Distributed spatio-temporal spectrum sensing: An experimental study

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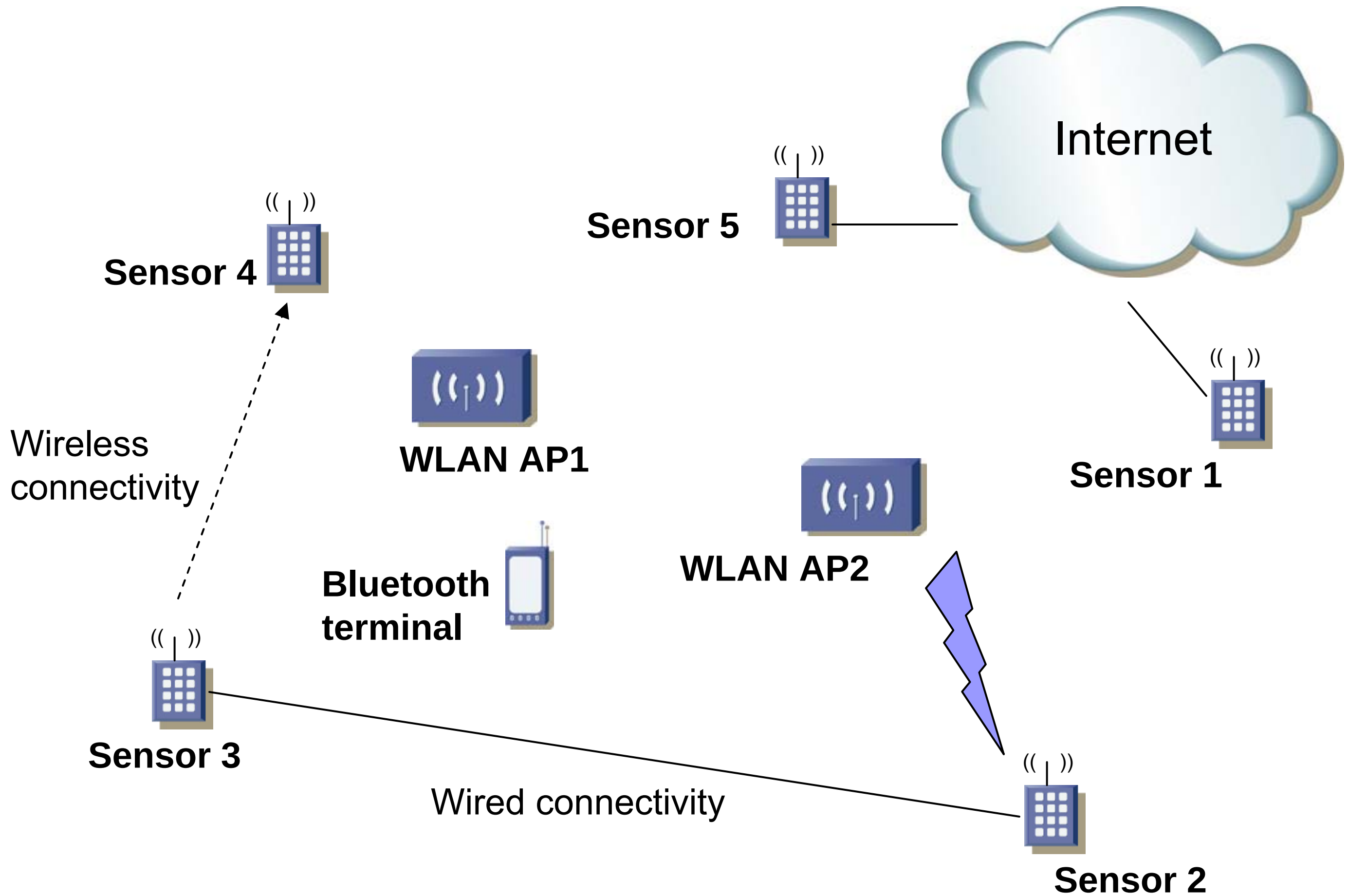
IAB Fall 2007

Spatio-temporal spectrum sensing



How do we localize multiple transmitters in *space and frequency* using multiple (collaborating) sensors?

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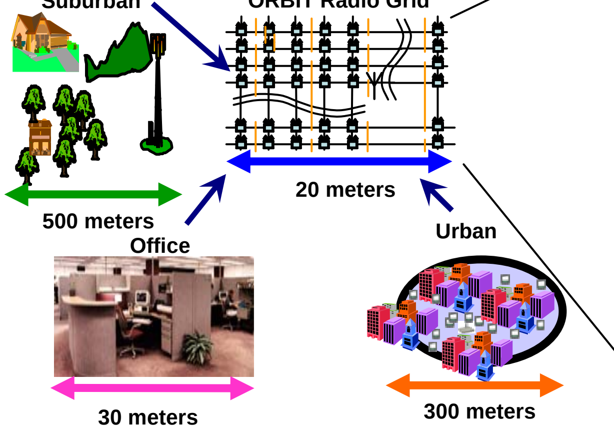
Spectrum sensing for Dynamic Spectrum Access

- Spectrum sensing mandated in cognitive radio standards, e.g., IEEE 802.22
- Usage of unused white spaces require faster sensing
  - coarse localization OK
- Challenges of identifying transmitters in unlicensed band
  - multiple heterogeneous radios
  - sporadic transmissions
  - transmission over a wide band

Radio platforms in ORBIT, WINLAB



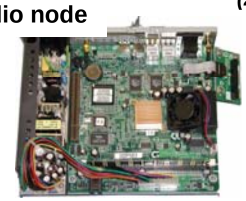
Radio Mapping Concept for ORBIT Emulator

400-node Radio Grid Facility at WINLAB Tech Center

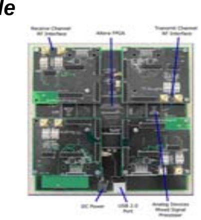
Current ORBIT sandbox with GNU radio

Interfaces supported: Zigbee, WiFi, Bluetooth, GNU Radio

Programmable ORBIT radio node



Planned upgrade (2007-08)

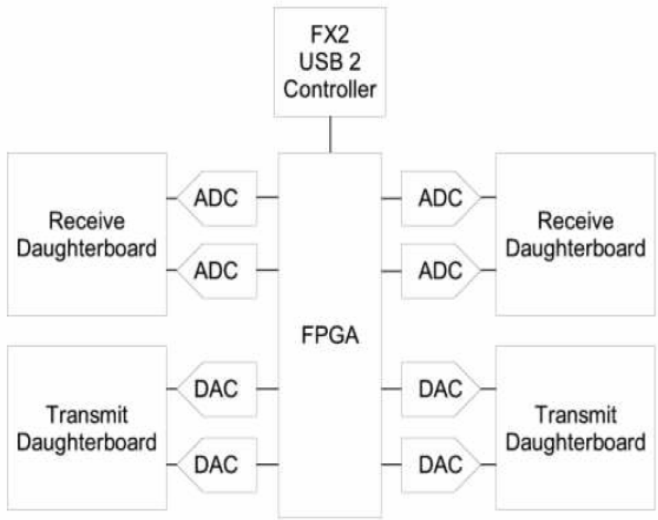


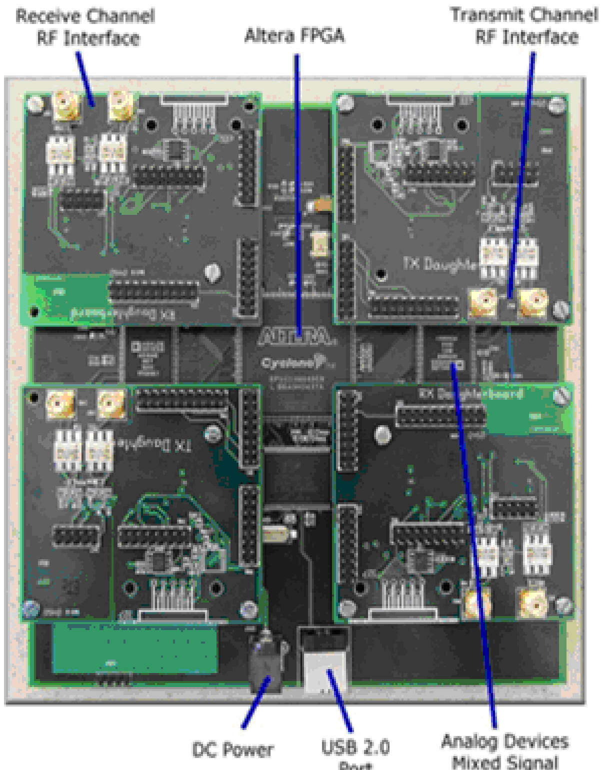
URSP2 CR board

http://www.orbit-lab.org

GNU Hardware/Software platform (Blossom)

