ISSN: 2321-7782 (Online)
Volume 2, Issue 8, August 2014
International Journal of Advance Research in Computer Science and Management Studies
Research Article / Survey Paper / Case Study
Available online at: www.ijarcsms.com

Reducing Energy Consumption in Wireless Sensor Networks

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***Abstract:** Wireless sensor networks (WSNs) have become increasingly available for data-intensive applications such as micro-climate monitoring, precision agriculture, and audio/video surveillance. A key challenge faced by data-intensive WSNs is to transmit the sheer amount of data generated within an application's lifetime to the base station despite the fact that sensor nodes have limited power supplies such as batteries or small solar panels. This paper, proposed to use low-cost disposable mobile relays to reduce the energy consumption of data-intensive Wireless Sensor Networks (WSNs). This approach does not require complex motion planning of mobile nodes, and hence can be implemented on a number of low-cost mobile sensor platforms. Moreover, the energy consumption due to both mobility and wireless transmissions are integrated into a holistic optimization framework. The optimal relay configuration is shown to depend on both the positions of nodes and the amount of data to be sent. Two algorithms are used to refine the configuration of mobile relays and converge to the optimal solution. These algorithms have efficient distributed implementations that do not require explicit synchronization. The simulation results based on realistic energy models obtained from existing mobile and static sensor platforms show that the algorithms are significantly outperform the best existing solutions.*

***Keywords:** Wireless sensor networks, autonomous sensors, energy consumption.*

I. Introduction

Wireless sensor networks enable dense sensing of the environment ,offering unprecedented opportunities for observing the physical world. A sensor network is a static ad hoc network consisting of hundreds of sensor nodes deployed on the fly for unattended operation. Each sensor node is equipped with a sensing device, a low computational capacity processor, a short-range wireless transmitter-receiver and a limited battery-supplied energy. Sensor nodes monitor some surrounding environmental phenomenon, process the data obtained and forward this data towards a base station located on the periphery of the sensor network. Base station(s) collect the data from the sensor nodes and transmit this data to some remote control station.

The problem of data collection in sparse sensor networks is encountered in many scenarios such as monitoring physical environments such as tracking animal migrations in remote-areas, weather conditions in national parks, habitat monitoring on remote islands, city traffic monitoring etc[1][3]. The objective is to collect data from sensors and deliver it to an access point in the infrastructure. These systems are expected to run unattended for long periods of time (order of months). The principal constraint is the energy budget of the sensors which is limited due to their size and cost.

Many communication protocols for energy conservation in wireless sensor networks have been proposed recently[10]. All these protocols achieve their optimization goals under certain conditions, they always focus on the sensor nodes. Multi-hop routing is usually implemented for the transport of the sensed data to special data collection nodes (the sinks). Among the challenges posed by the problem of data delivery to the sinks one that has recently received considerable attention concerns the minimization of the node energy consumption for increasing the overall network lifetime[2].

Energy is a key concern in wireless sensor network design because, once the nodes are embedded into the environment, it becomes impractical to replace their batteries. One of the major energy expenditures is in communicating the sensor readings, in raw or processed form, from the sensors to a central user location[9][11]. Usually, these readings are relayed to a base station using ad hoc multihop routes in the sensor network.

Recent research has exploited controlled mobility as a promising approach to reduce communication energy consumption of WSNs. For instance, a mobile base station (BS) may roam about a sensing field and collect data from sensor nodes through short-rangecommunication.the energy consumption of static nodes is thus reduced because fewer number of wireless relays are needed in the network.

