OFDM-based Distributed Estimation for Rich Scattering Environments

Robert Santucci, Mahesh Banavar, Sai Zhang, Andreas Spanias, Cihan Tepedelenlioğlu

Sensor Signal Processing for Defence
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Presenter A. Spanias

School of Electrical, Computer, and Energy Engineering
Sensors, Signals, and Information Processing (SenSIP) Center
Arizona State University
Tempe, AZ USA

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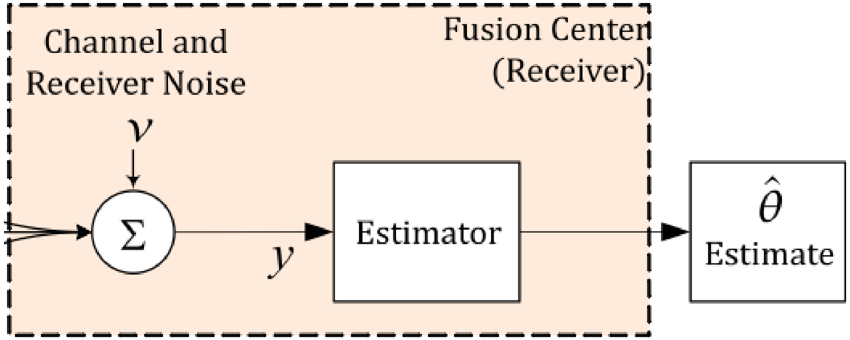
Problem

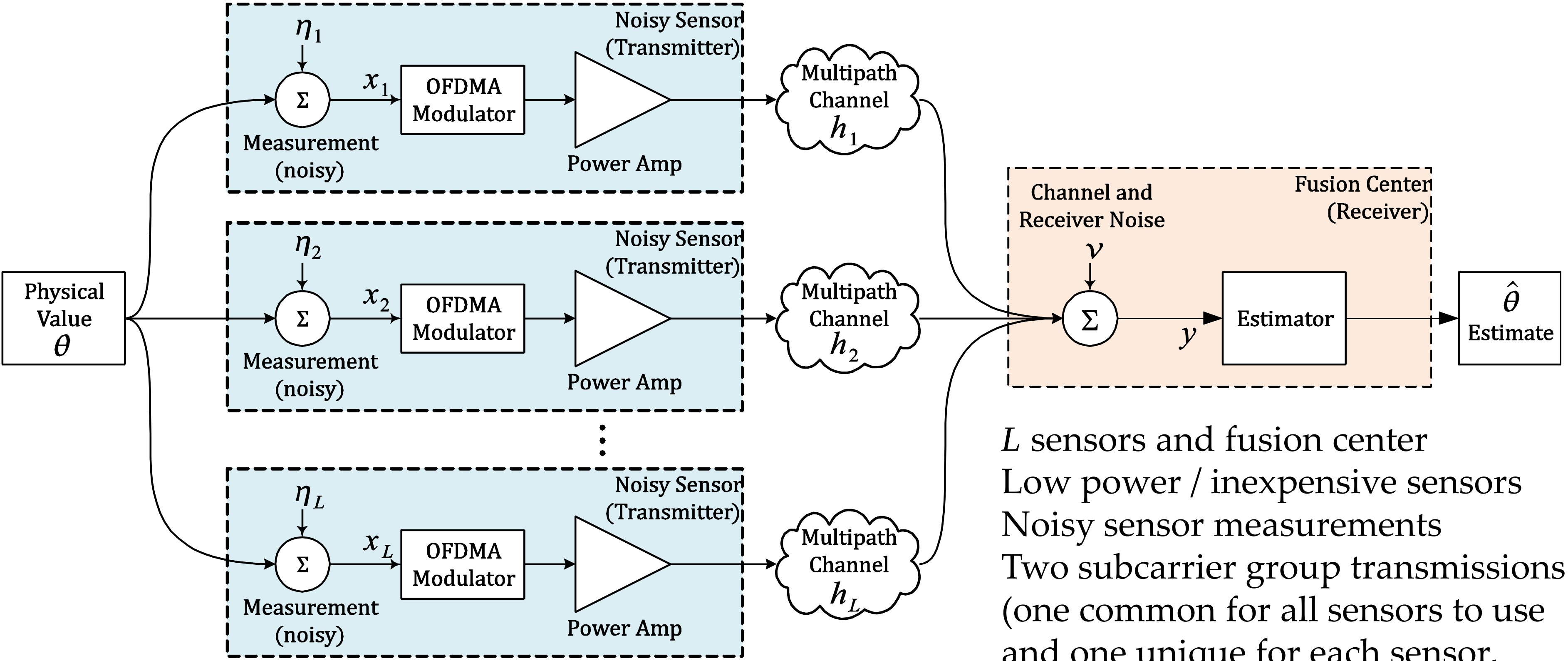
- Using OFDM for distributed estimation
- Intense multipath and fading
- Sensors estimate parameter of interest in noise through a fusion center.
- Heavily scattered environment:



