Narrowband Interference Parameterization for Sparse Bayesian Recovery

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Introduction

Single Carrier-FDMA (SC-FDMA) is used in LTE uplink [1]

Narrowband Interference (NBI) Sources

- Coexisting systems in unlicensed bands
- Garage door openers
- Cordless phones etc

Introduction

Interference Impact on SC-FDMA

- A single strong interference source can completely destroy the data in single carrier-FDMA.
Bayesian Sparse Recovery

How and Why?

- Active interference on few frequencies $\rightarrow$ **Compressed Sensing** based recovery is possible
- Randomly chosen data points are kept data free to sense interference at the receiver

\[
y = A \cdot x + n
\]
Bayesian Sparse Recovery

Sparse Signal Recovery Approaches

Greedy \textit{(fast)}
- OMP
- CoSaMP
- StOMP

Bayesian \textit{(utilize prior statistics)}
- FBMP
- SBL

Convex optimization \textit{(robust)}
- BP
- BPDN
- LASSO

Use Bayesian schemes for sparse recovery
- Low computational complexity
- Good reconstruction accuracy

Acknowledge Gaussianity of noise
Bayesian Sparse Recovery

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Bayesian Sparse Recovery

Fast Bayesian Matching Pursuit (FBMP) [2]

- Low complexity
- minimum mean squared error (MMSE) estimation
- Gaussian prior

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Challenge: → How to estimate mean, variance, and sparsity rate.

Interference Parameterization

1. Transmiter Power
2. PathLoss Coefficient
3. Location
Interference Parameterization

1: Transmitter Power ✓
2: PathLoss Coefficient ✓
3: Location?
Interference Parameterization

Homogenous Poisson Point Process

- Tractable Analysis [3]
- Accurate expressions
- Widely used
- Applicable to diverse types of networks
  - ad-hoc networks
  - cellular networks

Process $\rightarrow \Psi$, Intensity $\rightarrow \lambda$

\[ I_{agg} = \sum_{i \in \psi} \sqrt{E} s_i h_i \]

Interference Parameterization

For interference $I_{agg} = \sum_{i \in \Psi} \sqrt{E_s} h_i$, Characteristic Function (CF) is

$$\Phi(\omega) = \exp\left\{-\lambda \pi \gamma^2 \sum_{q=1}^{+\infty} \gamma_q E \left[|s|^2 q\right] \left(\frac{|\omega|^2 E\Omega}{\gamma^2 b}\right)^q\right\}$$

Obtain mean and variance by differentiating the CF

$$\mu_{I_{agg}} = \mathbb{E}[I_{agg}] = j^{-1} \Phi'(0) = 0$$

$$\sigma^2_{I_{agg}} = \mathbb{E}[|I_{agg}|^2] = j^{-2} \Phi''(0) = 2\pi \lambda \gamma^2 \gamma_1 \mathbb{E}[|s|^2] \left(\frac{E\Omega}{\gamma^2 b}\right)$$
Interference Parameterization

Gaussian Assumption

Sparsity Rate
- $\rho$ dominant elements
- $N - \rho$ elements at noise level
- Decide a threshold $\xi^a$.
- Assume Gaussianity on interference

\[ \hat{s} = \frac{2\rho}{N} Q(4\sqrt{\text{INR}^{-1}}) + 2 \frac{N - \rho}{N} Q(4) \]

INR: Impulse-to-noise ratio, $Q(\cdot)$ is $Q$ function.

a. We use $\xi = 4\sqrt{\sigma_z^2}$. 

Bayesian Interference Mitigation for SC-FDMA
Anum Ali et. al.
Results

Mean and Variance as a function of intensity $\lambda$

Simulation Parameters:
- $b=2$
- $\gamma=2m$
- $R=20m$
- Subcarriers=256
- Users=2
- Modulation=64 QAM
Results

Mean and Variance as a function of pathloss coefficient $b$

Simulation Parameters:
- $\lambda = 1$
- $\gamma = 2m$
- $R = 20m$
- Subcarriers = 256
- Users = 2
- Modulation = 64 QAM
Results

Sparsity rate as a function of INR and dominant elements $\rho$

Simulation Parameters:
- $\xi = 4 \sqrt{\sigma^2}$
- $\gamma = 2m$
- $R = 20m$
- Subcarriers = 256
- Users = 2
- Modulation = 64 QAM
Results

BER performance of the proposed scheme

Simulation Parameters:
Measurements = 25%,
SIR = −10dB, ρ = 4,
Subcarriers = 256, Users = 2,
Modulation = 64 QAM
Summary

- Interference has a dire impact of SC-FDMA systems
- Compressed sensing can be used to mitigate interference
- Bayesian compressed sensing has good performance and low complexity
- Bayesian schemes require interference parameters
- Parameters can be obtained analytically using stochastic geometry
- Analytical parameter estimation reduces computational complexity significantly
Thank you for your Attention!