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Massive MIMO: more than “more antennas”

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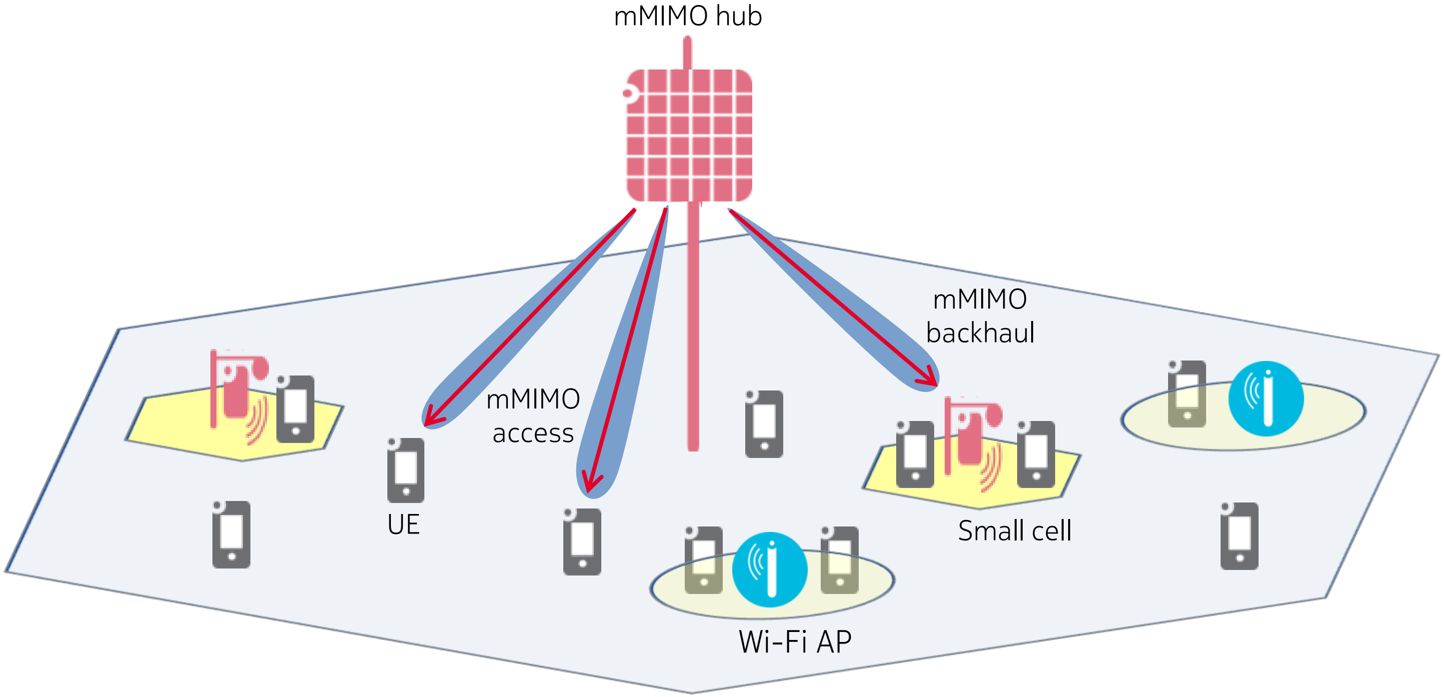
The playground



How to play with more antennas?

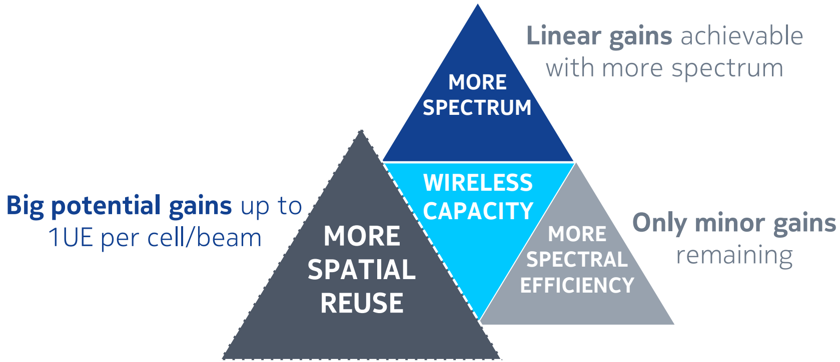
Three ways:

