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A Novel Approach using Parallel Ant Colony Optimization Algorithm for Detecting Routing Path based on Cluster Head in Wireless Sensor Network

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Abstract

More energy in wireless sensor network is spent in routing part as compare to other operation in sensor network. To route data in efficient manner detecting optimal path for routing is better solution. For time critical application, detection of optimal path should be faster enough to make the application efficient. This paper focus on detecting of optimal path by using parallel ant colony optimization algorithm. K-Mean clustering approach is used for grouping of sensor nodes because it is faster than other hierarchical clustering algorithm. Rotating the cluster head while implementing algorithm based on friss free space propagation model, increases the lifetime of the network. This proposed system is developed using Java. The results shows that proposed system detect the optimal path faster than existing system with better lifetime of the network.

Keywords: Ant Colony Optimization, Cluster Head, K-Means Clustering, PACO Wireless Sensor Network

1. Introduction

The Micro-Electro-Mechanical Systems (MEMS) technology development leads to a greater development in Wireless Sensor Networks (WSN) which make the device cheap and portable. WSN is the collection of nodes which are capable of sensing, computing and communicating the data in the network. WSN is used in various applications such as military surveillance, application based on environmental monitoring, agriculture, structural health and smart parking. Most of the research in the WSN is targeted to increase the lifetime of the network by using various methods and technology. Clustering and routing are the techniques through which the efficiency of the network is improved by increasing the lifetime of the sensor nodes. The energy of a sensor node depends on the data rate transferred by the sensor nodes, distance between the nodes and the sink node. In WSN after the clusters are formed cluster head is to be determined. Detecting of cluster head has also placed a crucial role in WSN. Cluster head is determined in various ways in network and in maximum case it is determined by using the residual energy. The major role of cluster head is to collect and aggregate the data from various sensor nodes,after aggregating transfer the data to sink node which also consume energy of the network. So it is necessary to reduce the energy consumption taken for making the cluster and aggregating the data in cluster head. Recent development in the Artificial intelligence technology leads to development in the various technologies in other fields. Using such artificial intelligence technology will also reduce the energy consumption of WSN which increases the lifetime of the complete network. One of artificial intelligence technique is Ant Colony Optimization (ACO) which is

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generally used for finding the optimal path. By using this technique energy consumption of the sensor node can be reduced and lifetime can be increased.

2. Related Works

A cluster based on voronoi ant system where the cluster head is determined by using voronoi control packet. Here loop-backing and multiple broadcasting are avoided but only the nodes which receive voronoi control packet can able to broadcast again[1]. In another study, migration of nodes in a greedy manner for reducing energy hole problem in WSN is done using ACO[2]. ACO algorithm is also used as energy saving model in WSN where DBSCAN (Density based Scanning Method) is used to form a clusters of sensor nodes[3]. A transmission schemefor WSN using ACO algorithm is defined by Liu, Xuxunin in which deployment of sensor nodes are done in a concentric coronas model, at the center Base Station (BS) is located. Parallel ants are used in which the single ant is deployed in each and every sector of the model. As ACO algorithm commenced all ant started moving, the ant which is in the next sector of BS reaches BS in a single move. This make the system more efficient by using parallel ants and by using concentric coronas model. The drawback of this system is the occurence of deploymentissues. Mostly sensor nodes are deployed in dense places and military application where this kind of deployment is highly difficult[4]. Energy aware Routing protocol is designed in a manner, when the data is routed through the sensor nodes, the selection of next node is based on the energy of remaining node in that particular cluster.Which node has the higher energy level willconsidered for sending the packets[5]. Low-Energy Adaptive Clustering Hierarchy (LEACH) protocol whichrotate the role of cluster heads adaptively based on energy level of nodes. In this protocol each and every node will get a chance to become cluster head for routing data in network[6]. By using Population based Ant Colony Optimization algorithm the lifetime of sensor nodes areincreased by using the factors such as Hops, Energy and population[8].

