Key Solutions for a Massive MIMO FDD System

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Wolfgang Zirwas (Nokia Bell Labs),
Mikael Sternad, Rikke Apelfröjd (Uppsala University)

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Outlook

Motivation and Challenges

How to design a massive MIMO FDD system

Some Simulation Results

Conclusions
Motivation and Challenges
At below 6 GHz, both *paired* and *unpaired* bands have to be supported.

**Downlink channel estimation + uplink reporting is a challenge:**

Massive MIMO, with tens to hundreds of antenna elements + coherent joint transmission from multiple base stations

→ We must control the CSI estimation overhead and the reporting overhead
Massive MIMO & JT CoMP for FDD - Challenges and Options

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Massive MIMO & JT CoMP for FDD - Challenges and Options

a) **Orthogonal CSI Reference signals (RS)**
   - Up to 288 RS resources needed per time-frequency correlation block
   - → large overhead or poor performance

b) **Use a Subset of beams?**
   - UE specific subsets of beams/antenna ports (AP)
   - → often reconfigurations of CSI RSs and scheduling limitations
   - Performance ???
   - Overhead ???
### a) Orthogonal CSI Reference signals (RS)
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### b) Use a Subset of beams?
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### c) Use non-orthogonal CSI reference symbols = Coded CSI RS
- Short CSI RS sequences per AP or beam → 20 to 40 resource elements
- Non orthogonal sequences per beam:
  - Exploits sparsity of relevant channel components
  - Avoids UE specific CSI RSs
Typical **sparse** sets of relevant channel components per UE

- An interesting synergy: The GoB typically **generates beams of unequal power**, as seen from one user. From **288 beams**, the UEs receive only **10 to 40 relevant beams** or channel components (left).

  *(Relevant channel components (CCs)): beams above a specified relative power threshold, here -20 dB)*

- Suitable UE beamformers can help to further reduce the number of relevant channel components (right).
Coded CSI RS – exploiting sparse number of relevant CCs

- Relation of CSI RS to user data has to be optimized

- For large # of antenna elements or beams, orthogonal CSI RSs lead to *high overhead* and/or *poor performance*

- **orthogonal CSI RS** → large OH

- → massive MIMO often seen as a TDD- only solution !!!
Coded CSI RS – exploiting sparse number of relevant CCs

- **orthogonal CSI RS** → large OH

- **Coded CSI RS** = set of limited length of non-orthogonal CSI RS sequences

![Diagram of Coded CSI RS and coherence area](image)
Performance of Coded CSI RS with Kalman filter channel estimation

- Utilizing time and frequency correlations
  - Improves estimate of all channels
  - Weak channels are not over-estimated

- Provides a framework for channel prediction (needed for JT CoMP)

- But: performs unnecessary precise estimations of irrelevant channels.
  - Unnecessary computational complexity
  - Can be re-design for estimating only relevant CCs
Beam Deactivation
Beam Deactivation - nine cell Cooperation Area (288 beams)

Benefit: lower CSI feedback load
+ higher quality Coded CSI estimation
+ higher precoding performance

→ strong interconnectivity of relevant beams

Typical distribution of relevant beams per UE
Beam Deactivation - nine cell Cooperation Area (288 beams)

Benefit: low CSI feedback
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→ # of beams reduced from 288 to 120
→ # of rel beams per UE reduced from 42 to 18
→ # of interfering beams from 19 to 6

Beam deactivation by optimization of weighted cost function
### Performance of 5G below 6GHz clean slate approach

#### - Simulation Parameters

- **RF:** 2.6 GHz
- **Radio channel:** Quadriga urban macro / including spatial consistency
- **Bandwidth:** 100 MHz
- **ISD:** 500 m
- **NF:** 7 dB
- **Tx-power:** 49 dBm
- **# of Tx-antennas (gNB):** 16 x 16 x 2 (Xpol) = 512
- **# of Rx-antennas (UE):** 8
- **GoB - beams per cell:** 8 azimuth x 2 vertical x 2 polarizations
- **UE placement:** random
- **# of UEs:** 16 per cell
- **Scheduler:** round robin + „bad apple“-removal
- **JT CoMP:** 9 cell cooperation areas, with cover shift „tortoise“ inter-area scheme
- **Precoding:** regularized zero forcing
- **CSI outdating:** ideal (assuming 1ms delay, pedestrian users) (?)
Simulation Results - Example for 9 cell Cooperation Area

Key Solutions for massive MIMO FDD, which synergistically produce these results:

- massive MIMO GoB
- spatial UE processing over 8 UE antennas
- beam deactivation per user group
- Coded CSI reference signals
- CSI reporting per relevant channel components and relevant taps
- adaptive quantization per relevant tap

Coded CSI + explicit CSI feedback maintains almost 90% of ideal system

Gross spectral eff. = \(47.1787\) b/s/Hz/cell

Average DR per UE = \(4.1628\) b/s/Hz

Gross spectral eff. = \(40.1961\) b/s/Hz/cell

Average DR per UE = \(3.5467\) b/s/Hz

N_bits_per_TTI = \(457.4683\) bit / TTI
Discussion and Conclusions:

Key Components in a solution for massive MIMO below 6 GHz FDD:

- Use (adaptive) grid-of beams (GoB)
- Use (superposed) coded CSI reference signals
- Reporting of relevant channel components only
- Beam deactivation provides added benefits.

Adaptive GoB allows for suitable scenario adaptation of wideband beams to user distribution

Explicit per beam CSI estimation and reporting combines high accuracy with modest feedback overhead

Paper download and additional references:
http://www.signal.uu.se/Publications/abstracts/c1704.html
Discussion and Conclusions:

Note that TDD downlink design based on channel reciprocity has several challenges:

• tight calibration needed
• pilot contamination for (many) uplink sounding reference signals
• limited UE Tx-power and battery lifetime
• hard to estimate interference situation at UEs by uplink channel estimation.
• limited support for channel prediction, requiring long term observations of the radio channel

⇒ consider explicit CSI feedback based on Coded CSI RS also for TDD as add on
Backup
Flexible Interference Mitigation for 5G below 6GHz - FDD & TDD

1. **massive MIMO**: 4 to 1028 antenna elements
   - Fixed GoB → limited # of beams per cell

2. MU MIMO with >10 UEs per cell

3. Network MIMO precoder with mode switching:
   - adaption to UE speed, load, CSI reporting parameters, ...

4. Non-orthogonal Coded CSI RS

5. 4 to 8 UE antenna elements
   - Narrow beamformers

6. CSI reporting per relevant beams and relevant taps
   - With or without channel prediction

7-10x spectral efficiency over LTE 4x4
5-10% overhead for CSI RS
2 to <400 bit/subframe CSI feedback