- GNU/USRP boards with GNU Software with API's for flexible PHY and MAC are currently available for experimentation
- Various RF front-ends (0-100MHz, 400MHz, 900MHz, 2.4GHz) with data rates upto 64 MSamples/sec
  - Limitation of USB 2.0 interface
- All DSP functions in software on general-purpose CPU





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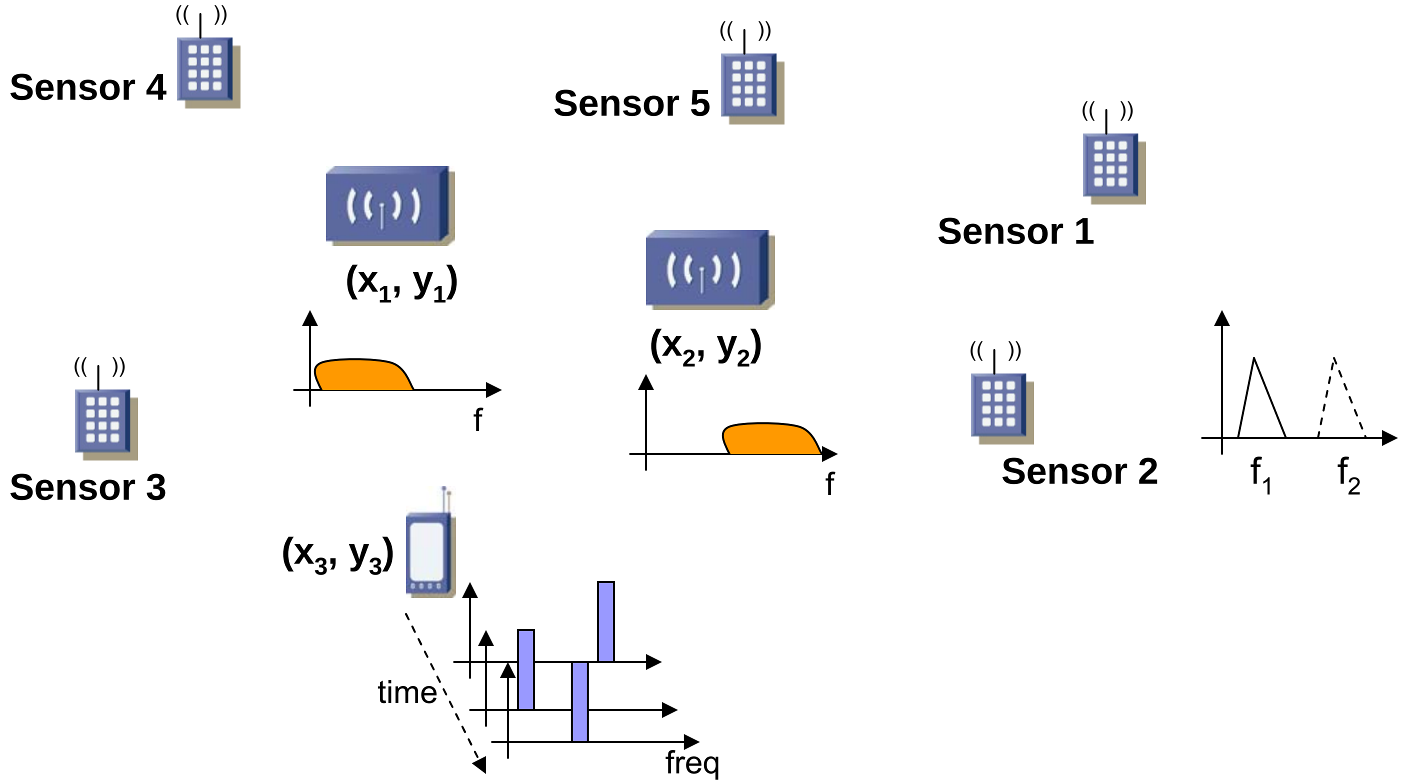
Spectrum sensing problem



- Using frequency agile sensors capable of sensing limited band
  - How do we localize interfering transmitters in space?
  - How can we find the spectral occupancy in a given band of frequencies?

Overview of topics

- Localization of single transmitter
- Localization of two transmitters in the same band
- Spectral occupancy over a wide band
  - Localizing the frequency of a single transmitter
- Challenges and future work