- play with the backhaul
- play with the access
- play with the unlicensed band

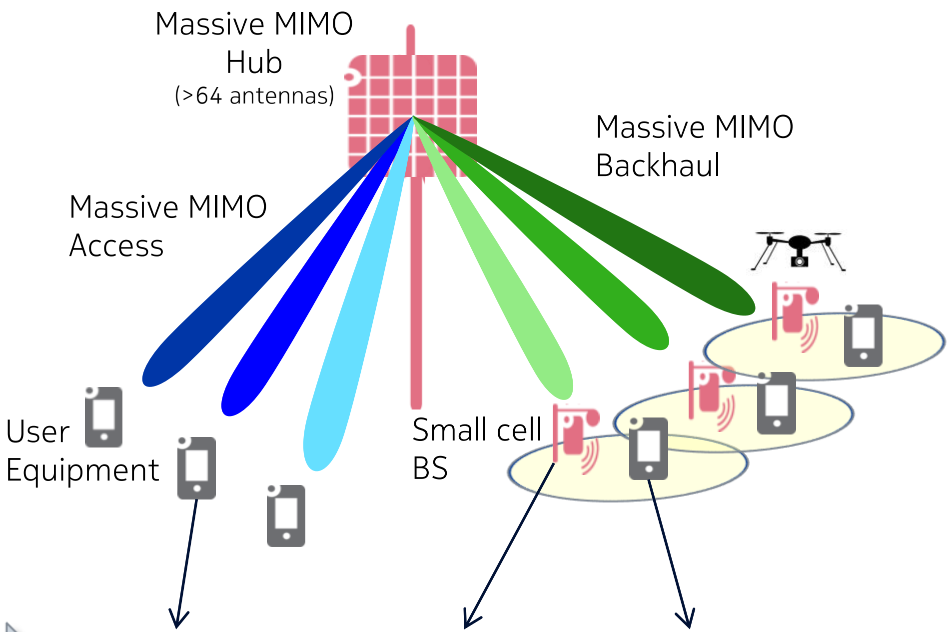
mMIMO for backhaul

Massive MIMO and Ultra-Dense Small Cells

10X



- 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



One UE per beam, one cell per beam, one UE per cell

Massive MIMO dimensioning: resource splitting, inband vs outband, #RF chains, etc.

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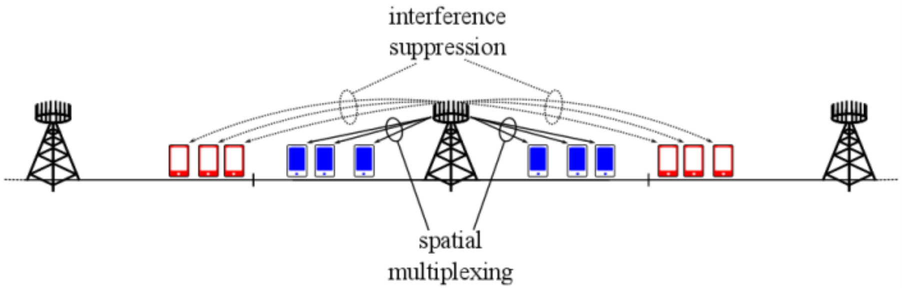
mMIMO for access

