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Distributed Clustering Based Data Aggregation Algorithm for Grid Based WSN

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Abstract— Dynamic clustering in wireless sensor networks causes asymmetric division of cluster heads and extremely variable number of nodes in the clusters. Also, some of the clusters are spread over large areas in the network, causing limited spatial correlation between sensor nodes. These irregularities in cluster position have negative impact on the efficiency of a wireless sensor network. One critical issue in wireless sensor networks is how to collect sensed data in an energy-efficient way as the energy is a rare resource in a sensor node. Grid-Cluster-based aggregation is an effective architecture for data-gathering in wireless sensor networks. In this paper, we have developed a Distributed Clustering Based Data Aggregation (DCDA) algorithm for grid based WSN. In DCDA, cluster formation mechanism is based on a virtual-grid system. Simulation results show that DCDA improves the distribution of cluster heads and reduces the energy consumption within a range of 15%to 30% as compared to the existing protocols.

Keywords—Aggregation,Clustering,DCDA,Sleep/awake

I. INTRODUCTION

Recent advances in micro-electro-mechanical systems (MEMS) technology, wireless communications, and digital electronics have enabled the development of low-cost, low-power, multifunctional sensor nodes (SNs) that are small in size and communicate at short distances. These tiny SNs, which consist of sensing, data processing, and communicating components, leverage the idea of sensor networks based on collaborative effort of a large number of nodes. A Wireless Sensor Network (WSN) consists of a large number of SNs, which are densely deployed either inside the observable fact or very close to it. SNs are fitted with an on-board processor. Instead of sending the raw data to the nodes responsible for the fusion, SNs use their processing abilities to locally carry out simple computations and transmit only the required processed data. The above described features ensure a wide range of applications for sensor networks. Some of the application areas are health, military, and security. For example, the physiological data about a patient can be monitored remotely by a doctor. While this is more convenient for the patient, it also allows the doctor to better understand the patient's current condition. Sensor networks can also be used to perceive foreign chemical agents in the air and the water. They can help to identify the type, concentration, and location of pollutants. In essence, sensor networks will provide the end user with intelligence and a better understanding of the environment. We envision that, in future, WSNs will be an integral part of our lives, more so than the present-day personal computers [1].

In a large scale WSN, key idea is to combine data from different nodes to eliminate redundant transmissions, and provide a rich, multi-dimensional view of the environment being monitored and forward data in a hierarchal manner. For this purpose, cluster based protocols are commonly employed. In majority of the cluster based protocols, the clusters are formed dynamically and repeatedly to collect the data from multiple SNs. In this work our main objective is to select CH based on grid topology for data aggregation in WSNs without consuming extra energy of the network. Unlike previously proposed grid-cluster based protocols, cluster head is selected dynamically based on improved LEACH [9].Proposed DCDA protocol ensures the selection of CH in each virtual grid of WSN.

