Key Solutions for a Massive MIMO FDD System

PIMRC 2017 TR1/S13 Massive MIMO I

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Outlook

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Motivation and Challenges

How to design a massive MIMO FDD system

Some Simulation Results

Conclusions

Motivation and Challenges

Massive MIMO & JT CoMP for FDD - Challenges and Options

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- 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

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Massive MIMO & JT CoMP for FDD - Challenges and Options

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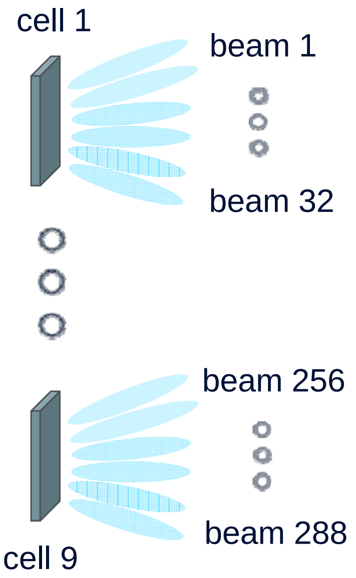
GoB as first step:

typ. $N_{beam} < N_{antennas}$



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Massive MIMO & JT CoMP for FDD - Challenges and Options

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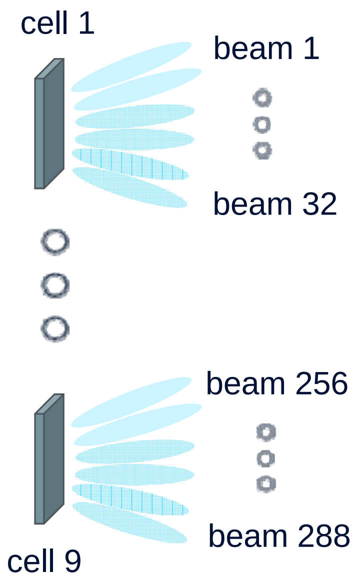

a) **Orthogonal CSI Reference signals (RS)**

- Up to 288 RS resources needed per time-freqeuncy 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 ???

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Massive MIMO & JT CoMP for FDD - Challenges and Options

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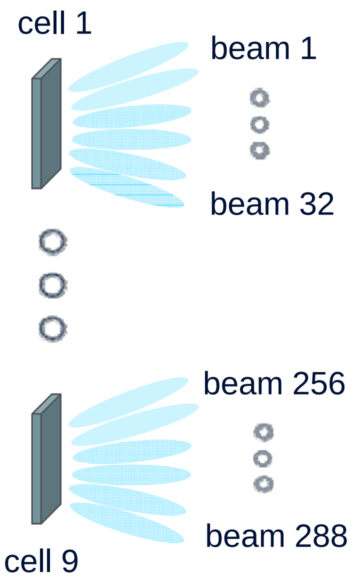

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- Performance ???
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c) **Use non-orthogonal CSI reference symbols = Coded CSI RS**

- 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**

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Typical ***sparse*** sets of relevant channel components per UE