Overview

- Distributed Estimation over Frequency Selective Channels
- Many sensors all measuring the same quantity with different noise conditions.
- Urban Environment:
  - Fusion Center may not have line-of-sight path to each measurement sensing transmitter

System Diagram



L sensors and fusion center
Low power / inexpensive sensors
Noisy sensor measurements
Two subcarrier group transmissions (one common for all sensors to use and one unique for each sensor, plus pilot tones for each)
FC combines to improve estimate

Basic Technique

- Scenario:
  - Many sensors measuring almost the same data
  - Similar data sent to FC through independent paths
  - Looks similar to a single transmitter sending same message through multiple data paths to FC
- Proposed study with OFDM to handle:
  - Transmit / Receive Multi-path data
  - OFDM choice offers opportunities for inexpensive implementation
  - Robustness in **non line of sight** situations can be demonstrated

Simulation Setup

- Each data subcarrier surrounded by two pilots
- Each sensor transmits two tone groups:
  - Common Subcarrier to all sensors and its pilots
  - Orthogonal subcarrier per sensor and its pilots
- Data encoded on subcarrier using simple AM
- Determine performance under variety of channel conditions

Simulation Setup (2)

Nominal Conditions

- 18 sensors each with 5 possible paths to FC
- Path delays uniformly distributed between 0 and 2 symbols
  - 8 oversampled points in 2 symbols (4x OSR)
- Individual path gains have Rician distribution with K=5

Simulations

- Nominal + # of Paths swept Between 0 and 15
- Nominal + Maximum delay swept between 0 and 15 symbols
- Nominal + Rician K Factor swept between 0.01 and 100

Channel Information

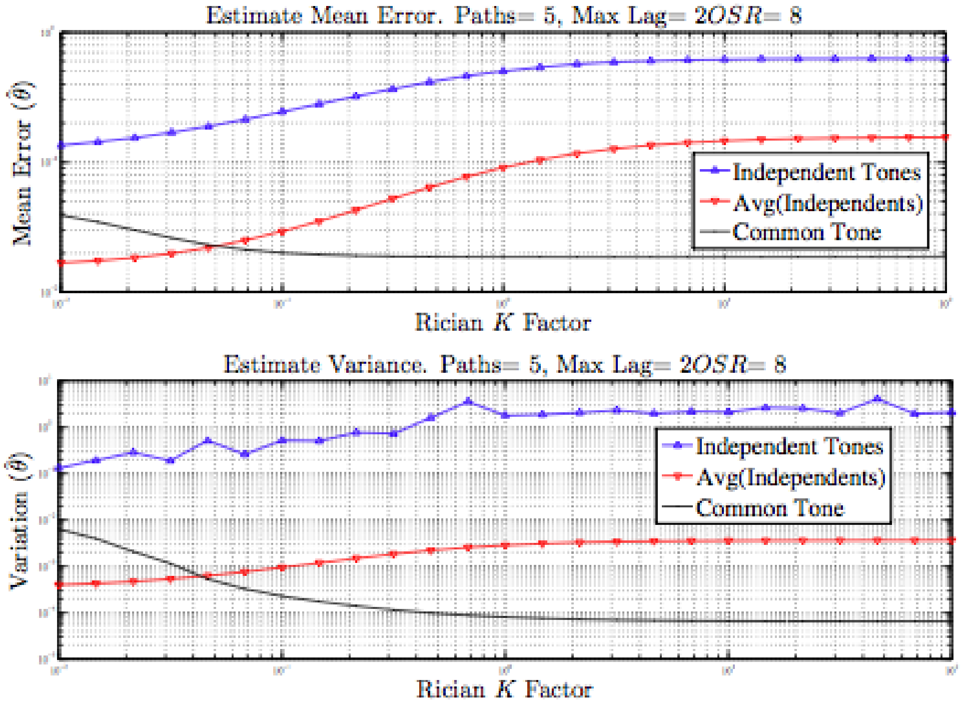
- Channel from sensor l to Fusion Center (FC): $h_l(n)$
- Orthogonal and Multiple Access subcarrier gain, $H_{\mathrm{D}}(l)$, determined from pilot tones

