Overview: Chapter 2

- Localization and Tracking
  - Assume a large number of sensors that are deployed in the field
  - Goal is for these sensors to collectively process information. Tracking allows the sensors to track an object that traverses the sensed field
  - Multiple objects might be tracked simultaneously
  - Challenges are in performing this in realistic scenarios, where the nodes are not distributed uniformly, sensing models are complex and communication state requires energy resources

Deployment issues

- Uniform distribution (in 2D) or random distribution
- Environment
  - Flat space with no variations
  - Terrain variations, air density variations, light variations
    - Needs models of environment to understand observations

Tracking scenario

- Discovery: Node *a* detects *X* and initializes tracking
- Query processing: User query *Q* enters the system and is routed towards the region around *a*
  - Long running queries also co-exist
- Collaborative processing: Node *a* estimates location of target (triangulation, least squares computation, Bayesian estimates)
- Communication: As target moves, new nodes take responsibility for tracking. Hand-off is distributed and is a 1-hop neighbor of *a*. Poor choice means lost tracking
- Reporting: The track information is summarized and sent back

Fundamental challenges

- Collaborative processing: target detection, localization, tracking, sensor tasking and control
- Networking: data naming, aggregation and routing
- Databases: data abstraction and query optimization
- HCI: data browsing, search and visualization
- Infrastructure services: network initialization and discovery, time and location services, fault management and security

Problem formulation

- The system continuously operates with K nodes, tracking N objects. Sensing should happen among data from the same time
- Collaborative localization:
  - Triangulation (GPS): Model of signal propagation, sensors. Each sensor figures the range. Multiple sensors collaborate to triangulate the location. Need to avoid frequent communication
  - Bayesian State Estimation: Estimates probabilistically based on the current sensor readings.
    - Commonly used estimator: minimum mean squared error
    - Centralized estimation: all readings sent to a single sensor
      - Scale linearly with more nodes, not robust (single failure point)
    - Sequential estimation: newer readings are used

Distributed Representation & Inference

- Choice of representation
  - Parametric approximation (e.g. Gaussian)
    - All sensors are aware of the parametric class
      - If gaussian, then we can transmit mean and covariance
    - Kalman filters can be used to represent measured data
  - Non parametric (discrete samples)
    - More accurate, but expensive for network
- Distributed tracking
  - Fixed node stores state
  - Leader node is selected in succession based on motion
  - All nodes know all state

Tracking multiple objects

- Curse of dimensionality: more phenomenon scales exponentially
  - State space decomposition
- Mapping to distributed platforms:
  - Data association
    - No signal mixing
    - Composite measurement

Sensor models

- Amplitude sensors
- Direction-of-arrival sensors
  - Accuracy depends on the model of transmission
    - Lossless and isotropic, RMS amplitude

Performance comparison and metrics

- Detectability
  - E.g. Source SNR
- Accuracy
  - E.g. Obstacle density
- Scalability
- Survivability
  - Percentage of track loss
- Resource usage
  - E.g. Network sleep efficiency