PERFOMANCE EVALUATION OF K-MEDOIDS TECHNIQUE FOR NODE CLUSTERING IN WSN ROUTING SYSTEM SIBER-DELTA

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Abstract—Wireless sensor networks (WSNs) have become a very hot research area in recent years, as a result of their wide potential applications such as military surveillance, agricultural monitoring, industrial and smart home with multimedia sensors to accumulate visual data such as image or video. In general, energy consumption is one of the biggest challenging research issues for WSNs since the tiny sensor nodes cannot be easily re-energized after random deployment. In this paper, an efficient energy reduction method is proposed and is applied to SIBER-DELTA model in order to reduce energy consumption and to prolong network lifetime. Swarm Intelligence based Efficient Trust Aware Routing protocol for Wireless Sensor Networks termed as SIBER-DELTA considers trust rating of the nodes along with energy, distance, link quality of the path to select the best quality path from source to sink for packet forwarding. SIBER-DELTA is a flat routing protocol. One of the trendy scenarios to reduce energy consumption for WSNs is the implementation of clustering technique. The main initiative of this process is to provide efficient energy saving method for WSNs. To get the outstanding result of clustering, K- medoids clustering algorithm is employed to compute the optimal medoids between sensor nodes. Subsequently, suitable cluster heads are selected. By distributing the load among the clusters, energy efficiency can be enhanced and network lifetime can be increased efficiently. Simulation results prove the outperformance of proposed SIBER-DELTA with K -Medoids when compared to the existing SIBER-DELTA model in terms of energy consumption and network lifetime.

Keywords: Wireless Sensor Networks; K-Medoids Clustering algorithm, SIBER-DELTA, Energy Balancing, Network life maximization, Swarm Intelligence

I.INTRODUCTION

Due to the tiny inexpensive sensors deployed in Wireless Sensor Networks, to provide cost-effective solutions to a wide range of real world challenges, WSNs have gained immense popularity in industry, military, society and academia [1]. WSNs have been deployed in various scenarios to perform wide variety of functions including climate auditing, military surveillance, forest wildlife monitoring, earthquake monitoring, target tracking, infrastructure evaluation, health inspection, precision agriculture, and also Internet of Thing (IoT) [2-5]. WSNs consist of large number of tiny and low-cost sensor nodes. These sensors are self-organized, which can form a multi-hop network adaptively and transmit the compressed data to base station [6, 7]. With the growth of WSNs, multimedia WSNs have been extensively applied. Transmitting Multimedia data like image or video is the characteristic of multimedia wireless sensor networks, and more visual information can be collected in military surveillance, industrial and agricultural monitoring, healthcare and smart home etc. [8]. The size of multimedia data is usually large and as a result more amount of energy will be consumed. Power saving is one of the most essential factors for sensor nodes to extend their life span in WSNs. Most of the energy consumption involves data packets transmitting and receiving. Due to a large number of sensor nodes, battery cannot be recharged easily, and the power becomes the most expensive resource for each sensor node. Thus, the energy consumption plays a vital role in wireless sensor networks. This can be achieved by using K-Medoids Clustering Algorithm when compared to other clustering protocols.

In this paper, we used a K-medoids based Clustering Algorithm (KCA) for our existing work named Swarm Intelligence based Efficient Routing with Distance, Energy, Link quality and Trust Awareness (SIBER-DELTA) to provide efficient energy saving scheme for wireless sensor networks. In order to acquire the ideal outcome of cluster, we use K-medoids algorithm to avoid negative influence of the outliers and then calculate the optimal medoids between sensor nodes. By balancing the network workload, K-Medoids clustering for SIBER-DELTA can improve the energy efficiency and extend network lifetime effectively.

The rest of the paper is organized as follows. In Section 2, we present some of the previous work related to clustering techniques for WSNs. In section 3, we briefly describe K-Medoids Clustering for SIBER-DELTA model. Section 4 provides present Performance Evaluation of our approach with the existing clustering techniques. followed by concluding remarks.

