Location Estimation in Distributed Ad-Hoc Wireless Sensor Networks

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Abstract: The growth of wireless networking has generated commercial and research interest in statistical methods to track people and things. Inside stores, hospitals, warehouses and factories where Global Positioning System devices generally do not work. Indoor Positioning Systems aim to provide location estimates for wireless devices such as laptop computers, handheld devices and electronic badges. Therfore, in this paper, location estimation algorithms were suggested to address the global positiong problem in an ad-hoc wireless network and algorithms were compared to offer suitable solutions.

1. Introduction

Emerging applications for wireless sensor networks will depend on automatic and accurate location of thousands of sensors. In environmental sensing applications such as water quality monitoring, precision agriculture, and indoor air quality monitoring, "sensing data without knowing the sensor location is meaningless". In addition, by helping reduce configuration requirements and device cost, relative location estimation may enable applications such as inventory management, intrusion detection[1], traffic monitoring, and locating emergency workers in buildings.

On the other hand, all devices, regardless of their absolute coordinate knowledge, estimate the range between themselves and their neighboring devices. Such location estimation is called "relative location" because the range estimates collected are predominantly between pairs of devices of which neither has absolute coordinate knowledge. These devices without *a priori* information we call blindfolded devices. In cellular location estimation and local positioning systems (LPS) location estimates are made using only ranges between a blindfolded device and reference devices.

In this paper, we will introduce the local positioning problems in an ad-hoc sensing networks and thus possible local positioning estimation algorithms will be suggested to address the global positioning challenge under multihop network scenario. Possible suggested algorithms are then compared according to position error and range requirements.

2. Motivation of research

A large number of nodes with a dense distribution consists in a sensor network. To reduce the power consumption attributed to communication and to minimize interference, every node can only communicate to its immediate neighbors resulting in a mesh of connections. Clustering as well as the depletion of a local area can occur when mobile nodes move about as sown in Figure 1.

Due to motion or obstacles blocking the radio signals, on occasion it might happen that a partition of a network looses contact to the remaining network. So, network graph is ensured to be connected well to prevent this from happening. More specifically, the power range of the radios is adaptively set so that each node has a reasonable number of neighboring nodes (first and second order) at any point in time.

The network activity in sensor networks is low and random. Many nodes will be stationary for most of the time, enabling long iteration periods. Within this static framework, a few nodes may move around with limited mobility.

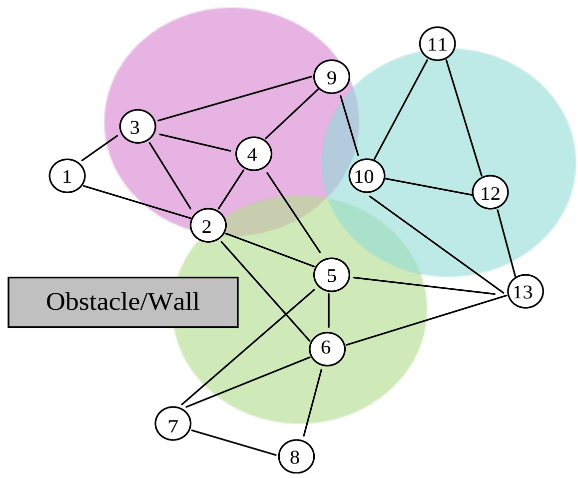

Figure 1. Overlapping ranges of many pico-nodes

When applied to an ad-hoc sensor network, the radiolocation approaches face several new complications: sparse reference points that are not directly visible by all nodes in the network, limited accuracy in the range measurements, and the need for low-power implementation on limited resources. *Anchor nodes*, or nodes with *a prior* knowledge of their locations relative to a global coordinate system, are assumed to be sparse and randomly located. Like the other sensor nodes, their communication range is limited to their immediate neighborhood. This makes it difficult, if not impossible, for *requesting nodes*, or nodes attempting to *estimate* their positions, to acquire enough reference points to perform traditional triangulation. It is only assumed that there will be at least four anchor nodes in a connected network.

Fortunately, sensor networks possess two properties that may help to overcome these concerns: (i) dense interconnectivity leading to redundancy in the range measurements; (ii) limited mobility which allows for long observation times and the removal of some of the fast-fading effects through integration. In the following section, we first discuss how these properties can be used to solve a local positioning problem (i.e. positioning between nodes that are within communication range). The following section will extend these techniques to a system where not all nodes are within range and finally will address the global positioning problem under the same scenraio.

