

Distributed Algorithms for energy efficient Routing in Wireless Sensor Networks

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Abstract - Sensor networks have appeared as a promising technology with various applications, where power efficiency is one of the critical requirements. Each node has a limited battery energy supply and can generate information that needs to be communicated to a sink node. We are assuming that each node in the wireless network has the capacity to transform information in the form of packets and also each node is assumed to be able to dynamically adjust its transmission power depending on the distance over which it transmits a packet. To improve the power efficiency requirements, without affecting the network delay, we propose and study a number of schemes for deletion of obsolete information from the network nodes and we propose distributed algorithms to compute an optimal routing scheme that maximizes the time at which the first node in the network runs out of energy. For computing such a flow we are analyzing a partially distributed algorithm and a completely distributed algorithm. The resulting algorithms have low computational complexity and are guaranteed to converge to an optimal routing scheme that maximizes the lifetime of a network. For reducing the power consumption we are taking source node as dynamically move from one location to the other where it is created and the sensor nodes are static and cannot move from one location to the other location where it is created. The results of our study will allow a network designer to implement such a system and to tune its performance in a delay-tolerant environment with intermittent connectivity, as to ensure with some chosen level of confidence that the information is successfully carried through the mobile network and delivered within some time period.

I. INTRODUCTION

A network of wireless sensor nodes distributed in a region. Each node has a limited battery energy supply and can generate information that needs to be communicating to a sink node. It is assumed that each wireless node has the capability to relay packets. Also each node is power depending on the distance over which it transmits a packet. We focus on the problem of computing a flow that maximizes the lifetime of the network - the lifetime is taken to be the time at which the first node runs out of energy. Since sensor networks need to self configure in many situations, the goal of this paper is to find algorithms that do this computation in a distributed manner. We analyze partially distributed algorithm and completely distributed algorithm to compute such a flow. The algorithms described can be used in static networks, or in networks in which the topology changes slowly enough such that there is enough time between topology changes to optimally balance the traffic energy efficient algorithms for routing in wireless

networks have received considerable attention over the past few years. Distributed algorithms to form sparse topologies containing Minimum-energy routes were proposed in “Minimum energy mobile wireless networks [1],” “Minimum energy mobile wireless networks revisited [2].” An approximate approach based on discretization of the coverage region of a node into cones was described in “Distributed topology control for power efficient operation in multi-hop wireless ad hoc networks[3],” “Analysis of a cone-based distributed topology control algorithm for wireless multi-hop networks” [4]. All the above mentioned works focused on minimizing the total energy consumption of the network. However, as pointed out in this can lead to some nodes in the network being drained out of energy very quickly. Hence instead of trying to minimize the total energy consumption, routing to maximize the network lifetime was considered in “Energy conserving routing in wireless ad-hoc networks [5],” “Routing for maximum system lifetime in wireless ad-hoc networks [6].” The problem was formulated as a linear program, and heuristics were proposed to select routes in a distributed manner to maximize the network lifetime. However, as illustrated in these papers, these heuristics do not always lead to selection of routes that are globally optimum and a similar problem formulation for selection of relay nodes was given in “Topology control for wireless sensor networks [7],” We note that distributed iterative algorithms for the computation of the maximum lifetime routing flow were described in “Energy efficient routing in ad hoc disaster recovery networks” [8]. Each-iteration involved a bisection search on the network lifetime, and the solution of a max-flow problem to check the feasibility of the network lifetime. The complexity of the algorithm was shown to be polynomial in the number of nodes in the special case of one source node. We use a different approach based on the sub gradient algorithm for the solution of the dual problem. We exploit the separable nature of the problem using dual decomposition to obtain partially and fully distributed algorithms. This is similar to the dual decomposition approaches applied to other problems in communication networks

When power efficiency is considered, ad hoc networks will require a power-aware metric for their routing algorithms. Typically, there are two main optimization metrics for energy-efficiency broadcast/ multicast routing in wireless ad hoc networks:

- (1) Maximizing the network lifetime; and

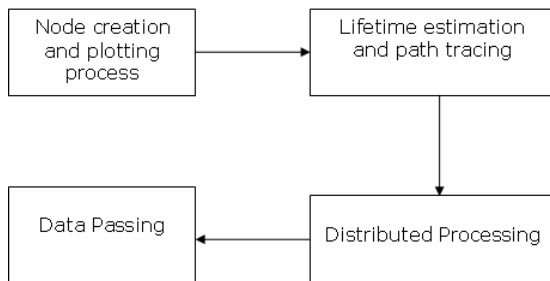
(2) Minimizing the total transmission power assigned to all nodes.