Swapna B. Sasi paper investigated about various secure communication based on cryptography method using optimization technique, where ACO algorithm is suggested for encrypting the message based on image[9]. Amin Rezaeean used ACO algorithm for detecting optimal cross section of embankment in construction approach[10]. Abhishek Varma paper overcomes the disadvantage of multi-path routing by clustering mechanism in which complete network is divided and restriction is applied to multipath of particular cluster by which traffic is applied to one cluster instead of entire network[11]. A study on protocols that will consume less energy for data gathering and routing protocol by using dynamic clustering technique done by S. Anand gives idea about various protocol that consume less energy in mac layer[12]. An unequal clustering approach makes the even energy distribution in the network which increases the lifetime of the network[13].

In existing system where Adaptive virtual area partition clustering routing protocol[7] using ACO algorithm for WSN in which the nodes are clustered using virtual area partitioning algorithm and then optimal path is detected using single ant for routing data in sensor network. Using of single ant for detecting optimal path will reduce overall efficiency of the system because for detecting optimal path it will consume more time. In time critical application, it can affect the system performance. Finally the optimal path is determined based on which path is taken for routing maximum number of time. Energy is one of the important parameter in WSN, detecting optimal path without considering energy may result in path which may consume more energy, and also usage of single ant will increase the time consumption for detecting the optimal path.

3. Ant Colony Optimization

Generally ACO algorithm is successfully applied for NP-hard combinatorial optimization problem. This algorithm is inspired by real ant behaviour of searching the food. Real ants are communicated by using a chemical substance called pheromone indirectly between the ants. While solving a particular problem pheromone trails are modified by ants. Candidate solution is generated by iteratively usage of ants in ACO algorithm. Problem dependent heuristic information and pheromone trails will guide to construct a solution. Ant starts with empty solution, then adds solutions iteratively to get an integrated candidate solution. Artificial ants give feedback by depositing pheromone on the path that are visiting for obtaining the complete solution. During next iteration the path taken by maximum number of ants will get higher pheromone value, and in the future iteration path with the higher pheromone value is used more likely by ants. Pheromone value can't reach infinite because before updating pheromone trails are decreased by a certain factor.

There are two main phases present in ACO algorithm are transition probability and pheromone updating factor. Transition probability factor determines the next cluster node to be visited and the pheromone updating factor determines the path to be transmitted. The probability of the transition function from one cluster head to another cluster head is defined as

$$p_{ij}^{k}(t) = \left\{ \frac{[\tau_{ij}(t)]^{\alpha}.[\eta_{ij}]^{\beta}}{\sum_{k allowed_k}[\tau_{ij}(t)]^{\alpha}.[\eta_{ij}]^{\beta}} \right\}, j \in allowed_k \quad (1)$$

Where i and j are source and destination cluster head where ant k has to visit. The heuristic factor of pheromone is defined using α and the expected heuristic factor is defined as β, $\eta_{ij}(t)$ indicates the degree of transit from i to j. $allowed_k$ is the cluster head that the ant k does not visited and has to visit. The value of $\eta_{ij}(t) = 1/d_{ij}$ which means that if the value of dij is smaller than the value of ηij is larger for a particular ant k.

3.1 Updating Pheromone

For updating the pheromone value following formula is used

$$\tau_{ij}\,(t+1) = (\,1-\rho).\,\tau_{ij}(t) + \Delta\tau_{ij} \quad (2)$$

$$\Delta\tau_{ij}(t) = \textstyle\sum_{k=1}^{m} \Delta\tau_{ij}^{k}(t) \quad (3)$$

Where the evaporation factor is defined by using and $\Delta\tau_{ij}$ pheromone quantity that was laid on the edges of source i and destination j.

3.2 Parallel ACO Algorithm

Development of Parallel ACO (PACO) is the method in which more than one ant take part while doing the above-phases. Each and every ant in PACO algorithm will find the transition probability and do pheromone updating operation simultaneously. The major advantage of using PACO is reduction of computational time, which result in faster detection of path.

4. Proposed System

In proposed model sensor nodes are deployed randomly, after distributing sensor nodes are grouped using K-Means clustering algorithm and ACO algorithm is implemented along the cluster head of selected cluster.

