, direction of living creatures. Computation is the task of processing the data and controlling the other components in the sensor node. Sensor nodes communicate with the Base Station (BS) as well as with other sensor nodes within the community. Communiqué consumes most of the power. When considering the efficiency of wireless sensor community the lifetime could be very vital aspect. Therefore, researcher always tried to improve the lifetime by maximizes the battery life and reduces the power consumption. [1]These sensor nodes are power limited; thereby designing energy-conscious algorithms turns into an important aspect for extending the life of sensors.

*Author for correspondence

Data is collected by different sensor nodes therefore data must be aggregated and to support data aggregation, nodes can be partitioned into a number of small groups called clusters. In a network, there may be many clusters and each cluster must have a cluster head, which is the leader that aggregates the data, commonly referred to as Cluster-Head (CH)[2]. A CH may be elected by the sensor nodes in the cluster or pre- assigned by the network designer. A CH may be a normal sensor node or may be one of the sensors or a node that is richer with energy[3]. CH collects the data and sends it to the BS is shown in Figure 1. The cluster membership may be fixed or variable. The basic advantage is that, it conserves the bandwidth and supports network scalability. Moreover, topology maintenance overheads may be reduced and stabilize the network topology at the level of sensors. The CH maximizes the lifetime of network by implementing optimized management strategies. A CH can schedule activities in the cluster, sensor nodes, which are not participating in the communication, can be switched in to sleep node therefore reduces the energy consumption[1].

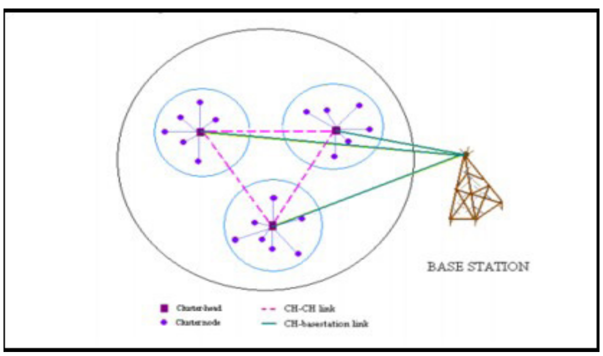

Figure 1. Schematic diagram of clustering mechanism.

[4]In centralized clustering mechanism if central node fails the entire network will go down, therefore reliability is not guaranteed. Hence, instead of centralized clustering mechanism the distributed mechanism is employed for a few specific reasons like node failure/central node backup downside, information aggregation etc. As there is no central node, the network has to be self-organized. In addition, it minimizes the sensed redundant information forwarding due to self-organized network.

[2]In Distributed clustering mechanism cluster heads are not fixed but the selection is based on some pre-assigned parameters. LEACH and HEED are the two most popular distributed clustering algorithms for wireless sensor networks. Clusters are formed using different cluster formation algorithms.

In[5] Developed a Particle Swarm Optimization (PSO), a populace based totally stochastic optimization method stimulated via social behavior of bird flocking or fish schooling. In PSO, the functionality solutions, known as particles, fly through the hassle location via following the contemporary top of the line particle. Each particle continues song of its coordinates in the hassle area, which might be associated with the quality answer (fitness) it has performed up to now (The fitness price is also stored). This price is referred to as pbest. Some other "best" cost this is tracked with the aid of the particle swarm optimizer is the pleasant fee, received to this point via any particle inside the neighbours of the particle. This area is referred to as lbest. [6]When a particle takes all the population as its topological neighbours, the satisfactory cost is a global excellent and is called gbest.

It has been found that PSO gets better faster and cheaper results compared with other methods, therefore applied successfully in many research and application areas from last few years. There are only few parameters with slight variations works well while working with PSO for many applications.

In[7] have already done a good deal of work in this field and present Linear/Nonlinear Programming (LP/NLP). Two algorithms proposed based on PSO, the routing algorithm and the cluster formation algorithm. Multi-objective fitness function and particle encoding scheme used in the routing algorithm while load balancing used in clustering algorithm for conservation of energy. The proposed algorithm compared with existing algorithm in terms of energy consumption, network lifetime, number of live nodes and throughput. In[8] gave a survey of various clustering algorithms like heuristic schemes linked clustering, highest connectivity clustering, MAXMIN D clustering, weighted schemes weighted clustering; hierarchical schemes LEACH, TLLEACH, EECS, HEED grid schemes –PEGASIS in order to reduce the energy consumption and compared their strength and limitations. In[2] gave a survey of some frequently used distributed clustering algorithms like LEACH, HEED, EEHC, LCA, CLUBS, FLOC, ACE, DWEHC, stating their advantages and disadvantages and made a comparative analysis of the various presented algorithms in the state of research. LEACH is further enhanced in[9] and proposed a protocol to reduce the energy consumption in each round. Results shows significant energy conservation compared to

LEACH. In[10] it has been showed that a sensor node might not responds to the advertisements received by the closest CH but join a farthest CH for better energy efficiency and longer lifetime. Anew cluster formation strategy is proposed and correctness of their analysis verified through simulation results.