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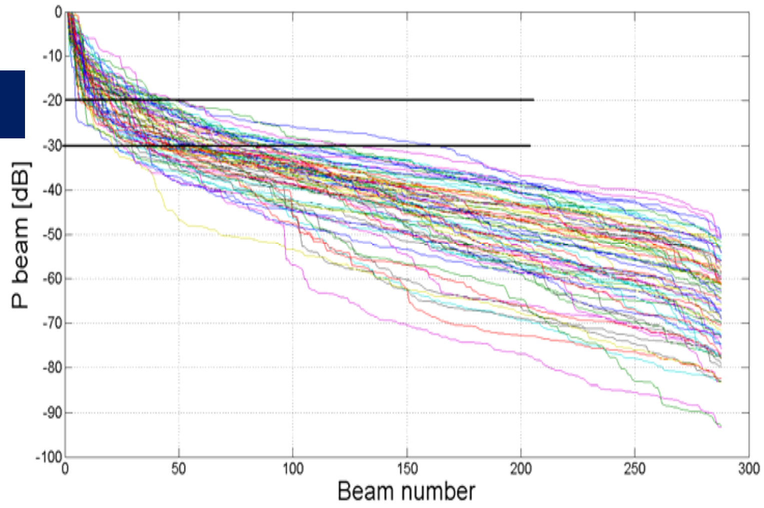
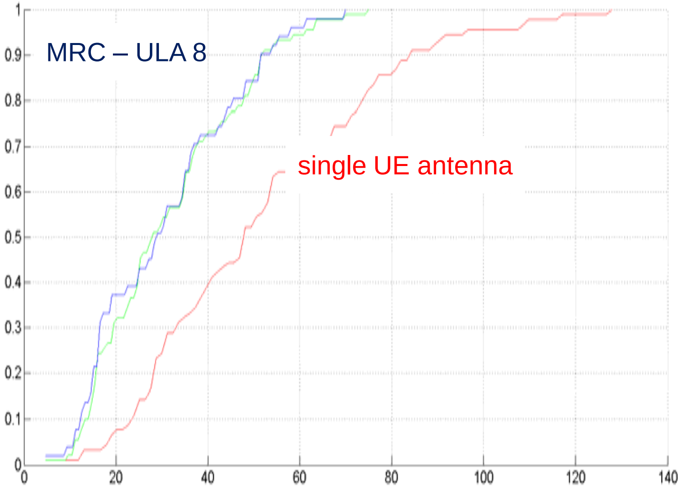
sorted Rx-power over beams per UE

10 to 40 rel CC



CDF of # of relevant channel components



- 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).

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Coded CSI RS – exploiting sparse number of relevant CCs

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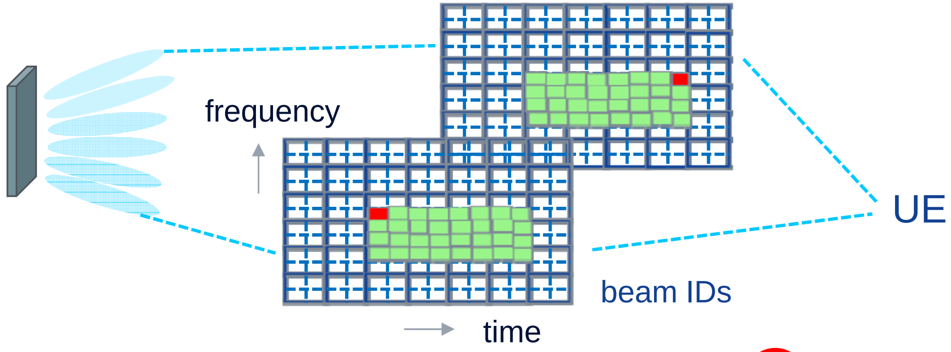

- orthogonal CSI RS → large OH ☹

- 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***

- → **massive MIMO often seen as a TDD- only solution !!!**

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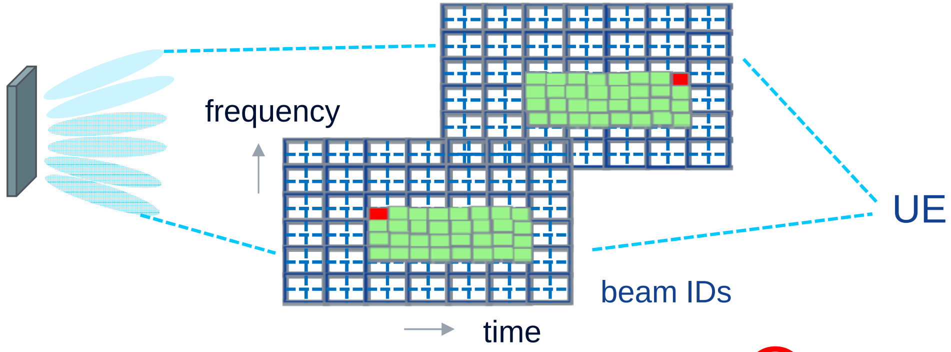
Coded CSI RS – exploiting sparse number of relevant CCs