II. Energy Consumption Models

Nodes consume energy during communication, computation, and movement, but communication and mobility energy consumption are the major cause of battery drainage. Radios consume considerable energy even in an idle listening state, but the idle listening time of radios can be significantly reduced by a number of sleep scheduling protocols. In this, the focus is made on reducing the total energy consumption due to transmissions and mobility. Such a holistic objective of energy conservation is motivated by the fact that mobile relays act the same as static forwarding nodes after movement. The energy consumed by moving a distance d is modeled as:

$$E_M(d) = kd \qquad (1)$$

In the definitions, assumption made that all movements are completed before any transmissions begin. So there are no obstacles that affect mobility or transmissions. In this case,, the distance moved by a mobile relay is no more than the distance between its starting position and its corresponding position in the evenly spaced configuration which often leads to a short delay in mobile relay relocation. Furthermore, that all mobile nodes know their locations either by GPS units mounted on them or a localization service in the network. We focus on the case where all nodes are in a 2D plane <2, but the results apply to <3 and other metric spaces.

III. Problem Formulation

The problem formulation considers the initial positions of nodes and the amount of data that needs to be transmitted from each storage node to the sink. The formal definition of the problem is given below.

Definition 1 (Optimal mobile relay configuration): Input Instance: S, a list of n nodes (s1; . . . ; sn) in the network; O, a list of n locations (o1; . . . ; on), where oi is the initial position of node si for 1 < i < n; Ssources, a subset of S representing the source nodes; r, a node in S, representing the single sink , a set of data chunk sizes for all sources in Ssources. So mi defined, which is compute later, to be the weight of node si which is equal to the total number of bits to be transmitted by node si. A configuration (E,U) as a pair of two sets: E, a set of directed arcs that represent the directed tree in which all sources are leaves and the sink is the root and U, a list of locations (u1; . . . ; un) where ui is the transmission position for node si for 1 < i < n. The cost of a configuration (E,U) is given by:

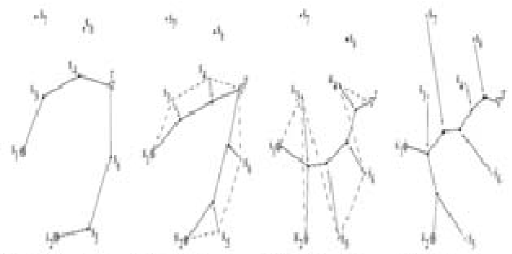
$$C(E,U)=\sum_{si,sj£E} ami+b\|u_i-u_j\|^2 m_i+k_i\|o_i-u_i\|^2 \qquad (2)$$

The Optimal Mobile Relay Configuration problem is challenging because of the dependence of the solution on multiple factors such as the routing tree topology and the amount of data transferred through each link. For example, when transferring little data, the optimal configuration is to use only some relay nodes at their original positions. As the amount of data transferred increases, three changes occur: the topology may change by adding new relay nodes, the topology may change by changing which edges are used, and the relay nodes may move closer together. In many cases, we may have restrictions such as no mobility for certain relay nodes or we must use a fixed routing tree. These constraints affect the optimal configuration.

We illustrate how the optimal configuration depends we illustrate how the optimal configuration depends on the amount of data to transfer using the example from Fig. a. When there is very little data to transfer, the optimal routing tree Ta depicted in

Fig.a uses only some of the relay nodes in their original positions. When the amount of data to transfer from s1 and s2 increases to 15 MB, the relay nodes in tree Ta move to their corresponding positions in tree Tb of Fig.b but the topology does not change.

When the amount of data to transfer from s1 and s2 is between 25 and 60 MB, the optimal routing tree has a different topologyas shown in Fig.c. For even larger messages, new trees with even more nodes included are optimal. For example, when the amount of data to be transferred is between 100 and 150 MB, the optimal tree is depicted in Fig.d. No existing tree construction strategy handles all these cases. For example, the minimum spanning tree that includes all network nodes has two fundamental problems. It will typically include unneeded nodes, and it typically creates nonoptimal topologies as it focuses only on the current location of nodes as opposed to where nodes may move to.



(a) Optimal routing tree for $0 \leq m \leq 15$MB.