II. RELATED WORK

In order to optimize the network topology, improve the energy utilization rate and reduce the energy consumption of sensor nodes, many scholars have carried out a lot of researches on WSNs routing algorithm, and gained some achievements [9, 10, 11]. These researches can be categorized as: tree-based routing algorithm and cluster-based routing algorithm. In tree-based routing algorithms, optimal routing tree construction is a difficult problem. But, in cluster-based routing algorithms, node management is efficient and collaboration of node is low. The only thing matter in this is the cost of the maintenance of all clusters.

LEACH [12] is a proactive network protocol uses a hierarchical clustering involves distributed cluster formation methodology. LEACH protocol randomly selects a only some sensor nodes as Cluster Heads (CHs) and rotates this job amongst the cluster members so as to uniformly distribute the energy dissipation across the cluster. In LEACH, the CHs compress data which arrives from the nodes that fit in to the respective cluster, and send an aggregated packet to the Base Station so as to reduce the amount of information that must be transmitted. LEACH uses a TDMA MAC to reduce intra-cluster and CDMA MAC to reduce inter-cluster collisions. But, data collection is centralized and is performed periodically. Hence, this protocol is better suitable when there is a necessitate for constant monitoring by the sensor network. In contrast, a user may not need all the data immediately. Therefore, periodic data transmissions may consume high energy unnecessarily. After a particular interval of time, the job of Cluster Head is rotated among the members so as to distribute the energy uniformly. LEACH protocol helps in reducing energy consumption in WSNs. But, the random selection of Cluster Head nodes may achieve a poor clustering result. An uneven distribution of cluster head nodes will burst the network load balance and makes network inefficient.

An Ant Colony Clustering Routing Algorithm for Wireless Sensor Networks (ACA) [13] is applied to inter-cluster routing mechanism for the best path from cluster heads to the base station. The data transmission along the best path from cluster head to the base station was achieved and the energy consumption of cluster heads was decreased. In this routing, not only the node's remaining energy is taken into account, but also the distance between the cluster heads was considered for the selection of cluster heads. It resulted in the more even distribution of cluster heads. The algorithm has the uniqueness of low expending on routing, self-organized and multi-path. However, may not be suitable for larger networks.

In this paper, K-medoids based clustering algorithm is applied to SIBER-DELTA [14] to provide efficient energy consumption in WSNs. K-medoids algorithm is used to optimize the selection of cluster head nodes and set up a more appropriate network topology. In this paper, we compare SIBER-DELTA model with K-Medoids, ACALEACH and LEACH algorithms.

III. K-MEDOIDS CLUSTERING FOR SIBER-DELTA

This section gives a brief explanation of SIBER-DELTA model followed by the K-Medoids Clustering technique for SIBER-DELTA model in WSNs.

SIBER-DELTA

The Steps involved in SIBER-DELTA protocol:

- Initialization phase
- Neighbour Discovery phase
- Route Discovery phase
- Packet forwarding phase

Initialization Phase

Nodes are deployed in the network and each node maintains its routing table and is initialized.

Neighbour Discovery Phase

1. makebroadcast

Select a node to broadcast and make a broadcast by sending hello packets containing node identity, node energy, node pheromone, node trust

2. addentry

Update neighbor table of neighboring nodes by the broadcasting node entry when they hear the broadcasting node information

3. loop

Repeat this process for all the nodes in the network

Route Discovery Phase

1.sendant

Forward ants are released on the source node and its mission is to find route to destination

2. getnextneighbourtosink

A next node is found based on the probability distribution of each neighbor of a node using Forwarder Selection Function.

Forwarder Selection Function

The Forwarder Selection Function in this model is evaluated based on the trust parameter with the objective to provide a secure trustworthy path from source to sink by avoiding insider attacks.