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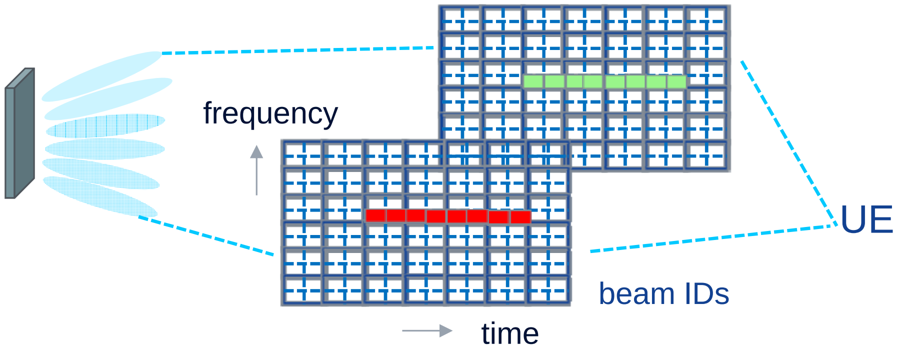
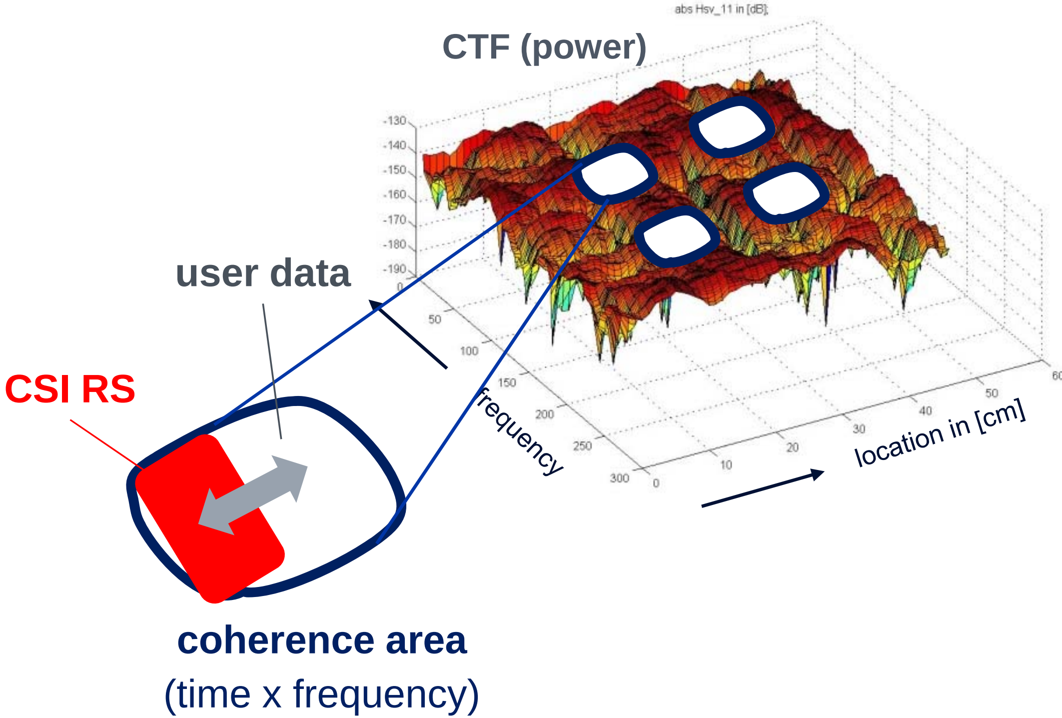


- ***Coded CSI RS*** = set of limited length of non orthogonal CSI RS sequences ☺