Cell-Edge Interference Suppression

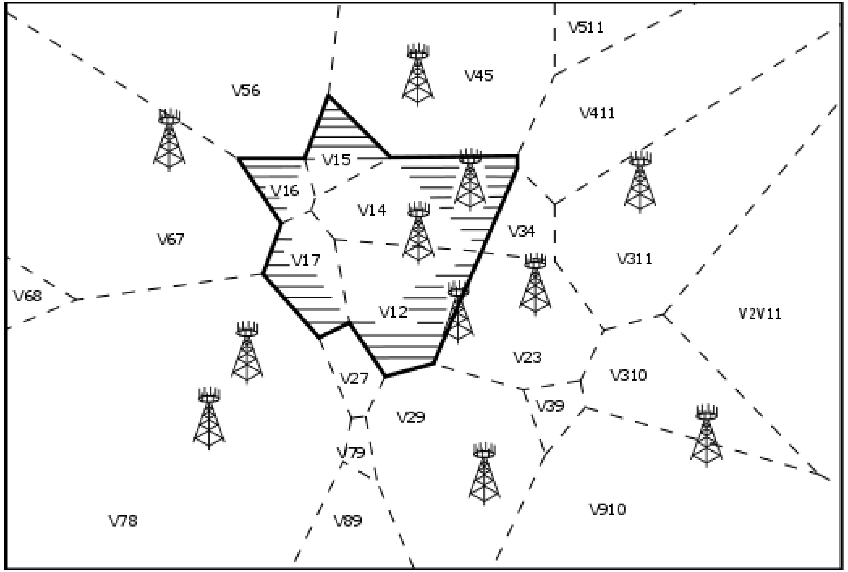
Fundamental Idea

- 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

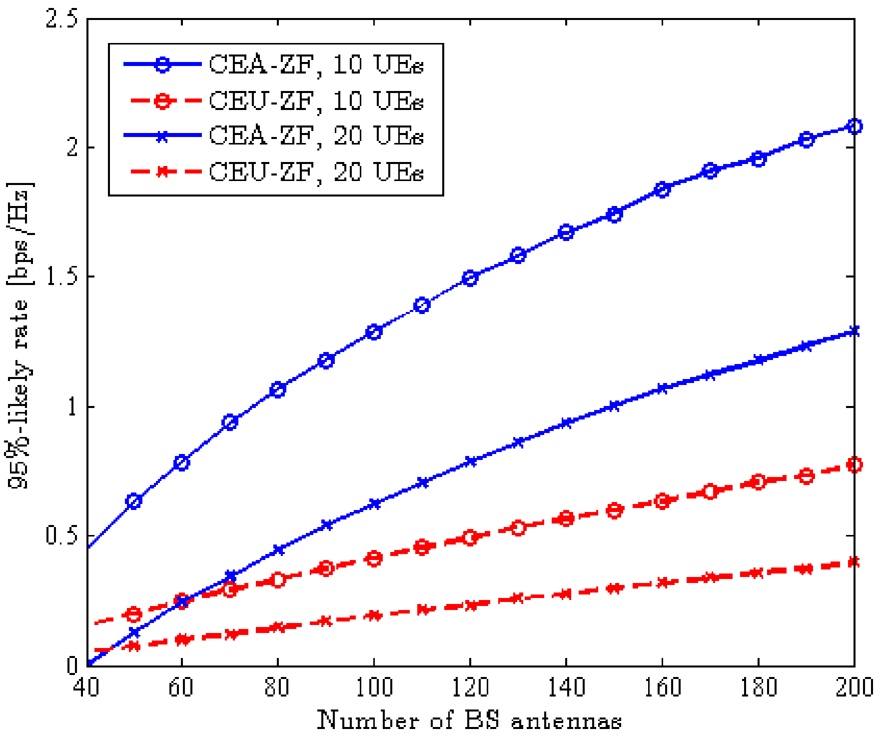
Performance (theoretical)

Main Takeaways

- Outage scales as ~$1/N^2$ (CEA-ZF) vs ~$1/N$ (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



~3X increase in the 95%-likely rate

Larger amount of resources needed for CSI acquisition, depending on mobility

Mobility-Aware, Adaptive Frame Design

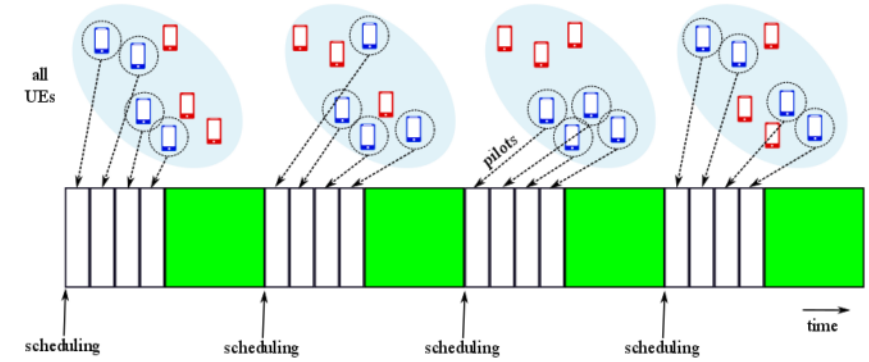
Fundamental Idea

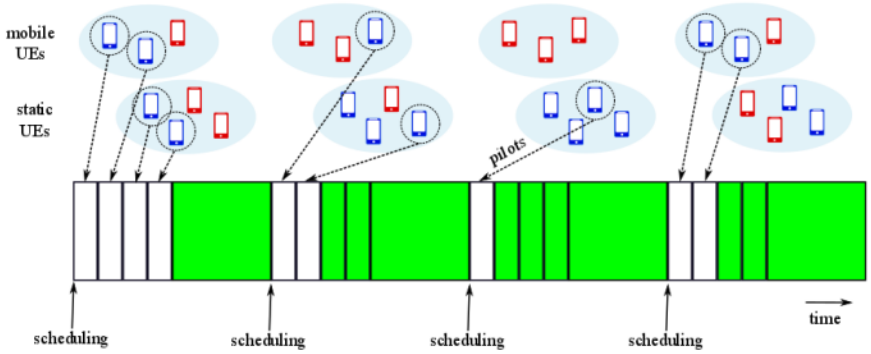
- Exploit mobility state information (MSI) to reduce resources spent for CSI acquisition, i.e., pilots