In this system model after grouping sensor nodes, parallel ants are implemented such that every ant will

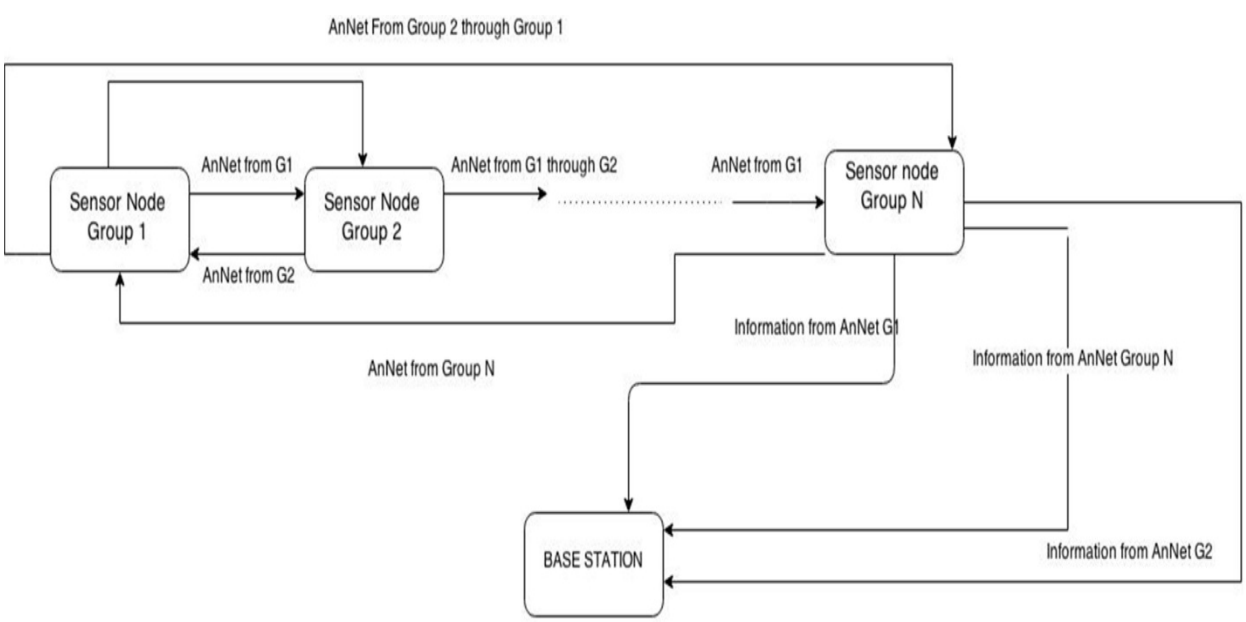

Figure 1. Proposed System Model.

trigger at the same time. Single ant is triggered for each and every cluster and visit cluster's head of other selected clusters using formula[1]. After visiting all cluster head BS will receive the path and energy consumption from every ant in each iteration. Finally path is detected based on the energy consumed by each and every ant. This optimal path detection is done by using PACO algorithm which will give the result earlier as compared to sequential ant colony optimization.

4.1 K-Means Clustering Approach

K-Means clustering in which n-objects are partitioned into k clusters in which each object is belong to one cluster. Several advantages of k-mean algorithm make the system much more efficient and effective such as:

- If k-value is small, k-mean clustering computes faster than hierarchical clustering method even though the objects need to be clustered are huge.
- Compare to other hierarchical clustering method k-means produce tighter clusters, especially when clusters are globular.

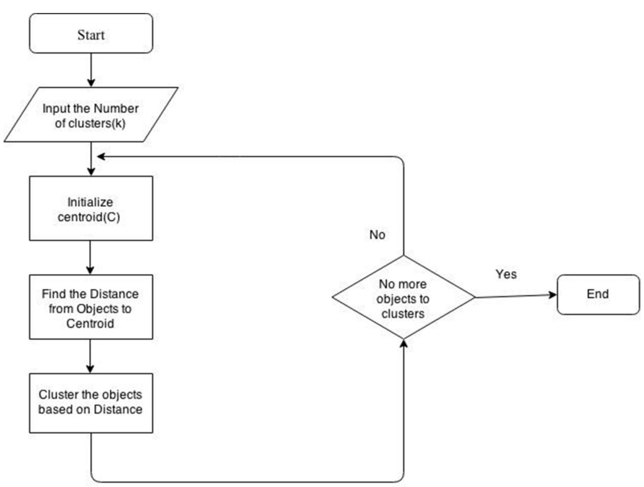

Figure 2. Procedure for K-Mean clustering algorithm.