Maximum lifetime broadcast/multicast routing algorithms can distribute packet relaying loads for each node in a manner that prevents nodes from being overused or abused. By maximizing the lifetime of all nodes, the time before the network is partitioned is prolonged

II. OBJECTIVE

- A. We reduce the power consumption for packet transmission.
- B. We achieve maximum lifetime using the partially and fully distributed processing techniques.

III. General Block Diagram



IV. EXISTING SYSTEM

Power consumption is one of the major drawbacks in the existing system. When a node traverses from one network to another network located within topology, the average end-end delay time is increased because of more number of coordinator nodes present in the topology. By traversing more number of coordinators from the centralized node, battery life is decreased. So network connectivity doesn't maintain while the sensor node is traversing. The sensors collect all the information for which it has been for. The information collected by the sensors will be sent to the nearest sensor

- A. Existing works focused on minimizing the total energy consumption of the network.
- B. Nodes in the network being drained out of energy very quickly.
- C. Energy consumption is high
- D. It is not robust.
- E. The sensors have a limited power so they are not capable of transforming the information to all the other sensors.
- F. Because of this power consumption network lifetime is low.

V. PROPOSED SYSTEM

In the proposed system the base station can dynamically move from one location to the other for reducing the power consumption. The problems faced in the existing systems are overcome through the proposed system. Each mobile estimates its life-time based on the traffic volume and battery state. The extension field in route-request RREQ and route reply RREP packets are utilized to carry the life-time (LT) information. LT field is also included into the routing tables. When a RREQ packet is sent, LT is set to maximum value (all ones). When an intermediate node receives the RREQ, it compares the LT field of the packet to its own LT. Smallest of the two is set to forwarded RREQ packet. When a node having a path to the destination hears the RREQ packet, it will compare the LT field of the RREQ with the LT field in its routing table and put the smaller of the two into RREP. In case destination hears the RREQ, it will simply send RREP with the lifetime field equal to the LT in the RREQ. All intermediate nodes that hear RREP store the path along with the life time information. In case the source receives several RREPs, it selects the path having the largest LT.

- Unattended operation
- Robustness under dynamic operating conditions
- Scalability to thousands of sensors
- Energy consumption is low
- Efficiency is high

VI. OVERVIEW

We describe the system model and formulate the problem of maximizing the network lifetime as an optimization problem. We are introducing the sub-gradient algorithm to solve a convex optimization problem via the dual problem since the objective function is not strictly convex in the primal variables, the dual function is non-differentiable. Hence, the primal solution is not immediately available, but it can be recovered. We derive the partially and fully distributed algorithms. We describe a way to completely decentralize the problem by introducing additional variables corresponding to an upper bound on the inverse lifetime of each node. The problem of maximizing the network lifetime can be reformulated as the following convex quadratic optimization problem. The flow conservation violation is normalized with respect to the total flow in the network and the minimum node lifetime is normalized with respect to the optimal value of the network lifetime given by a centralized solution to the problem. We considered the network lifetime to be time at which the first node runs out of energy. Thus we assumed that all nodes are of equal importance and critical to the operation of the sensor network. However for a heterogeneous wireless sensor network, some nodes may be more important than others. Also, if there are two nodes collecting highly correlated data, the network can remain functional even if one node runs out of energy. Moreover, for the case of nodes with

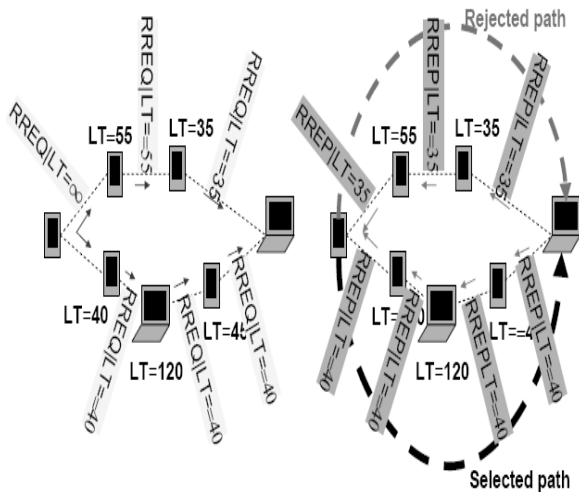
highly correlated data, we may want only one node to forward the data at a given time. Thus we can activate the two nodes in succession, and still be able to send the necessary data to the sink. We will model the lifetime of a network to be a function of the times for which the nodes in the network can forward their data to the sink node. In order to state this precisely, we redefine the node lifetime and the network lifetime for the analysis in this section. We will relax the constraint on the maximum flow over a link at a given time. We also describe various extensions to the problem for which we can obtain distributed algorithms using the approach described in this paper. We extend the simplistic definition of network lifetime to more general definitions which model more realistic scenarios in sensor networks.