Hence, the Forwarder Selection Function, FSF(ni, nj) to select the best forwarder node nj among the neighboring nodes of the current node ni can be defined as

FSF(ni,nj)=

$$\begin{cases} \dfrac{[PT(ni,nj)]^{\alpha}[EN(nj)]^{\beta}[LP(ni,nj)]^{\gamma}\;[TR(ni,nj)]^{\delta}}{\sum_{nj \epsilon NBS(ni)}[PT(ni,nj)]^{\alpha}[EN(nj)]^{\beta}[LP(ni,nj)]^{\gamma}[TR(ni,nj)]^{\delta}}, & if\, nj \epsilon NBS(ni), \\ 0, & otherwise, \end{cases}$$

where Where NBS(ni) represents the set of neighboring nodes of ni, PT(ni,nj) represents the concentration of pheromone deposited on the path between the nodes ni & nj, EN(nj) represents the energy level of the neighbor node nj.

Let EI(nj) be the initial energy of node nj and ER(nj) be the Remaining (Actual) Energy of node nj, then the node energy level, EN(nj) is defined as

$$EN(nj) = \frac{ER(nj)}{EI(nj)} \quad where\ ER(nj) > Eth$$

Threshold Energy, Eth is defined as the energy at which the node loses its right to participate in packet forwarding and is excluded from the path.

LP(ni,nj) represents the quality of the link between nodes ni & nj, i.e., link probability. The Expected Transmission Count, ETX is a measurement of the transmission link which is calculated based on the past events occurred on that link. Then the link probability LP(ni, nj) between nodes ni & nj is given by the expression :

$$LP(ni, nj) = \frac{1}{ETX(ni, nj)}$$

and TR(ni, nj) represents the Trust rating of the neighbor node nj as given by node ni.

α, β, γ, δ are the parameters to control the significance or importance of pheromone trail of the path, node energy level, link quality between nodes and node trust rating. When α = β = γ = δ =1, all four parameters PT, EN, LP, TR are given equal importance in the selection of the forwarder node. If one is interested in giving higher importance to TR, node trust rating, then one could make α = β = γ =2, δ =1, similarly α = 2,β = 1, γ = δ =2 to raise importance of EN, Node Energy Level, α = 2, β = δ = 2, γ =1 to make importance of link quality more significant in the selection of forwarder node.

Once the next node is found and if it is not the destination the same process of selecting & forwarding continues

3.updatepheromonetosink

If destination node is reached, then forward ant is converted to backward ant and the traversed path is updated by Pheromone Update Function.

Pheromone Update Model

Once the forward ant reaches the destination, the parameter such as Path Link Quality, Path Energy Quality and Path Trust Rating is analyzed in this model.

Average ETX of the links in the path P_{tk},

$$ETX_{av}(P_{tk}) = \frac{\sum_{i=1}^{Nh_{sd}(P_{tk})} ETX_i}{Nh_{sd}(P_{tk})}$$

Hence Link quality of the path P_{tk},

Path Link Quality,

The path Energy Quality is represented by the Average Energy, E_{avg}, and minimum energy, E_{min} of the nodes along the path. Hence, Energy quality of path P_{tk} is given by the following expression :

$$\text{Path Energy Quality, } PEQ(P_{tk}) = \frac{E_{avg}}{E_{in}} - (1 - \frac{E_{min}}{E_{avg}})$$

Trust Rating of path P_{tk} is given by the following expression:

Path Trust Rating $PTR(P_{tk}) = \frac{\sum_{n_k \epsilon NS(P_{tk})} TR(n_k)}{|NS(P_{tk})|}$

The Pheromone update or the concentration of additional pheromone to be deposited is computed as given by the following expression:

$$\Delta PT = \text{Path Energy Quality} * \text{Path Link Quality} * \text{Path Trust Rating}$$

$$PEQ(P_{tk}) * PLQ(P_{tk}) * PTR(P_{tk})$$

$$= \left(\frac{E_{avg}}{E_{in}} - \left(1 - \frac{E_{min}}{E_{avg}}\right) \right) * \frac{LP(P_{tk})}{Nh_{sd}(P_{tk})} * \frac{\sum_{n_k \epsilon NS(P_{tk})} TR(n_k)}{|NS(P_{tk})|})$$

Once the ant reaches the source, backward ant is also destroyed. This phase is repeated for several iterations to get the optimal path.