Estimation, Orthogonal Subcarriers

- Estimate of l-th subcarrier determined from effective channel gain:
  - $\hat{\theta}_l = \frac{Y(l)}{H_{\mathrm{D}}(l)}$
- Use weighted average of orthogonal subcarriers
  - $\hat{\theta} = \frac{\sum_{l \in s} \hat{\theta}_l \left\| \mathbf{H}_l^{\mathrm{est}} \right\|^2}{\sum_{l \in s} \left\| \mathbf{H}_l^{\mathrm{est}} \right\|^2}$

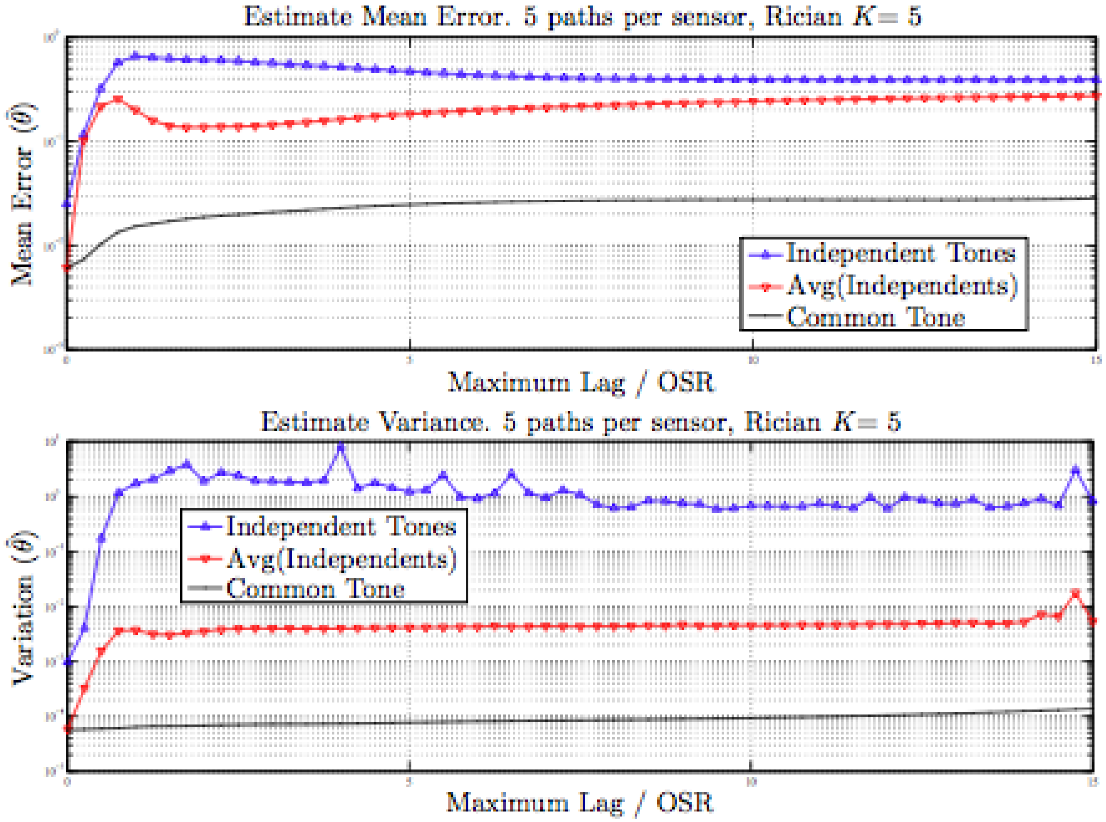
Estimator works well for multipath fading

