



Communication and localization problems in wireless sensor networks

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Cooperative beamforming for wireless networks

(joint work with Ben Wild, Prof. K. Ramchandran, UC Berkeley, Prof. J. Hespanha, UCSB, Gwen Barriac, Qualcomm)

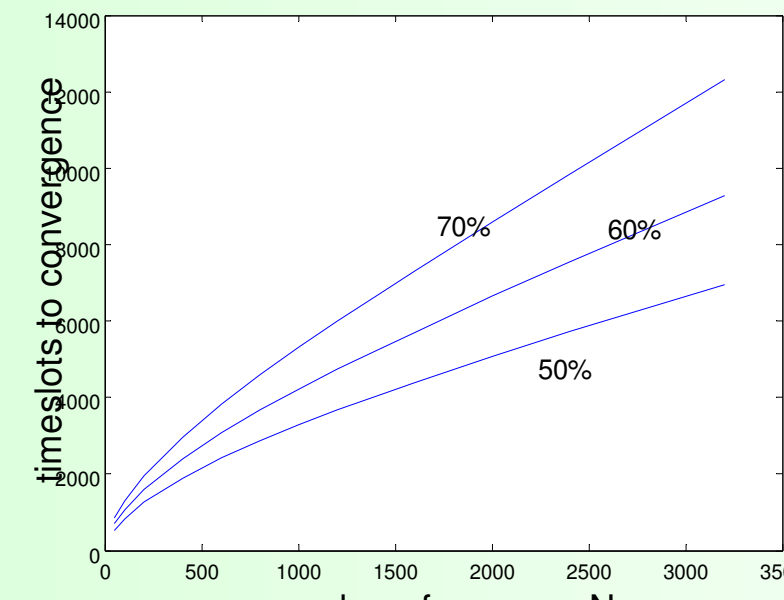
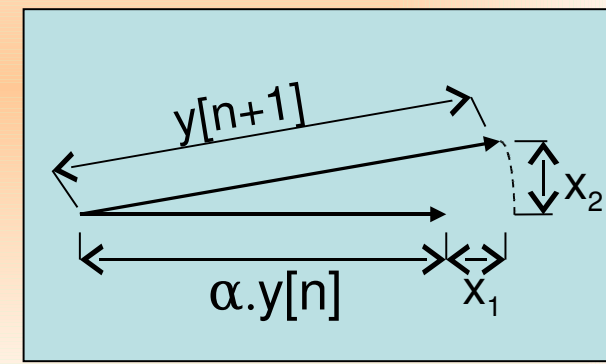
Modeling the convergence behavior

Random phase perturbations has two effects:

