Random Orthogonalization for Federated Learning in Massive MIMO Systems

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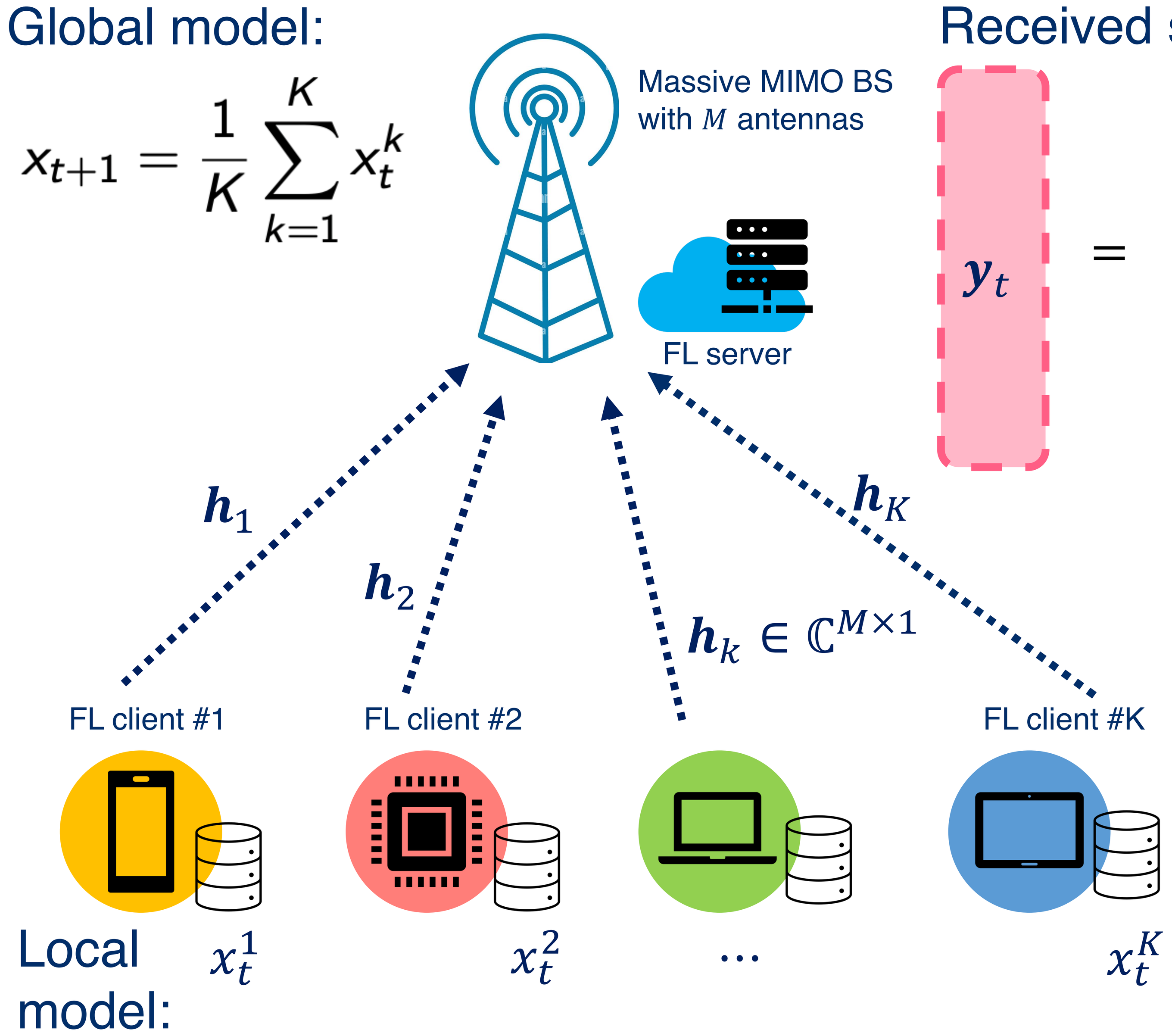
▪ Goal: AirComp federated learning without CSIT

Global model:

$$x_{t+1} = \frac{1}{K}\sum_{k=1}^{K} x_t^k$$



Local model:

Received signal:

$$y_t = h_1 x_t^1 + h_2 x_t^2 + \cdots + h_K x_t^K + n_t$$

Goal: Find **a linear projector**

$$\tilde{x}_{t+1} = \mathbf{v}^H \mathbf{y}_t$$

▪ Solution: random orthogonalization

Channel hardening

$$\mathbf{h}_k^H \mathbf{h}_k \to 1, \quad \text{as} \quad M \to \infty, \forall k$$

+

Favorable propagation

$$\mathbf{h}_k^H \mathbf{h}_j \to 0, \quad \text{as} \quad M \to \infty, \forall k \neq j$$

