Efficient Data Collection in Wireless Sensor Networks with Dynamic Deadlines

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Abstract - Mobile element is used in wireless sensor network (WSN) to minimize the data collection overhead and hence to enhance the network lifetime. Scheduling of mobile element in WSN is an important research area topic. Different sensor nodes sample data at different rates, so mobile element has to visit sensor nodes before their buffer overflow occurs. One such scheduling algorithm is Earliest Deadline First algorithm (EDF), in which mobile element visit is determined based on deadline of the sensor nodes. But EDF algorithm suffers from certain drawback. In this paper we highlight the drawback of EDF algorithm and propose Modified Earliest Deadline First (MEDF) algorithm which overcomes the drawback of EDF algorithm.

Keywords—Wireless sensor network; Mobile element; Buffer overflow

I. INTRODUCTION

Wireless sensor network (WSN) consist of collection of large number of randomly deployed sensor nodes. They are used to sense various environmental parameters such as temperature, pollution level and pressure. WSN has got applications in variety of fields such as environmental monitoring, military purposes and gathering sensing information in inhospitable locations. Each sensor node consists of components such as battery, sensor unit, microprocessor, transceiver and memory.

Sensor node consumes energy when they transmit or receive data. Lifetime of sensor network heavily depends upon battery power of sensor nodes [1]. In order to extend network lifetime, energy consumption during multi-hop communication should be minimized [2]. Many routing protocols are proposed by researchers to improve energy efficiency in WSN. During selection of protocols for data transfer, various types of theoretical and practical challenges arise. Thus achieving energy efficiency is an important challenge in WSN. Since the sensor nodes are usually deployed in remote areas, manual replacement of battery is not a feasible solution for achieving energy efficiency. We consider energy optimization in WSNs where nodes have different deadline values. i.e. they sample data at different rates and hence their buffer overflows at different rates. For example pollution level can be monitored at different areas in a large city with the help of sensor nodes. Pollution level varies from region to region. The region in which pollution level varies rapidly should be sensed more frequently than other areas where pollution level remains relatively low.

Sensor readings can be transferred to the central location in various ways. Typically, data sensed by the sensor nodes are transferred to a central base station via multi-hop transmission. Even though this technique is suitable for transfer of data, nodes near the base station receives heavy traffic from far away nodes which results in non uniform depletion of the energy in the network. Due to heavy traffic, nodes near the base station losses battery power quickly than nodes that is far away from base station. When nodes die due to absence of energy, network gets disconnected. This phenomenon is called as “Energy Hole Problem”. Mobile element is used as a solution to overcome energy hole problem. Mobile element plays the role of data collector. Mobile element travels around the sensor field and collects data from sensor nodes regularly.

Each sensor node has got buffer of finite capacity for storing sensed data. When sensed data exceeds buffer capacity, packet loss occurs. To prevent data loss due to buffer overflow, mobile element is introduced in WSN. Mobile element move towards sensor nodes based on their deadline values and collects data before buffer overflow occurs. Earliest Deadline First (EDF) algorithm is used for scheduling of mobile element towards sensor nodes. In EDF algorithm, mobile element visits the sensor node whose deadline is minimum. This algorithm is designed to be used in sensor network where sensor nodes sample data at varying rates.

In this paper, we highlight EDF algorithm and mention its drawback. We made a small change in EDF algorithm to overcome this drawback. Modified Earliest Deadline First (MEDF) algorithm enables mobile element to collect data from sensor nodes before their buffer overflow occurs. The aim of this algorithm is to minimize data loss by scheduling mobile element based on the nodes deadlines.

This paper is organized as follows. Section 2 discusses about various research work carried on sink mobility. In Section 3 we define Mobile Element Scheduling (MES) problem. Section 4 highlights drawback of EDF algorithm with the help of an example. MEDF algorithm is presented in Section 5. Results and performance analysis are highlighted in Section 6. Section 7 concludes the paper.