- 3. Change in SNR
- 4. Rotation of received signal

Large number of transmitters

- Use statistical model
- Predicts convergence behavior accurately

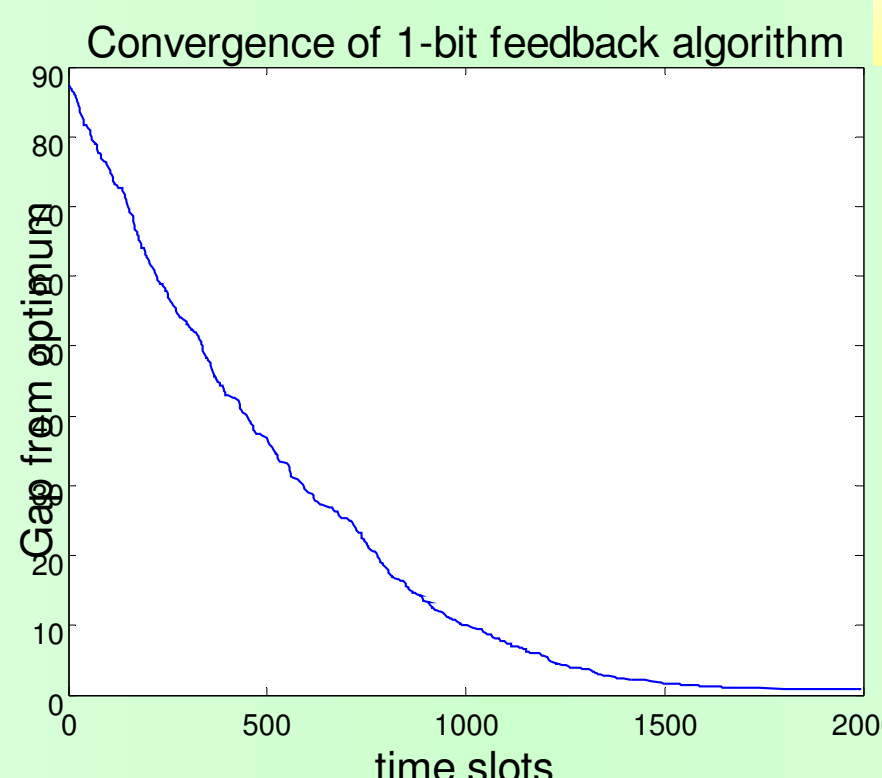
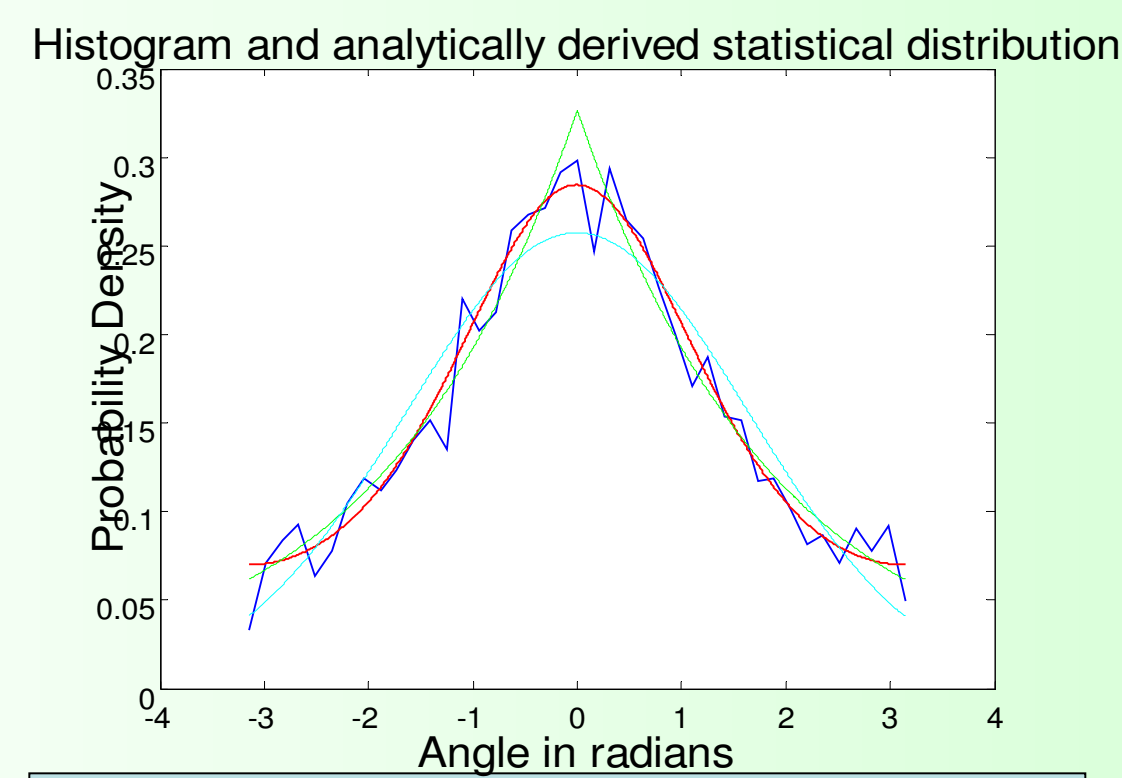


Analytical model for optimizing convergence

- time to convergence scales linearly with N
- Same scaling as centralized scheme!!