Figure 2 indicates procedure for K-Mean clustering. K-Means clustering algorithm is mainly used here for grouping of sensor nodes for implementing ACO algorithm in it.

The Figure 3 indicates about the clustering of sensor nodes and using transition probability with single ant between the cluster heads.

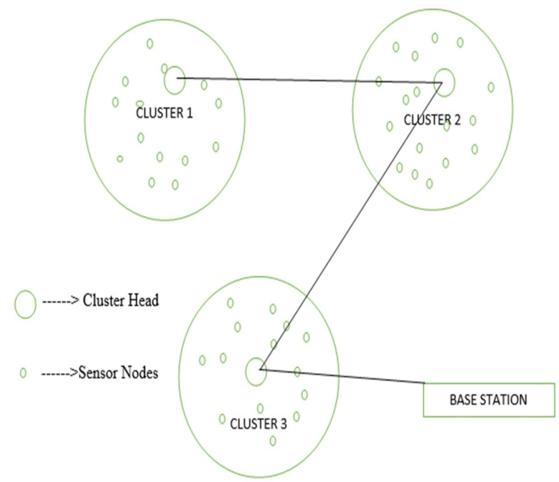

Figure 3. Clustering of Sensor nodes and using single ant in the network.

4.2 Changing Cluster Heads

To increase the network lifetime, it is necessary to change the cluster head because when maintaining a single cluster head energy loss by that single node will be more, which will result in less network lifetime. To increase the overall lifetime, it is effective to change Cluster head. By changing the cluster head every time all nodes in the network get the chance to become cluster head, so single node is not getting affected while routing through the cluster head of each cluster. The change in cluster head is based on their energy of the nodes in a particular cluster. A node which has higher energy will become a cluster head for particular iteration, for the next iteration cluster head is determined again based on the residual energy of nodes in a particular cluster. The energy dissipation model for the sender and receiver is adopted from LEACH protocol[6]. The sender cluster head will dissipate the energy based on this formula.

$$E_T(l,d) = \begin{cases} l(E_e + \epsilon_f d^2), & if\ d < \delta \\ l(E_e + \epsilon_m d^4), & if\ d \geq \delta \end{cases} \quad (4)$$

Energy dissipated by receiver cluster head is given by using the following formula

$$E_R(l) = lE_e \quad (5)$$

Where $E_T(l,d)$ and $E_R(l)$ indicate the energy dissipated for transmitting l bit of data over the distance d and energy dissipated for receiving l bit of data respectively. Other factors which are involved in energy dissipation is E_e [J/bit] which indicatesthe energy dissipated to operate the circuit per bit. ϵ_f [J/bit/m^2] and ϵ_m [J/bit/m^4] factors are friss free space propagation model and threshold value δ can be indicated as $\sqrt{\epsilon_f / \epsilon_m}$.

Based on equations (4) and (5) for each iteration the cluster head will changed, which node hasa higher energy value that will become the cluster head for next iteration, this changing of cluster head will increase the lifetime of a network in an efficient manner.

4.3 Path Detection

The network traffic loads and communication delay are reduced by using multi-hop communication between the cluster heads. This path detection is done only after doing k-means algorithm. The algorithm for path detection is as follows:

- Initializing parameters such as maximum number of iteration N_{cmax}, initial pheromone value $\tau_{ij}(t)$ = const.
- Place one ant in each cluster and start the iteration.
- Increment the iteration as the processing starts. (Nc ← Nc+1).
- Trigger K ants from each cluster, which means each cluster has one ant in it that is the value of ant K and the number of clusters N, both are equal.
- Calculate the transition probability for selecting the next cluster head, which is tobe visited.
- Check whether allants are visited each cluster heads, if not go to previous step which calculate transition probability and move to the next cluster head.
- Once all ants visited entire cluster head calculate the energy consumed by ant.
- Update the pheromone value for the visited paths.
- Calculate the residual energy of each and every node in all the clusters and change the cluster head such that the highest energy node in all cluster will become the cluster head.

