Overview: Chapter 4

- Infrastructure Establishment
  - Necessary for the functioning of the sensor system
    - Neighbor discovery and organization
    - Placement in common temporal and spatial framework
      - Time and location
      - E.g., when a sensor notices a truck at t1 in location l1, we can make correlate that with other sensors
    - Topology control, clustering, time synchronization and localization

Topology control

- Neighbor discovery
  - nodes die or turn off/lower range to save power
- Simple setup:
  - All nodes must transmit at the same power/range
  - Critical transmitting range problem: compute the minimum common transmitting range such that the network is connected
    - Length of the longest edge of the minimum spanning Euclidean spanning tree (MST) connecting nodes
    - Probablistic solutions: geometric random graphs
- Realistic setup
  - Allow varying transmission ranges
    - Shorter range in dense deployments, longer in sparse
    - Range assignment problem: NP complete
- Resource intensive for sensor scenarios
- Distributed approaches (e.g. COMPOW)

Clustering

- Nodes organize as hierarchical clusters, either naturally or for convenience
- Resource rich sensors can act as cluster heads (GPS, energy etc.)
- Frequently, nodes are picked to be cluster heads, rotating around to reduce resource demands on a single node
- Resources managed locally within cluster
  - Communication between clusters (especially dense) are mediated via cluster heads
- Group of Cluster heads work with gateways

Time synchronization

- Readings must be correlated to a common time frame
  - Localization algorithms use ranging techniques that need time of flight
  - TDMA radio schedules need commonly understood time
- Wired world, we use NTP (synchronize with multiple and well known stable clocks)
  - Constant communication to reduce drift
- Sensors can tolerate local synchronization as well as time ordering of events (and not absolute time values)

Clocks

- Hardware oscillator provides heartbeat clocks
  - Environmental conditions cause drift (skew)
  - Clock phase difference (clock bias)
- To synchronize clocks, we use messages
  - Send time: Sending side, including OS delays
  - Access time: MAC specific access to wireless channel
  - Propagation time: long for multi-hop. Depends on environment, multipath etc.
  - Receive time: Network interface to OS
    - Interface can time stamp to reduce dependency

Clock phase difference estimation

- Node I sends local clock t1 to node j
- Node j records local time t2 = t1 + D + d
- Node j at t3 sends message to node I with t1, t2, t3
- Node I receives message at t4 = t3 + D - d
  - D = (t2 - t1 - t4 + t3)/2
- Node I sends d to node j

Interval methods

- Transform node I's notion of interval into node j's
- Use acknowledgements to measure delays, piggyback measurements in future packets
  - Need to keep track of all prior communications - assume they will be needed in the future
- Reference broadcasts
  - Clusterhead or some such node transmits one time. Receivers synchronize amongst themselves (because they all heard the same reference broadcast)
  - Repeat many times to offset measurement anomalies
  - Hierarchy of (overlapping) neighborhoods

Localization (spatial component)

- For some scenarios, it is important to know where the event occurred
  - Especially true for ad hoc deployments
- Self-localization- nodes figure out their location
  - GPS is becoming inexpensive, but still consumes energy
  - Use nodes with GPS as landmarks to localize other node
- Ranging techniques
  - Estimate distance of receiver from a transmitter using received signal strength
    - Inaccurate because of fading, shadowing, multipath etc.
    - Sensor components are cheap and not precise
    - Bats seem to be fairly good at it though
  - Time of arrival * signal propagation speed
  - Time difference of arrival at two receivers

Range based localization algorithms

- Use landmarks to localize
- Collaborative multilateration
  - Create collaborative subtrees
  - Refine using iterative techniques such as kalman filters
- Multipe triangle containment tests
- Location services
  - Spatial quad-tree to allow node u to look for object at a certain location. The sensor at the location should let the location server know about it. U needs to be able to find this server