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A Cluster Based Data Gathering for WSNs

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ABSTRACT: Optimizing data gathering in wireless sensor network is a challenging task. Research has been carried out to establish an energy efficient data gathering schemes to avoid heavy traffic received by the nodes near the sink. Introducing mobility in the network can increase network lifetime and reduce early depletion of nodes close to the sink. In this paper, we propose an energy efficient data gathering approach by introducing mobility into the wireless sensor network via mobile data collector. The proposed approach finds a shortest traversal path for the mobile data collector to collect data from the cluster heads. Shortest tour plan saves time and energy in data gathering.

KEYWORDS: Wireless Sensor Networks, Mobile Data Collector, Cluster Heads, Sink

I. INTRODUCTION

A Wireless Sensor Network (WSN) consists of sensor nodes to sense and route the information to the sink [1]. These sensor nodes are used to monitor certain events like overheating, fire etc. in the environment. WSN is an emerging technology and plays a significant role in variety of applications, such as environmental monitoring, health monitoring, emergency response, military applications etc. Recent advancement in technology has resulted in the development of small-sized low-cost, low-power and multi-functional sensor devices [2]. While the sensors sense and route the information to the sink there may be uneven energy consumption among the sensors as the sensors near the sink receive heavy traffic. Thus, nearby nodes are depleted of their energy and the sink becomes isolated resulting in network failure. So, how to collect the data efficiently without these negative issues is known as data gathering problem [3].

Data gathering problem is the most challenging issue in WSNs as it determines the network lifetime. Introducing mobility in WSNs has been an effective solution to eliminate the uneven energy consumption among the sensors and data gathering problem. In this paper, we propose cluster based WSN for optimizing data collection using mobile data collector (MDC). Here, MDC is utilized for data gathering. Initially cluster heads are selected among the sensor nodes to collect data through short range communications and the clusters are formed. The shortest traversal path for the MDC is calculated. The MDC moves in this calculated path and collects data from the cluster heads. The shortest traversal path saves time and energy. The MDC finally carries the data to the sink. The network lifetime can be increased when this proposed scheme is used.

The rest of the paper is structured 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

In this section, we have reviewed the related research work regarding MDC for data gathering. Few works pertaining to data filtration and aggregation in WSNs are also reviewed.

Data gathering approach using M-collector has been proposed by Ming Ma et al. [4]. Here, the data gathering periodically starts from the static-data sink by M-collector and the M-collector polls sensor nodes while traversing the communication range of the sensor nodes, and gathers data within a single-hop and finally forwards the data to the static sink. Single hop data gathering problem is discussed in this paper where the main intension is to reduce the length of the data collection tour.

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Utilization of multiple mobile data collectors and spatial division multiple access (SDMA) technique for data collection in WSNs has been proposed by Miao Zhao et al. [5]. Here, the division of sensing field into many non-overlapping regions is done and each region have mobile collector known as SenCar. The main focus is on solving the data gathering problem with multiple mobile data collectors and also SDMA (DG-MS) problem.

Mobile data gathering scheme using MDC where MDC dynamically changes its gathering tour has been proposed by Upasana Sharma et al. [3]. Here, each cluster head creates a Neighbour Information Table (NIT) by learning about its neighbours. MDC decides its tour by utilizing the information in NIT. Data filtering is applied while collecting the data. The focus is on dynamic path reduction and data filtering in this approach.

Data Collection Point (DCP) based scheme has been proposed by S. Chowdhury et al. [6]. Here, subsets of sensors are selected as the DCPs. A set of minimum paths connecting each sensor node to a DCP is found. The focus is on minimizing the average relay-hop count and also tour-length of MC that visits all DCPs.

Data Gathering Cost Minimization (DaGCM) optimization framework has been proposed by S. Guo et al. [7]. In this framework sensors upload data concurrently to the mobile collector (MC). Shortening of data-gathering latency with significant reduction of energy consumption with the use of space-division multiple access technique and multiple antennas can be obtained with simultaneous data uploading from sensors to MC.