The Low Energy Adaptive Clustering Hierarchy or LEACH algorithm directly or indirectly influenced the past research on efficient clustering algorithms for wireless sensor networks[11]. LEACH was a highly influential model in the 1990s but failed to live up to its reputation in real world scenarios. This sparked the development of many LEACH derivatives such as Advanced LEACH (Ad-LEACH), LEACH-C, TL-LEACH and Hybrid Energy Efficient Distributed (HEED) hierarchy. Later on, the focus was shifted to various new and improved optimization algorithms such as Genetic Algorithm and Particle Swarm Optimisation. Taking a similar approach, we started our research by studying the already documented techniques for sensor network clustering. The first technique we studied was Advanced LEACH. Ad LEACH is a technique, which expanded upon the classical LEACH protocol by considering two distinct sorts of sensor nodes in the network, ordinary nodes and advanced nodes where the advanced nodes are at a default energy level higher than that of ordinary nodes. The model thus considered the factor that several nodes may be at different energy levels initially a point, which the classical LEACH ignores. Though the results were better than what we got from the classical LEACH algorithm, it was still falling short in many areas. Following this, we forayed into the realm of optimization algorithms where we studied the working of the PSO technique. The PSO technique is a very versatile optimization algorithm having roots in the way groups of animals in nature search for food. PSO has been used to solve a variety of problem, most importantly those in Digital Image Processing. The flexible nature of the PSO technique made it an attractive choice. Its ability to handle hybrid data models in two-dimensional and three-dimensional space combined with binary, discrete and combinatorial data sets inspired confidence in this technique. In addition, the excellent research paper by[12] was also a source of inspiration.

The problem of efficient clustering in Wireless Sensor Networks is not a new one. It has spanned years of research and has included classical as well as Heuristic and Metaheuristic approaches. In a two-tier WSN, sensor nodes are grouped together to form a clusters, hence several no. of clusters in a network. In[10] each cluster has its own CH. Sensor nodes send the aggregated data to the head of the cluster. CH sends the data to the BS directly or via other CHs or in a single hops depending on the range of the sensors. The problem here arises that sensors are battery operated and therefore power constrained. In[13] to keep a network up and running for the maximum possible time it is important to extend the lifetime of its nodes. As distance is the major source of energy dissipation, by reducing the distance we can ensure more efficient transmission. But due to the time critical nature of WSN operation, we cannot possibly take too many hops to reach the BS. Hence we need to minimize the number of hops to the BS to improve efficiency. As we can see, there is an obvious tradeoff in these two methods that we have discussed. Therefore, while designing routing algorithms we need to incorporate a trade-off between transmission distance and number of forwards as they pose two conflicting objectives.

2. Proposed Model

PSO is influenced by behaviour of birds or fish in a group. They always travel in-group in search of food without colliding and hence reduce their own individual effort while searching for food, water and shelter. PSO inspired by random search methods of evolutionary algorithm. The particles in the swarm update their position relative to the position and velocity of the group. The flowchart in Figure 2 describes the various activities in PSO.

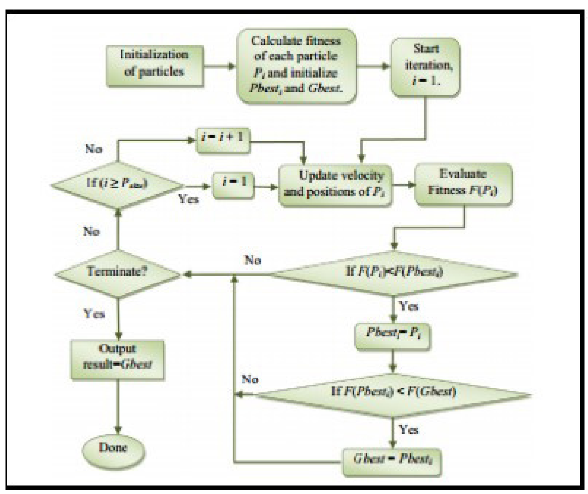

Figure 2. Flowchart for the PSO algorithm.

For answer of a multidimensional optimization issue, the swarm of particles is consisted in PSO, which are of equal size (say NP). The equal dimension of all the particles i.e. D=2is taken into account for the scope of this paper. The notation for representing the ith particle Pi of the population is as follows:

$$P_i = [X_{i,1}, X_{i,2}, X_{i,3} \dots, X_{i,D}]$$

Each particle's position is evaluated using a fitness function which judges the quality of the solution provided by it in that iteration. To reach the global best position, a particle tracks its personal best position *Pbest* and the globally best position *Gbest.* The velocity and position of each particle in each iteration V_{id} and X_{id} are updated as follows:

$$V_{id}(t) = w * V_{id}(t-1) + c_1 * r_1 * \left(Xpbest_{id} - X_{id}(t-1)\right) + c_2 * r_2 * (Xgbest_d - X_{id}(t-1))$$

Where w = inertial weight

c1 and c2 = acceleration factor (non-negative constants)

r1 and r2 = distributed random numbers in the range of [0, 1]

Until Gbest is achieved or a fixed number of iterations tmax is reached the update process is iteratively repeated.