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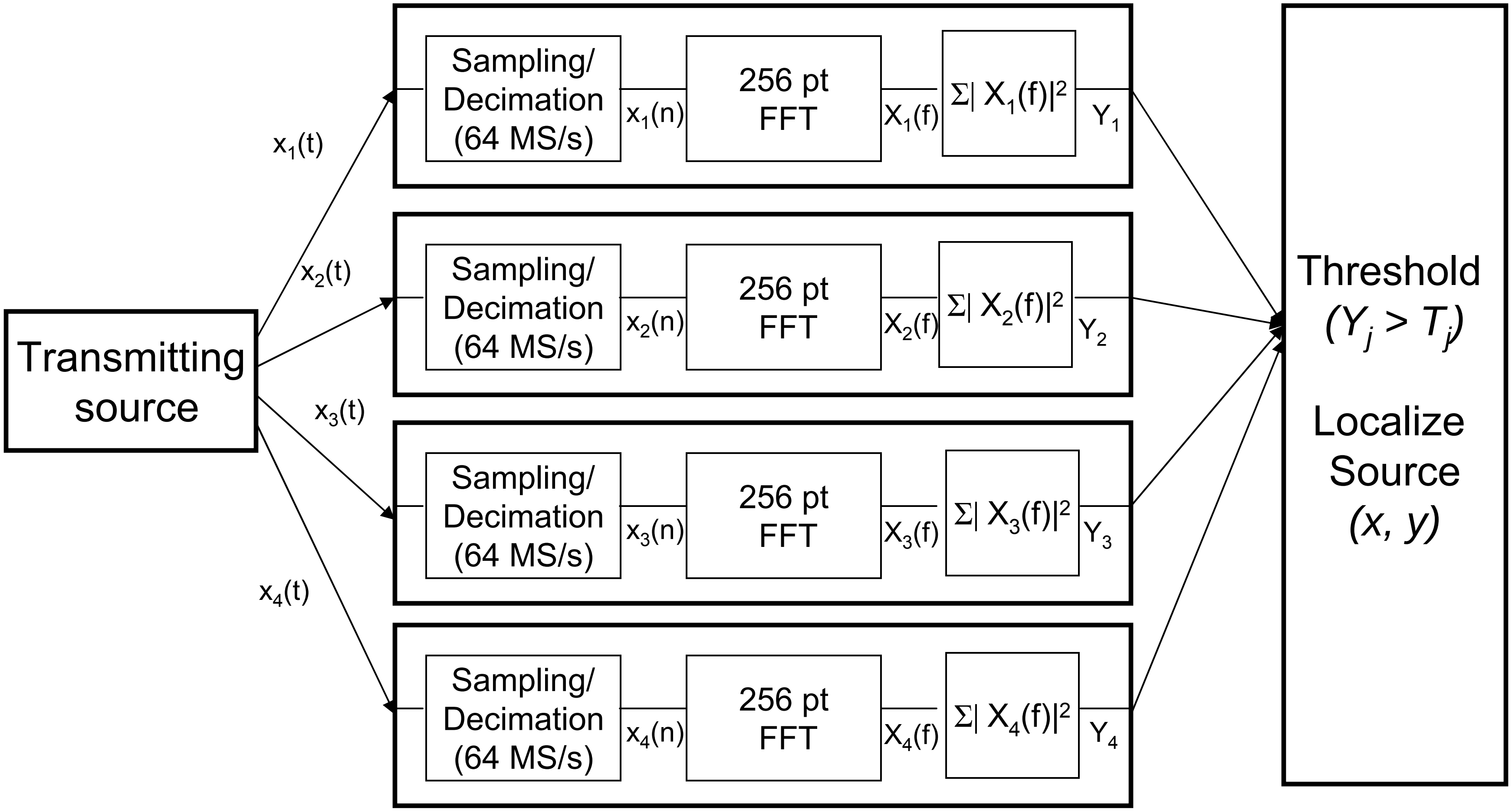
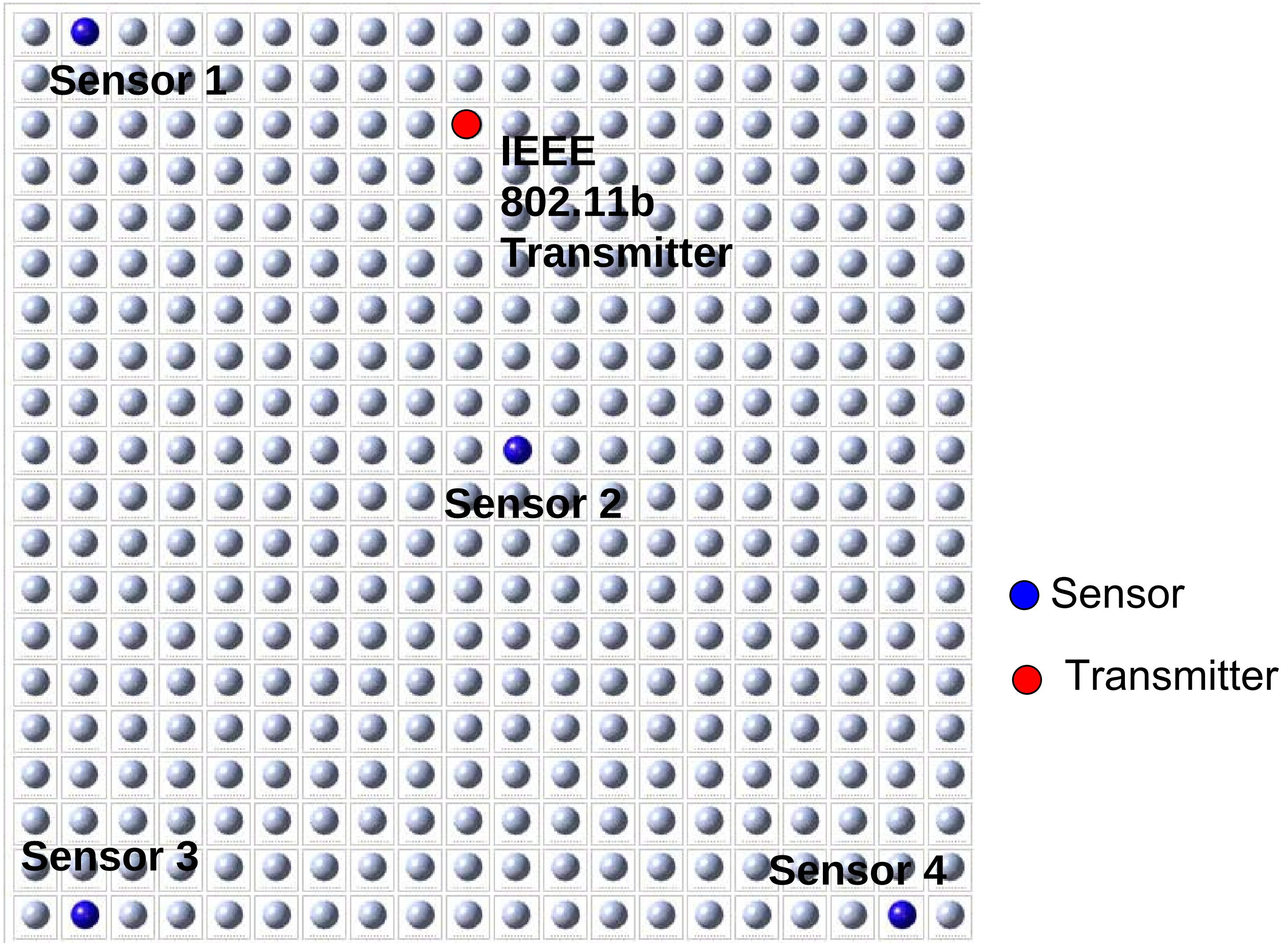
Algorithm for localizing single transmitter

- Assumption: Transmitting bandwidth W known, i.e., $[f_0 - W/2, f_0 + W/2]$
- Sensors tuned to center frequency $f_c \in [f_0 - W/2, f_0 + W/2]$
- Multiple snapshots of time samples collected
- Find sensed power over sensing bandwidth
- Transmitter localized from sensed power at each sensor by triangulation

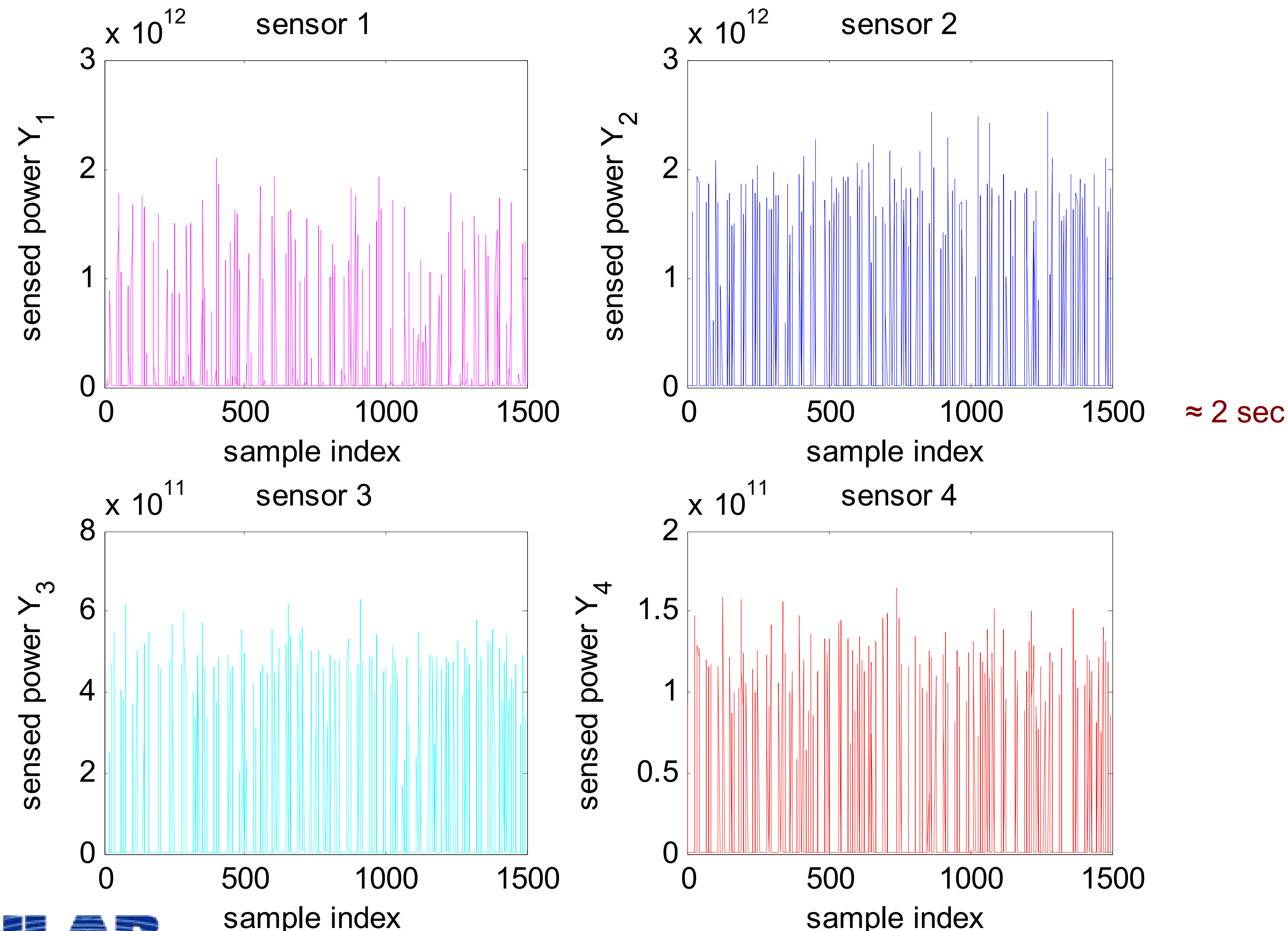
Example: Localizing one transmitter using 4 sensors



