Positioning, Localization and Tracking in Large Scale Wireless Sensor Networks

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Motivating Problem

- Localization And Tracking (LAT) of people and objects:
  - in environments or particular situations in which traditional localization and tracking systems fail (e.g. GPS).
  - with an accuracy of 50 cm in three dimensions.
  - both indoors and outdoors.

Application Scenarios

- Health Care and Assisted Living.
- Indoor Localization and Navigation
  - in normal or emergency situations
- Surveillance or Monitoring people or objects for other reasons (individuals, groups or crowds).
- Logistics and goods tracking.
- …

General Approach to the LAT Problem

- Every possible solution to the LAT problem needs some kind of localization and tracking infrastructure.
- Therefore, there are two possible approaches:
  1. the person or mobile object can compute their position using appropriate devices and data provided by localization infrastructure.
  2. the localization infrastructure directly detects the positions and tracks people and mobile objects.
- Most localization and tracking systems use the first approach (e.g. GPS).

Positioning, Localization and Tracking

Positioning and Localization

Introduction

- Determine *physical position* or *logical location*
  - Coordinate system or symbolic reference
  - Absolute or relative coordinates
- Options
  - Centralized or distributed computation
  - Scale (indoors, outdoors, global, …)
  - Sources of information
- Metrics
  - Accuracy (how close is an estimated position to the real position?)
  - Precision (for repeated position determinations, how often is a given accuracy achieved?)
  - Costs, energy consumption, …

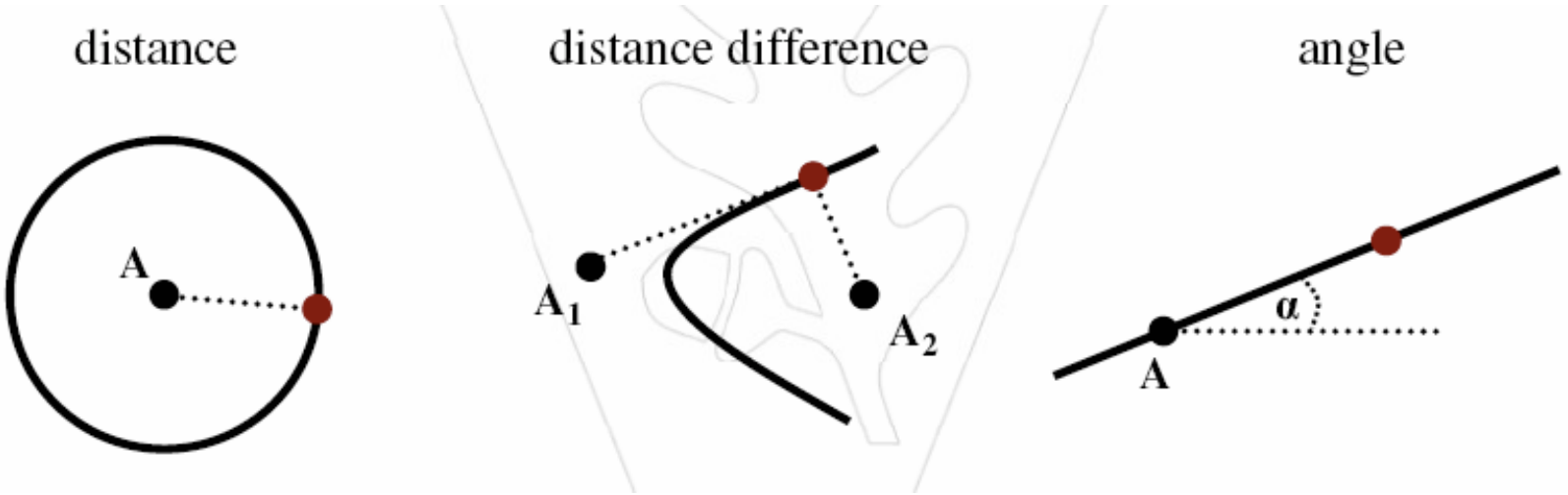
Positioning and Localization

Main Techniques

- Range-Free (Proximity)
  - No distance estimation
- Ranging and Localization
  - Use distance or angle estimates, simple geometry to compute position estimates
  - (Tri-/Multi-)lateration and angulation
  - Multihop schemes
- Scene analysis
  - Radio environment has characteristic "signatures"
  - Can be measured beforehand, stored, compared with current situation

Ranging

- measure low-level spatial relations between nodes
  - distances, distance differences or angles.