Distributed synchronization algorithm

- Try indep. random phase adjustments
- $\phi_i \leftarrow \phi_i + \delta_i$
- If SNR increases
- add δ_i to best known phase estimate
- Else
- discard δ_i and try again

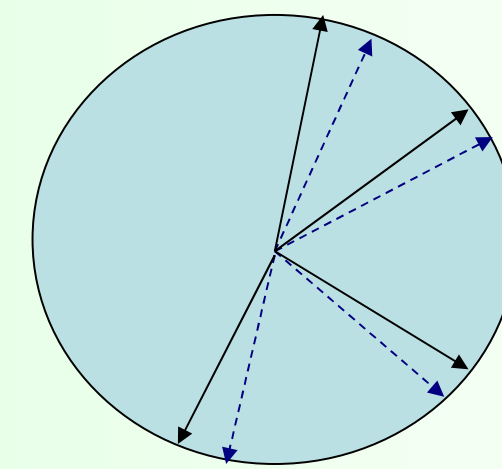


Main bottleneck: unsynchronized oscillators

- Frequency lock to broadcast reference carrier easy
- Standard order-2 PLL can correct arbitrary freq offset

Phase reference harder to obtain

- Arbitrary phase offset from propagation delays



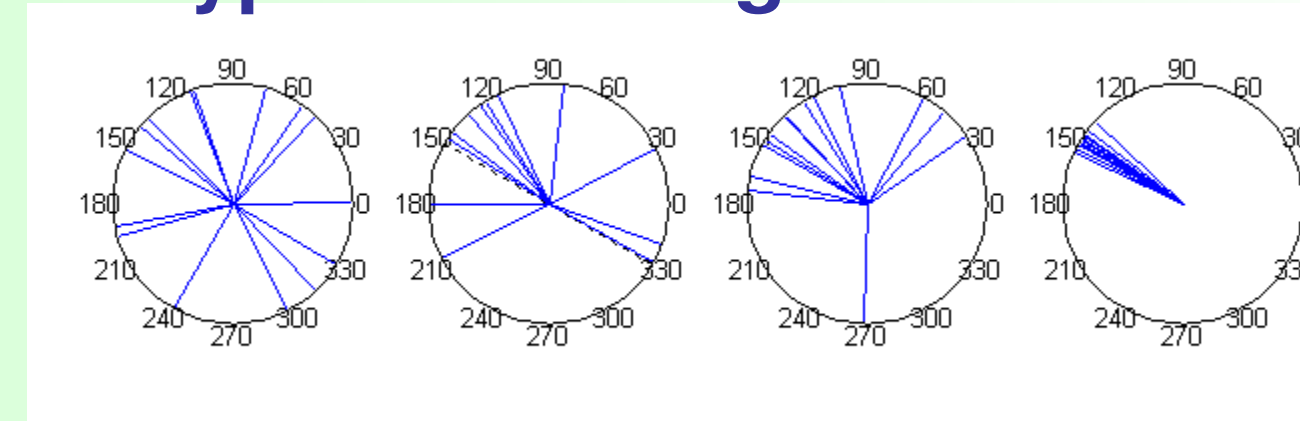
Multiple transmitters transmit the same message cooperatively

- Coherent combining for beamforming gains
- N transmitters \rightarrow N fold increase in energy efficiency

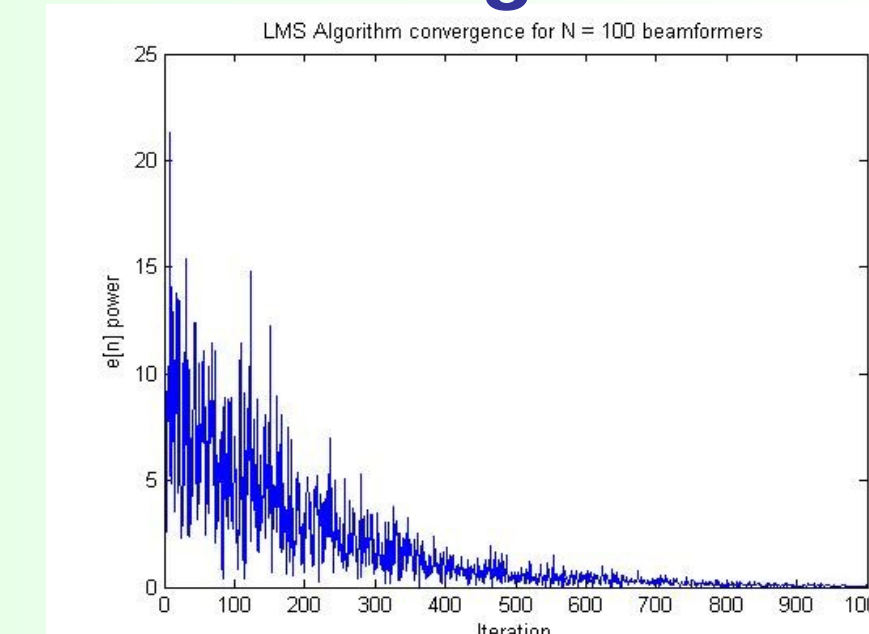
Solution for phase sync:

- A stochastic gradient approach
- 1-bit feedback from receiver

Typical convergence behavior

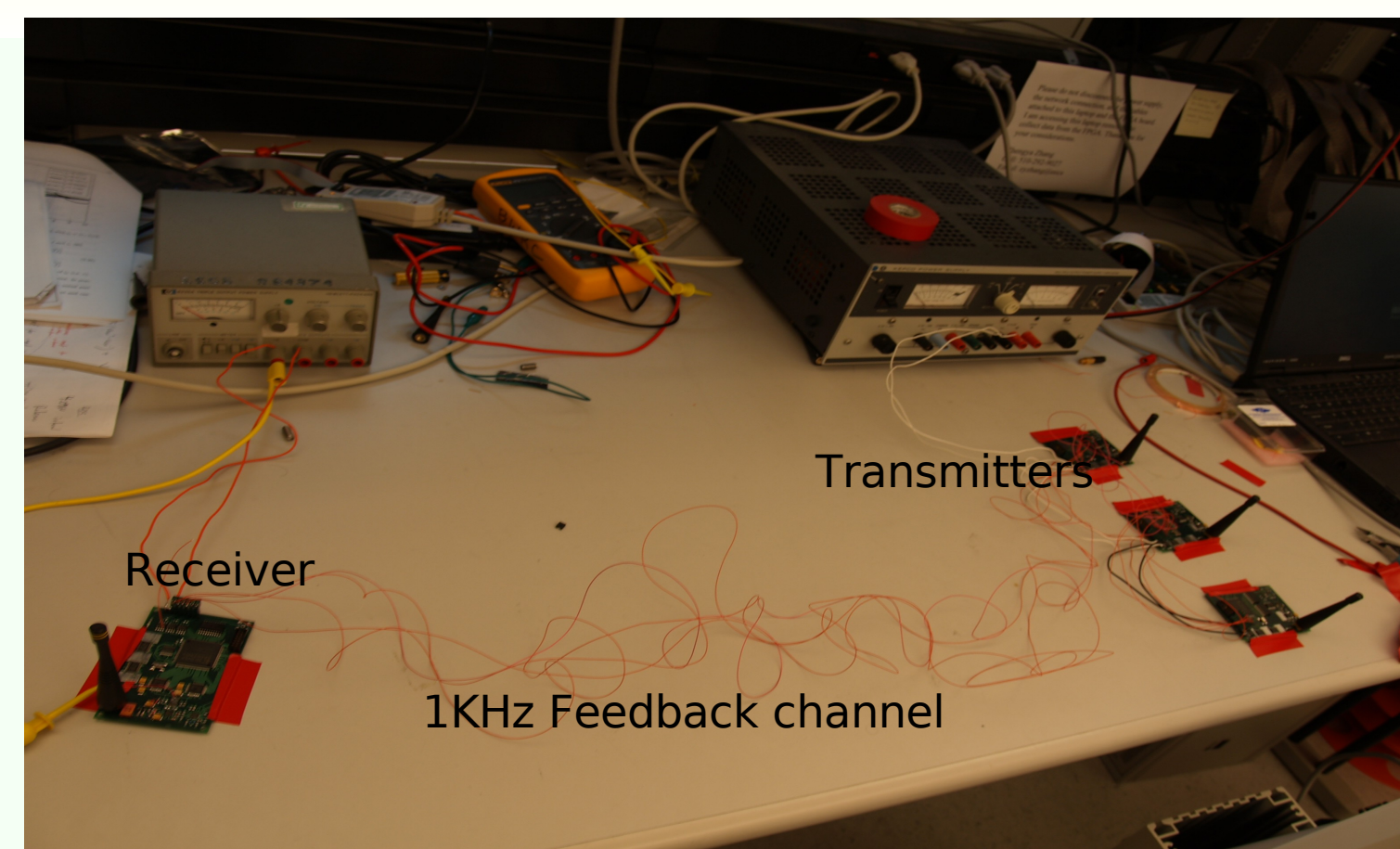


