Localization in Wireless Sensor Networks

Research proposal

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1 Introduction

A Wireless Sensor Network (WSN) is a network of many small sensing and communicating devices called sensor nodes. Each node has a CPU, battery supply, limited number of sensors and a radio transceiver for communication. Interconnection between nodes is achieved via the transceiver. Typically, a WSN contains a node that connects the network to a more capable computer, and probably to a network of general purpose computers through it. Sensors attached to these nodes allow them to sense various phenomena within the environment. The typical purpose of a sensor network is to collect data via sensing interfaces and propagate those data to the central computer, allowing easy monitoring of an environment.

Although a node is capable of dealing with a variety of jobs, it has many shortcomings as well. The majority of the nodes currently available in the market are battery-operated, and hence they have a limited life-time. Moreover, the memory capacity of a node is also limited. Lifetime, processing and storage restrictions directly affect the algorithms designed for sensor networks. As an example, a routing algorithm for WSNs must be energy and memory efficient. Since radio transmissions consume a significant amount of energy, researchers generally seek ways to reduce radio communication as much as possible. However, when more information is stored and more computation is done as to reduce the communication costs, energy consumption of the processor and memory components are becoming an important issue. Design choices have to be made, and these also depend on the intended application.

2 Problem statement

Currently there is a prototype of a system available, developed within Logica's Working Tomorrow program[1], which uses motion sensors to secure an area based on the Smart Dust concept [16]. The idea of the system is to monitor an area or room by a network of sensors with the size of a dust particle. To be more precise, the Smart Dust project is 'exploring whether an autonomous sensing, computing, and communication system can be packed into a cubic-millimeter mote (a small particle or speck) to form the basis of integrated, massively distributed sensor networks' [19]. In the prototype the size of a sensor is significantly bigger than a dust particle. The moment a sensor detects movement in the area a message is sent to a central server. The server processes the data and then uses Google Maps to produce a map which shows the detected movement. A GPS receiver is used to determine an absolute position, while RSSI (Received Signal Strength Indicator) is used to locate the sensors relative to the GPS receiver. RSSI uses the decrease in energy of the radio signal as it propagates in space to estimate the distance [6]. Experimentation with the prototype system shows this method becomes unreliable when the batteries of the sensors are getting weaker [16]. Simply using GPS receivers for all sensors is not an option as GPS cannot function in indoor and many outdoor applications, especially when there is no direct line of sight

[1]Working Tomorrow is Logica's graduate program that focuses on the feasibility and opportunities of innovative ICT solutions.

from nodes to terrestrial satellites. Besides, the use of these devices on sensor nodes is still a challenging issue due to their size, energy and price constraints [2]. As a result, there is a need for reliable localization in WSNs without the use of (a considerable amount of) GPS receivers.

Research will be focused on algorithms suitable for mobile indoor networks. The goal is to develop a prototype in which localization is reliable and which could be used in a convincing demonstration. The research questions reflect this twofold approach:

- Which algorithms exist for reliable localization in mobile indoor wireless sensor networks that use a minimal number of beacon nodes?
- Can we develop a prototype by implementing such an algorithm or an improvement thereof?

3 Motivation

A key advantage of a WSN is that the network can be deployed on the fly (ad-hoc deployment) and can operate unattended, without the need for any preexisting infrastructure and with little maintenance [4]. When the network size is small and the area to be monitored is human-accessible, each node can easily be deployed manually and their locations can be registered during deployment. Possibly, this is the simplest scenario. In more complex cases, when the area is not human-accessible or there are many nodes in the network, then manual deployment is infeasible or impossible to achieve. In the case of a forest fire detection system, where nodes should be deployed by a plane over the region, the locations of nodes cannot be registered during deployment. Another example scenario is that of a WSN deployed as part of the static infrastructure to detect fire as well as to locate and guide fire fighters during fire emergencies by communicating with mobile nodes they carry or wear [20]. Thus, the need for localization is closely related to how nodes are deployed [2].

Localization is not only needed for detection of the location of an event or an object; it is also needed for finding optimum coverage of an area and finding optimal routes in geographic routing [2]. Other applications employing localization in WSNs include monitoring of wildlife habitats [14], nature reserves such as the Great Barrier Reef [11], and forest fire detection systems [7, 8, 13]. Examples of military applications are battlefield surveillance [4, 10] and the previously mentioned securing of an area or room.