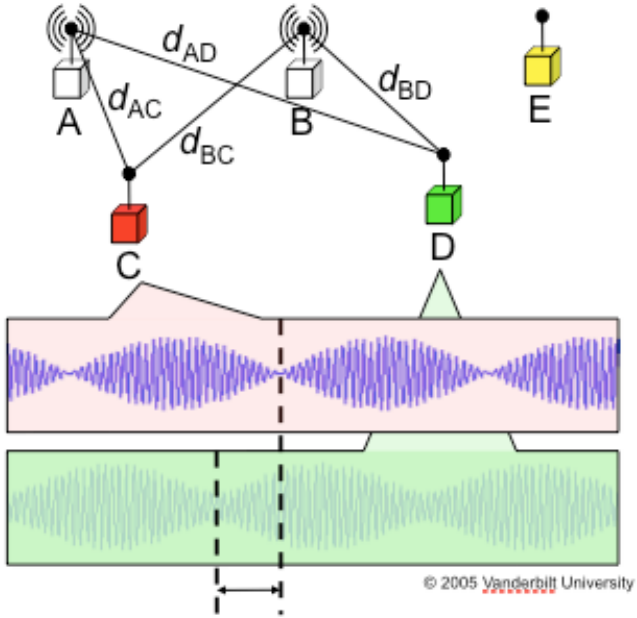


Ranging Techniques

- Received Signal Strenght Indicator (RSSI)
- Time of Arrival (ToA)
- Time Difference of Arrival (TDoA)
- Angle of Arrival (AoA)
- Radio Interferometric Measurement (RIM)