Performance of Coded CSI RS with Kalman filter channel estimation

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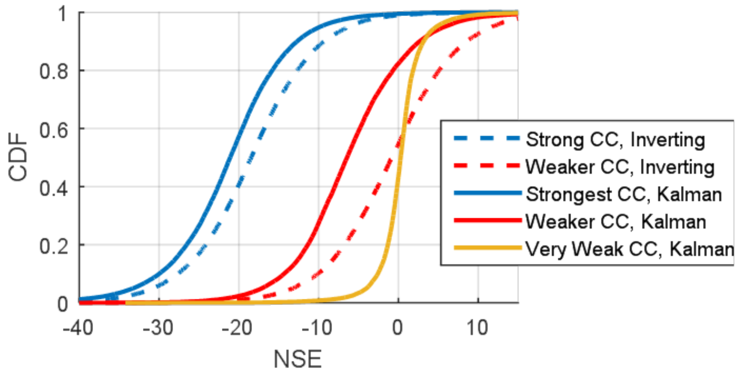
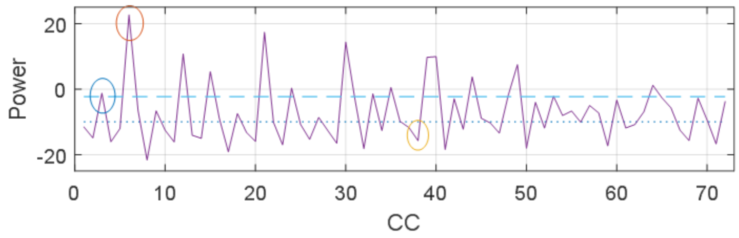
- Utilizing time and frequency correlations
  - Improves estimate of all channels
  - Weak channels are not over-estimated

- 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





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Beam Deactivation

Beam Deactivation - nine cell Cooperation Area (288 beams)

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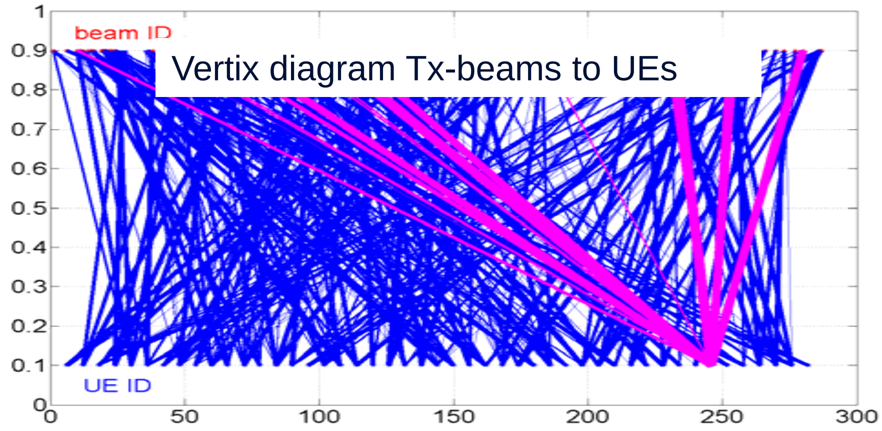
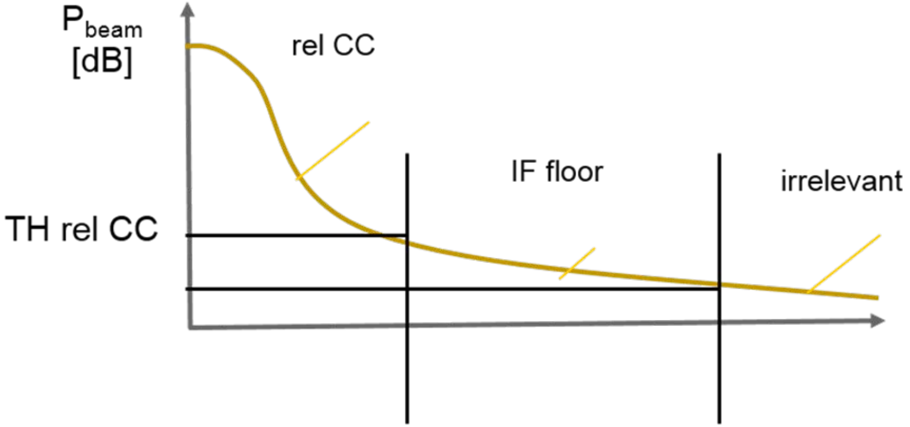
Benefit: lower CSI feedback load
+ higher quality Coded CSI estimation
+ higher precoding performance



→ strong interconnectivity of relevant beams



Typical distribution of relevant beams per UE

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Beam Deactivation - nine cell Cooperation Area (288 beams)