3. Proposed Solutions of global positioning challenges

Since network-covering beacons represent an unnecessary burden with regards to simple deployment, energy consumption, and network architecture, the only option is to engage in a *cooperative ranging* approach to address the global positioning problems. *Cooperative Ranging* exploits the high connectivity of the network to translate the global positioning challenge into a number of distributed local optimization problems that iteratively converge to a global solution by interacting with each other.

The advantage of this approach is that no global resources or communications are needed. The disadvantage is that convergence may take some time and that nodes with a high mobility may be hard to cover. Fortunately, this is not a real issue in sensor networks where nodes rarely move and long discovery times are acceptable given the very long lifetime of the network. This cooperative approach is, to our knowledge, quite original.

Existing approaches to localization in sensor networks tend to rely on a global computational engine that receives the range measurements and turns them into an overall optimization problem. An example of such is [2]. The disadvantage of this clever approach are that (i) a global resource is needed challenging the ad-hoc nature of the network, and (ii) that all the range and position information has to be sent back-and-forth to the sensor nodes, resulting in routing bottlenecks and unnecessary energy dissipation.

In the proposed cooperative ranging methodologies, every single node plays the same role, and repeatedly and concurrently executes the following functions:

- Receive ranging and location information from neighboring nodes
- Solve a local localization problem (using some local localization problem solving technique)
- Transmit the obtained results to the neighboring nodes

After the system has converged to a solution, updates are only rarely needed and will be triggered by a mobile node in a localized area of the network.

A number of different cooperative-ranging approaches can be considered. It is worthwhile to differentiate between discovery (startup) and update modes. The former occurs infrequently and last for a short period of time, relative to lifetime of the network, and is responsible for establishing accurate estimates of the stationary nodes in the system. The update mode is invoked after startup, and monitors node movement, updating position information as mobile nodes change their physical location. We will briefly introduce a number of possible approaches.

3. 1 Global Topology Discovery

In this approach, every node assumes initially to be at the center of the coordinate system and performs a local topology discovery(using the ABC algorithm[3]). The resulting information is forwarded to the neighboring nodes. Every anchor node removes a degree of freedom in the coordinate space, and forces the neighboring nodes to linearly transform their own coordinate system (both from a transposition and rotational perspective). This information is propagated through the system and ultimately causes the system to converge to a single global coordinate space.

3. 2 Iterative Local Triangulation

Once an initial estimation is obtained, the location accuracy can be improved through an iterative refinement process. Each node uses the most recently computed coordinates of each neighboring node and the range measurements to recompute its own coordinates. This process is iterated several times until the positions of all of the nodes in the network have converged.

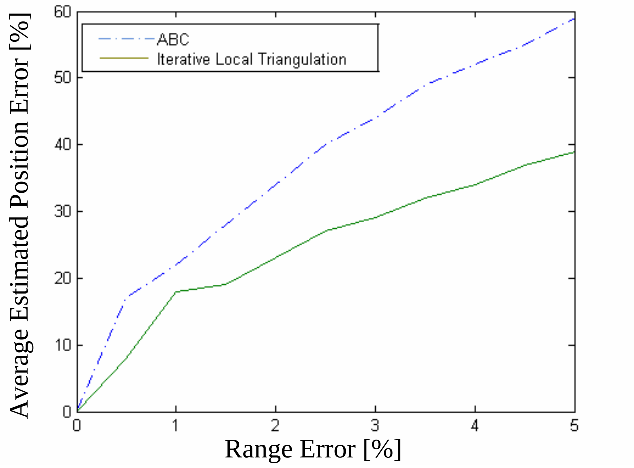

Figure 2. ABC vs. Iterative local algorithm, 32 nodes total, 4 anchor nodes.

Figure 2 presents the improvement gained from the iterative local traingulation algorithm compared to the global topology discovery approach where 32 nodes were taken in total with 4 anchor nodes.

4. Conclusion

In this paper, we suggested co-operative ranging approaches to address the global positioning problems in ad-hoc wireless sensor networks and compared the algorithms presented. In the furure, algorithms will be compared with more performance metrics.

References

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