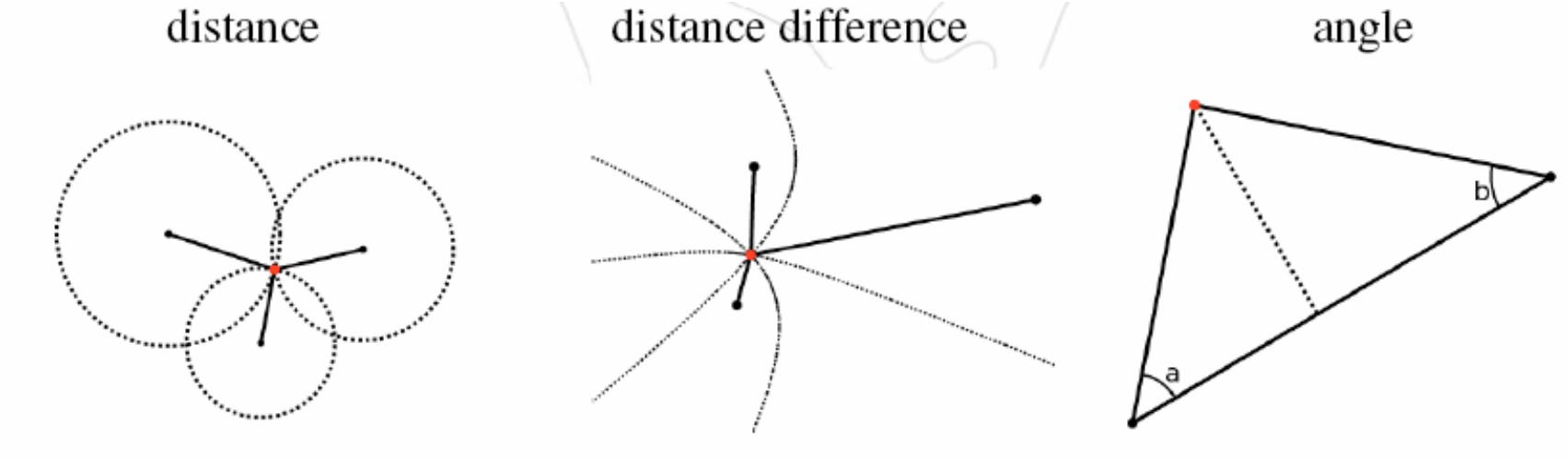
Radio Interferometric Measurement

- RIM is a novel technique that requires two sensors, *a* and *b*, transmitting simultaneously at slightly different frequencies, f_a and f_b .
- The combined signal exhibits a beat frequency, $| f_a - f_b |$, with a phase that is a function of receiver location.
- The difference in this phase at two different receiving sensors *c* and *d* is a function of the coordinates of the two transmitters and two receivers.



Localization

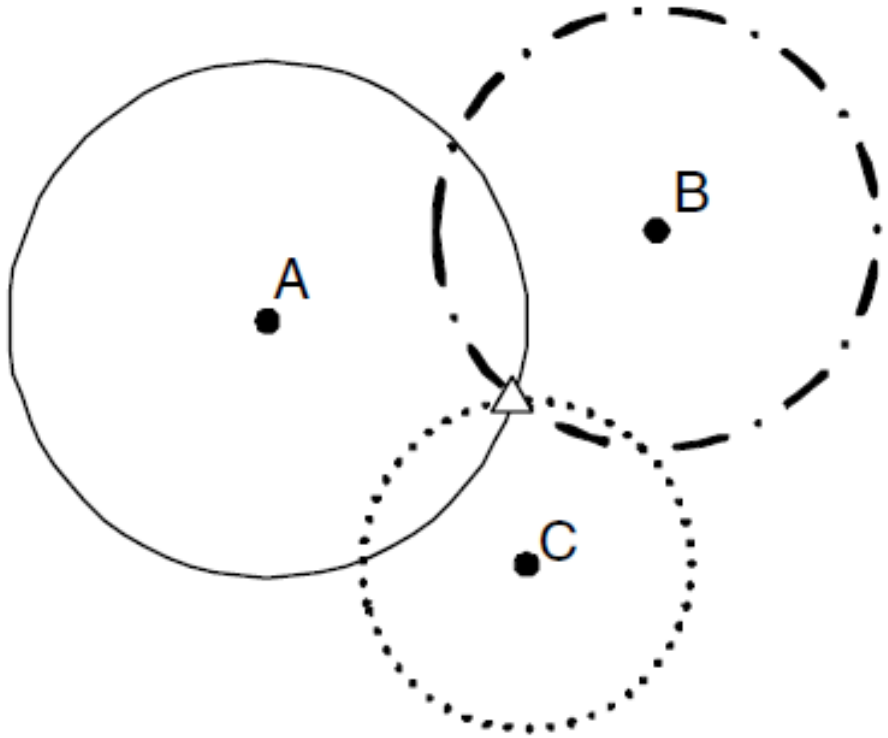
- establish a common coordinate system across the network
  - absolute or relative



Localization

Trilateration

- Case (a)
  - Precise distance measurements
- Using elementary geometry we can derive the position of an object.

