Massive MIMO: more than “more antennas”

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The playground

How to play with more antennas?
Three ways:

• play with the backhaul
• play with the access
• play with the unlicensed band
mMIMO for backhaul
Massive MIMO and Ultra-Dense Small Cells

- Dense deployments of small cells have been proven effective to increase capacity, but...
  - Backhaul is a cost/performance bottleneck
- Massive MIMO can provide a share of backhaul
  - Allows ultra-dense small cell deployments
  - Reuse increases capacity by orders of magnitude

Massive MIMO dimensioning: resource splitting, inband vs outband, #RF chains, etc.
mMIMO for access
Cell-Edge Interference Suppression

Fundamental Idea

- **Cell-edge-aware ZF precoding**: exploit large spatial dimensions to increase rates at the cell-edge
- Use some **spatial dimensions** to suppress inter-cell interference at cell-edge neighboring UEs
- Use remaining **d.o.f.** to multiplex UEs within the cell

System Model

- Capture the effect of irregular BS deployments, and randomness of fading and precoding
- Model massive MIMO BSs and UEs locations as PPPs
- Use large-system analysis for multi-user precoding gain and interference

Improved coverage w.r.t. conventional ZF precoding
Performance (theoretical)

Main Takeaways

- Outage scales as $\sim 1/N^2$ (CEA-ZF) vs $\sim 1/N$ (ZF)
- Performance gain is sensitive to CSI quality

Future Research

- Power control as a complement/alternative
- Comparison with other existing interference suppression schemes (M-MMSE, P-ZF, M-BD, etc.)
- Densification may cause NLoS-LoS transition: training/data propagation conditions change
- Spatial channel correlation and loss of d.o.f.
- Analytical models are tractable but simplistic, simulations needed for more realistic scenarios

Larger amount of resources needed for CSI acquisition, depending on mobility
Mobility-Aware, Adaptive Frame Design

Fundamental Idea

- Exploit mobility state information (MSI) to reduce resources spent for CSI acquisition, i.e., pilots

System Model

- Classify UEs into mobility classes (e.g. mobile vs. static)
- Only estimate channels for those UEs whose motion has outdated the channel estimate
- Allow for adaptive frame structure, where #resources allocated for CSI acquisition can change
- Mobility-aware scheduler allocates consecutive tx to static UEs whenever possible/fair

Estimate UEs coherence intervals and use them in the scheduling process
mMIMO for the unlicensed band
LTE – WiFi Coexistence (currently two main approaches)

- **Carrier Sense Adaptive Transmission (CSAT)**
  - Targets markets where LBT is not mandatory
  - BS leaves idle times between tx (e.g. 50% on-off)

- **Listen Before Talk (LBT)**
  - BS senses channel via energy detection and applies random access to gain tx opportunity
  - Usually not aligned with LTE subframe boundary

WiFi defers tx when it detects the channel to be busy, but...

WiFi tx may start towards the end, causing collision

Jamming signal to keep the channel reserved: overhead

LTE tx must be aligned with subframe boundaries

Can coexistence be enhanced via multiple antennas at the BS?
Unlicensed Applications for Massive MIMO

Fundamental Idea

- Massive MIMO beams steered towards desired UEs while blanking out WiFi nodes
- Avoid interference generated at WiFi devices
- LBT/jamming phases could be avoided

System Design

- CSI is required for all WiFi devices in the massive MIMO coverage area
- Limit to the number of nulls we can point:
  \[ \text{#nulls} + \text{#UE served} \leq \text{total #d.o.f.} \]

How to obtain channel estimates for neighboring WiFi devices?

Meet regulations + increase efficiency

Massive MIMO and WiFi coexistence

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Meeting regulations + increase efficiency

Smart UE scheduling policy

Massive MIMO and WiFi coexistence