In our research, we have been assumed that the sensor nodes are desk bound and are deployed randomly. A sensor node can be deployed as a cluster head if it is in its communication range. The fundamental knowledge model remains similar to classical algorithms such as leach. All though, each new iteration every node sends information to the cluster head in which the facts is aggregated, the redundant statistics is discarded and the remaining is passed on to the next hop, which can be either another head or the BS. All communication is assumed to happen on a wireless link. [12]The fitness function is proposed in such a way that it accounts for the energy intake of the cluster heads in addition to the sensor nodes. As discussed above the conflicting objectives of the clustering problem create a trade-off, which is represented by the fitness function given as:

Fitness= W1* MaxDist + W2* MaxHops

To increase the lifespan of the sensing element network, it's imperative that we have a tendency to concentrate on increasing the lifespan of the cluster head that has rock bottom remaining energy at the given moment because the failure of anyone head would stop the lifespan of the network. The cluster head that has the smallest amount residual energy ought to have rock bottom energy consumption per iteration. Let gi has the residual energy of Eresidual (g_i). Then the lifespan of g_i can be calculated as:

$$L(i) = \frac{E_{residual}(g_i)}{E_{Gateway}(g_i)}$$

Hence we are able to observe that life of the nodes is additionally directly proportional to the fitness function value.

3. Algorithm and Result

ALGORITHM

1. Initialise the node of the swarm.
2. Calculate the node with the most effective position and assign it Gbest.
3. Calculate the specific node's personal satisfactory Pbest.
4. Begin the iteration:
   - As the position and state of the node update, update them into the buffers.
   - Calculate the fitness function for the node where Fitness=W1*MaxDist + W2*MaxHops
   - Set Pbest=Pi
5. End iteration.
6. Start iteration:
   - If the current fitness of the node is less than the node best, then set Pbest=Pi.
7. End iteration.
8. Start Iteration:
   - If Fitness(Pbest)<Fitness(Gbest) then set Gbest= Pbest
9. End iteration.
10. End.
11. End.
12. Terminate operation option.
    - If yes Output=Gbest is the best node for head.
    - If no then i++ and Go back to (4).

Figure 3 indicates the comparison of number of cluster heads and the fitness value for four values of iteration. As we can see from the figure, the percentage difference in the fitness value for each value of iteration is almost the same. Hence, even for larger value of iterations the fitness function does not change its value. While the number of cluster heads is minimal, the fitness value is the maximum for all values of iteration.

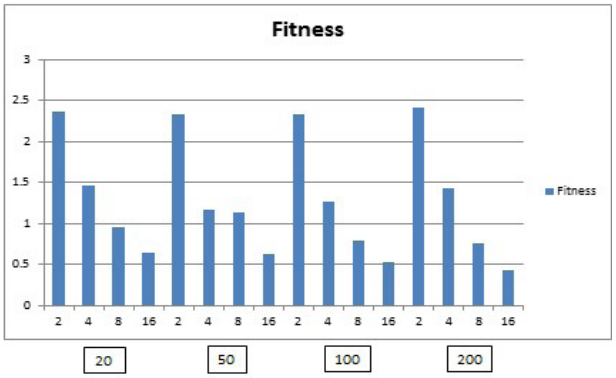

Figure 3. Number of cluster heads vs. fitness function.

4. Conclusion

In hierarchical clustered network, the sensor nodes send knowledge to the CHs wherever the info is aggregative. Then, the aggregative knowledge is transferred to the BS. Many goals are aimed while clustering the nodes like energy-efficiency, fault-tolerance, and topology control. In this paper, we studied two techniques for cluster formation - Advanced LEACH and PSO algorithm. We used PSO for our study of energy efficient clustering. The behaviour of the PSO algorithm was analyzed when one or more impacting parameters were varied. We simulated the PSO code to find the variation in fitness function by variations in the values of CHs, sensor nodes and the number of iterations. It was concluded that the life span of cluster head is directly related to the fitness function that is as the number of cluster heads increases the value of fitness function decreases so the lifetime of the CHs.

5. Future Scope

Even though there was, a flourish of studies effort for maximising the life of WSN using clustering but some aspects of clustering is required to be investigating. Right here we suggest a few areas for future work.

We can compare the optimisation of PSO with different optimisation algorithms such as Genetic Algorithms and so forth. For a comparative, observe for energy efficiency in WSNs.

Extending of network life span is the principle emphasis of clustering algorithm. There are a few different network demanding situations like to maintain the QoS[4] requirements of a WSN, encryption and authentication can be considered inside the layout stage and the CHs can perform the security protocols and information acquisition as the cluster- based protocols are exposed to special forms of attacks, inclusive of Hello flood, Sybel, and many others[14]. Full insurance of the network, may be promised and pursued in cluster-primarily based protocols as some other QoS requirement.

Solar and wind may be another source of energy for the sensor nodes. Those nodes are called energy harvested nodes and might act as relay nodes[15] or as a cluster heads. In such networks, the traditional CH selection metrics are not suitable and this can be an exciting studies venture.

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