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Efficient Cluster Based Data Collection Using Mobile Data Collector for Wireless Sensor Network

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ABSTRACT
Establishing an efficient data gathering scheme in wireless sensor networks is a challenging task. Lot of researches has been carried out to establish energy efficient data gathering scheme to avoid heavy traffic received by the nodes near the sink. Data gathering scheme is a significant factor in determining the network lifetime. In this paper we propose an efficient data gathering scheme by introducing clustering and mobility into the wireless sensor network. We consider data collection in wireless sensor networks by utilizing mobile data collector and cluster heads. Cluster heads are chosen and clusters are formed to collect data from the sensor nodes. The proposed scheme finds the shortest tour for the mobile data collector to collect data from the cluster heads. The shortest tour saves time and energy in data gathering.

Keywords: *Wireless Sensor Networks, Mobile Data Collector, Sink, Cluster Heads, Minimum Spanning Tree, LEACH, Network Lifetime*

I. INTRODUCTION

Wireless Sensor Network (WSN) has been emerged as a new paradigm for information gathering in recent years. WSN is a collection of sensor nodes which are deployed in an application area to monitor certain events [1]. WSN plays a significant role in diverse applications such as health monitoring, emergency response, agriculture, smart transportation, military applications etc. [2]. In spite of the application of WSNs being diverse, most of them have a common feature i.e. collection of data at the sink. While collecting the data at the sink, the nodes near the sink consume more energy as they receive heavy traffic. These nodes have the responsibility of forwarding the data to the sink which results in their early depletion compared to the nodes which are farther away from the sink. When these sensor nodes fail, the faraway sensors cannot reach the sink. This results in disconnected network and network failure. Therefore, to collect the data efficiently without these negative impacts is known as data gathering problem [3].

Finding an effective solution to the data gathering problem is a challenging task as it determines the network lifetime. By establishing a well-organized data gathering scheme, the network lifetime of the WSN can be increased. Mobility can be introduced in the WSNs to reduce the uneven energy consumption among the sensor nodes and to solve the data gathering problem. In this paper we introduce mobility into the WSN via mobile data collector.

In this paper, we propose a data gathering scheme which employs clustering and mobility in WSNs for data collection. Clusters are formed and the sensor nodes send data to the cluster heads. The shortest traversal order is calculated for the mobile data collector to visit the cluster heads in the WSN. The mobile data collector visits the cluster heads in the calculated traversal order and collects data from the cluster heads and finally delivers the data to the sink. The shortest traversal order saves time and energy in data gathering and hence is an effective data gathering approach which increases the network lifetime.

The rest of the paper is designed as follows: Related work is discussed in section II. Section III discusses the proposed scheme. Simulation results are discussed in section IV. Section V summarizes the paper.

II. RELATED WORK

Establishing energy efficient data gathering scheme has been a challenging research work and lot of researches have been carried out to achieve this. Researches already carried out in this field are discussed in this section.

Data gathering problem is considered in the paper proposed by Ming Ma et al. [4]. Here, the mobile collector (M-collector) visits the communication range of each sensor and collects data within a single hop communication. The data is collected without relay. Here, the focus is on prolonging the network lifetime.

Usage of multiple mobile data collectors and spatial division multiple access (SDMA) technique for data-aggregation in WSNs has been introduced by Miao Zhao et al. [5]. Here, mobile collector known as SenCar is employed in the divided non-overlapping regions of the sensing field. The data gathering problem is solved using multiple mobile collectors and the network lifetime is increased.

Upasana Sharma et al. [3] have proposed mobile data gathering scheme which uses Mobile Data Collector (MDC) to collect data from the cluster heads. MDC dynamically changes its gathering tour by making use of information in a Neighbour Information Table (NIT). Cluster heads create NIT by learning about its neighbours. MDC utilizes the information in NIT and decides its traversal tour. This paper discusses the dynamic path reduction and data filtration in WSNs.

Controllable mobility approach is considered in the paper proposed by S. Chowdhury et al. [6]. Here, the minimum set of sensors is chosen as Data Collection Points (DCPs). The mobile data collector visits these DCPs in a specific sequence. Minimization of hop count and tour length of mobile data collector to conserve energy is discussed in this paper.

Minimizing the data gathering cost has been discussed in the paper proposed by S. Guo et al. [7]. Here, the mobile data collector collects the data at the anchor points. The mobile data collector moves in the sensing field to collect data from the anchor points. The mobile data collector stays at the anchor point for a short duration to gather the data forwarded by the sensor nodes. Nonuniform energy consumption among the sensor nodes is eliminated and the data gathering latency is shortened in this approach.