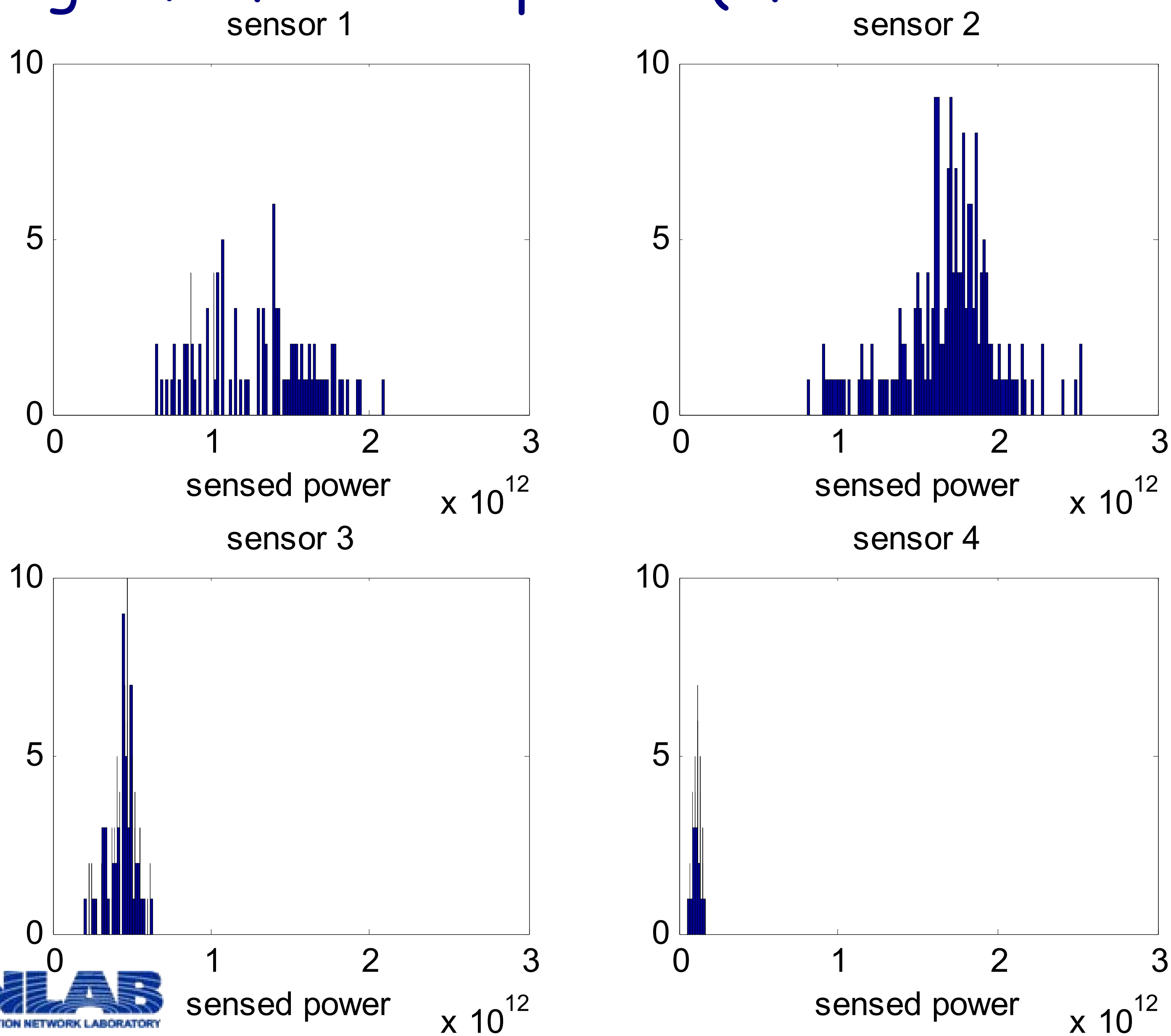
Experiment set-up



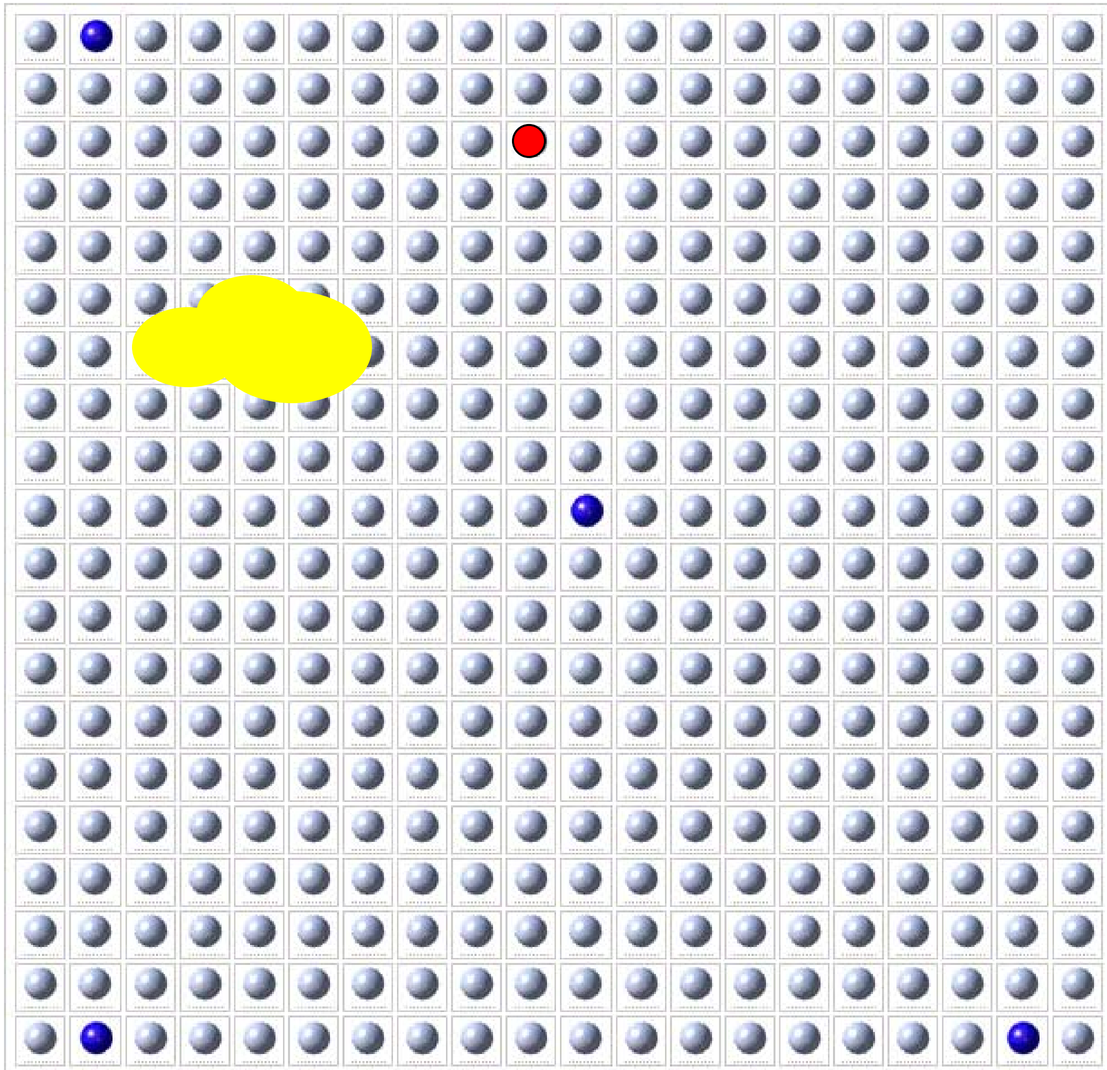
Sensed power over 4 MHz band



Histogram of sensed power (after thresholding)



