A Survey on Low Cost Disposable Mobile Relays to Reduce the Total Energy Consumption of Data-Intensive WSN

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Abstract: ***Wireless Sensor Networks (WSNs) are increasingly used in data-intensive applications such as microclimate monitoring, precision agriculture, and audio/video surveillance. A key challenge faced by data-intensive WSNs is to transmit all the data generated within an application's lifetime to the base station despite the fact that sensor nodes have limited power supplies. We propose using low-cost disposable mobile relays to reduce the energy consumption of data-intensive WSNs. Our approach differs from previous work in two main aspects. First, it does not require complex motion planning of mobile nodes, so it can be implemented on a number of low-cost mobile sensor platforms. Second, we integrate the energy consumption due to both mobility and wireless transmissions into a holistic optimization framework. Our framework consists of three main algorithms. The first algorithm computes an optimal routing tree assuming no nodes can move. The second algorithm improves the topology of the routing tree by greedily adding new nodes exploiting mobility of the newly added nodes. The third 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 does not change. We present efficient distributed implementations for each algorithm that require only limited, localized synchronization. Because we do not necessarily compute an optimal topology, our final routing tree is not necessarily optimal. However, our simulation results show that our algorithms significantly outperform the best existing solutions***

Keywords: Wireless sensor networks, energy optimization, mobile nodes, wireless routing.

1. Introduction

WSNs have been deployed in a variety of data intensive applications including micro-climate and habitat monitoring precision agriculture, and audio/video surveillance . A moderate-size WSN can gather up to 1 Gb/year from a biological habitat. Due to the limited storage capacity of sensor nodes, most data must be transmitted to the base station for archiving and analysis. However, sensor nodes must operate on limited power supplies such as batteries or small solar panels. Therefore, a key challenge faced by data-intensive WSNs is to minimize the energy consumption of sensor nodes so that all the data generated within the lifetime of the application an be transmitted to the base station. Several different approaches have been proposed to significantly reduce the energy cost of WSNs by using the mobility of nodes. A robotic unit may move around the network and collect data from static nodes through one-hop or multi-hop transmissions.The mobile node may serve as the base station or a "data mule" that transports data between static nodes and the base station. Mobile nodes may also be used as relays that forward data from source nodes to the base station. Several movement strategies for mobile relays have been studied.Although the effectiveness of mobility in energy conservation is demonstrated by previous studies, the following key issues have not been collectively addressed. First, the movement cost of mobile nodes is not accounted for in the total network energy consumption. Instead, mobile nodes are often assumed to have replenished able energy supplies which are not always feasible due to the constraints of the physical environment. Second, complex motion planning of mobile nodes is often assumed in existing solutions which introduces significant design complexity and manufacturing costs. In mobile nodes need to repeatedly compute optimal motion paths and change their location, their orientation and/or speed of movement. Such capabilities are usually not supported by existing low-cost mobile sensor platforms. For instance, Robomote nodes are designed using 8-bit CPUs and small batteries that only last for about 25 minutes in full motion. In this paper, we use low-cost disposable mobile relays to reduce the total energy consumption of data intensive WSNs. Different from mobile base station or data mules, mobile relays do not transport data; instead, they move to different locations and their main stationary to forward data along the paths from the sources to the base station. Thus, the communication delays can be significantly reduced compared with using mobile sinks or data mules. Moreover, each mobile node performs a single relocation unlike other approaches which require repeated relocations.

2. Literature Survey

We review three different approaches, mobile base stations, data mules, and mobile relays that use mobility to reduce energy consumption in wireless sensor networks. A mobile base station moves around the network and collects data from the nodes. In some work, all nodes are always performing multiple hop transmissions to the base station, and the goal is to rotate which nodes are close to the base station in order to balance the transmission load. In other work, nodes only transmit to the base station when it is close to them (or a neighbor). The goal is to compute a mobility path to collect data from visited nodes before those nodes suffer buffer overflows. In several rendezvous based data collection algorithms are proposed, where the mobile base station only visits a selected set of nodes referred to as rendezvous points within a deadline and the rendezvous points buffer the data from sources. These approaches incur high latencies due to the low to moderate speed, e.g. 0.1-1 m/s of mobile base stations. Data mules are similar to the second form of mobile base stations. They pick up data from the sensors and transport it to the sink. the data mule visits all the sources to collect data, transports data over some distance, and then transmit it to the static base station through the network. The goal is to find a movement path that minimizes both communication and mobility energy consumption. Similar to mobile base stations, data mules introduce large delays since sensors have to wait for a mule to pass by before starting their transmission. In the third approach, the network consists of mobile relay nodes along with static base station and data sources. Relay nodes do not transport data; instead, they move to different locations to decrease the transmission costs. We use the mobile relay approach in this work. Goldenberg et al. showed that an iterative mobility algorithm where each relay node moves to the midpoint of its neighbors converges on the optimal solution for a single routing path. However, they do not account for the cost of moving the relay nodes. mobile nodes decide to move only when moving is beneficial, but the only position considered is the midpoint of neighbors. Unlike mobile base stations and data mules, our OMRC problem considers the energy consumption of both mobility and transmission.