II. RELATED WORK

A. Grid-Cluster Based Protocol

In grid-cluster based protocols the Cluster Head (CH) selection decisions are distributed among the nodes themselves. Therefore, it can work well in a large scale network. The basic idea of grid-cluster protocols is to divide the network area into equal sized virtual grids where each grid is considered as a cluster with one CH in each cluster. Neng-Chung et al. [2] presented GBDAS divides the network into a grid of cells to minimize the amount of data transmitted to the BS. Each cell head aggregates its data with the data sensed by the other members of the cell. Besides, GBDAS also performs data aggregation for each cell heads in the chain. Yung-Kuei Chiang et al. [3] have proposed CBDAS in which the whole network region is partitioned into a logical grid of x*y cells, each has a head. All heads are linked together to form a cyclic chain. In EEDD Z. Zhou et al. [4] also divides the sensor field into small virtual grids and each grid has a head to transmit data. Each grid is further divided into four sub-grids if an event is continuous. Active nodes in the sub-grids are planned to stay active as per their slot. Neng-Chung Wang et al. [5] propose a dual-path-based data aggregation scheme (DPBDAS) for grid-based WSNs. The SNs are randomly classified as type A and type B. All SNs of type A and type B in the grid are further organized as group A and group B, respectively. Each cell has a head for each type. DPBDAS construct dual paths by linking each cell head of each group, respectively. Each group has a leader randomly chosen from cell heads on its own path, responsible for directly transmitting the data to the BS. In Group algorithm that is based on grid-based clustering randomly builds the cluster grid [6]. The CHs are arranged in a grid-like manner. Forwarding of queries from the sink to source node are propagated from the Grid Seed (GS) to its CHs, and so on. Rabia Noor Enam et al. [7] presented Distributed Uniform Clustering Algorithm (DUCA) divides the sensor area into grids and then head are selected based on LEACH. Therefore this method does not give assurance that each grid must have at least one head for data aggregation. GCMRA [8] divides the area into grids. Each grid forms a cluster. In each cluster, we select a normal sensor node as the CH, which has minimal distance from other SNs within the cluster and has residual energy more than threshold value. In order to avoid the delay of data transmission and the consumption of more energy, CHs communicate with sink through CHs which are closer to the sink.

B. Non-Grid Based Clustering Protocol

LEACH [9] is one of the hierarchical routing Protocols used for WSNs to improve the life time of network. LEACH performs self-organizing and re-clustering functions for every round. In every round node is elected as CH based on the probability. HEED [10] improves network life time over the LEACH. But, the performance of clustering in each round imposes significant overhead in the network. This overhead causes more energy dissipation. Similarly many clustering algorithms are proposed like TEEN [11], APTEEN [12] and CEBCRA [13].However, these are suffering from overhead and constructing a cluster in multiple levels is very complex task. EEUC [14] (Energy Efficient Uneven Clustering) algorithm is a distributed clustering algorithm, where CHs are elected by localized competition However; clustering in every round of EEUC imposes overhead. Power-Efficient GAthering in Sensor Information Systems (PEGASIS) is an efficient protocol [15] leads to significant redundant data transmission in the network. In Base Station Controlled Dynamic Clustering Protocol (BCDCP) [16], at the start of each round, all nodes send their current energy level to the sink. The sink chooses a set of CH based on their energy levels. To get a set of clusters with approximately equal sizes, the sink runs the cluster splitting algorithm iteratively.

III. DISTRIBUTED CLUSTERING BASED DATA AGGREGATION

We propose a distributed clustering based data aggregation approach for WSNs. The SNs are uniformly distributed in sensing region. All nodes can communicate with each other as well as with sink. We consider the assumptions as follows: SNs are aware about their location. After deployment nodes are stationary. Alternatively all SNs are of homogeneous type. Sink is located at center of region. Whenever node detects event it transmit data to sink via its cluster head. DCDA consists of the following phases; Grid Construction, Cluster head selection, Data transmission and Route maintenance phase.

A. Construction of Grid Structure

For simplification we consider square field as shown in Figure 1 which is further divided into equal grids of size $\alpha * \alpha$. Each grid is considered as cluster. Sink will provide the grid-ID based on the co-ordinates of the grid. In proposed scheme geographical coordinates (x,y) of sink become starting point for formation of square size grid. Let TH and TL be the transmission ranges of every SN while working in high and low power radio mode.

The grid cell is kept square with each side of size α set to:

$$\alpha = d / \sqrt{2} = (TH - TL) / \sqrt{2} \qquad (1)$$

Where *d* is the diagonal of a cell.