III. PROPOSED SCHEME

Proposed scheme creates well organized wireless sensor network for data collection by creating clusters. Mobile node i.e. Mobile Data Collector (MDC) is used to move and collect data from the Cluster Heads (CHs). Data is collected from CHs at low cost via. MDC. MDC visits the CHs in the shortest path and hence it results in efficient data collection. Fig-1 gives the basic idea of the proposed scheme. Fig-1 shows an example of shortest tour path of MDC visiting each CHs. Sensor nodes are randomly distributed in the WSN and they result in homogeneous network as the nodes are of similar type. It is assumed that the sensor nodes are aware of their coordinates.

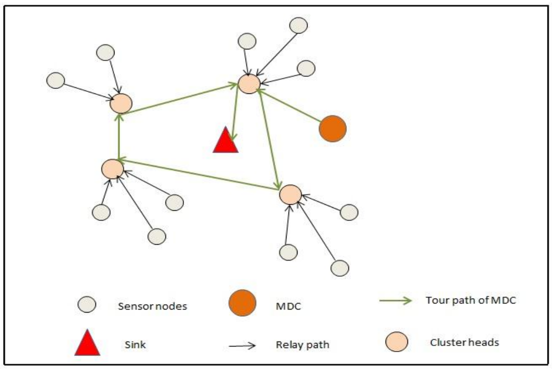

Fig 1 Proposed scheme

The goal of the proposed scheme is to increase the network lifetime and also to reduce traffic load and energy consumption of the sensor nodes near the sink. In this scheme, initially we select the CHs among the randomly distributed nodes using CH selection algorithm of LEACH. Next we form cluster of nodes and find the shortest traversal path for the MDC to collect data from the CHs. The MDC then has to approach each CH in this path and collect data from the CHs and finally transfer the data to the sink. We use a TSP solver to find the shortest path for MDC.

1.1. LEACH Protocol

One of the clustering based hierarchical-routing protocols is Low-Energy Adaptive Clustering Hierarchy (LEACH). Based on the threshold values the CHs are randomly selected in LEACH protocol.

1.2. CH Selection Algorithm of LEACH Protocol

Here, the nodes are randomly distributed in a network. Each node takes a decision whether to become a CH for current round or not. Here, each node will generate a random number in the range of 0-1. If the number is less than threshold value, then node is CH for the current round. Threshold is given by equation (1).

$$T_n = \frac{P_n}{1-P_n(R \bmod \frac{1}{P_n})} \qquad (1)$$

where T_n is the threshold value calculated for the node, P_n is the percentage of CHs in each round, R is the current round. P_n is calculated using equation (2).

$$P_n = \frac{Number\ of\ clusters\ (K)}{Number\ of\ nodes} \qquad (2)$$

To determine the number of clusters i.e. K, heuristics used in LEACH is used. Given N number of nodes, partition the sensor field into K uniform-sized clusters using equation (3), where K is a squared number.

$$K = \begin{cases} 4 & N \times 0.05 \leq 6 \\ 9 & 6 < N \times 0.05 \leq 12 \\ 16 & 12 < N \times 0.05 \leq 20 \\ . & . \\ . & . \end{cases} \qquad (3)$$

Thus the CHs are selected using the CH selection algorithm of the LEACH protocol. Once the CHs are selected, the sensor nodes form clusters by using the clustering approach which is discussed below.

1.3 Clustering approach

The clustering algorithm given below forms the cluster of nodes under the selected CHs. Each sensor nodes with co-ordinates (x, y) calculates minimum distance using equation (4).

$$d = \min\left\{\sqrt{(x - x_a)^2 + (y - y_b)^2}\right\} \ (x_a, y_b) \in CH\ coordinates \quad (4)$$

Sensor nodes form clusters by assigning themselves to the CHs which is at minimum distance to them. The clusters are formed using clustering algorithm and the traffic is set between CHs and the sensor nodes. Once the clusters are formed, the shortest traversal path for MDC is calculated.

Clustering Algorithm

Input: An array CH with M number of CHs, Nodes 0 to N in WSNs

Output: Cluster of nodes

1. Compute distance between each sensor nodes to elements of array CH
2. Store the results in matrix1
3. Find the minimum distance in matrix1
4. Find the corresponding column index of the minimum distance element
5. The corresponding column index gives the array index of the CH with minimum distance
6. Select the CH with minimum distance and store it in an array D
7. The array indices of D indicate nodes and the elements of array are the CHs with minimum distance
8. Create a matrix2 with number of rows and columns equal to number of nodes
9. If the row indices of the matrix2 matches with elements of array D, mark the corresponding column element of matrix2 as 1

1.4 Finding Shortest Traversal Path

The shortest traversal tour planning is required for MDC. The shortest traversal tour of MDC consists of CH nodes to be visited. For example, let $C = \{c_1, c_2, \dots\dots . c_t\}$ denote CH nodes selected for traversal and M be the MDC then the traversal tour for MDC can be denoted as $M \rightarrow c_1 \rightarrow c_2 \rightarrow \cdots \rightarrow c_t$. The problem of finding shortest traversal path is to determine the shortest visiting order for CH nodes.