(b) Optimal configuration for $15\text{MB} \leq m \leq 25$MB: same topology but nodes relocate.

(c) Optimal configuration for $25\text{MB} \leq m \leq 60$ MB. A new topology is used.

(d) Optimal configuration for $100\text{MB} \leq m \leq 150$MB: a new topology with more nodes.

Fig. Example of optimal configurations as a function of amount of data to be transferred. In each part, source nodes s_1 and s_2 must send m bits of data to the sink r. We consider m up to 150 MB.

IV. TREE CONSTRUCTION BY TREE OPTIMIZATION ALGORITHM

The tree optimization algorithm improves the routing tree by relocating its nodes without changing its topology This iterative algorithm converges on the optimal position for each node given the constraint that the routing tree topology is fixed.

A. NODE INSERTION

The improvement of the routing tree by greedily adding nodes to the routing tree exploiting the mobility of the inserted nodes. For each node S_{out} that is not in the tree and each tree edge S_i,S_j, we compute the reduction (or increase) in the total cost along with the optimal position of Sout, if Sout joins the tree such that data is routed from Si to S_{out} to S_j instead of directly from Si to S_j using the LocalPos algorithm.The outside node is repeatedly insert with the highest reduction value modifying the topology to include the selected node at its optimal position, though the node will not actually move until the completion of the tree optimization phase. After each node insertion occurs, the reduction in total cost is computed and optimal position for each remaining outside node for the two newly added edges (and remove this information for the edge that no longer exists in the tree). At the end of this step, the topology of the routing tree is fixed and its mobile nodes can start the tree optimization phase to relocate to their optimal positions. The optimal position of nodes is given by:

$$x_i = P_i + \frac{\sqrt{Bx^2+By^2 \pm k}}{\sqrt{A\,Bx^2+By^2}} \qquad (3)$$

B. DISTRIBUTED ROUTING MODULE

The solutions to the three sub problems assumes a centralized scheme in which one node has full knowledge of the network including which nodes are on the transmission paths to each source, the original physical position of each node, and the total message length to be sent from each source. The first phase, the tree construction phase, to use a fully distribute routing algorithm. The greedy geographic routing is picked since it does not require global knowledge of the network although any algorithm with such property can be used. After a routing tree is constructed, the tree restructuring phase begins. Network nodes outside the tree broadcast their availability (as NODE_IN_RANGE message) to tree nodes within their communication range and wait for responses for a period of time. Each tree node that receives one or more NODE_IN_RANGE message responds to the sender by giving it its location information and its parent s location information.Giving tree nodes the ability to wait before accepting an offer increases the chances of using mobile relay nodes to their full potential. For example, consider a scenario where several mobile relay nodes can greatly improve the capacities of several tree links but are all closest to one specific link. They will all send offers to the same tree node while the rest of the tree nodes in their proximity will receive modest offers from more distant mobile nodes. If the tree nodes cannot wait, they will be forced to accept a modest offer and the mobile nodes will either remain, unused or they will help more distant tree nodes where their impact is reduced since they use up more energy to get to their new location.

C. ENERGY CONSUMPTION

Nodes consume energy during communication, computation, and movement, but communication and mobility energy consumption are the major cause of battery drainage. Radios consume considerable energy even in an idle listening state, but the idle listening time of radios can be significantly reduced by a number of sleep scheduling protocols. In this work, focus is made on reducing the total energy Consumption ie the energy consumption due to transmissions and mobility. Such a holistic objective of energy conservation is motivated by the fact that mobile relays act the same as static forwarding nodes after movement.

V. CONCLUSION

In this paper, a holistic approach to minimize the total energy consumed by both mobility of relays and wireless transmissions is proposed. Most previous work ignored the energy consumed by moving mobile relays. When we model both sources of energy consumption, the optimal position of a node that receives data from one or multiple neighbors and transmits it to a single parent is not the midpoint of its neighbors; instead, it converges to this position as it.

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