Comparison with LMS algorithm



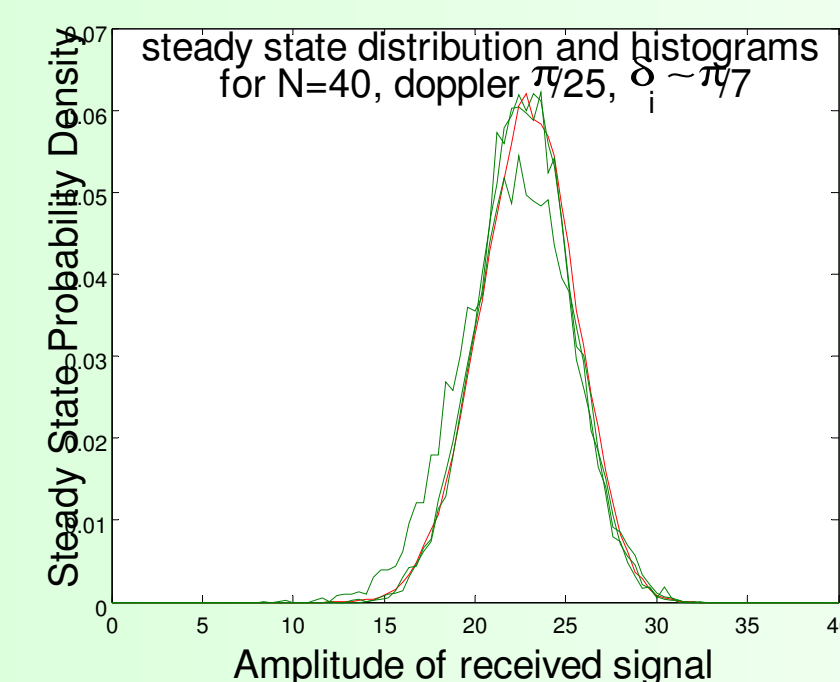
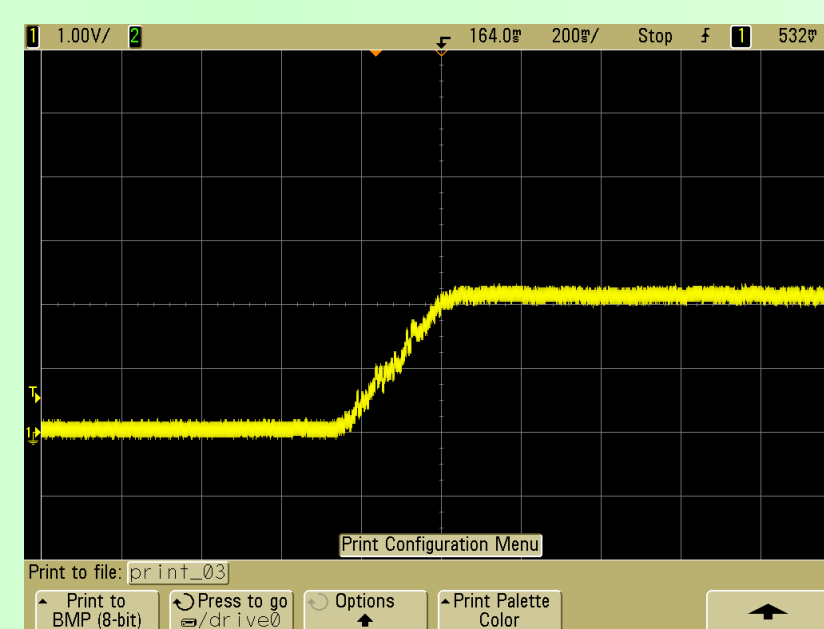
Practical limitations