VII. MODULES

- A. Node Creation and Plotting process
- B. Lifetime Estimation and path tracing
- C. Partially Distributed Processing
- D. Fully Distributed Processing
- E. Data Passing

VIII. ALGORITHM USED

A. Partially Distributed Processing:



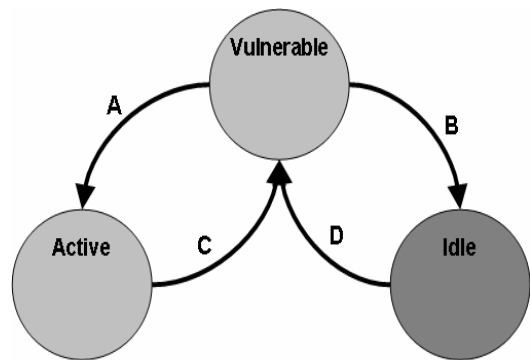
- a) Each mobile estimate its life-time based on the traffic volume and battery state.
- b) The extension field in route-request RREQ and route reply RREP packets are utilized to carry the life-time (LT) information.
- c) When a RREQ packet is send, LT is set to maximum value.

- d) When an intermediate node receives the RREQ, it compares the LT field of the packet to its own LT. Smallest of the two is set to forwarded RREQ packet.
- e) When a node having a path to the destination hears the RREQ packet, it will compare the LT field of the RREQ with the LT field and put the smallest of the two into RREP. In case destination hears the RREQ, it will simply send RREP with the lifetime field equal to the LT in the RREQ.
- f) All intermediate nodes that hear RREP store the path along with the life time information.
- g) In case the source receives several RREPs, it select the path having the largest LT.

B. Fully Distributed Algorithm

The distributed network and ad hoc networks makes resource allocation strategies very challenging since there is no central node to monitor and coordinate the activities of all the nodes in the network. Since a single node cannot be delegated to act as a centralized authority because of limitations in the transmission range, several delegated nodes may coordinate the activities in certain zones. This methodology is generally referred to as clustering and the nodes are called clusterheads. The clusterheads employ centralized algorithms in its cluster; however, the clusterheads themselves are distributive in nature.

A first consideration is that the requirement for sensor networks to be self-organizing implies that there is no fine control over the placement of the sensor nodes when the network is installed (e.g., when nodes are dropped from an airplane). Consequently, we assume that nodes are randomly distributed across the environment.



- a. We first put all the nodes in *vulnerable* state
- b. If there is a face which is not covered by any other active or vulnerable sensor, then go to active state and inform neighbors.
- c. If all its faces are covered by one of two types of sensors: active or vulnerable sensors with a larger energy supply, i.e., the sensor is not a champion for

- any of its faces, then go to idle state and inform neighbors
- d. After sensor node goes to *Active*
- e. state, it will stay in Active state for pre-defined time called Reshuffle-triggering threshold value.
- f. Upon reaching the threshold value, node in Active state will go to Vulnerable state and inform the neighbors.
- g. If sensor node is in Idle or Active state then it will go in vulnerable state, if one of its neighbor goes into Vulnerable state.
- h. It causes global reshuffle and it will find new minimal sensor cover.

VIII.LITERATURE SURVEY

There are two major techniques for maximizing the routing lifetime: the use of energy efficient routing and the introduction of sleep/active modes for sensors. Extensive research has been done on energy efficient data gathering and information dissemination in sensor networks. Some well-known energy efficient protocols were developed, such as Directed Diffusion [9], LEACH [10], PEGASIS [11], and ACQUIRE [12]. Directed Diffusion is regarded as an improvement over the SPIN [13] protocol that used a proactive approach for information dissemination. LEACH organizes sensor nodes into clusters to fuse data before transmitting to the BS. PEGASIS improved the LEACH by considering both metrics of energy consumption and data-gathering delay.

In [14], an analytical model was proposed to find the upper bound of the lifetime of a sensor network, given the surveillance region and a BS, the number of sensor nodes deployed and initial energy of each node. Some routing schemes for maximizing network lifetime were presented in [15]. In [16], an analytic model was proposed to analyze the tradeoff between the energy cost for each node to probe its neighbors and the routing accuracy in geographic routing, and a localized method was proposed. In [17] and [8], linear programming (LP) formulation was used to find energy-efficient routes from sensor nodes to the BS, and approximation algorithms were proposed to solve the LP formulation.