Localized regions of transmission



Error ≈ 16 ft

Sensor

Transmitter

Localized Regions

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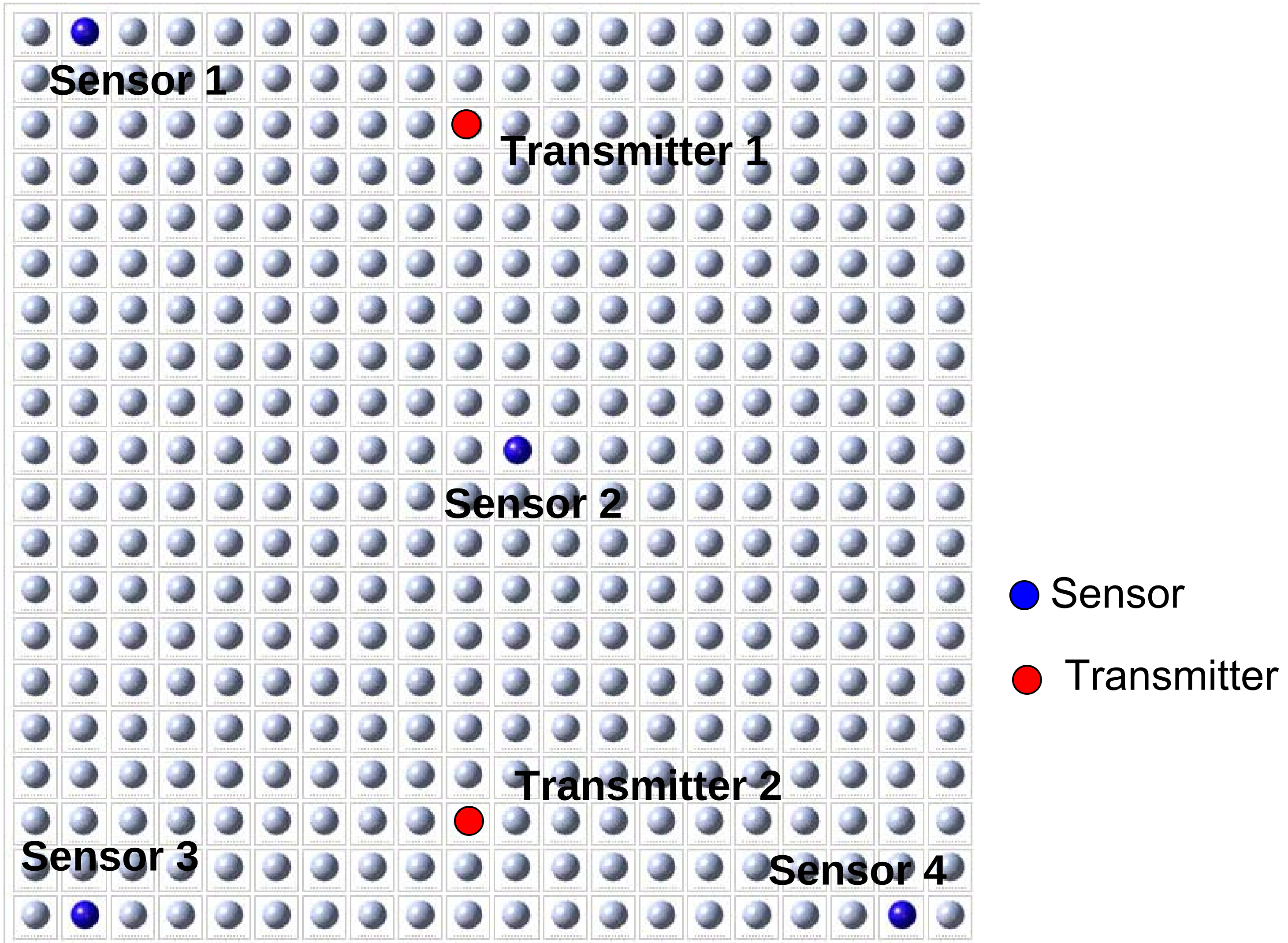
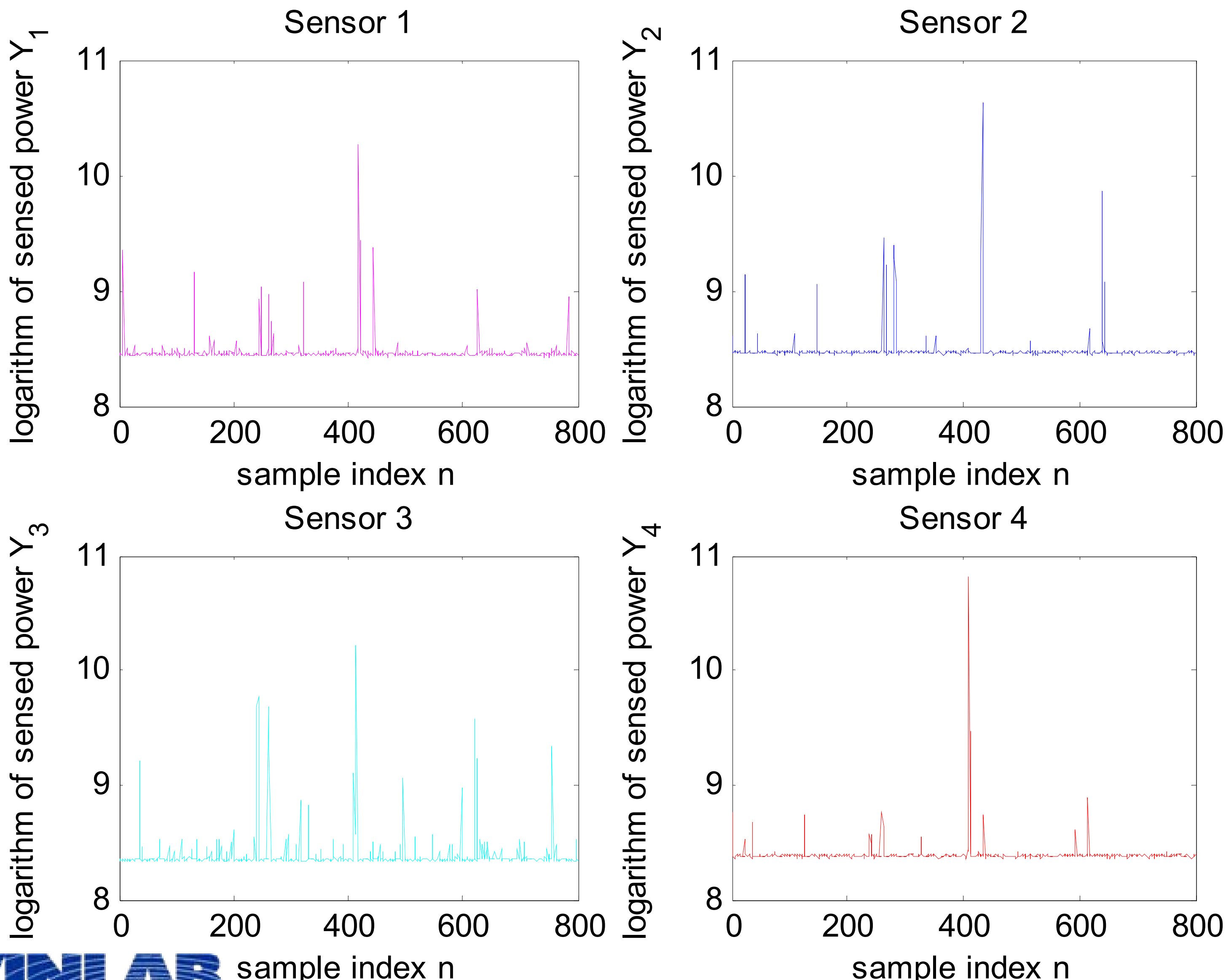
Localizing two sources