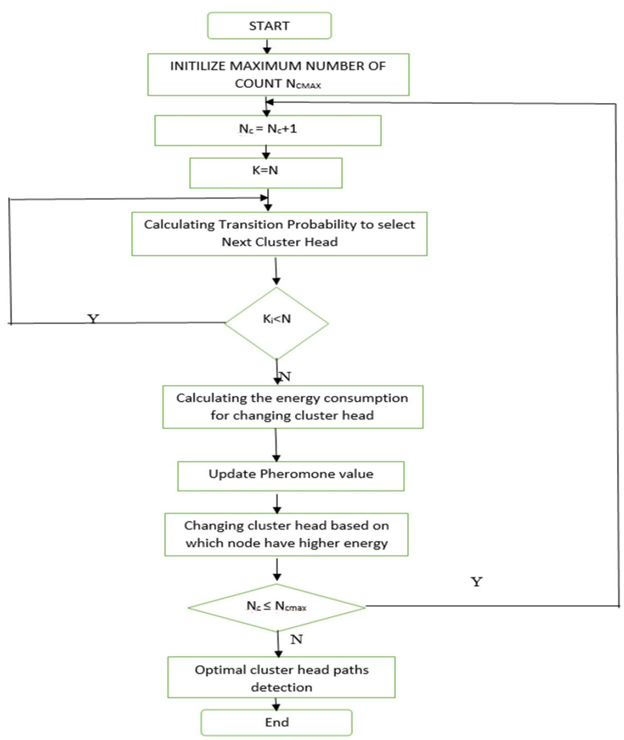

Figure 4. Flow chart for Path detection Algorithm.

- Check whether the number of iterations have reached the maximum number of iterations, if the maximum number of iterations are reached give the results, otherwise go to step 3 and follow the procedure again.
- Continue the steps until optimal paths are detected.

Figure 4 represent the flow diagram of the path detection algorithm. The above steps are represented as a flow diagram. ACO algorithm has an advantage of maintaining entire colony memory instead of having only previous generation in memory with less affected to poor initial value.

5. Experimental Analysis

Implementation of this algorithm is done using Java programming. The assumptions are made according to survey that nodes are deployed in the region of 100 X 100 m network field with 100 nodes randomly distributed between (x = 0, y = 0) and (x = 100, y = 100). Our protocol is faster in detecting the path and also it increases the lifetime of complete network due to change of cluster head for every iteration. This protocol takes the advantage of the parallel ACO algorithm to detect best path for routing. For reducing the energy from the sensor node 4 and 5 formulas are used. The value of E_e depends on various factors such as spreading of signal, digital coding, modulation and filtering whereas the value of $\epsilon_f d^2$ and $\epsilon_m d^4$ is amplified energy depends on various factors such as receiver node distance and bit-rate (which indicate the bit-rate). In this paper for experimental results the communication parameter is set as E_e = 50 nJ/sec ϵ_f = 10 pJ/bit/m^2 and ϵ_m = 0.0013 pJ/bit/m^4 and value of l is considered as 1. After considering these values implementation of the parallel ACO framework has less time compared to sequential implementation of ACO algorithm. If the time taken by a sequential execution of ants are defined as 'T' then the time taken by parallel execution of ant is

$$T/_k + communication\ overhead \qquad (6)$$

Where, T is time for executing, k is number of ants and due to usage of parallel ant there will be some communication overhead.

