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Sparsity Learning-Based Multiuser Detection in Grant-Free Massive-Device Multiple Access - Tian Ding, Xiaojun Yuan and Soung Chang Liew

Goal

- Multiuser detection (MUD) problem for a grant-free massive-device multiple access (MaDMA) system
- Random sparsity learning and structured sparsity learning
  - Time slotted and non-time slotted schemes

Contributions

- Blind detection of user data
- Random sparsity learning MUD for the time slotted system
  - Blind MIMO detection as a dictionary learning problem
  - Solved by bilinear generalized approximate message passing (BiG-AMP)
- Structured sparsity learning for the non-time slotted system
  - Sliding window based detection framework
  - Users transmit short packets (structured sparsity in a large time window)
  - Solved using Turbo-BiG-AMP
  - Partitions the graphical model into two subgraphs: one modeling the bilinear constraints of the channel model and the other modeling the structured sparsity of the user signals
  - Inference on the wo subgraphs iterates until convergence (follows the idea of Turbo CS)

System Model

- Time-Slotted Grant-Free MaDMA: To identify all the active users in $\mathcal{N}$ and to decode all the transmitted packets $\{\mathbf{c}_i : i \in \mathcal{N}\}$

$$\mathbf{Y} = \sum_{i \in \mathcal{N}} \mathbf{h}_i \mathbf{c}_i^T + \mathbf{W} \in \mathbb{C}^{M \times T}$$

- Non-Time-Slotted Grant-Free MaDMA:

$$\mathbf{y}_t = \sum_{i=1}^{U} \mathbf{h}_{i,t} s_{i,t} + \mathbf{w}_t \in \mathbb{C}^{M \times 1}$$

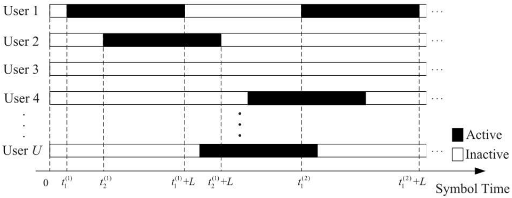


Fig. 2. The activity states of users over a range of symbol intervals.

RSL-MUD for Time-Slotted Grant-Free MaDMA

- N active users transmit data packets with random sparsity (transmission with probability γ)

$$\mathbf{Y} = \mathbf{H}\mathbf{X} + \mathbf{W}$$

- $\mathbf{X}$ is a sparse matrix

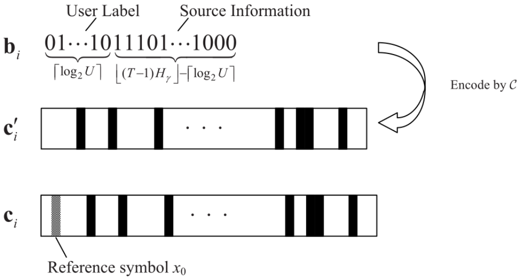


Fig. 3. Sparse packet generation process of active user $i \in \mathcal{N}$. For the modulated signals $\mathbf{c}'_i$ and $\mathbf{c}_i$, the zero and non-zero symbols are represented by white and black rectangles, respectively.

- Solved using BiG-AMP

SSL-MUD for Non-Time-Slotted Grant-Free MaDMA

- Sliding window framework to detect the data symbols
  - Window size much larger than the data duration
  - Structured sparsity since each row of $\mathbf{X}$ has only one active packet in the observation window

$$\mathbf{Y}_{t_0} = \mathbf{H}_{t_0}\mathbf{X}_{t_0} + \mathbf{W}_{t_0}$$

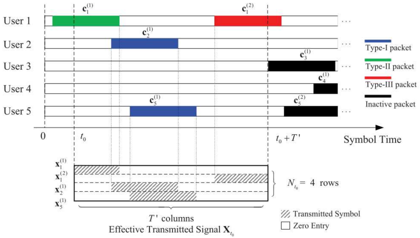


Fig. 5. An example of packets transmitted in the non-time-slotted grant-free MaDMA. Although 5 users transmit 7 packets in total, only 4 packets, i.e., $\mathbf{c}_1^{(1)}, \mathbf{c}_1^{(2)}, \mathbf{c}_2^{(1)}, \mathbf{c}_5^{(1)}$, are active in the observation window $[t_0, t_0 + T')$, and the effective transmitted signal $\mathbf{X}_{t_0}$ has 4 rows. Further, user 1 has 2 active packets, corresponding to 2 different rows in $\mathbf{X}_{t_0}$.