- Challenge:
  - Localizing two interfering transmitters
  - Multiple access schemes, e.g., collision avoidance necessary to distinguish transmitters
- Solution:
  - Synchronous sensing
  - Exploit asynchronous transmissions

Experiment set-up



Sensed power over 4 MHz band



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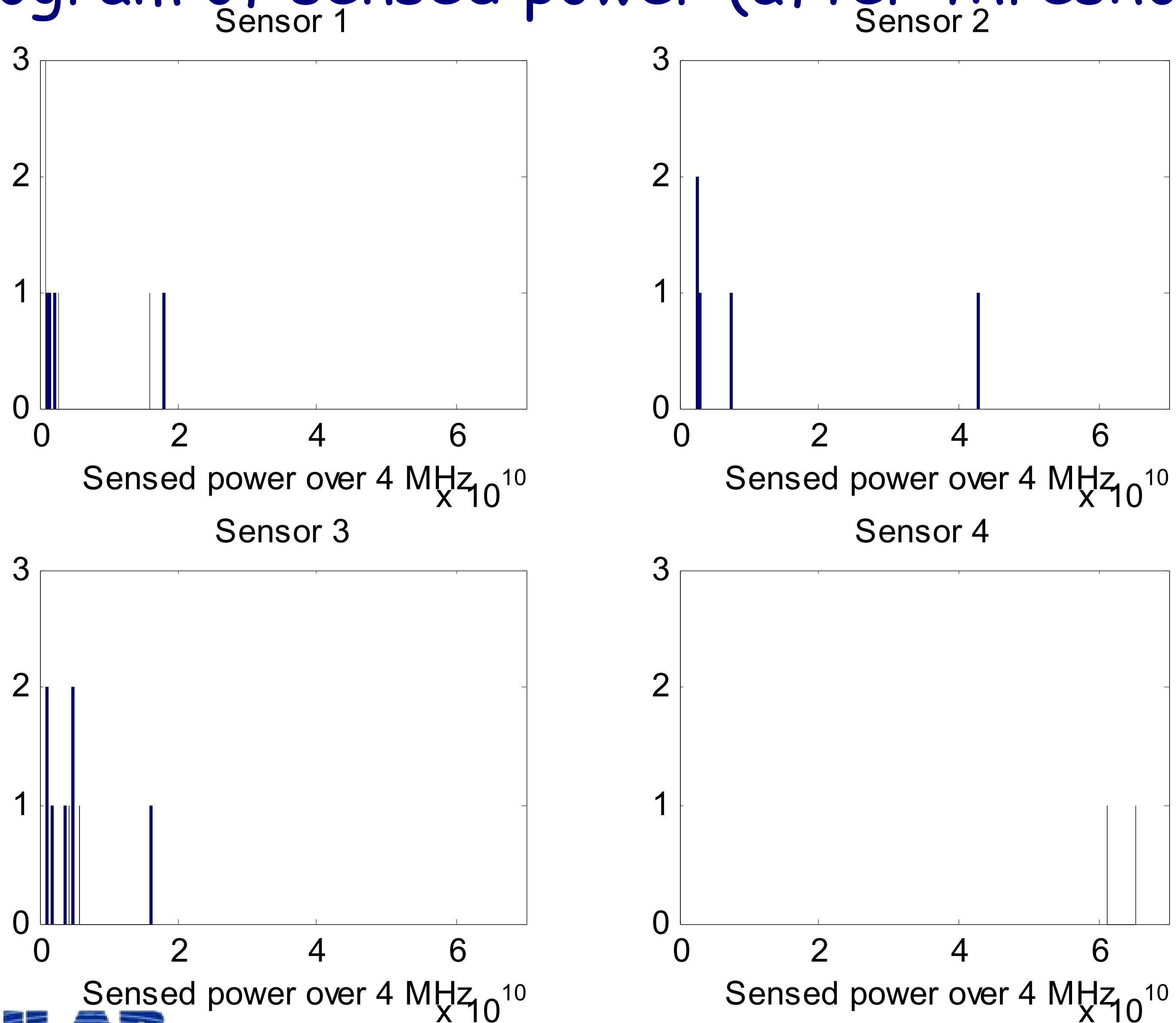
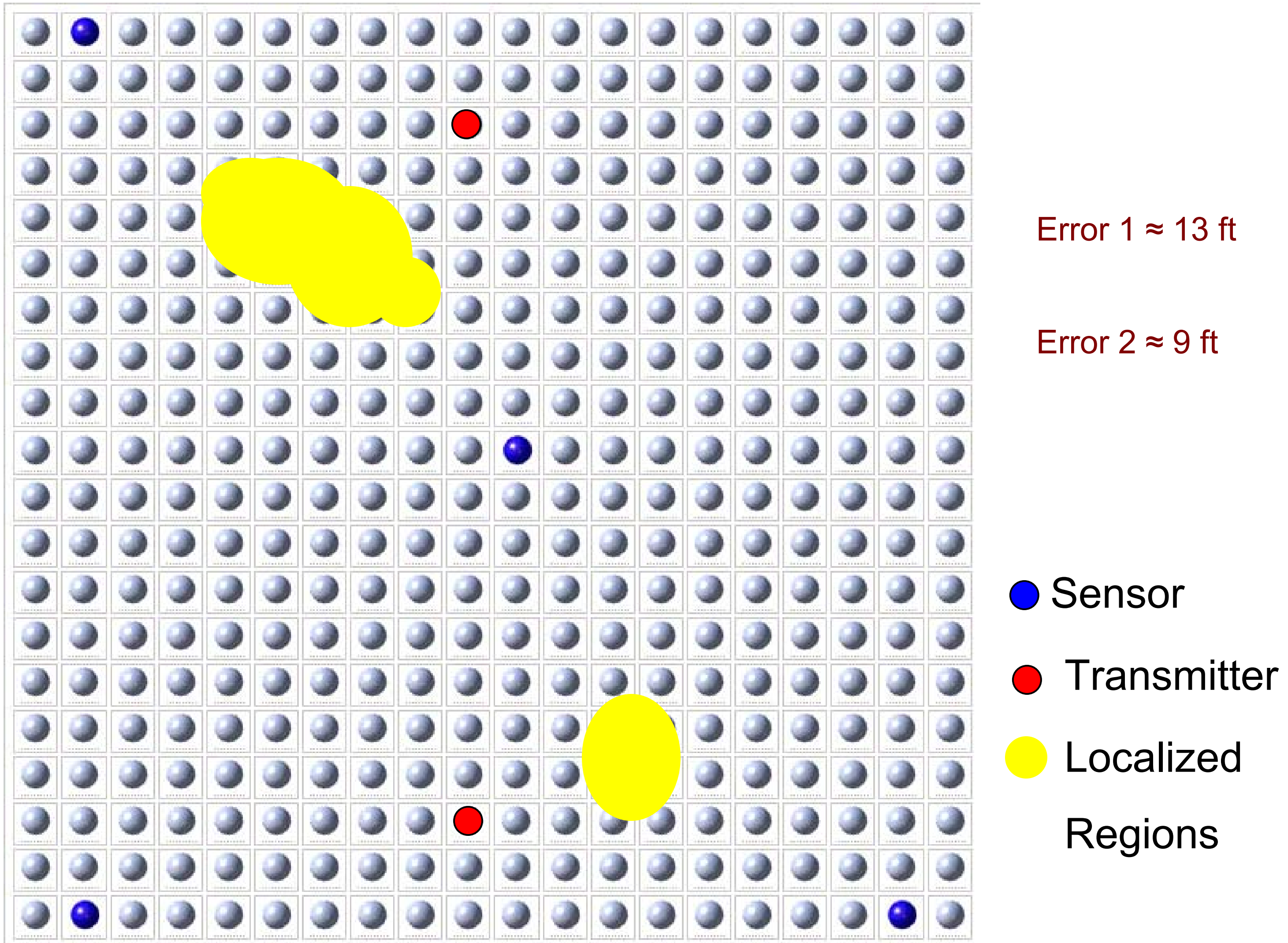
Histogram of sensed power (after thresholding)



Localized regions of transmission



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Determining spectral occupancy