In this way, all the above schemes have investigated various issues. Majority of the techniques propose different strategy of routing for the static WSNs where nodes are stationary. Pre-existing information for the MDC movement is required in majority of the techniques proposed. Considering these issue and to deal with some of them, cluster based wireless sensor network for optimizing data collection using mobile data collector has been proposed in this paper.

III. PROPOSED SCHEME

Proposed scheme creates cluster based wireless sensor network for optimizing the data collection and uses a mobile node known as Mobile Data Collector (MDC) to collect data from the Cluster Heads (CHs). MDC is used to collect data from sensor nodes at low-cost in the network. The main intention of the proposed scheme is to solve the data gathering problem and use an efficient method to collect the data. Tens to hundreds of sensor nodes are distributed randomly in the application area. These all nodes are similar type of nodes constituting a homogeneous network. We assume that the sensor nodes are aware of their location.

The goal of the proposed scheme is to reduce traffic load and energy consumption, and it can also reduce burden of the sensor nodes near the sink. In this scheme, we first select the CHs among the randomly distributed nodes using CH selection algorithm of LEACH. The second step is to form cluster of nodes. The third step is to find the shortest traversal path for the MDC to collect data from the CHs. The MDC then has to visit 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.

A. LEACH protocol

One of the clustering based hierarchical-routing protocols is Low-Energy Adaptive Clustering Hierarchy (LEACH). In this protocol CHs are selected randomly based on a threshold value. To reduce the energy consumed by surrounding sensor nodes of the static sink this protocol is used. To increase the lifespan of the network LEACH protocol is used.

B. 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).

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

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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).

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

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.

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

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.

C. Clustering approach

The clustering algorithm is used to form the cluster of nodes under the selected CHs. Each sensor nodes with coordinates (x, y) calculates minimum distance using equation (4).

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

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

D. 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 $C = \{c_1, c_2, \dots, c_T\}$ denote CH nodes selected for traversal and M be the MDC then the traversal tour for MDC can be denoted as $M \rightarrow c_1 \rightarrow c_2 \rightarrow \dots \rightarrow c_T$. 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 Prim's algorithm. This MST gives a tree with minimum weight of edges connecting any two vertices in a graph.

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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 and 80 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: Parameters of Simulation

Parameters	Values
Number of Nodes	20,40,60,80,100
Communication Range	50m
Initial Energy of Sensor Node	100J
Traffic Source	CBR
Channel Type	Wireless
MAC	MAC/802.11
Transmission Protocol	UDP

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.

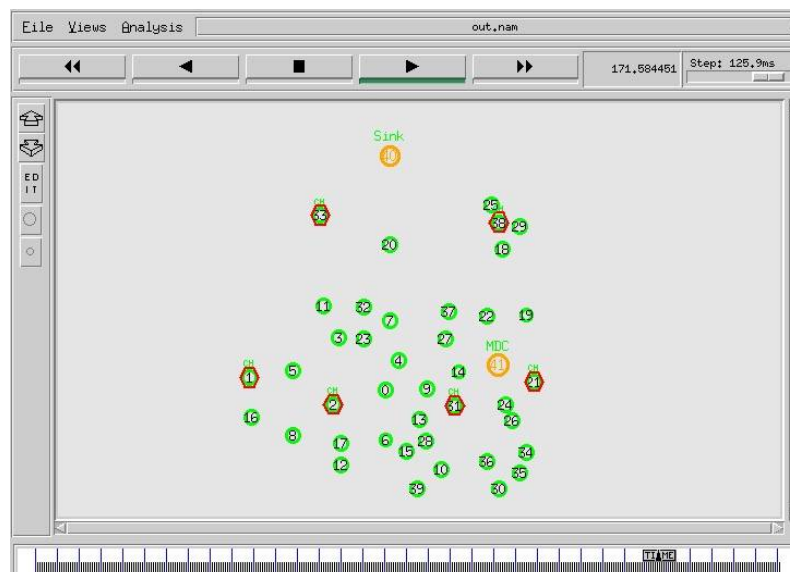


Figure 1: Simulation of proposed scheme

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The sensor nodes are randomly distributed as shown in Figure-1. Some of the nodes selected as cluster heads are labeled as CH as shown in the Figure-1. Figure-1 shows the simulation of proposed scheme for 40 sensor nodes. The mobile node MDC moves in the shortest traversal order and collects data from the CHs. MDC finally delivers the data to the static sink.

