Hybrid Compression and Message Sharing Strategy for the Downlink Cloud Radio Access Network

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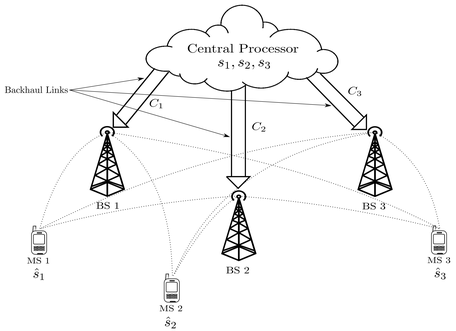
Future Cellular Wireless: Dense, Massive, and Cooperative

- Bottlenecks for cellular networks: Path-loss, fading, **interference**.
- Emerging ideas:
  - Dense: Heterogeneous network.
  - Massive: Large scale MIMO in each base-station (BS).
  - Cooperative: Signal processing for interference cancellation.

The poster is about **cooperative communications**.

Cloud Radio Access Network (CRAN) Architecture

- BSs connected to a centralized cloud-processing based processor.
- Backhaul links have high but not infinite capacity.

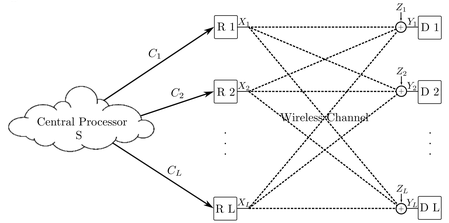


- Motivation:
  - To enable joint multi-cell processing for interference cancellation.
  - Centralized service provisioning; easy BS upgrade, etc.
- Uplink (from mobile users):
  - Joint decoding at the cloud possible.
  - Overall virtual multiple access channel with BSs as relays.
- Downlink (to mobile users):
  - Joint encoding at the cloud possible.
  - Overall virtual broadcast channel with BSs as relays.

This poster looks at **downlink transmission strategies for CRAN with finite backhaul capacity**.

Downlink CRAN as a Broadcast-Relay Channel

- Data originate from the cloud and is destined for end mobile users.



- Infinite backhaul: Downlink CRAN is just a broadcast channel.
- Finite backhaul (practical): Challenging, even in approximate sense!

Existing Tranmission Strategies for Downlink CRAN

BSs need to broadcast: Beamforming + dirty paper coding
BSs also act as relays:

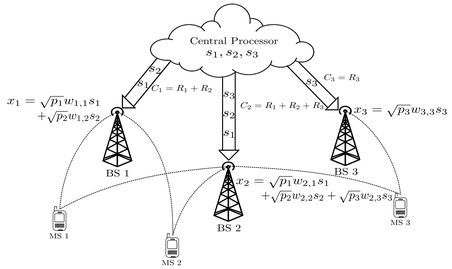
- Decode-and-forward relaying strategy:
  - User messages are shared with BSs for joint beamforming, e.g., [Marsch and Fettweis, 2009].
  - To limit backhaul, we need to form clusters. [Ng et al., 2008], [Zakhour and Gesbert, 2011], [Zhao et al., 2013].
- Compression-and-forward relaying strategy:
  - Precode at the cloud, compress the signals and send compressed versions to BSs. [Simeone et al., 2009], [Marsch and Fettweis, 2008].
- Compute-and-forward relaying strategy [Nazer et al., 2009]:
  - Reverse-compute-and-forward and integer-forcing ideas studied in [Hong and Caire, 2013].

Contribution

- We propose a hybrid scheme where messages of strong users are shared directly and signals from weak users are compressed.
- Optimization technique for such scheme is provided and system level performance benefit is quantified.

Message Sharing

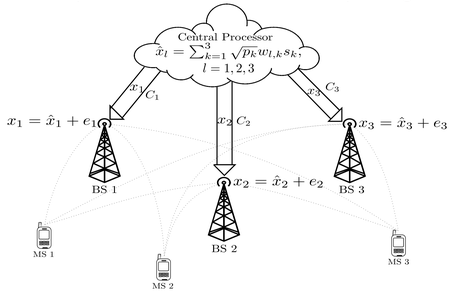
- Directly share user messages to BSs through backhaul links. BSs then encode the messages to form the signals to be transmitted.



- Advantage: BSs receive clean copies of user messages.
- Limitation: Due to limited backhaul available, each BS gets messages for only a subset of users, resulting in partial cooperation.

Pure compression

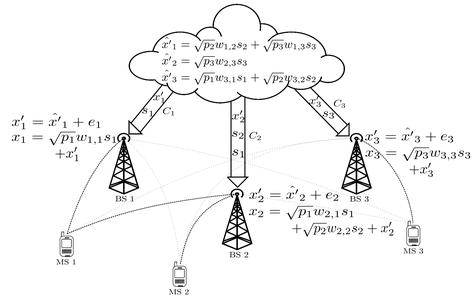
- Cloud performs joint precoding of user messages. Resulting analog signals are compressed and forwarded to corresponding BSs.



- Advantage: Full cooperation possible at cloud. Oblivious BSs.
- Limitation: Compression introduces quantization noises.

Proposed Hybrid Compression and Message Sharing Strategy

- Part of backhaul used to send direct messages for some users and remaining part to carry compressed signals of rest of the users.
- Direct messages for the strong users and compression for the rest.



- Design methodology:
  1. Design fixed network-wide beamformers using, for example, the regularized zero-forcing approach or the weighted MMSE approach;
  2. Assuming pure compression, optimize the quantization noise level in each backhaul link, obtain the user rates;
  3. Appropriately select users for message sharing.

Simulation Results

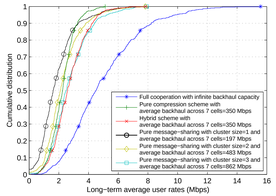


Figure : 7-cell network with B2B dist. 800m. Sum-power, Sum-backhaul constraint.

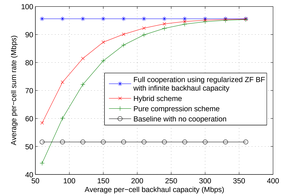


Figure : 19-cell sectorized. Per-BS power constraint. Center 7 cells form a cluster.

Details at Pratik Patil and Wei Yu, "'Hybrid Compression and Message-Sharing Strategy for the Downlink Cloud Radio-Access Network'", Information Theory and Application (ITA) Workshop, Feb 2014