II. RELATED WORK

Many researchers focused on exploiting sink mobility in WSN. Sink mobility helps in overcoming energy hole problem and improving network lifetime. R. C. Shah et.al [3] proposed three tier architecture for collection of data from sparse sensor networks. In sparse sensor networks mobile entities are called as MULEs. MULEs are responsible for collection of data from sensor nodes. When MULES come in close range of sensor nodes, they capture data. Captured data is buffered and sent to wired access points. This will result in lot of power savings at the sensor nodes, because only short range transmission is needed for sensor node. MULE architecture consists of three tiers. They are Top tier, Middle tier and Bottom tier. Top tier is made up of access points. Access point is responsible for collecting the data from MULE and sending it to WAN. Middle tier consists of mobile transport agents. Transport agents provide connectivity to the network. Bottom tier contains randomly scattered sensor nodes. Kansal et al. [4] proposed adaptive algorithm to control mobility in WSN. Arun A Somasundara et al. [5] proposed EDF algorithm for mobile element scheduling. In EDF algorithm mobile element move towards the sensor node whose deadline is minimum. They also proposed Minimum Weighted Sum First (MWSF) algorithm in which weight is assigned to each sensor node. In MWSF, mobile element should visit sensor node whose weighted sum is minimum. EDF differs from Travelling Salesman Problem (TSP) [6] because in EDF, a node may be visited more than once depending upon deadline value. Zhao et.al. [7] proposed Message Ferrying (MF) scheme for adhoc networks. Using this scheme efficient data delivery is achieved in disconnected ad hoc networks. Sensor nodes move voluntarily and send or receive messages. Non-randomness is introduced in node's proactive movement and thus performance in a disconnected network is enhanced.

III. PROBLEM FORMULATION

We consider a complete graph having m number of sensor nodes with different deadline values. We consider a single mobile element for data collection which is scheduled based on the deadline of sensor nodes. We assume that mobile element has the complete topology information and aware of the deadline at every node. The goal is to find a mobile element schedule that visits nodes, such that it minimizes data loss due to buffer overflow. The Mobile Element Scheduling (MES) problem deals with proper identification of sensor nodes which should be visited before its buffer overflows. Whenever node is visited its deadline is updated. Nodes with smaller deadlines will suffer from early buffer overflow; hence those nodes should be visited early compared to nodes with larger deadline values. EDF algorithm is one of mobile element scheduling algorithm which is explained in detail in next section.

IV. EARLIEST DEADLINE FIRST ALGORITHM

In EDF algorithm, mobile element visits the sensor node whose deadline is minimum. Whenever a sensor node is visited by mobile element, its deadline is updated for the next visit. Fig. 1 shows a randomly deployed WSN with four sensor nodes. Each sensor node is assigned with deadline value. Cost assigned to an edge is the time taken by mobile sink to reach the other end node. The node at which the mobile element is collecting data is called as current node. After the data collection, deadline of the current node is updated for the next visit. Updating deadline of a particular sensor node indicates that mobile element has visited it and hence its buffer is freed so that it can start collecting the data for the next visit. Table I shows sequence of visits of mobile element in EDF algorithm and algorithm terminates after visiting certain sensor nodes.

In EDF, if the mobile element fails to meet the deadline of a node, the algorithm terminates immediately and data collection process ends. For example, the node D is currently visited by the mobile element as shown in row 4 of the Table I. The next node to be visited is C (node with next shortest deadline) but the mobile sink fails to meet the deadline and the algorithm terminates immediately. Even though sink node can still satisfy deadline constraints of node A and B, EDF algorithm terminates when it fail to meet the deadline of node C. Therefore we can incorporate a small change into EDF, such that the algorithm continues if any other visit satisfies deadline constraint. In this way the number of packets collected can be increased and data loss can be minimized. In the next section we present the modified algorithm.

TABLE I. EARLIEST DEADLINE FIRST ALGORITHM

Current time	Current Node	Deadline (A,B,C,D)
0	A	700,1000,100,300
24	C	700,1000,124,300
93	D	700,1000,124,393
		Failure and terminate

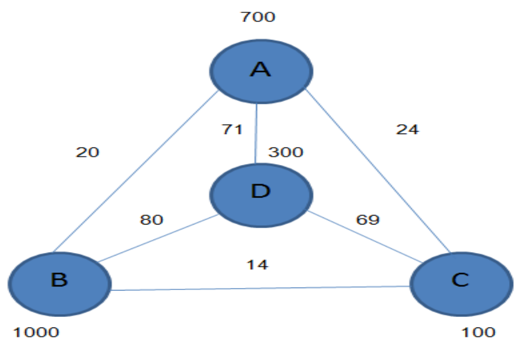

Fig.1.Randomly deployed sensor nodes

V. MODIFIED EARLIEST DEADLINE FIRST ALGORITHM

In this section we explain Modified Earliest Deadline First (MEDF) algorithm in detail. The MEDF algorithm takes same input parameters as EDF algorithm and proceeds to collect more data until none of the nodes meets the deadline. MEDF algorithm is given below.