- In reality, transmission frequency is unknown
- Localization techniques require localizing the transmitters in frequency
- Sweeping contiguous bands leads to longer sensing time
- Dividing band among sensors => more sensors required

Algorithm to determine spectral occupancy

- Assume single transmitter in band of width W Hz centered at f_0, i.e., $[f_0 - W/2, f_0 + W/2]$
- Sensor j randomly jumps to center frequency $f_j \in [f_0 - W/2, f_0 + W/2]$
- Each sensor senses the spectrum in the band $[f_j-2, f_j+2]$
- Samples taken for enough time to capture burstiness, e.g., 5 – 7 mins
- Sensor data "correlated" to detect activity in the band of W Hz

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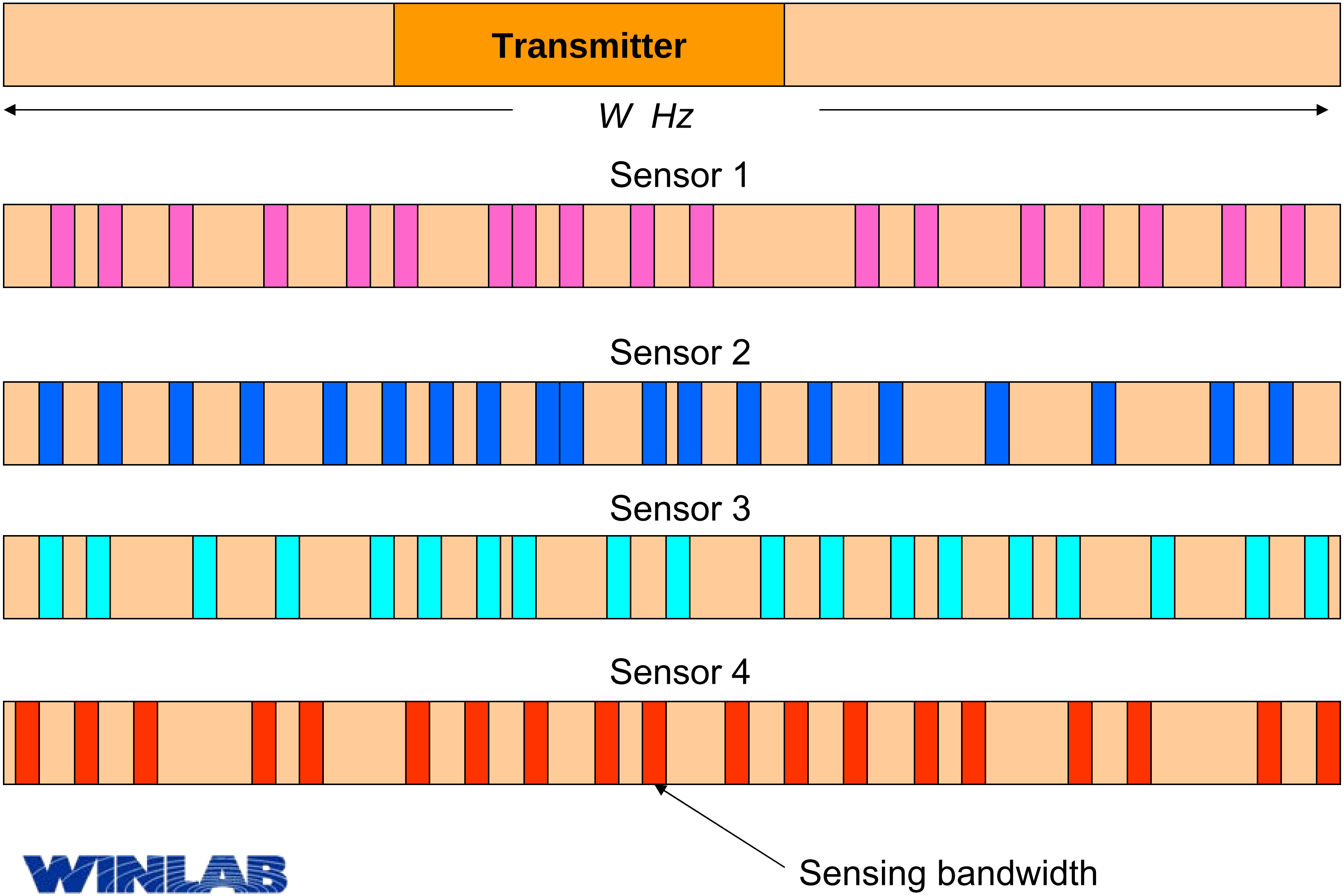

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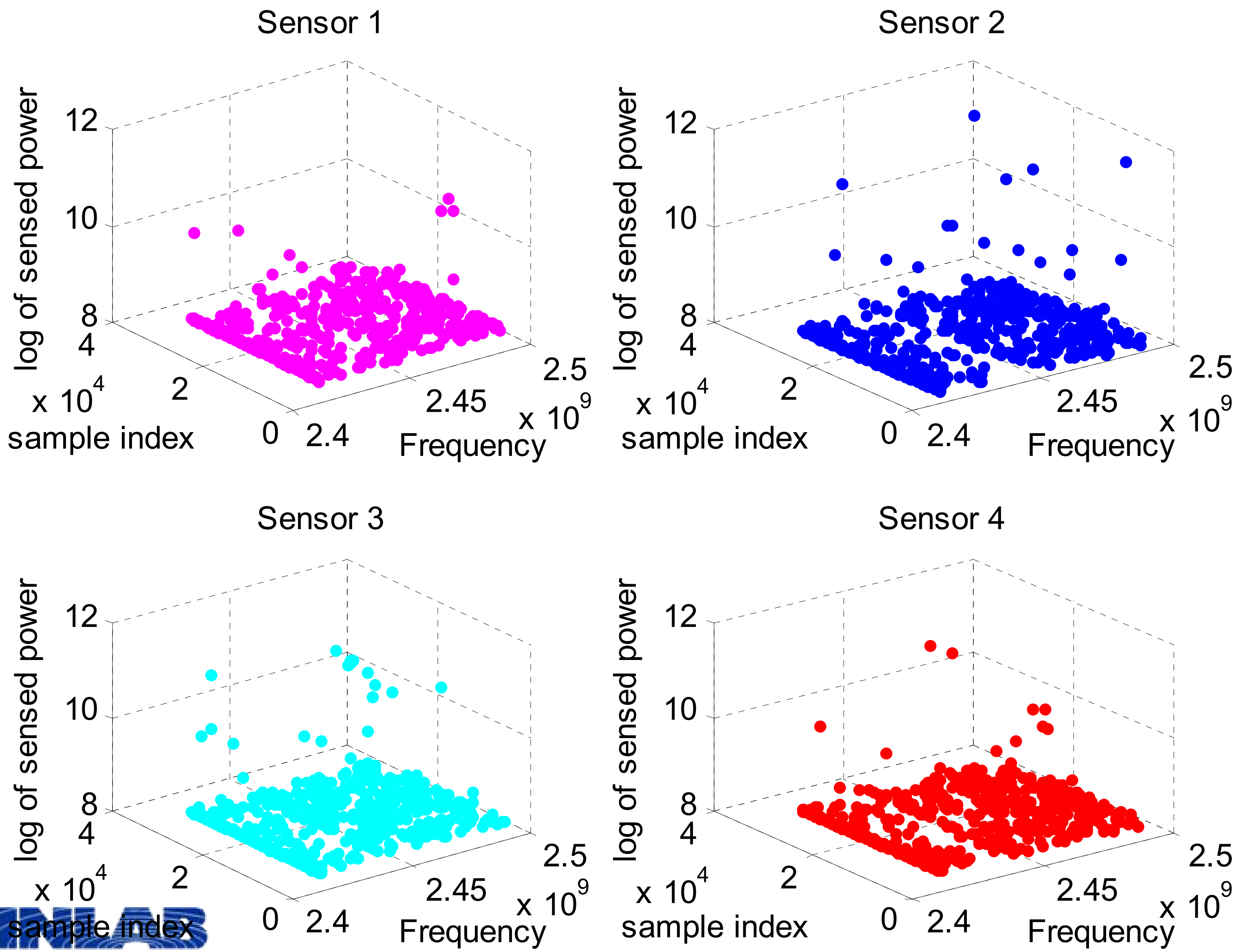
Spectral occupancy