Proposed projector: **sum channel**

$$\mathbf{v}_s = \mathbf{h}_s = \frac{1}{K}\sum_{k=1}^{K} \mathbf{h}_k$$

Linear projection: **an unbiased estimator**

$$\tilde{x}_{t+1} = \frac{1}{K}\mathbf{h}_s^H \mathbf{y}_t$$

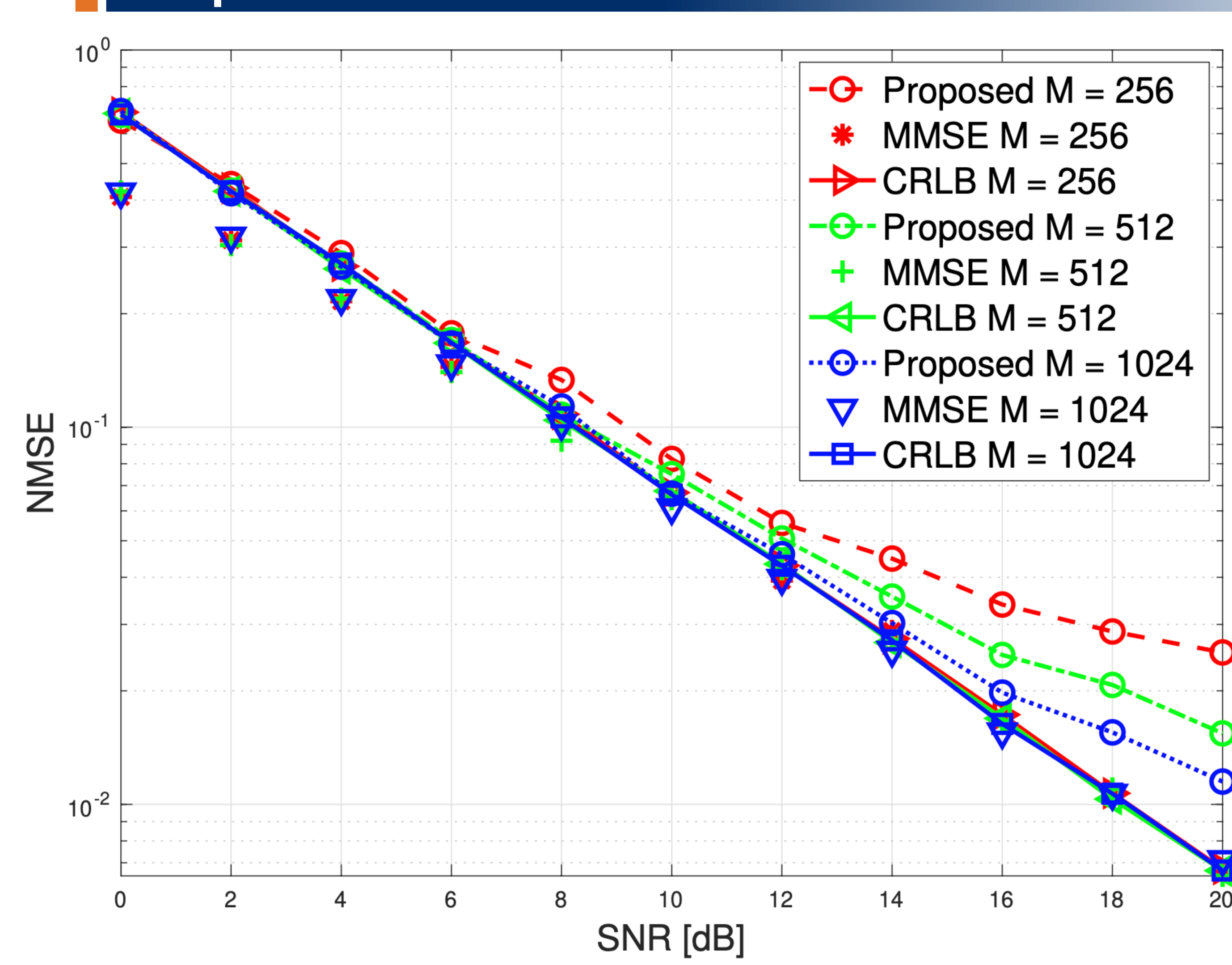
Motivation

- Traditional over-the-air computation (AirComp) methods for FL are efficient but require CSIT.
- Design a low-complexity AirComp method that removes the CSIT requirement.

Random Orthogonalization Solution

- Leveraging channel hardening and favorable propagation in massive MIMO channels.
- A low-complexity 3-step procedure:
  - Step#1: uplink sum channel estimation;
  - Step#2: uplink local model transmission;
  - Step#3: linear projection to estimate global model.

Experiment results



- Estimates yielded by random orthogonalization become closer CRLB as M goes larger

Summary

Random orthogonalization preserves all the advantages of AirComp and enjoys:

- Low communication overhead: partial CSIR
- Low complexity receiver: linear projection
- Asymptotically efficient: estimates achieves CRLBs as M goes infinity

Reference

X. Wei, C. Shen, J. Yang and H. Vincent Poor, "Random Orthogonalization for Federated Learning in Massive MIMO Systems," in *IEEE Transactions on Wireless Communications*.