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

Fixed frame structure





Adaptive frame structure

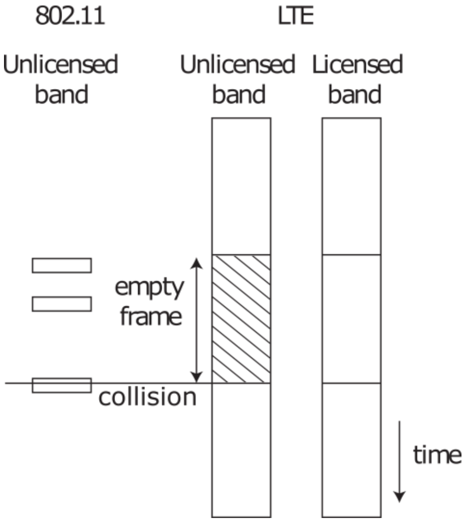
Estimate UEs coherence intervals and use them in the scheduling process

mMIMO for the unlicensed band

LTE – WiFi Coexistence (currently two main approaches)

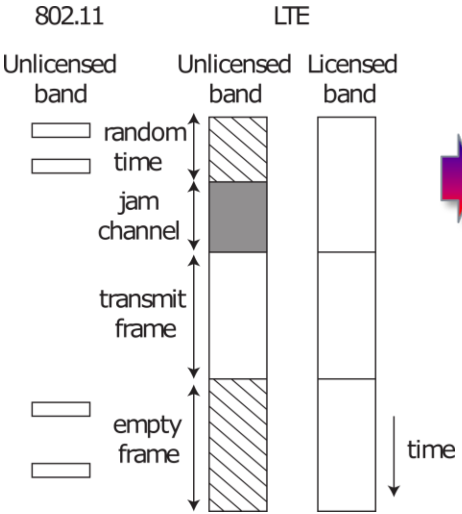
- Carrier Sense Adaptive Transmission (CSAT)
  - Targets markets where LBT is not mandatory
  - BS leaves idle times between tx (e.g. 50% on-off)

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



WiFi tx may start towards the end, causing collision

- 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



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?

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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

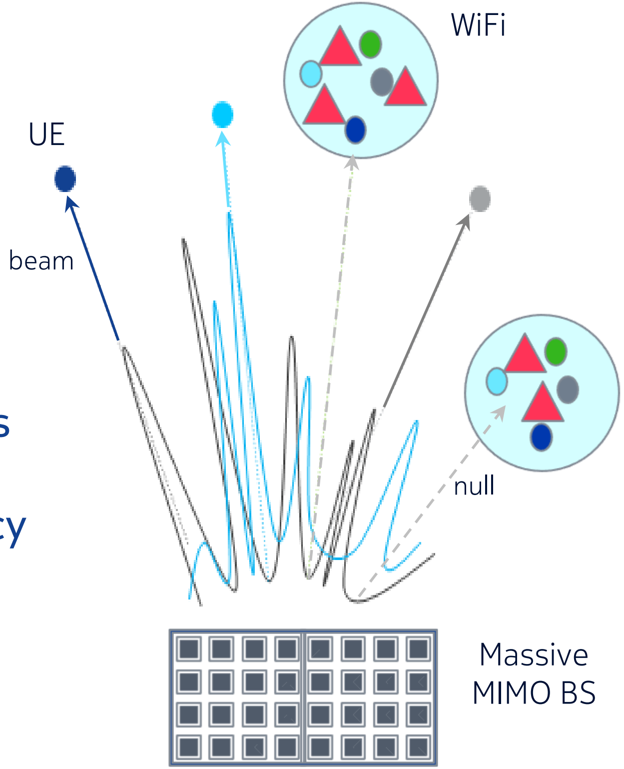
meet regulations
+
increase efficiency

System Design

- CSI is required for all WiFi devices in the massive MIMO coverage area
- Limit to the number of nulls we can point:

#nulls + #UE served ≤ total #d.o.f.

tradeoff → **smart UE scheduling policy**



Massive MIMO and WiFi coexistence

How to obtain channel estimates for neighboring WiFi devices?

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