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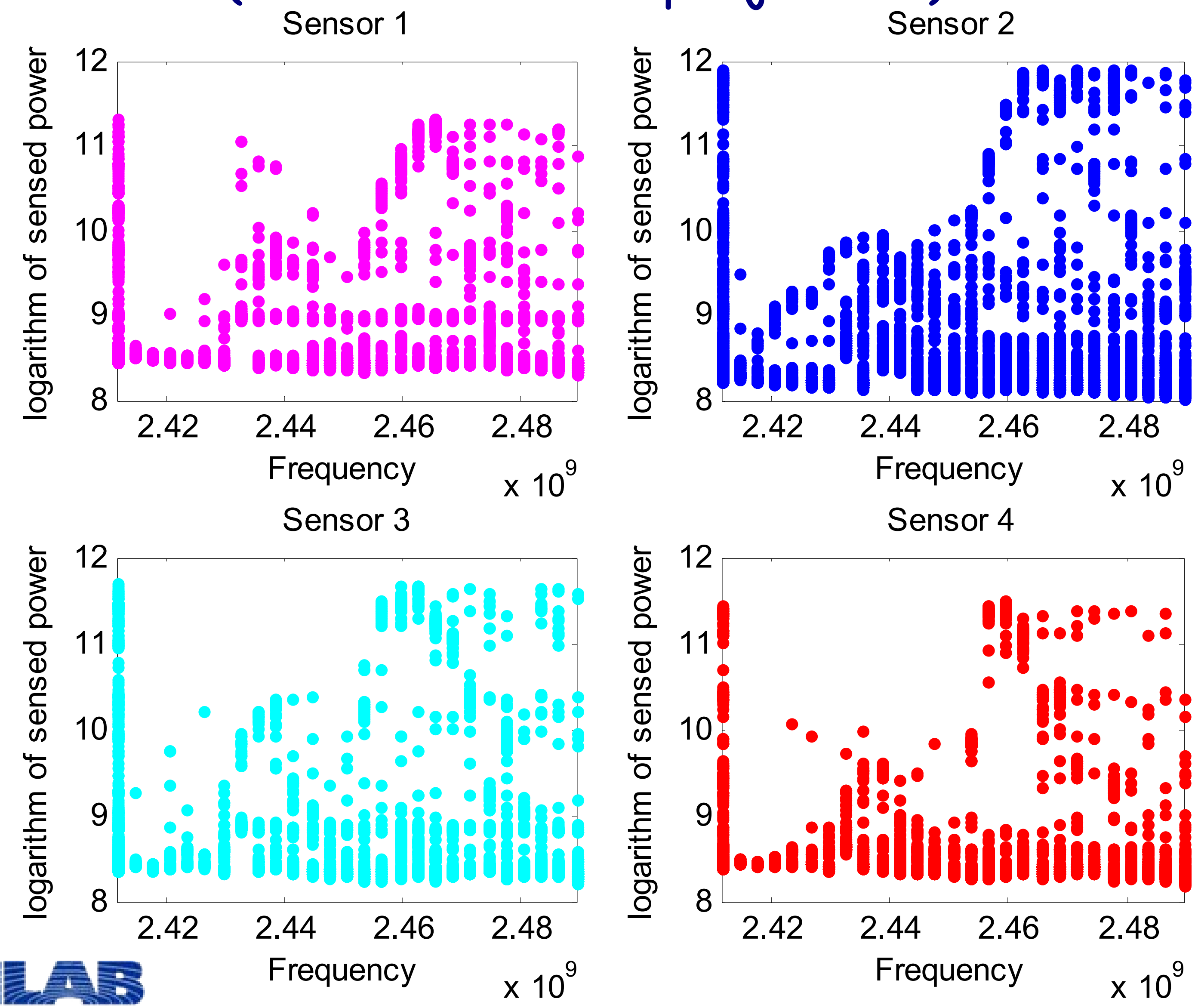
Spectral occupancy
(two dimensional projection)



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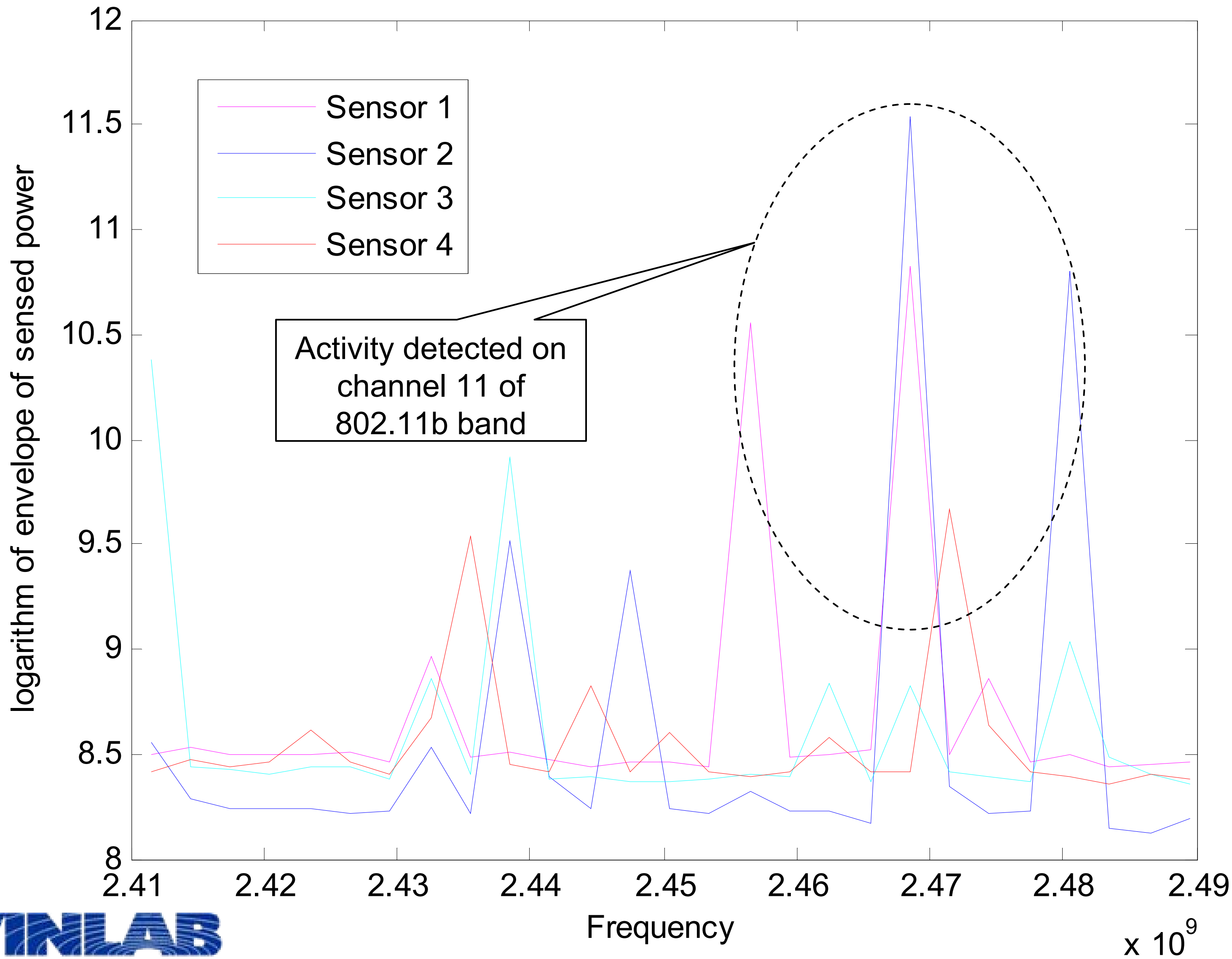
Envelope of sensed power



Challenges in spectrum sensing

- Calibration of sensing devices
  - Problem when there is a large number of sensors
- Trade-off between Cost and Complexity of sensing
  - Advanced signal processing/detection techniques for better localization
- Localizing heterogeneous transmitters
  - Device identification e.g., Bluetooth and Wi-Fi
- Granularity of coordination among sensors
- Improving time for localization

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