- Channel time variations
- Noisy feedback
- No asymptotic coherence
- Algorithm tracks fades
- Dynamic steady state
- Insight from analytical model
- Steady-state pdf



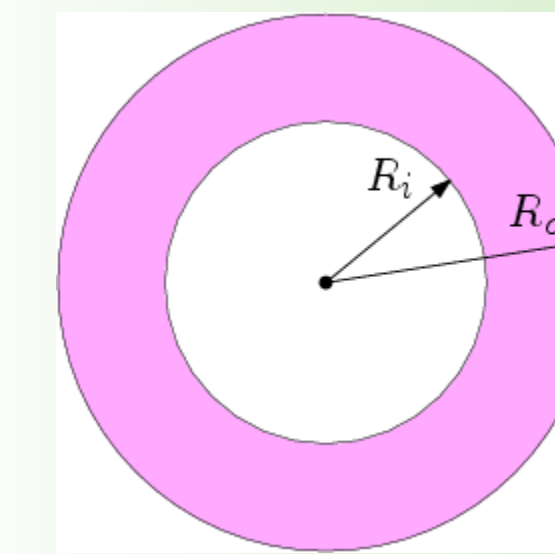
Preliminary results

- 1-bit feedback gives SNR gains
- Highly sensitive to PLL parameters
 - careful choice of loop filter needed
- Soon: more detailed data from prototype



Fundamental limits of binary localization sensors

(joint work with N. Shrivastava, Prof. S. Suri, UC Santa Barbara)

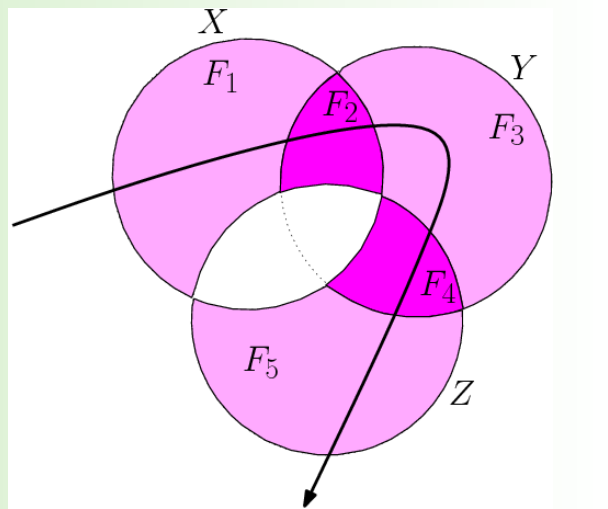


Simple binary detection model

- detect objects within some radius
- only yes/no detection, no range info

Practical imperfections

- detection errors
- misses and false positives
- variations among sensors



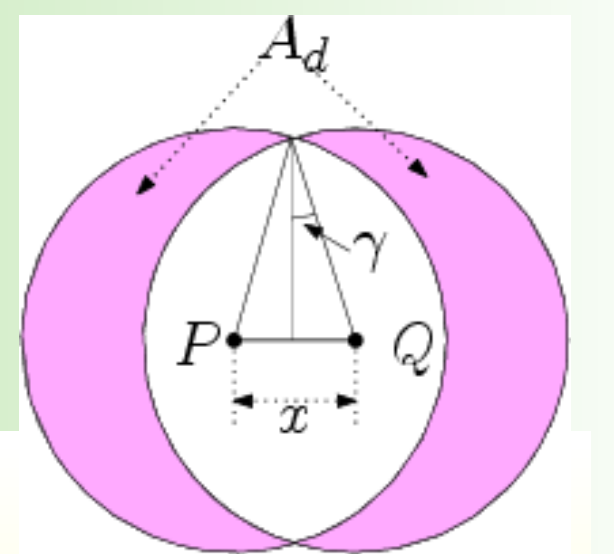
Localization patches

How well can we localize with a network of sensors

- Each sensor can localize to within detection range
- Better localization by aggregating sensor data
- Intuition: more sensors \rightarrow better localization
- Does larger detection radii improve localization?