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Benefit: low CSI feedback
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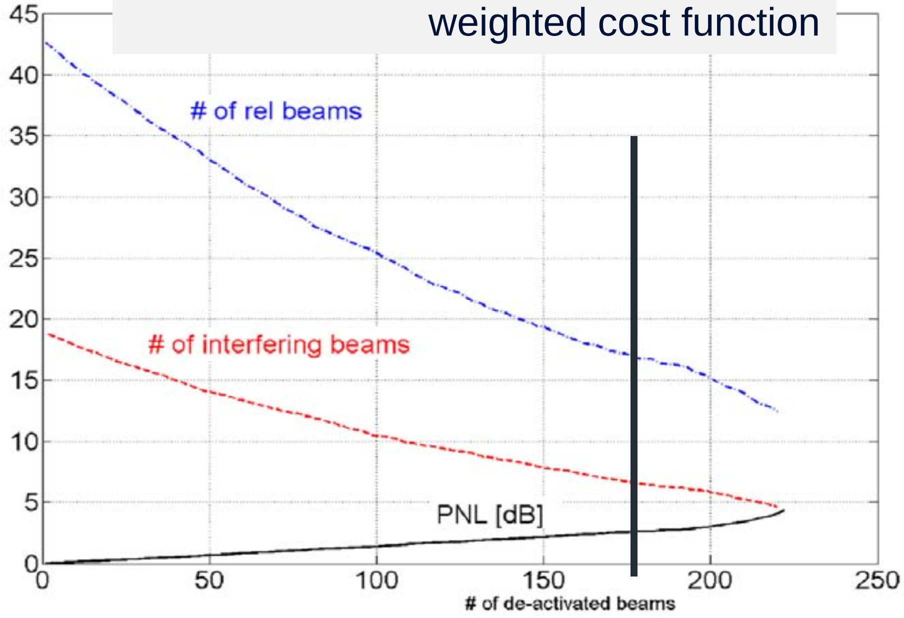
Beam deactivation by optimization of weighted cost function



→ # of beams reduced from 288 to 120

→ # of rel beams per UE reduced from 42 to 18

→ **# of interfering beams from 19 to 6**

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Performance of 5G below 6GHz clean slate approach - Simulation Parameters

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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) (?)

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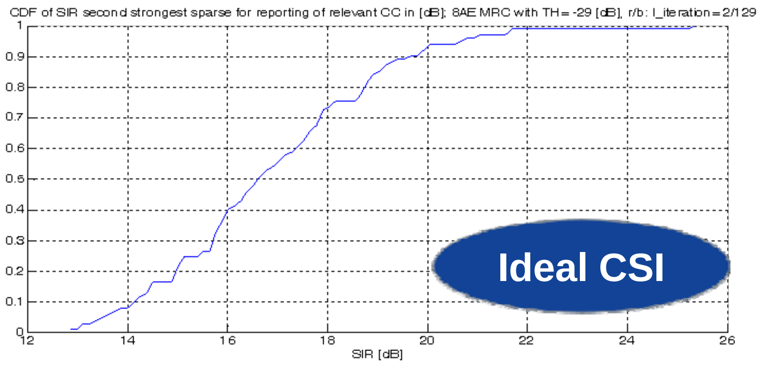
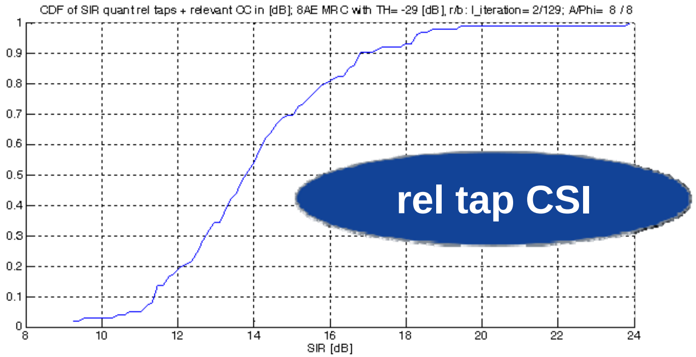
Simulation Results – Example for 9 cell Cooperation Area



gross spectral eff. = **47.1787** b/s/Hz/cell
avg_DR_per_UE = **4.1628** b/s/Hz



gross spectral eff. = **40.1961** b/s/Hz/cell
avg_DR_per_UE = **3.5467** b/s/Hz
N_bits_per_TTI = **457.4683 bit / TTI**

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

Discussion and Conclusions:

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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

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Discussion and Conclusions:

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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, requireing long term observations of the radio channel