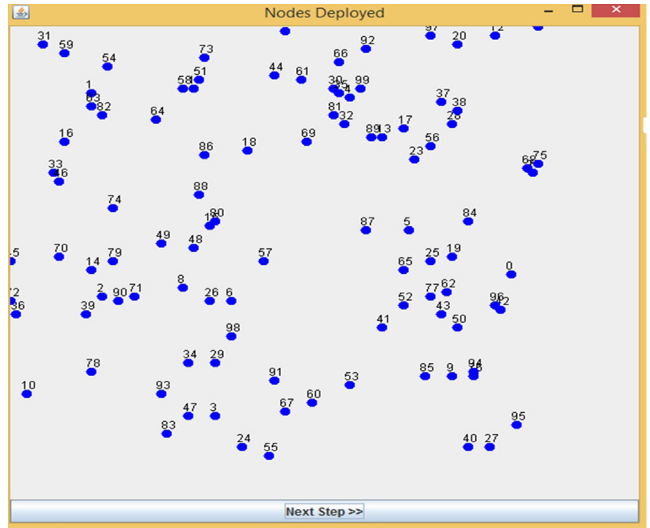

Figure 5. Node deployment.

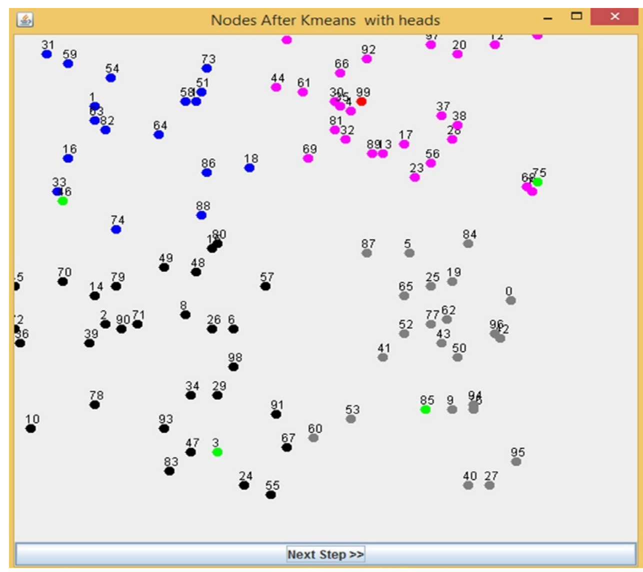

Figure 6. Clusters with Cluster head.

Figure 5 indicates the deployment of 100 nodes in the environment and Figure 6 indicates the K-Means clustering with the cluster head selection. For initial rounds nodes with higher energy will be the cluster head. In Figure 6, the nodes which are in green color (node 46, 75, 3, 85) indicate cluster head, the node which is in red indicate base station.

Figure 7 Indicates the optimal path for routing the data based on energy that are consumed. This are the paths the ant can follow for routing the data.

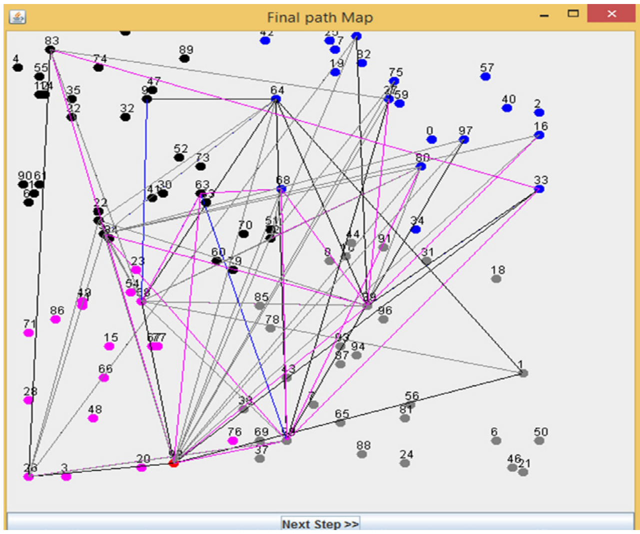

Figure 7. Detection of optimal paths after all iterations.

6. Conclusion

In this paper the sensor network is clustered effectively using K-means algorithm and uses the parallel ACO algorithm for finding the path to route the data. Using this algorithm time taken to find the optimal paths is less as compare to other existing methods. This algorithm is mainly depends on cluster heads and the lifetime of complete network which is incremented by changing the cluster head based on energy consumption. The future work is to find the optimal path by considering the internal nodes and applying ACO algorithm.

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