Packet Forwarding Phase

1.getnexthop

The packet is forwarded from the source and next hop is determined by the same probability function. The path selected to send a packet will be the optimal path, which was discovered by ants as there is an update pheromone trail on the path traversed by ants. Once the packet reaches destination, packet is freed up and a new packet is sent. This process continues for a particular amount of time and again ants are released on the source nodes to discover optimal path based on the prevailing conditions. This process is repeated until all packets are sent to destination.

K-Medoids Clustering for SIBER-DELTA

The proposed K-Medoids Algorithm is applied for SIBER-DELTA model as it is a partitioned clustering algorithm or segregating around Medoids. It minimizes the squared-error and is more robust to noise. The algorithm determines the centre of a cluster using an actual point in the cluster. The object called medoids with the minimum sum of distances to other points is most centrally located. Each data set object is assigned to the nearby medoid after finding the set of medoids. So when medoid mv_i is nearer than any other medoid m_w object '*i*' is put into cluster v_i.

Step1: Selection of Initial medoids

1.1 The distance between each pair of all objects is computed using Euclidean distance as a dissimilarity measure as follows:

$$\left\{ d_{ij} = \sqrt{\sum_{a=1}^{p} \left(X_{ia} - X_{ja}\right)^2}\ \mathrm{i} = 1, \ldots\ldots, \mathrm{n};\ \mathrm{j} = 1, \ldots\ldots, \mathrm{n} \right\}$$

1.2 To build an initial guess at the centres of the clusters, P_{ij} is calculated

$$\left\{ P_{ij} = \frac{d_{ij}}{\sum_{l=1}^{n} d_{il}}\ \mathrm{i} = 1, \ldots\ldots, \mathrm{n};\ \mathrm{j} = 1, \ldots\ldots, \mathrm{n} \right\}$$

1.3 Calculate $\sum_{i=1}^{n} d_{ij}$ $(\mathrm{j} = 1, \ldots\ldots, \mathrm{n})$ at every object and arrange them in ascending order. The k objects having the least value are selected as first group medoids.

1.4 Every object is assigned to the closest medoid.

1.5 The sum of distance from each and every object to their medoids and the current best possible value is to be calculated.

Step2: Determine new medoids

2.1 The sum of the distance to other objects in its cluster is minimized by replacing the current medoid in every cluster by the object.

Step3: Computation of new optimal value

3.1 Select every object to the closest new medoid.

3.2 The total distance from all objects to their new medoids and new best value is calculated. Stop the algorithm when the optimal value is one and the same to the preceding one. Otherwise, go back to the Step 2.

IV.PERFORMANCE EVALUATION

The simulation environment consists of a Base Station and 50 sensor nodes. The Base Station is fixed and located far from the sensing region. All sensor nodes are randomly deployed in sensing area. The cluster members can transmit data to their cluster heads. The cluster head collects the data, compresses it and transmits the data to Base Station.