All other grid points (x_i, y_i) are calculated from sink(x,y) as:

$$\{x_i = x + i . \alpha,\ y_i = y + j . \alpha;\quad i,j = \pm 1, \pm 2, \pm 3, \dots\} \qquad (2)$$

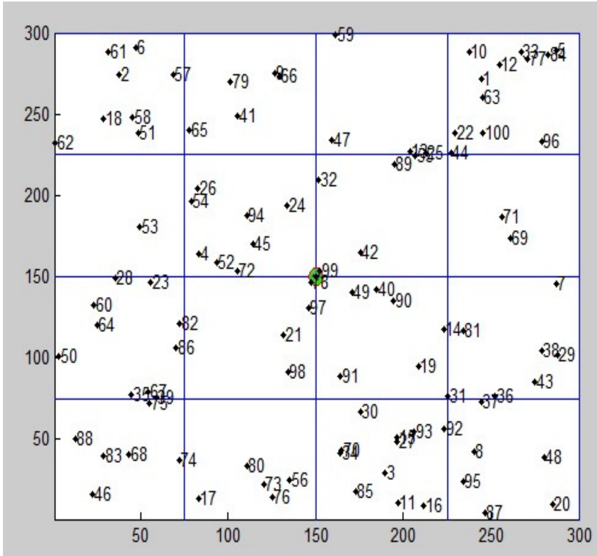

Fig .1.WSN with grid structure

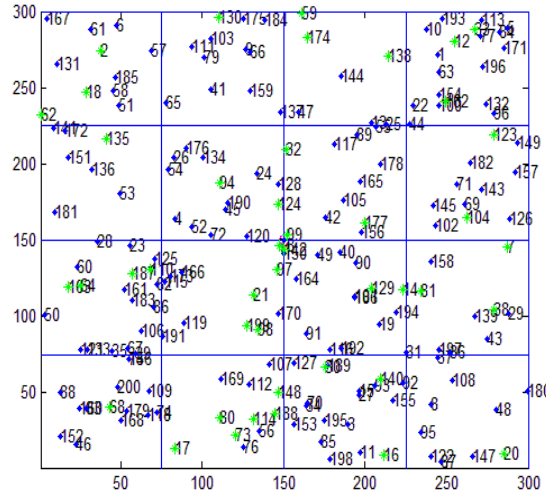

Fig .2. Cluster Head (shown by green color) selection

B. Cluster Head Selection

Phase 1: In each cluster, all members select their head which is responsible for collecting data from its members and transmitted aggregated data to sink. The method of Cluster head selection is adopted from improved LEACH (QBCDCP) [18] shown in Figure 2.In this approach, every node selects a number between 0 and 1 randomly. If this number is found below a threshold T(i), the node is decided as a CH for current round. In this case, the threshold T (i) is defined as:

$$T(i) = \frac{p}{1-p\left(r \bmod \frac{1}{p}\right)} \times \left[\left(\frac{E_{icurrent}}{E_{imax}}\right) + (rs*p)\left(1-\frac{E_{icurrent}}{E_{imax}}\right)\right] \quad if\ i \in G \qquad (3)$$

$$0 \quad otherwise$$

p : the desired percentage of cluster heads
G : the set of nodes that have not been cluster heads in last 1/P rounds
rs: the number of successive rounds in that a node has not been cluster head. It is reset to 0 after
a node becomes cluster head in a round and is increased for each round in which it does not
become cluster head.
r : current round.

Phase 2: In phase 1 more than one CH is selected in each grid. Therefore the aim of this phase is to elect one CH for each grid. For this all CHs elected in phase 1 broadcast their energy and IDs. One with highest energy is selected as CH. Once the CH has been elected, it broadcast hello packet with its ID to all members. On receiving this hello packet, the members send join packet to its CH.

C. Data Aggregation Phase

A CH C_i in a particular grid G_i collect the data from its members and forwards aggregated data to a CH C_j belonging to a neighbor grid G_j, which has the less distance from the sink. C_j Follow the same procedure for forwarding the data CH of one of its neighbor grids and the same procedure is continued until the data finally reached to the sink. However, all the CHs with one hop distance from the sink can directly communicate with the sink.