- Two subgraphs - bilinear subgraph and structured sparsity subgraph
- Solved using Turbo-BiG-AMP

Message Passing-Based Joint CFO and Channel Estimation in mmWave Systems with One-Bit ADCs- Nitin Jonathan Myers and Robert W.Heath Jr

Goal

- To develop a joint carrier frequency offset and wideband channel estimation algorithm which exploits the sparse nature of mmWave channels in the angle-delay domain

Contributions

- Formulate the joint CFO and wideband channel estimation problem as a noisy quantized sparse bilinear optimization problem
- Low complexity vector variance version of the parametric bilinear generalized approximate message passing (PBiGAMP) used to solve the joint CFO and channel estimation problem
- Propose the concept of "CFO propagation" using circulant training
- Prove that any circulant training based joint CFO and channel estimation technique that exploits channel sparsity in a DFT-based dictionary suffers from CFO propagation

System Model

- Received Signal

$$\mathbf{Y}_{(n)} = \mathcal{Q}_q \left(e^{j(\epsilon n + \phi_n)} \sum_{\ell=0}^{L-1} \mathbf{H}[\ell] \, \mathbf{t}[n-\ell] + \mathbf{V}_{(n)} \right)$$

- Channel Model

$$\mathbf{H}[\ell] = \sum_{n=1}^{N_{\mathrm{cs}}} \sum_{m=1}^{M_n} \gamma_{n,m} \mathbf{a}_{N_{\mathrm{rx}}} (\omega_{\mathrm{r},n,m}) \, \mathbf{a}^*_{N_{\mathrm{tx}}} (\omega_{\mathrm{t},n,m}) \, \mathrm{sinc} \left(\ell - \frac{\tau_{n,m}}{T} \right)$$

- Sparse in angle and delay domain

$$\mathbf{H}[\ell] = \mathbf{U}_{N_{\mathrm{rx}}} \mathbf{C}[\ell] \, \mathbf{U}^*_{N_{\mathrm{tx}}}, \quad \forall \ell \in \{0, 1, 2, \ldots, L-1\}. \qquad (4)$$

- Bilinear formulation of joint CFO and channel estimation using the structure of the matrices (sparsity structure in **b** and **c**)

$$\mathbf{y} = \mathcal{Q}_q \left(\mathrm{diag}\left(\mathbf{G}\mathbf{b} \right) \mathbf{A}\mathbf{c} + \mathbf{v} \right). \qquad (10)$$

- Solved using PBiGAMP

Generalized Channel Estimation and User Detection for Massive Connectivity with Mixed-ADC Massive MIMO - Ting Liu et al.

Goal

- To provide a partial DFT pilot sequence assisted joint channel estimation and user activity detection scheme for massive connectivity

Contributions

- Proposed the GTurbo-SMV algorithm to investigate the activity detection and channel estimation in single antenna case and extended it to GTurbo-MMV algorithm for the MIMO case
- GTurbo-MMV for a mixed ADC architecture and derived theoretical bounds on the channel estimation MSE by using state evolution (SE) analysis
- Partial DFT pilot matrix allocation to the users which provides stronger guarantees of convergence compared to the AMP algorithm

System Model

- Pilots selected from a sequence pool

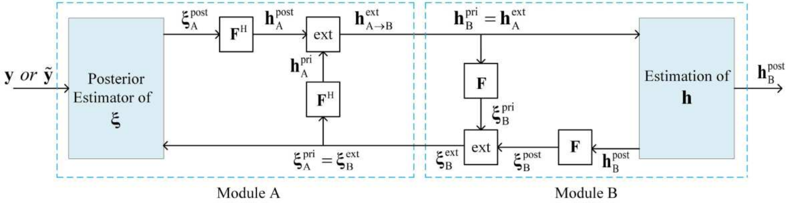
$$\mathbf{S} = \boldsymbol{\Upsilon}\mathbf{F}$$

- Received signal at the BS

$$\mathbf{Y}^{\mathrm{T}} = \mathbf{S}\mathbf{H}^{\mathrm{T}} + \mathbf{Z}^{\mathrm{T}} = \boldsymbol{\Upsilon}\boldsymbol{\Xi} + \mathbf{Z}^{\mathrm{T}}$$

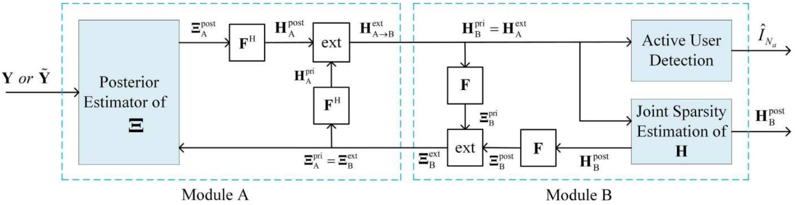
$$\widetilde{\mathbf{Y}} = Q_c(\mathbf{Y}^{\mathrm{T}}) \triangleq Q(\mathbf{Y}_R^{\mathrm{T}}) + jQ(\mathbf{Y}_I^{\mathrm{T}})$$

- $\mathbf{H}^T$ is row sparse
- GTurbo-SMV



Block diagram of the GTurbo-SMV algorithm.

- GTurbo-MMV for mixed-ADC architecture



Block diagram of the GTurbo-MMV algorithm.

- Performance analysis of GTurbo-MMV

Other Interesting Papers

1. Massive MIMO Forward Link Analysis for Cellular Networks
2. Optimal Signaling Schemes and Capacity of Non-Coherent Rician Fading Channels With Low-Resolution Output Quantization
3. On the Diversity of Uncoded OTFS Modulation in Doubly-Dispersive Channels
4. Millimeter-Wave Base Station Diversity for 5G Coordinated Multipoint (CoMP) Applications
5. User Fairness Non-Orthogonal Multiple Access (NOMA) for Millimeter-Wave Communications With Analog Beamforming
6. Fast Blind MIMO Decoding Through Vertex Hopping