Common Tone: Better for Line-of-Sight Independent Tones: Better for Rayleigh



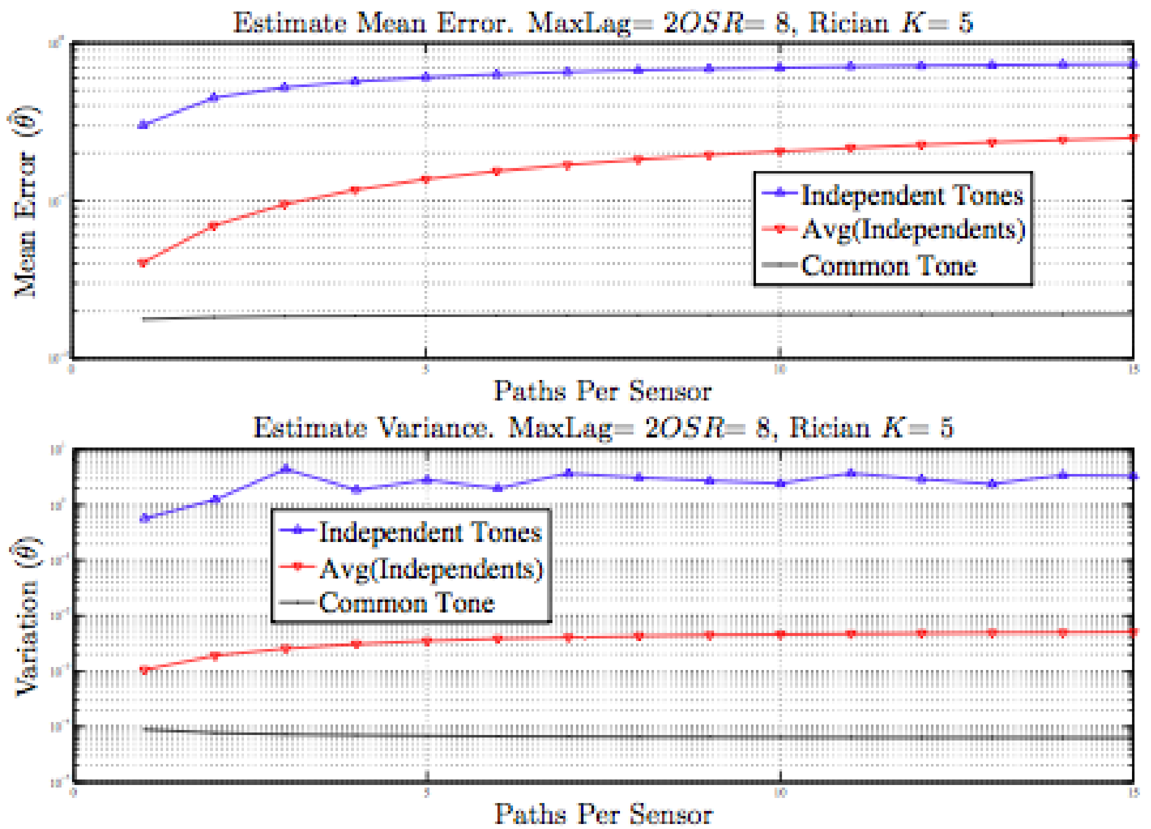
Observe for low *K*, weighted averaging for dedicated subcarriers has provided improved estimates

Robust with regard to Lag



Consistent with regard to lag

Robust with regard to number of paths



Opportunities

- Can utilize multiple FC and coordinate to localize individual sensors.
- Can assign sensors to transmit on subcarriers with other sensors in a local cluster to measure independent values by region

Implementation Complexities:

- Frequency Mismatch between transmitters:
  - Inter-carrier Interference (ICI)
- Power management
- Estimation of Rician K-factor

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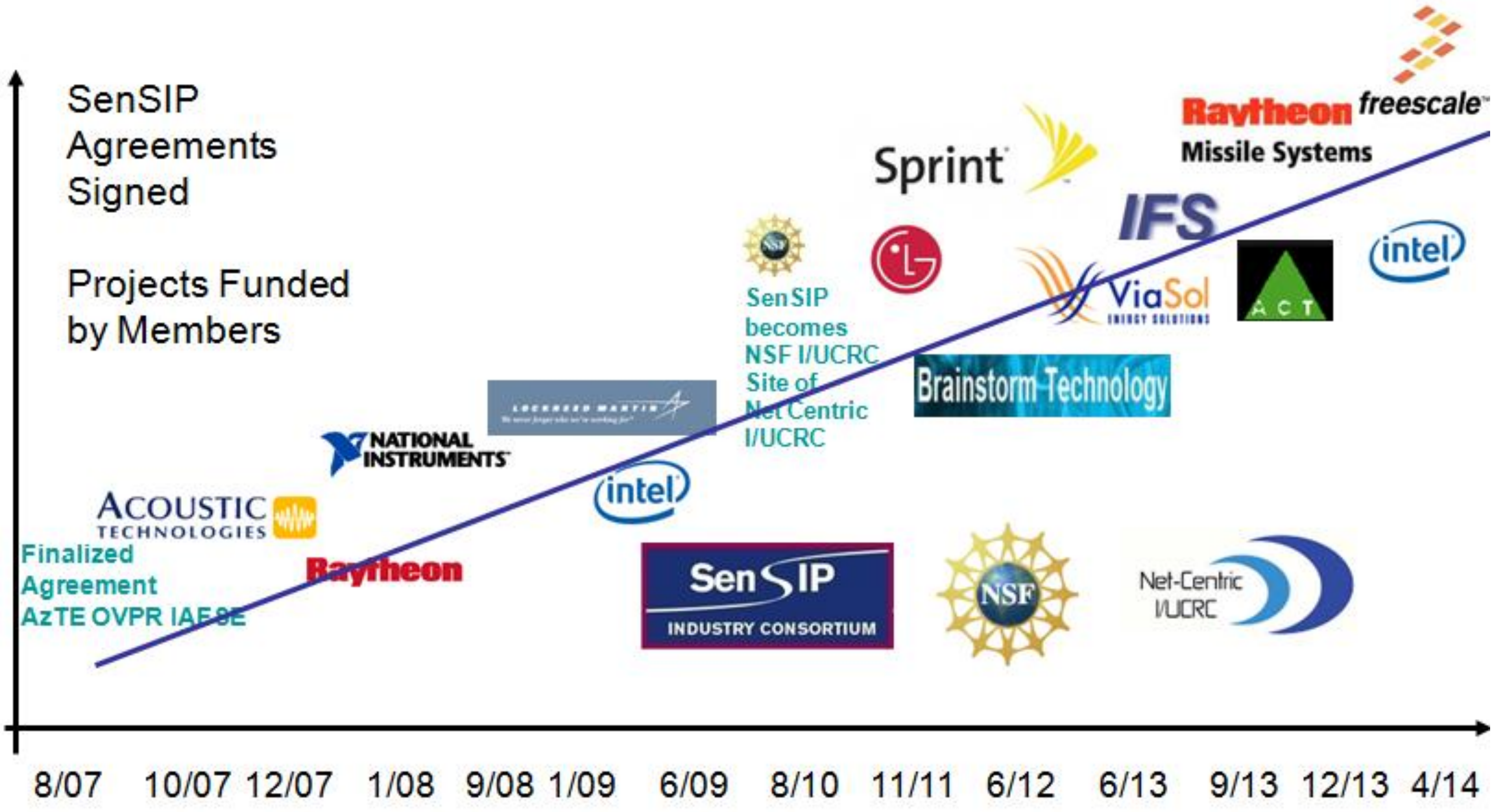

Thank You

Questions?