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A Heuristic Approach to Enhance the Energy Consumption, Packet Delay and Lifetime in Wireless Sensor Networks

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Abstract: **The growth in technology has enabled wireless sensor nodes to be used for a wide range of applications in the field of environment monitoring, scientific observation and emergency detection. In these applications extending the life of nodes and ensuring packet delivery to the destination is very important to achieve acceptable Quality of Services. Hence to meet the entire core of challenges a data collection protocol EDAL is used which stands for energy efficiency, delay- aware, lifetime balancing is used. It is found that EDAL algorithm is inherently NP-hard. Therefore a centralised heuristics approach based on tabu search is used to reduce its computational overhead and a distributed heuristic approach based on Ant colony gossiping is used to make algorithm scalable for large networks. Finally the performance of EDAL is compared with the standard algorithm like Minimum Spanning Tree to evaluate the results.**

Keywords: Wireless Sensor Network, Centralised Heuristics, Distributed Heuristics, NP-hard.

I. INTRODUCTION

The wireless sensor network are known to be independent network of battery driven device which hold data generated by source node and project it to sink nodes. The node may be deployed over a wide range of areas for collecting data for various purposes including commercial and Scientific [1]. A sensor node is composed of four parts as shown in Fig.1. Nodes are equipped with a Sensing unit, a radio transceiver, a small microcontroller and an energy source usually a battery. Hence in such applications increasing the lifetime of WSN and guaranteeing packet delivery delays is crucial.

In many applications the packet delivery from source node to the sink node occurs via a shared multiple hop which leads to problem on how to deliver all the packets to the sink node within the limited time frame keeping in mind the efficiency and load balance. All the major researchers have tried to achieve tradeoffs in terms of delay, load balancing and energy cost only.

Motivated by the above observation, this paper develops EDAL, an *E*nergy-efficient *D*elay-*A*ware *L*ifetime-balancing data collection protocol. Specifically, EDAL is formulated by treating energy cost of the transmitting packets in WSNs in a similar way as delivery cost of goods in Open Vehicular Routing and by treating packet latencies similar to delivery deadlines

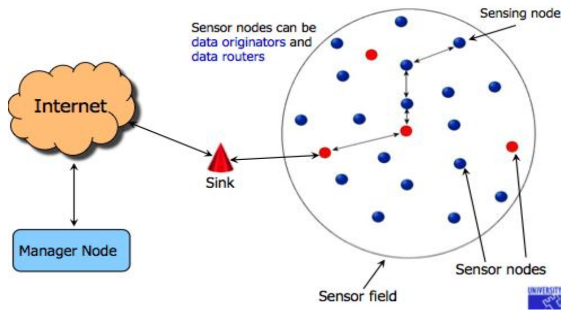

Fig 1. WSN Components

To reduce its computational overhead, a centralized meta heuristic based on tabu search[6] and a distributed heuristic based on ant colony gossiping are used to obtain approximate solutions. These approaches are evaluated using large-scale simulations with NS-2.35[5] and evaluation results are presented.

The rest of the paper is organised as follows: section II deals with related work. Section III introduces the energy efficiency and delay aware technique. Section IV presents the simulation results and conclusion and future work are covered in the section V.

II. LITERATURE SURVEY

Dantzig and Ramser [1] were the first to introduce the ``Open Vehicle Routing Problem (OVRP)", modelling on how to find routes between a depot and customers with given demands so that the transportation cost is minimized with the involvement of the minimal number of vehicles, while satisfying capacity constraints. The current OVRP models, however, are immensely different from the one introduced by Dantzig and Ramser, as they increasingly aim to incorporate real-life complexities, such as for instance time-dependent travel times, time windows for pickup and delivery, and input information that changes dynamically over time. These features bring along substantial complexity.

Z. Ozyurt, D. Aksen, and N. Aras [2] In the open route version of the well-known vehicle routing problem, vehicles are not required to return to the depot; or if they are required, then they return by travelling the same route back. In this study, we present a modified Clarke-Wright parallel savings algorithm, a nearest insertion algorithm and a tabu search heuristic for the open vehicle routing problem with time deadlines. Some random test problems and a real-life school bus routing problem are solved by these heuristics, and results are compared.

M.M.Solomon [3] developed the push forward insertion heuristic (PFIH), which repeatedly selects the customer with the lowest additional insertion cost as the next node, until all customers are connected. Once initial routes have been found, various algorithms are developed to generate near-optimal solutions based on simulated annealing, tabu search, or genetic programming.

III. ENERGY EFFICIENCY AND DELAY AWARE TECHNIQUE

This approach assumes that there are heterogeneous sensor nodes deployed, which are modelled by a connectivity graph of G= (V, E), where E represents wireless links between nodes. For different types of nodes, the radio bandwidth and transmission power are different. All links are assumed to be directional, and each is associated with a metric representing its link quality. To perform sensing tasks, there are M nodes selected as sources. All packets must be sent to the sink within the required deadline, where different types of nodes have their own deadline requirements. The objective function of the delivery tasks is that all packets need to be delivered with the minimum total cost.

A. Centralised Heuristic

It is known that the data collection problem is NP hard. Hence it is feasible to use the heuristic[8] solution to reduce its computational overhead. There are two phases of heuristic algorithm: Route construction, to find an initial route and route optimization, to improve the initial results.
The route construction phase of the algorithms is based on the revised push forward insertion (RPFIH) method. The original RPFIH [4] algorithm is modified accordingly to fit the needs of WSN. To begin with, the minimum cost path to the sink is found using the dijkstra’s algorithm for each node. Then it finds nodes that have the largest path to the destination. If no candidate node can guarantee delay.