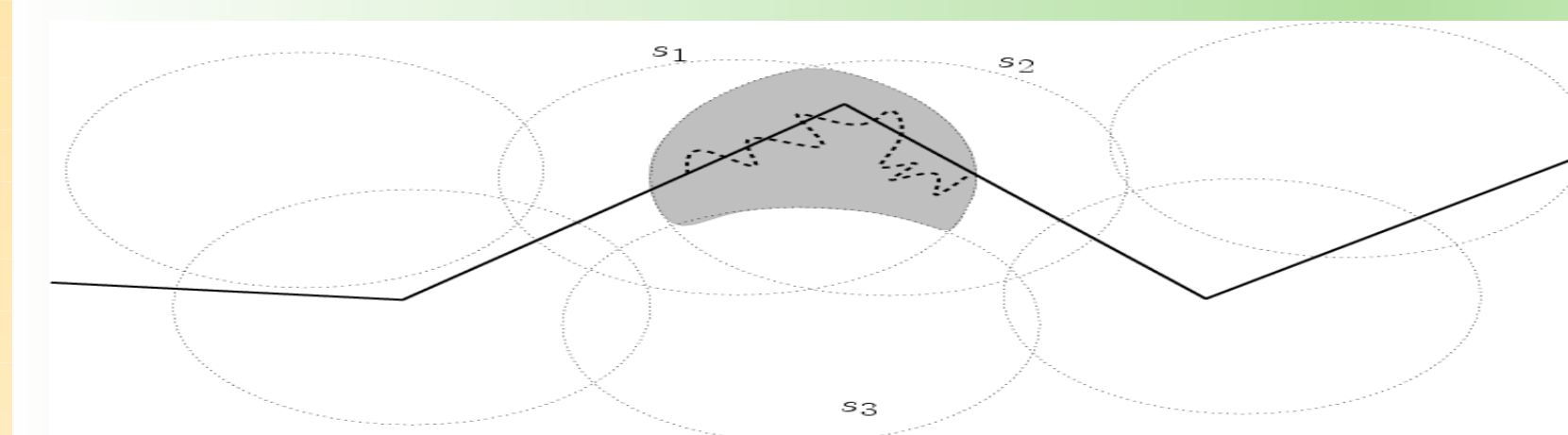
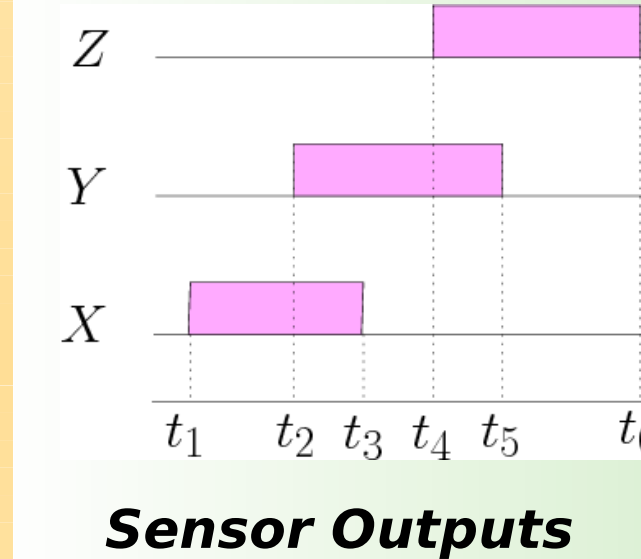
Fundamental limits with geometric methods

- Probability that P & Q be distinguished
- For random deployment density ρ
- Localization accuracy $\propto \frac{1}{\rho R}$



Binary network for tracking

- Tracking \rightarrow localization over time
- Binary sensors give sampled trajectory
- "Low-pass" version of actual path
- Simple geometric approach
 - motivated by Occam's Razor
 - works well for smooth paths
- Does NOT work well with detection errors
- Combination of geometric and particle-filtering



Experiment with acoustic notes

- uses a tone-detection circuit for detection
- Extremely noisy and unreliable
- One sensor failed completely!
- Geometric approach not optimal
- Needs to be combined with particle filtering
 - works even with extreme imperfections