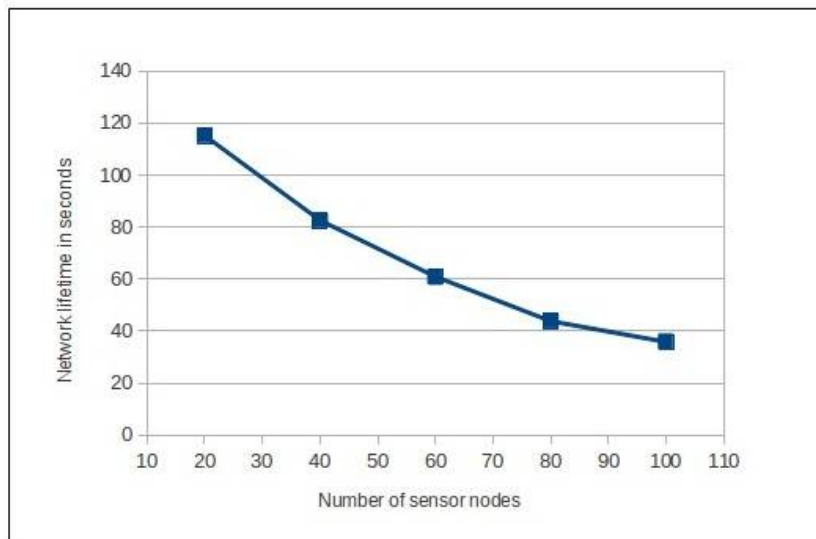


Figure 2: Number of nodes vs. network lifetime

Figure-2 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. Figure-3 shows the graph plotted for the average energy consumption of the network for 20, 40, 60, 80 and 100 nodes.

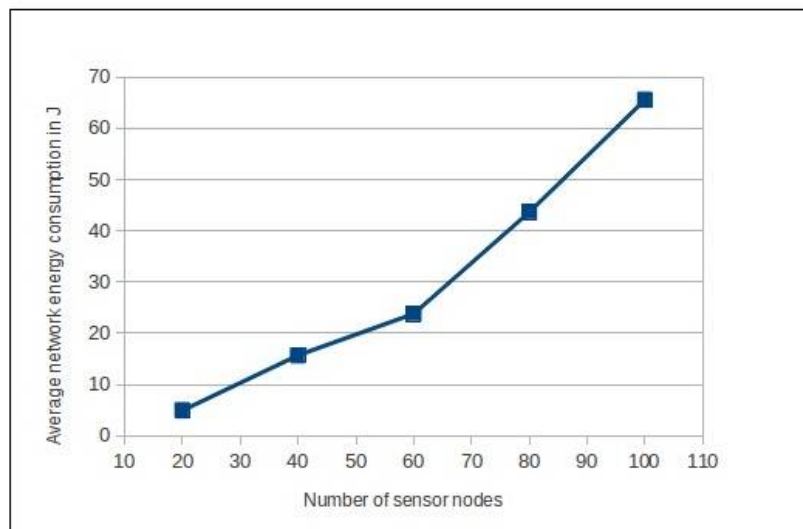


Figure 3: Number of nodes vs. average energy consumption

V. CONCLUSION

Effectiveness of MDC in data-gathering is better compared to static data collector. Improving these schemes by making them more energy-efficient and reducing the data transmission among MDC and sink is necessary. The

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proposed approach uses the cluster based WSN wherein sensor nodes form clusters. One of the nodes is chosen as a CH. Sink receives the data which is aggregated by the CHs from its children and which is sent via MDC. MDC follows the best traversal order and approaches the CHs with this order to collect data and saves time and energy. Burden faced by the sensor nodes near to the sink can be reduced by this proposed approach and hence increase in network lifetime can be achieved.

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