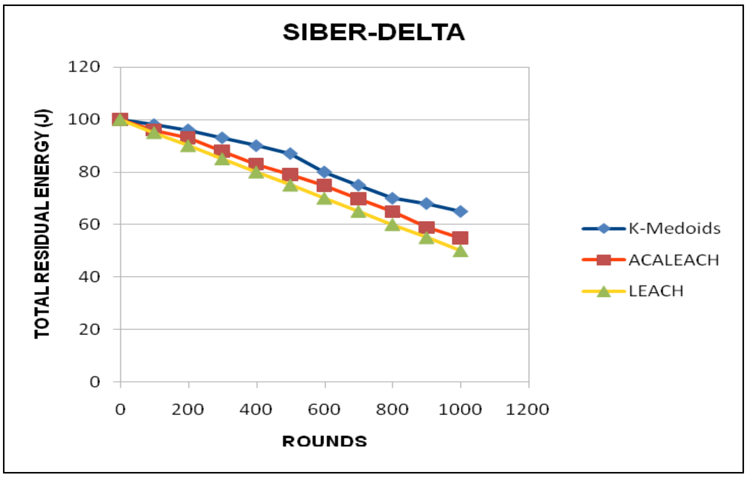

Fig1: Total Residual Energy Versus Rounds

From the Fig.1, it is evident that the total residual or remaining energy of different cluster routing algorithms is recorded. The residual energy of K-Medoids for SIBER-DELTA is higher than that of ACALEACH and LEACH. Because of determining actual point as cluster head and reducing the sensitivity of outliers, K-Medoids for SIBER-DELTA has the superior performance. The data transmission distance from each Cluster member to its cluster head nodes is minimized. Therefore, less energy is consumed and network lifetime is prolonged.

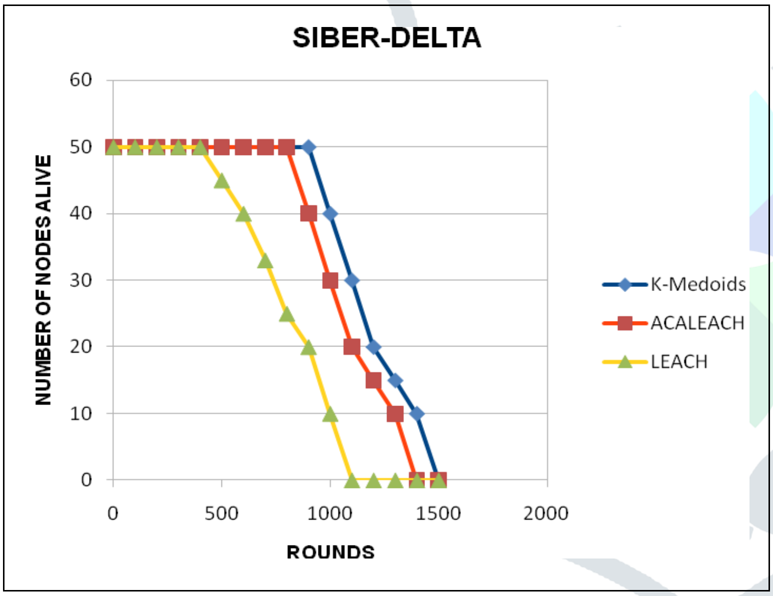

Fig2: Number of Nodes Alive Versus Rounds

In Fig.2, it is clearly shown the number of alive nodes in the network at each round. As we can see, the node begins to die around 450 rounds in LEACH algorithm. After about 1100 rounds, the number of alive nodes begins to die in ACALEACH algorithm and the number in K-Medoids is about 1400. However, the first dead node appears until about 1100 rounds in K-Medoids. As can be seen from different survival number of node in different wireless sensor networks, the survival time of sensor nodes in K-Medoids Clustering is the longest. K-medoids algorithm reduces sensitivity of outliers and minimizes absolute-error criterion and achieves optimal clustering result. These strategies can efficiently decrease the energy consumption. Hence network lifetime or network performance is improved efficiently.

V. CONCLUSION

In the transmission of huge amount of data, clustering plays an important role and to improve the performance of wireless sensor networks, a K-medoids based clustering algorithm is applied to our earlier designed SIBER-DELTA model in this paper. According to the experimental results and analysis, it can be concluded that our proposed scheme K-medoids based clustering for SIBER-DELTA can reduce the energy consumption and can prolong the network lifetime than LEACH and ACALEACH.

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