Introduction and Motivation

- Random access (RA) is a key yet challenging component of the communication process between User Equipment (UE) and base station (BS) in 5G and beyond 5G (B5G) wireless networks.
- We consider $K$ users consisting of $K_M$ mobile and $K_S$ stationary users.
- $K_s \ll K$ users aim to access the BS and send their data within time interval $T$.
- The channel is considered to be flat within the coherence interval $T$.
- BS with $N$-element antenna array + single-antenna users.

Challenges and Limitations of prior works

- Limited number of allowable active users.
- A huge waste of resources for RA.
- Not suitable for fast fading channels.
- Direct dependence on the total number of users.
- Massive connectivity is impossible.

System Model

Channel Model:

$$h_k = \rho_k \sum_{i=1}^{L_k} \alpha_i e^{j\theta_i} \in \mathbb{C}^{N \times 1}$$

The observation model at BS $Y_k = P_k |Y_k| = P_k |(h_k \phi_k^T)| + E$

- $\phi_k$: the transmitted data of $k$th user.
- $L_k$: number of multi-path components of $k$-th user.
- $\Omega_k$: the set of observed antenna elements.
- $\rho_k$: Large scale fading coefficient.

BGOD strategy

- Solve the following goal-oriented optimization that encourages the angular sparse feature with the goal of active user detection in mind.

$$\min_{Y \in \mathbb{C}^{N \times C}, W \in \mathbb{C}^{C \times T}} \Re(\langle v, Z \rangle) + \frac{1}{2} \|Y - Y^*\|^2_F$$

s.t. $\begin{cases} Z_{\ell,1} W_{1,1} & \geq 0, \ Y^* = -2 \alpha \Omega (Z) \\ \end{cases}$

- Obtain the dual matrix variable $V$ corresponding to $Y^*$.
- Find the angles that maximize the $\ell_2$ norm of the goal-oriented dual polynomial function $q_\gamma(\theta) = \langle P_\gamma V, \phi(\theta) \rangle$.
- Place the angles into several clusters.
- Use alternative minimization to jointly recover the data and channel gains of active users.

BGOD unique features

- Arbitrary channel distribution
- Arbitrary noise distribution
- Not dependent on the total number of users.
- The allowable number of active users is directly related to the computational complexity that BS can bear.
- Communication costs at the user side are somehow transferred into the computational complexity at the receiver side.
- BGOD finds the information of active users without searching.
- BGOD performs active user detection, channel estimation and data recovery.

Simulation Results

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- Arbitrary noise distribution
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Figure 1: A typical uplink massive access scenario

Figure 2: Prior RA schemes: Top image: Four-step RA. Bottom image: Two-step RA.

Figure 3: Angular sparse feature of channel.

Figure 4: BGOD scheme

Figure 5: $\ell_2$ norm of the goal-oriented dual polynomial function.$q_\gamma(\theta)$

Figure 6: Our contributions in connection with prior RA works.

Figure 7: $K_S = 1500, K_M = 500$. Detection accuracy.

Figure 8: $K_S = 1500, K_M = 500$. Detection accuracy.