Algorithm: Modified Earliest Deadline First (MEDF)

- Input: cost [1..m][1..m], overflow_time[1..m], start_node
- Initialization: current_time = 0, current_node = start_node ,deadline [1...m] = overflow_time[1...m]

1. Choose the node i ≠ current_ node whose deadline is closest
2. If deadline[i] < current_time +cost[current_node][i]

   Then choose node i such that deadline[i] > current_time+ cost[current_node][i] and deadline[i] is minimum and update the following.

   - current_time += cost [current_node][i]
   - current_node =i
   - deadline [i]=current_time +overflow_ time[i]

   Otherwise declare Failure and stop
3. Else
   - current_time +=cost [current_node][i]
   - current_node =i
   - deadline[i]= current_time + overflow_ time[i]

TABLE II. MODIFIED EARLIEST DEADLINE FIRST ALGORITHM

Current time	Current Node	Deadline (A,B,C,D)
0	A	700,1000,100,300
24	C	700,1000,124,300
93	D	700,1000,124,393
164	A	864,1000,124,393
235	D	864,1000,124,535
306	A	1006,1000,124,535

If condition in the step2 is satisfied, a node is chosen in such a way that deadline of chosen node is greater than sum of current time and time needed to move between current node and chosen node. If such a node does not exist then the algorithm terminates. Table II shows sequence of visits of mobile element in the MEDF algorithm. Even though sink node fails to visit node C after node D (as indicated in row 4) algorithm does not terminates. Sink node visit node A and thus satisfies its deadline requirements. Thus modified version enhances network lifetime.

VI. EXPERIMENT AND RESULTS

We simulated EDF algorithm and MEDF algorithm using NS2. The simulation is done for varying topology consisting of 20,40,60,80 and 100 nodes. Each sensor node is initially assigned with the energy of 100 Joules. We used fixed size of packets and constant bit-rate traffic. Transmitter power and receiver power is set as 1.0mW and 3.0mW respectively. The detail of simulation parameters is highlighted in Table III. Fig. 2 shows the screen shot of proposed MEDF algorithm.

TABLE III. SIMULATION PARAMETERS

No. of Nodes	20,40,60,80,100
Simulation Area	500m*500m
Initial Energy of Sensor Nodes	100J
Traffic Source	CBR
Channel Type	Wireless
Routing protocol	Dumb Agent
Sensing range of node	25 meters
Transmitter power	1.0mW
Receiver power	3.0mW
MAC	MAC/802.11
Agent Type	UDP

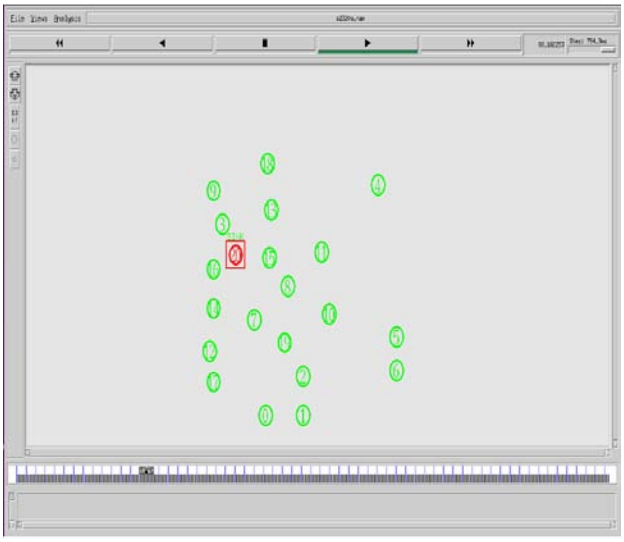

Fig. 2. Simulation of Modified Earliest Deadline First algorithm

Fig. 3 shows number of packets received by sink versus number of nodes. As number of nodes increases sink nodes receives more packets and hence throughput increases. Fig. 4 shows average network energy consumption (in joules) for different number of nodes. As number of nodes increases average network energy consumption increases. This is because as number of nodes increases more data transfer takes place hence more energy is consumed by individual sensor nodes. Fig. 5 shows number of nodes versus network lifetime. Network lifetime is the time at which first node of sensor network dies due to absence of energy. It is clear from figure that as number of nodes increases network lifetime decreases.