4 Theoretical scope

Localization in wireless sensor networks has been studied quite extensively and many different approaches exist [1, 3, 5, 9, 15, 17]. We have already described what a WSN is but will now introduce some terminology. Some aspects of localization algorithms to take into consideration are [2, 18]:

- *Input data*: range-free vs. range-based
  Range-free localization algorithms simply rely on connectivity information (whether nodes can hear each other or not and radio-range information). Ranged-based methods such as RSSI and GPS extract distance information from radio signals.
- *Accuracy*: fine-grained vs. coarse-grained
- *Positioning*: relative vs. absolute
- *Dynamics*: mobile vs. fixed
  In fixed networks nodes can establish their location in the initialization phase. Thereafter, their only task is to report events or relay information sent by other nodes. In mobile networks, however, nodes need to be aware of changes in their position and perhaps of position changes of other nodes.

- *Cost*: energy, price, memory, computation, infrastructure
- *Environment*: indoor vs. outdoor
- *Topology*: sparse vs. dense, uniform vs. random
- *Beacons*: beacon-free vs. beacon-based
  Nodes with known positions are called beacon or anchor nodes. In beacon-based algorithms, the percentage of beacon nodes over 'blind' nodes (nodes with unknown positions) is generally very small. The location of a beacon node can be determined using an attached GPS device or by manual deployment.
- *Processing location*: centralized vs. distributed
  If an algorithm collects localization related data from the network and processes the data collectively at a single station, then it is said to be centralized. If, on the other hand, each nodes collect partial data relevant to them and execute an algorithm to locate themselves, then the localization algorithm is categorized as distributed.
- *Hops*: single-hop vs. multi-hop
  A direct link between two neighbor nodes is called a hop. When the distance between two nodes is larger than the radio range but there are other nodes that create a continuous path between them, the path is called a multi-hop path.

5 Strategy

First, we will review the algorithms globally. The algorithm of choice often depends on the application and this also holds for localization algorithms. In a quantitative comparison of three distributed algorithms for large-scale sensor networks (100+ nodes) it is concluded that no single algorithm performs best; which algorithm is to be preferred depends on the conditions (range errors, connectivity, fraction of anchor nodes, etc.) [12]. For the purpose of a demonstration the localization time should preferably be not too long, the accuracy quite high and battery usage is not of prime importance as batteries can be replaced easily. However, a modest battery usage would be preferred in general. Although single-hop algorithms may suffice for a simple demonstration, it is said this approach is not scalable and requires the topology of the network to cover a very limited area [2]. Because part of the goal of the Smart Dust concept is to have massively distributed sensor networks in which not all nodes are within each other's range, a multi-hop algorithm is to be preferred over a single-hop one. Once a suitable algorithm has been decided on, a hardware platform for implementation will be searched for. Testing will take place indoors on a limited number of nodes. After testing the localization solution may be integrated with the existing prototype if time allows.

6 Time schedule

In the deliverables column chapters of the paper to be finished are shown. Activities take place in the specified week; deliverables are delivered at the end of the week. Every two weeks, starting September 22, a meeting is scheduled with the university supervisor. A separate meeting on the same day (following the same schedule) is held with the company supervisors.

Date	Activities	Deliverables
8-9	Explore literature, write proposal	Research proposal
15-9	Review literature globally, chapter outline	Introduction
22-9	Study literature in-depth, describe related work	
29-9	Study literature in-depth, describe related work	

6-10	Study literature in-depth, describe related work	
13-10	Study literature in-depth, describe related work	
20-10	Choose algorithm and hardware, describe related work	Related work
27-10	Read hardware documentation, explore platform	
3-11	Implement algorithm	
10-11	Implement algorithm	
17-11	Implement algorithm	
24-11	Implement and test algorithm	
1-12	Test algorithm, describe test setup	Test setup
8-12	Describe test results, improve results/algorithm	
15-12	Describe test results, improve results/algorithm	Test results
22-12	Integrate localization with motion detection	
29-12	Integrate localization with motion detection	
5-1	Write conclusion	Conclusion
12-1	Write final version	
19-1	Write final version	Final paper
26-1	Prepare usage of prototype for demonstration	Prototype documentation

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