RPFIH initiates a new route with the node that has largest path cost to the sink in the remaining sources and repeats this process until all sources are connected with the sink. Finally RPFIH generates a set of found routes as the final output.
The list of route generated by RPFI may not be optimal with respect to overall cost and delay. Therefore these initial routes are optimised with the help of Tabu search algorithm. This algorithm keeps the previous routes in memory and avoids the repetition. Tabu search keeps the following lists in its data structure. Tabu move list is a queue with fixed size to monitor the recent moves. Candidate list keeps the best route found so far.

B. Distributed Heuristic

The centralised heuristic algorithm that we discussed above has a disadvantage that all the information required has to be collected from all the nodes to the centralised one. But the WSN is a distributed network. Hence a distributed heuristic approach is needed where at the start of each period, each source node chooses the most-efficient path to send the packets.

This algorithm is based on ant colony optimization [10] and geographic forwarding. There are two stages in it: status gossiping and route construction. In the first stage the source node spreads its current status along with remaining energy levels to its neighbour nodes and at the same time it collects the data of the nearby nodes. The nodes with the maximum energy levels are chosen for transferring the data to the destination. The second stage is route construction stage and this is done using the RPFIH algorithm distributed based on the collected nearby neighbour status.

IV. SIMULATION RESULTS

In order to evaluate the results on a large network we use the simulation platform. Both centralised and distributed algorithms of EDAL are used. The performance is compared with respect to network lifetime, nodes selected and packet delay. The simulation design used for this experiment is network simulator 2.35 with 50 nodes and a link quality of 0.9. The period length is set to 2 minutes.

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For the above algorithms the following results are calculated viz network lifetime, average selected node numbers, average energy consumption, node remaining energy and packet delays. The first three metrics evaluate the energy efficiency whereas the last two metrics evaluate the lifetime balancing and delay aware respectively.

The results of the both the above centralised and decentralised heuristic approaches are compared with the conventional routing algorithm like minimum spanning tree (MST) algorithms which is widely used for data collection in the WSN. The results are compared in terms of average energy consumption, throughput, end-to-end delay, packet delivery ratio and over head. The experimental results are noted for different number of nodes like 10, 20, 30, 40 and 50 keeping all the other parameter constant. The noted results are plotted in the form of graphs as shown below. The graphs show that the proposed C-EDAL and D-EDAL both algorithms have a much higher throughput, higher efficiency, high packet to delay ratio, lesser delay, lower overload compared to baseline MST algorithm.

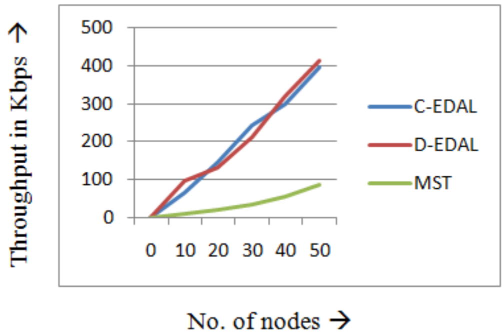

Fig. 2 Throughput

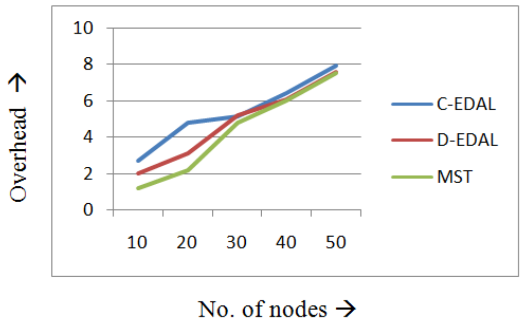

Fig. 3 Overhead

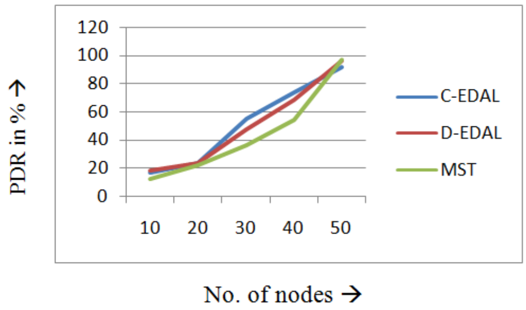

Fig. 4 Packet to delay Ratio

V. CONCLUSION AND FUTURE WORK

This paper proposes a novel approach to decrease the energy consumption in the wireless sensor nodes using a method called EDAL. The objective of this EDAL is to generate the path that connects the source node to the destination node under the packet delay constraints. It is found that the problem is NP-hard hence to overcome the computational overhead a centralised and a distributed approaches are used. From the experimental result comparison it is found that the EDAL achieves significant improvement in the overhead, throughput and packet loss as compared to the baseline protocols.

Network bandwidth is usually expressed in bits per second. The performance of the EDAL can be further increased by fine tuning the physical layer and the MAC layer of the system. On increasing the physical layer the range extends and instead of covering the one hop neighbours, now the system can cover the two hop nodes thus increasing the transmission range. Upon this tuning the MAC 802.11 layer decreases the cost to find the neighbouring node thus decreasing the energy consumption and increases the data rate which in turn increases the throughput.

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