D. Route Maintenance Phase

In WSNs, few nodes or CH may be blocked due to lack of power, physical damage, or any environmental interference. The failure of SNs should not affect the performance of the sensor network .Routing and Medium access control (MAC) protocols must accommodate the formation of new routes to the sink. In DCDA routing protocol, CH can die after certain round that cause unexpected failures. Once the CH dies or is blocked, leading a certain area to be unreachable. However, re-clustering a whole network only to solve one failure may result in significant waste of resources. To guarantee the delivery, each CH, which forwarded a data, is responsible for ensuring that alternate successor [19] of minimum distance from sink has successfully received the packet. Seeking an alternative successor CH starts by the immediate downstream node of the broken link to find alternate CH having minimum distance from sink. This route maintenance process is described in Figure 3.

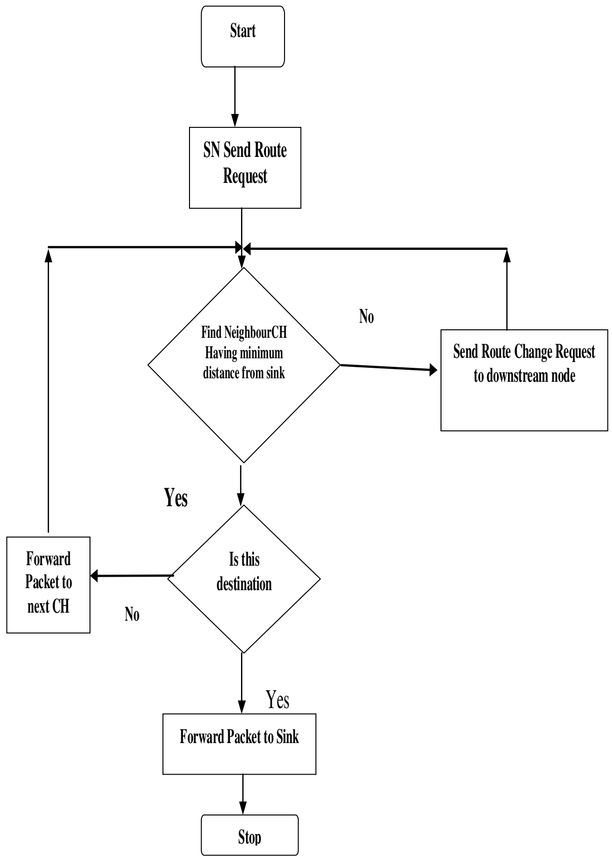

Fig .3. Flowchart for link failure maintenance [20]

IV. SIMULATION RESULTS

The proposed algorithm is implemented using MATLAB (version 7.5) on an Intel Core i7-2600 processor, 3.40 GHz CPU and 2 GB RAM running on the Microsoft Windows XP operating system. We considered a 300 × 300 square meter area in which 100 to 500 SNs are deployed randomly. Sink is assumed to be located at the centre of region. Each SN has an initial energy of 0.5 Joules. In the simulation, the energy model and the performance parameter values set same as LEACH. Evaluation parameters are residual energy and network lifetime. For the sake of comparison, we also simulate LEACH [9] and EEHC [17] on grid based WSN topology.

A. Network Lifetime

We evaluate the DCDA algorithm in terms of network lifetime which is defined as follows: time at which the first network node runs out of energy to send a packet. We compare the DCDA algorithm with grid based EEHC [17] and DUCA [7] by considering the different values of desired percentage of cluster head (p) varies from 0.3-0.4 as shown in Figure 4-5.