First calculate the distance between each CH nodes and create a complete weighted graph $G(V_i,E_i)$, where V_i is the set of homogeneous sensor nodes selected as CHs and E_i is the set of edges between the CH nodes present in G. Find the Minimum Spanning Tree possible for this complete graph using Prims algorithm. This MST gives a tree with minimum weight of edges connecting any two vertices in a graph.

Prims algorithm: Finding MST

1. Select any vertex V_i in $G(V_i,E_i)$
2. Select the shortest-edge connected to the selected vertex
3. Select the shortest-edge connected to any vertex already connected
4. Repeat step 3 until all the vertices are connected

Applying Depth First Search to the MST we find the traversal order of CH nodes to be visited by MDC. The MDC traverses the CHs in the calculated order and collects data from CHs and finally hands over data to the sink.

IV. SIMULATION RESULTS

The proposed scheme is simulated using ns2. It is simulated for different topologies with 20, 40, 60, 80 and 100 nodes. The shortest traversal path is calculated in C++. Mobile node moves with a speed of 5m/s and gathers data from the CHs. The simulation parameters used in this project are shown in Table-1.

Table 1. Simulation parameters

Parameter	Values
Number of Nodes	20,40,60,80,100
Simulation area	500*500
Initial Energy of Sensor Node	100J
Traffic Source	CBR
Transmission Protocol	UDP
Packet size	512 bytes
Communication range	50 meters

The simulation of proposed scheme is shown in Figure 1. The CHs selected are highlighted and even the MDC and the sink. The network lifetime is determined for various topologies and the graphs are plotted with number of nodes in X-axis and network lifetime along Y-axis.

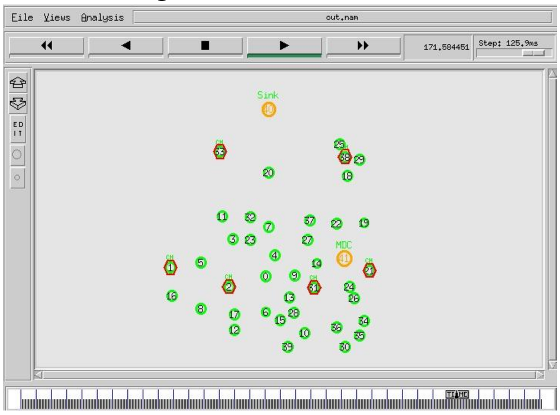

Fig 2. Simulation of proposed scheme for 40 nodes

The sensor nodes are randomly distributed as shown in Fig-2.The nodes selected as cluster heads are labeled as CH as shown in the Fig-2.

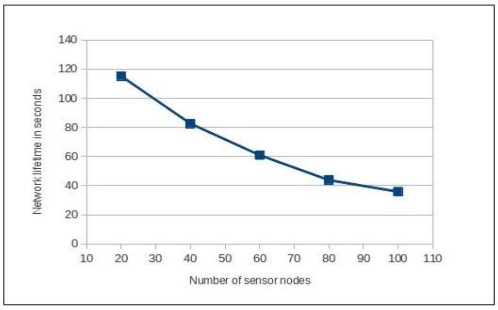

Fig 3. Number of nodes vs. network lifetime

Fig-3 shows the graph plotted for network lifetime. The threshold value is fixed and the network lifetime is calculated for 20, 40, 60, 80 and 100 nodes. Fig-4 shows the graph plotted for the average energy consumption of the network for 20, 40, 60, 80 and 100 nodes.

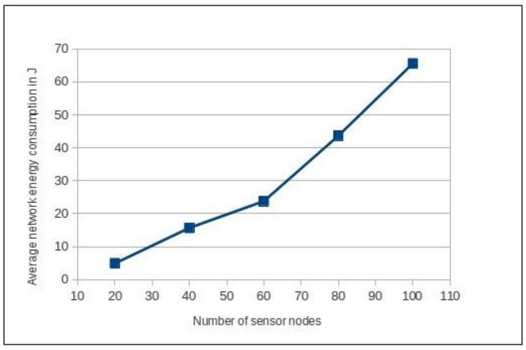

Fig 4. Number of nodes vs. average energy consumption

V. CONCLUSION

The proposed scheme achieves efficient data collection using MDC and it is more effective compared to the static data collector. This scheme can be improvised to reduce the energy consumption between the MDC and the sink by reducing the data transmission between MDC and the sink. Cluster based approach is used in the proposed scheme where sensor nodes form clusters and send data to the CHs. The data aggregated at the CHs are forwarded to the sink via MDC. The best traversal order is used by the MDC to visit the CHs to collect data. The shortest traversal order used by the MDC saves time and energy in data collection and hence is an effective solution for data gathering problem. The proposed scheme increases the network lifetime and reduces the load on the sensor nodes near the sink.

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