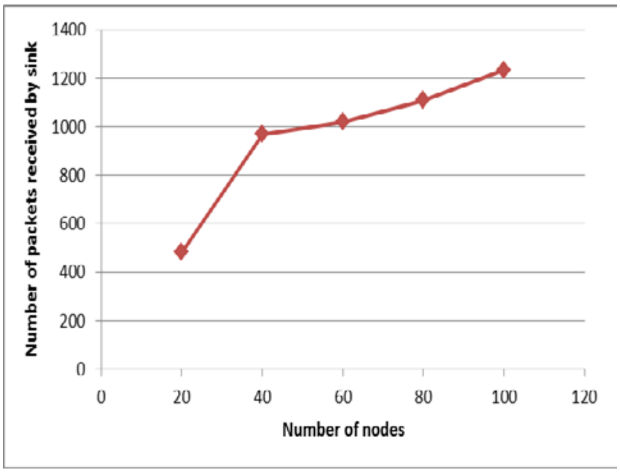

Fig. 3. Number of packet received by sink versus no of nodes

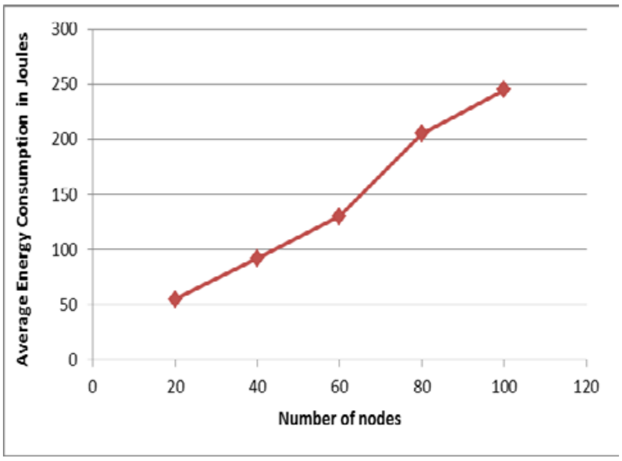

Fig. 4. Energy Consumption versus no of nodes

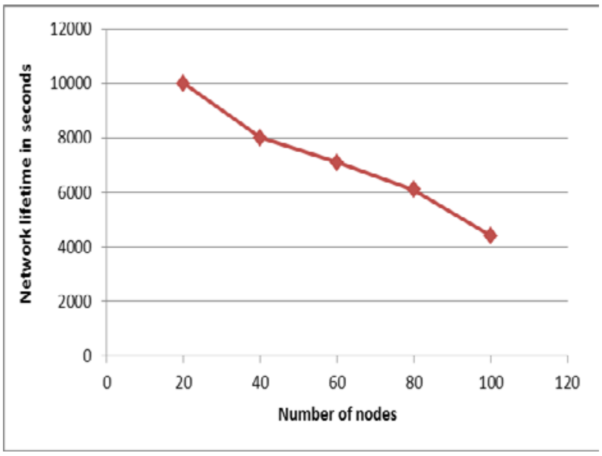

Fig. 5. Network lifetime versus no of nodes

VII. CONCLUSION

We presented a controlled data collection approach for wireless sensor network (WSN) that can be used to maximize the number of the packets to be collected. We considered WSN in which sensor nodes are sampling at different rates. Hence their buffer overflows at different rate. We schedule the mobile element in such a way that, mobile element collects data from sensor nodes before buffer overflow occurs. Scheduling differs from TSP since a node may be visited more than once and visit is based on the smallest deadline first. Unlike Earliest Deadline First (EDF) which terminates if a node fails to meet deadline, the modified one continue to collect the data by looking for a node that can meet the deadline. This method clearly increases the amount of data that can be collected from WSN. The method also minimizes energy consumption as the packets are collected via single hop communication.

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