Our approach also relocates each mobile relay only once immediately after deployment. Unlike previous mobile relay we consider all possible locations as possible target locations for a mobile node instead of just the midpoint of its neighbors. Mobility has been extensively studied in sensor network and robotics applications which consider only mobility costs but not communication costs. the authors propose approximation algorithms to minimize maximum and total movement of the mobile nodes such that the network becomes connected. In the authors propose an optimal algorithm to bridge the gap between two static nodes by moving nearby mobile nodes along the line connecting the static points while also minimizing the total/maximum distance moved. the authors propose algorithms to find motion paths for robots to explore the area and perform a certain task while taking into consideration the energy available at each robot. These problems ignore communication costs which add an increased complexity to OMRC, and consequently their results are not applicable. Our OMRC problem is somewhat similar to a number of graph theory problems such as the Steiner tree problem and the facility location problem . However, because the OMRC cost function is fundamentally different from the cost function for these other problems, existing solutions to these problems cannot be applied directly and do not provide good solutions to OMRC. For example, there is no obvious way to include mobility costs in the Steiner tree problem.

We use the mobile relay approaching this work. Goldenberg et al. Showed that an iterative mobility algorithm where each relay node moves to the midpoint of its neighbors converge on the optimal solution for a single routing path. However, they do not account for the cost of moving the relay nodes. Mobile nodes decide to move only when moving is beneficial, but the only position considered is the midpoint of neighbors. Unlike mobile base stations and data mules, our OMRC problem considers the energy consumption of both mobility and transmission. Our approach also relocates each mobile relay only once immediately after deployment. Unlike previous mobile relay schemes we consider all possible locations as possible target locations for a mobile node instead of just the midpoint of its neighbor

3. Proposed Work

In this paper, we use low-cost disposable mobile relays to reduce the total energy consumption of data-intensive WSNs. Different from mobile base station or data mules, mobile relays do not transport data; instead, they move to different locations and then remain stationary to forward data along the paths from the sources to the base station. Thus, the communication delays can be significantly reduced compared with using mobile sinks or data mules. Moreover, each mobile node performs a single relocation unlike other approaches which require repeated relocations.

Advantages of Proposed System**:**

- Our approach takes advantage of this capability by assuming that we have a large number of mobile relay nodes.
- On the other hand, due to low manufacturing cost, existing mobile sensor platforms are typically powered by batteries and only capable of limited mobility.
- Consistent with this constraint, our approach only requires one-shot relocation to designated positions after deployment. Compared with our approach, existing mobility approaches typically assume a small number of powerful mobile nodes, which does not exploit the availability of many low-cost mobile nodes

Our approach differs from previous work in two main aspects. First, it does not require complex motion planning of mobile nodes, so it can be sensor platforms. Second, we integrate the energy consumption due to both mobility and wireless transmissions into a holistic optimization framework.

3.1 System Architecture

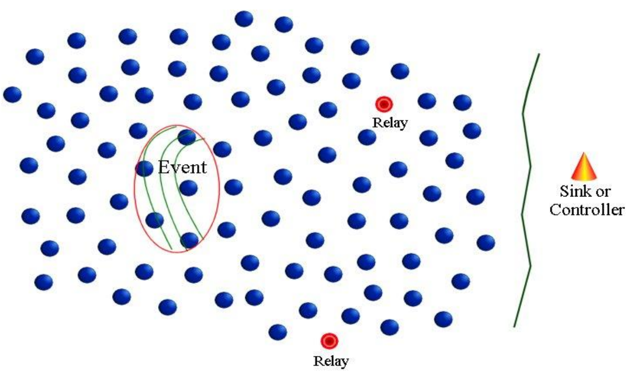

Figure 1

4. Conclusion

In this paper, we proposed a holistic approach to minimize the total energy consumed by both mobility of relays and wireless transmissions. 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 the amount of data transmitted goes to inanity. Ideally, we start with the optimal initial routing tree in a static environment where no nodes can move.

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