MoteTrack: Robust, Decentralized Approach to RF-Based Location Tracking

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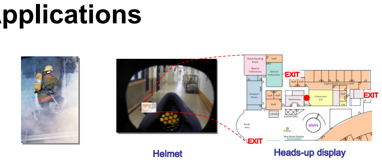
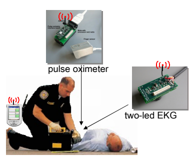
Introduction

Localization is essential to a wide range of applications. For some, the location tracking system must continue to operate despite the partial failure of the infrastructure. Our system, called MoteTrack, is based on low-power radios coupled with a modest amount of computation and storage. MoteTrack does not rely upon any back-end server or network infrastructure: the location of each mobile node is computed using a received radio signal strength signature from numerous beacon nodes to a database of signatures that is replicated across the beacon nodes themselves. This design allows the system to function despite a significant failure of the beacon nodes.

Applications



- Firefighters and rescuers can use a heads-up display to track their location and monitor safe exit routs.



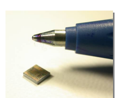
- Medics can track the location of patients instrumented with vital sign sensors.

Research Challenges

- Accurate RF-based localization with low-power radios
- Low device capability and memory size (Motes platform)
  - e.g., Mica2: 4KB RAM, 8-bit CPU, no floating point unit; Can't do real signal processing
- Robustness to failed nodes
- RF characteristics of building may change

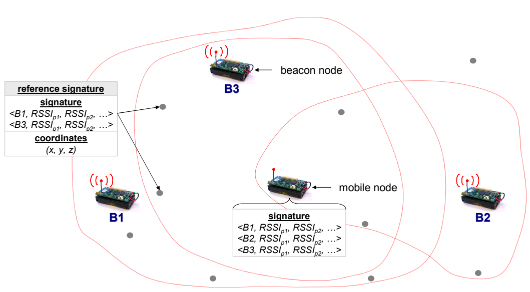
Why the Motes Platform

- Different technology curve than PDAs or laptops
  - inexpensive, small, low-power, programmable
  - can be readily incorporated into equipment and uniform
  - will eventually shrink to very small sizes



- Spec Mote (5 mm^2)

Estimating Locations



Phase I - offline setup (performed once)

- Placement of beacon nodes, which broadcast beacon messages
- Reference signature database construction
  - acquired by collecting ***beacon message*** {srcID, power} samples at known locations
  - ***reference signature*** - a known location (x, y, z) with the set of beacon messages received over some time interval along with the RSSI for each transmission power

Phase II - location estimation

- Mobile node acquires its location's signature by listening for beacon messages
- *k* closest (in signal space) reference signatures to the signature are selected
- The signature's location is estimated to be the centroid of the selected reference signatures

Achieving Robustness

Decentralized Location Estimation Protocol

- The location estimation runs on the programmable beacon nodes using their local reference signature database slice, rather than a back-end server

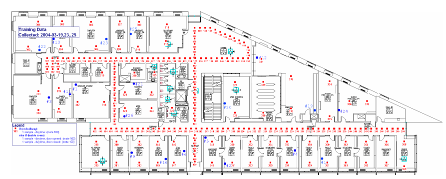
Distribution of Reference Signatures to Beacon Nodes

- Because of limited storage capacity, each beacon node stores a small slice of the entire reference signature database.
- Reference signatures are assigned to beacon nodes such that each beacon stores the "most relevant" set while ensuring that each reference signature is replicated across several beacon nodes in case of failures.

Adaptive Signature Distance Metric

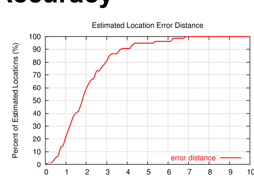
- The signature distance metric adapts to beacon node failures
- Beacon nodes periodically estimate the local failure ratio, which determines what distance metric to use:
  - ***bidirectional*** – more accurate, but introduces errors when there are failures
  - ***unidirectional*** – considers only operational nodes heard by the mobile node and therefore it has a smaller comparison space

Evaluation



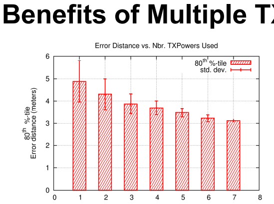
- Deployed in Maxwell Dworkin 2nd floor using 20 beacon nodes (1,742 m^2)
- Training data (reference signature database) – blue dots represent beacon nodes; red squares represent reference signature locations

Accuracy



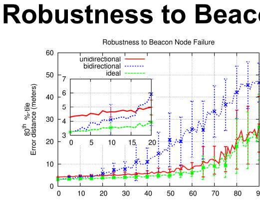
- 80% of the location estimates are within 3 meters of their true location
- The data is for 74 location estimates

Benefits of Multiple TX Powers



- Using more TX powers reduces error and standard deviation considerably
- TX powers range from -20 to 10 dBm

Robustness to Beacon Node Failure



- The *unidirectional* metric is more robust to significant beacon node failures, but yields poorer accuracy for few failures (less than 16%)
- *ideal case*: bidirectional metric using only non-failed nodes (requires perfect knowledge)

http://www.eecs.harvard.edu/~konrad/projects/motetrack