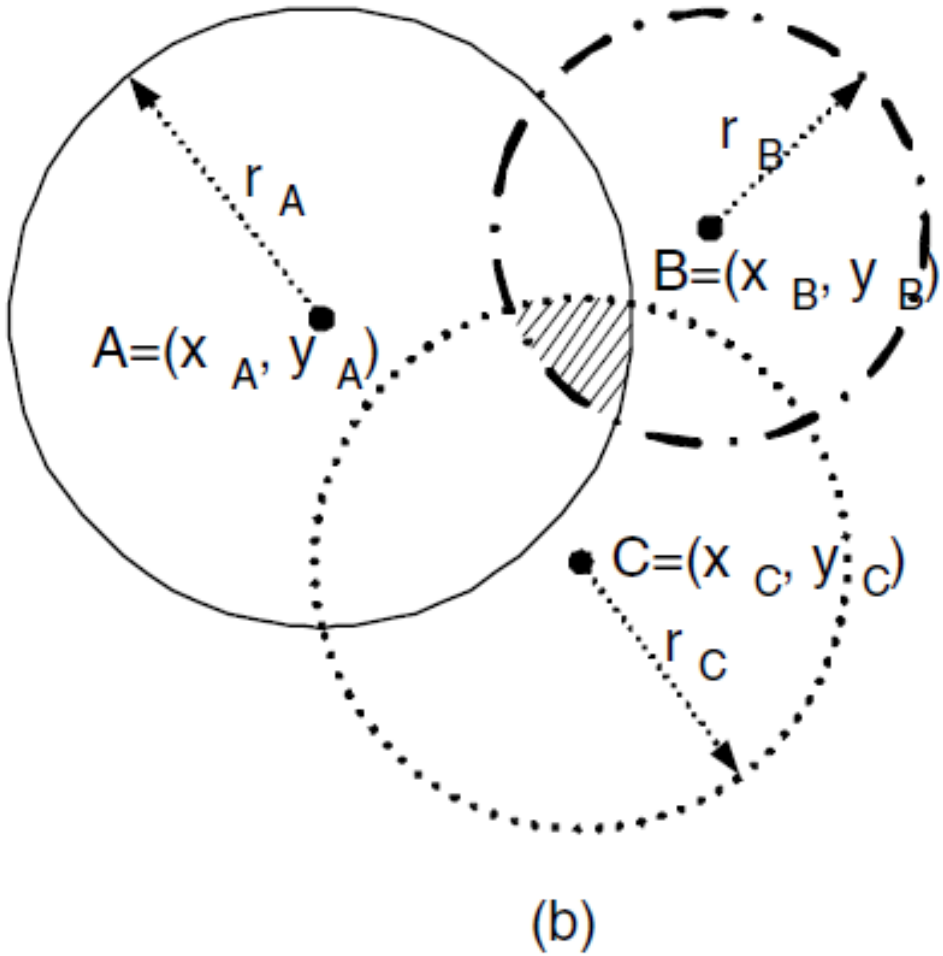


(a)

Localization

Trilateration

- Case (b)
  - In reality, distance measurements are never precise
- The intersection of these three circles will not result in a single point.



(b)

Tracking (1)

- *Tracking* is the problem of finding trajectories of possibly moving targets.
- It is a complex problem, involving multiple sub-problems:
  - target detection, classification, and identification problem
  - activation problem (which sensors to activate for tracking)
  - smoothing and filtering of location estimates

Tracking (2)

- Given the locations of the nodes and accurate range information to the target, it is straightforward to determine the target's position.
- Consequently, traditional tracking applications tend to be split into two separate phases.
  - Localization phase: the network is localized using a specialized algorithm.
  - Tracking phase: after localization completes, target positions are estimated based on the discovered sensor positions.
- Problem: Calibration

Localization and Tracking in WSN

Research Direction

- A huge number of WSN Localization and Tracking systems have been developed during last few years.
  - But the problem is still open

- The NOMADIS Lab is developing a localization and tracking system that aims to significantly improve current WSN-based localization systems.
  - improving the wireless sensor nodes
  - improving the localization infrastructure

Localization Infrastructure

- Improving localization and tracking infrastructure:
  - improving localization and tracking process (often very "statical").
    - ⋆ simultaneous localization, calibration and tracking
  - improving distributed inference capabilities and using heterogeneous sensors.
  - using topological data when available.
  - with new ranging and localization techniques (RIM).

Wireless Sensor Nodes

- Actively using the computing capabilities of Wireless Sensor Nodes
  - using more suitable sensors (e.g. inertial sensors)
  - using lightweight signal processing for in-network pre-processing of localization and tracking data.

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