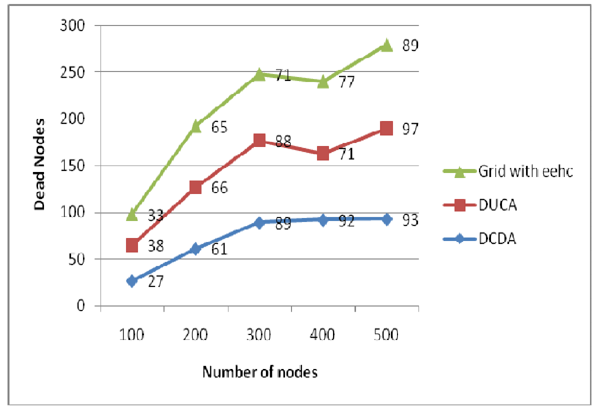

Fig. 4. Number of Dead Nodes at p=0.3

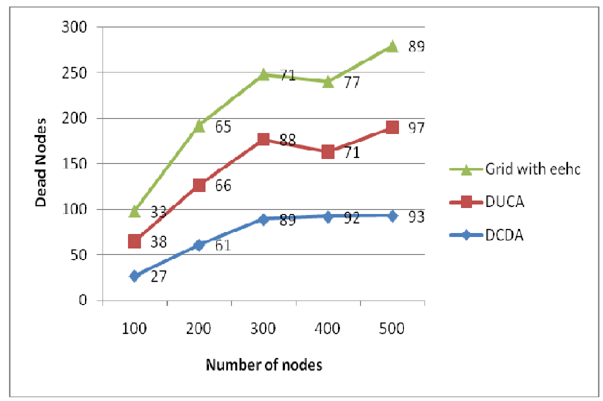

Fig . 5. Number of Dead Nodes at p=0.4

B. Impact of p on Residual Energy

Based on probability of desired percentage of cluster head we plot the results for the energy consumption of the network against number of nodes for the DCDA and compared grid based EEHC and grid based LEACH by considering the different values of desired percentage of cluster head (p) varies from 0.3-0.4. It is obvious to note that our work performs better than DUCA and grid based EEHC as shown in Figure 6 and Figure 7.

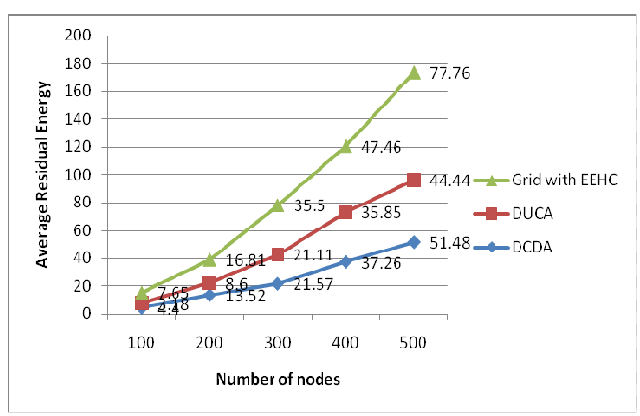

Fig. 6. Average Residual Energy at p=0.3

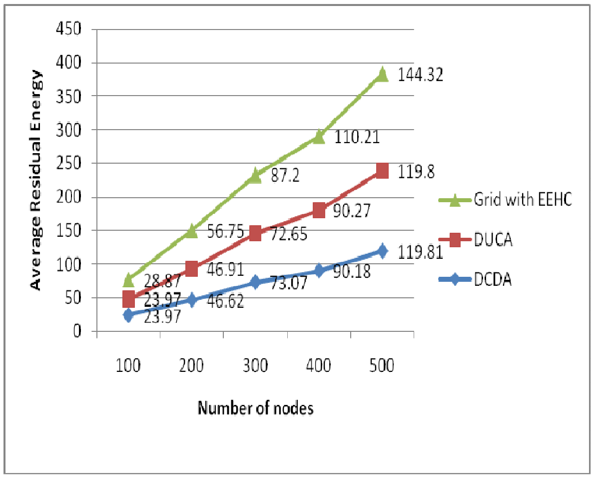

Fig. 7. Average Residual Energy at p=0.4

V. CONCLUSION

The WSNs have been envisioned to help in numerous monitoring applications. Cluster-based architecture is an effective architecture for data-gathering in wireless sensor networks. In this paper, we have developed a Distributed Clustering Based Data Aggregation (DCDA) algorithm for grid based WSN. Energy efficient grid based data aggregation is paramount to extend the lifetime of the system. Simulations are carried out to evaluate the performance which shows that the use of aforementioned parameters for clustering in protocol significantly reduces the overall energy consumption of whole network. Further direction of this work will deal with utilizing the same for duty cycling to improve the overall network performance.

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