Spotlight: Low-cost Asymmetric Localization System for Networked Sensor Nodes

University of Virginia

Tian He, Radu Stoleru, John A. Stankovic
{ Tianhe,rs6bd,Stankovic}@cs.virginia.edu

Many middleware services for sensor network applications have been developed successfully. Localization - finding the position of sensor nodes - remains one of the most difficult research challenges to be solved economically and practically.

Our answer to this challenge is a localization system called Spotlight. This system employs an asymmetric architecture, in which field motes do not need any additional hardware than what they currently have. All sophisticated hardware and computation reside on a single Spotlight device. We demonstrate that this localization is much more accurate than the range-based localization schemes and that it has a much longer effective range than the solutions based on ultrasound/acoustic ranging. Meanwhile, since only a single sophisticated device is needed to localize the whole network, the amortized cost will be much smaller than the cost to add hardware components to individual sensors.

The general idea of the Spotlight technique is to use a sophisticated spotlight device to generate controlled events that assist the localization of sensor nodes. An event could be, for example, the presence of light in an area. Using the time when an event is perceived by a sensor node the sensor node can be inferred. We envision, and depict in Figure 1, a sensor network deployment and localization scenario as follows: wireless sensor nodes are randomly deployed from a helicopter. A device (e.g. helicopter) flies over the network and generates light events over predefine traces. The sensor nodes detect the events and report to a base station the times when the events were detected. The base station computes the location of the sensor nodes.

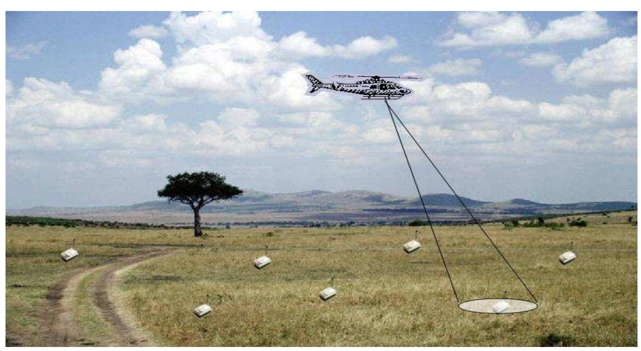

Figure 1: Localization of a sensor network using the Spotlight system

Formally, suppose that space *A* contains all sensor nodes *Ni*, and each node *Ni* is located at *Pi(x, y, z)*. To determine *Pi(x, y, z)*, a spotlight localization system needs to support three major functions as shown in Figure 2, namely a Detection Function *D(e)*, an Event Distribution Function *E(t)* and a Localization Function *L(t)*. The Detection Function *D(e)* is supported by the sensor nodes. It is a sensing module to determine whether an external event happens or not. The Localization Function *L(t)* and the Event Distribution Function *E(t)* are supported by a spotlight device. The Localization Function is an aggregation algorithm, which calculates the intersection of multiple sets of points. The Event Distribution Function *E(t)* describes the locations of the events (e.g. light spots) within the space A over a certain period of time. We implement multiple realizations of the *E(t)* function including Point Scan, Line Scan and Space Cover. Since the *E(t)* function is only realized at the spotlight device, its complexity is transparent to sensor nodes.

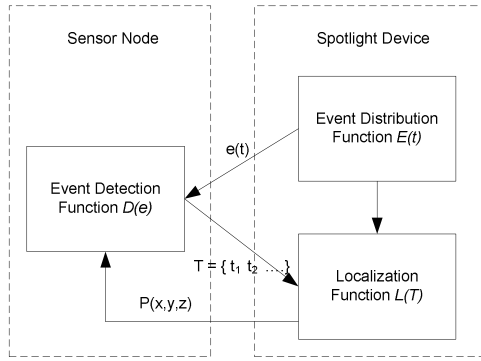

Figure 2: Spotlight system architecture

With the support of the three functions, the localization scheme proceeds as follows:

1. A spotlight device distributes events into the space *A* over a period of time.
2. During the event distribution, sensor nodes record the time sequence $T = \{t_1, t_2 \ldots t_n\}$ when they detect the event.
3. After the event distribution, each sensor node sends the detection time sequences to the spotlight device.
4. The spotlight device estimates the location of sensor nodes, using the time sequence *T* and the known *E(t)* function.

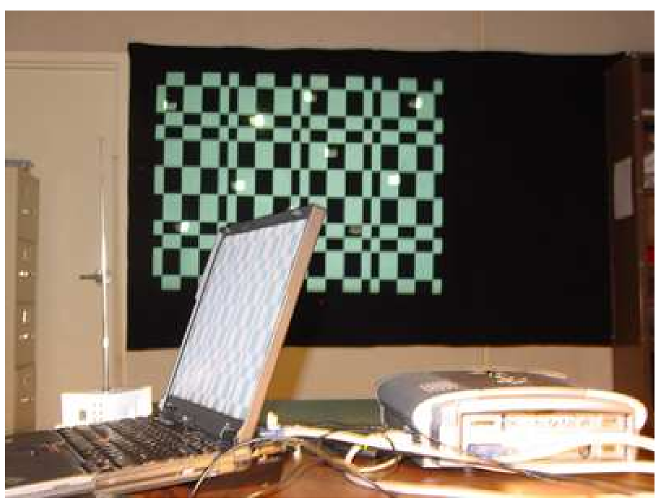

Figure 3: Spotlight System implementation

As shown in Figure 3, during this demonstration, we use a NEC MultiSync MT1030 projector connected to a DELL laptop. By projecting light to a vertical Veltex board, we distribute well-controlled events to the Mica2 motes attached to the board. Specifically, we will demonstrate the localization process of the point scan, line scan and area cover. We will also provide insights into how this localization scheme can be successfully applied to realistic outdoor environments.