→ ***consider explicit CSI feedback based on Coded CSI RS also for TDD as add on***

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Backup

Flexible Interference Mitigation for 5G below 6GHz - FDD & TDD

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

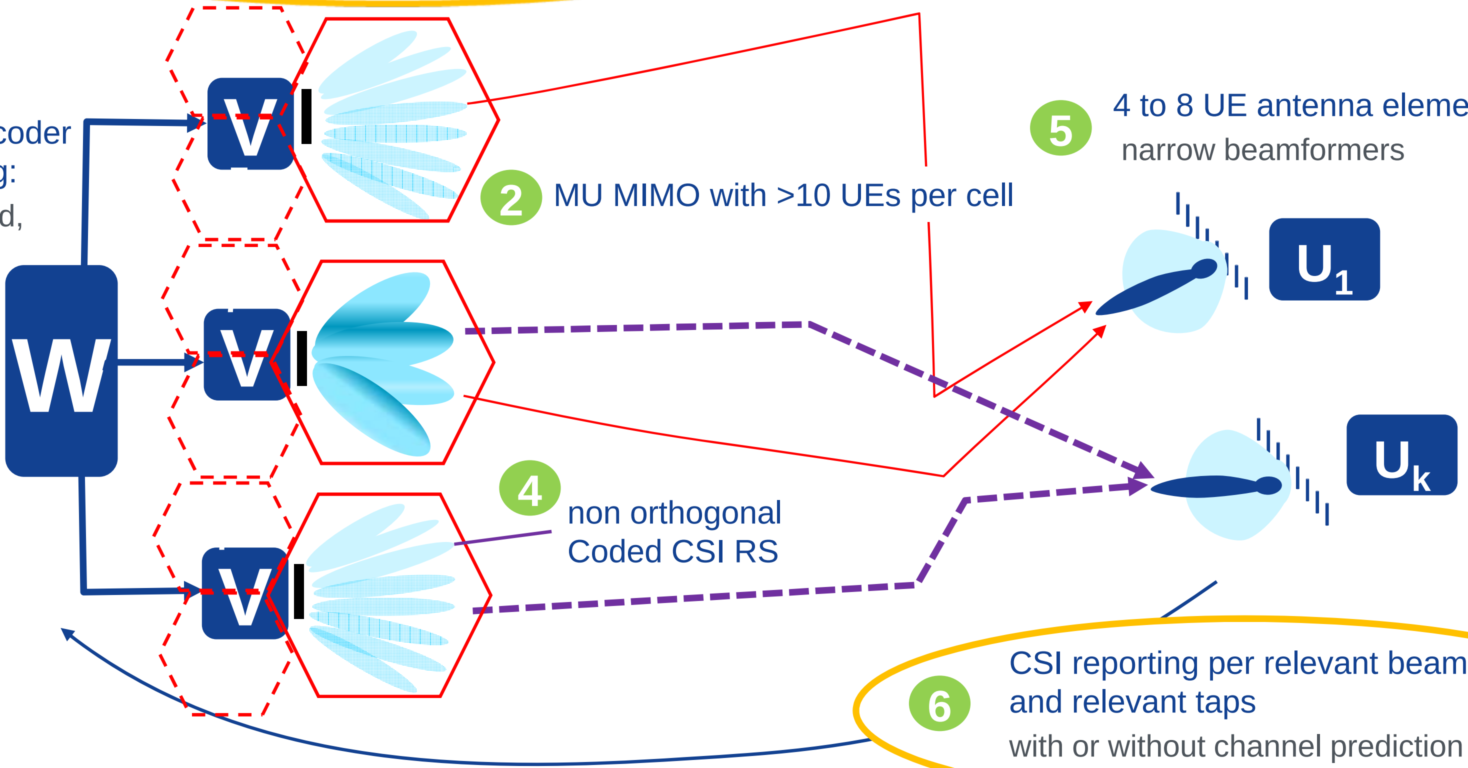
1 ***massive MIMO***: 4 to 1028 antenna elements
fixed GoB → limited # of beams per cell

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

2 MU MIMO with >10 UEs per cell

5 4 to 8 UE antenna elements
narrow beamformers

4 non orthogonal Coded CSI RS



6 CSI reporting per relevant beams and relevant taps
with or without channel prediction

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