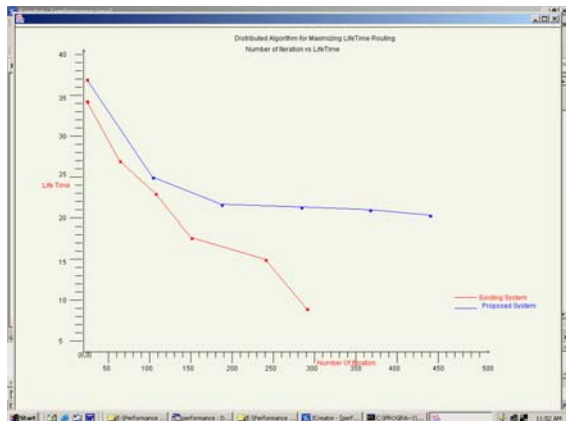
Another important technique used to prolong the lifetime of sensor networks is the introduction of switch on/off modes for sensor nodes. J. Carle *et al.* did a good survey in [18] on energy efficient area monitoring for sensor networks. They pointed out that the best method for conserving energy is to turn off as many sensors as possible, while still keeping the system functioning. An analytical model was proposed in [19] to analyze the system performance, such as network capacity and data

delivery delay, against the sensor dynamics in on/off modes. A node scheduling scheme was developed in [20]. This scheme schedules the nodes to turn on or off without affecting the overall service provided. A node decides to turn off when it discovers that its neighbors can help it to monitor its monitoring area. The scheduling scheme works in a localized fashion where nodes make decisions based on its local information. Similar to [21], the work in [22] defined a criterion for sensor nodes to turn themselves off in surveillance systems. A node can turn itself off if its monitoring area is the smallest among all its neighbors and its neighbors will become responsible for that area. This process continues until the surveillance area of a node is smaller than a given threshold. A deployment of a wireless sensor network in the real world for habitat monitoring was discussed in [23].

A network consisting of 32 nodes was deployed on a small island to monitor the habitat environment. Several energy conservation methods were adopted, including the use of sleep mode, energy-efficient communication protocols, and heterogeneous transmission power for different types of nodes. We use both of the above-mentioned techniques to maximize the network lifetime in our solution. We find the optimal schedule to switch on/off sensors to watch targets in turn, and we find the optimal routes to forward data from sensor nodes to the BS.

The algorithms were derived to solve the dual problems of programs (24) (4) and (8) in a partially and a fully decentralized manner, respectively. The computation results show that the rate of convergence of the fully distributed algorithm was slower than that for the partially distributed algorithm. However, each-iteration of the partially distributed algorithm involves communication between all the nodes and a central node (e.g. sink node). Hence, it is not obvious which algorithm will have a lower total energy consumption cost. If the radius of the network graph is small, then it would be more energy efficient to use the partially distributed algorithm even though each-iteration involves the update of a central variable. Conversely, for large network radius, the fully distributed algorithm would be a better choice. Also, we note that the computation at each node for the fully distributed algorithm involves the solution of a convex quadratic optimization problem. This is in contrast to the partially distributed algorithm, where each-iteration consists of minimization of a quadratic function of a single variable, which can be done analytically. We considered many different extensions to the original problem and showed how the sub gradient approach can be used to obtain distributed algorithms. In addition, we considered a generalization of the definition of network lifetime to model realistic sensor network scenarios, and reformulated the problem as a convex optimization problem with separable structure.

IX. SIMULATION RESULTS



CONCLUSION

In this project, we proposed two distributed algorithms to calculate an optimal routing flow to maximize the network lifetime. The algorithms were derived to solve the dual problems of programs “Analysis of a cone-based distributed topology control algorithm for wireless multi-hop networks [4],” and “Energy efficient routing in ad hoc disaster recovery networks [8],” in a partially and a fully decentralized manner, respectively. The computation results show that the rate of convergence of the fully distributed algorithm was slower than that for the partially distributed algorithm. However, each-iteration of the partially distributed algorithm involves communication between all the nodes and a central node (e.g. sink node). Hence, it is not obvious which algorithm will have a lower total energy consumption cost. If the radius of the network graph is small, then it would be more energy efficient to use the partially distributed algorithm even though each-iteration involves the update of a central variable. Conversely, for large network radius, the fully distributed algorithm would be a better choice. Also, we note that the computation at each node for the fully distributed algorithm involves the solution of a convex quadratic optimization problem. This is in contrast to the partially distributed algorithm, where each-iteration consists of minimization of a quadratic function of a single variable, which can be done analytically.

This communication paradigm has a broad range of applications, such as in the area of telemetry collection and sensor networks. It could be used for animal tracking systems, for medical applications with small sensors to propagate information from one part of the body to another or to an external machine, and to relay traffic or accident information to the public through the vehicles themselves as well as many other applications.

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