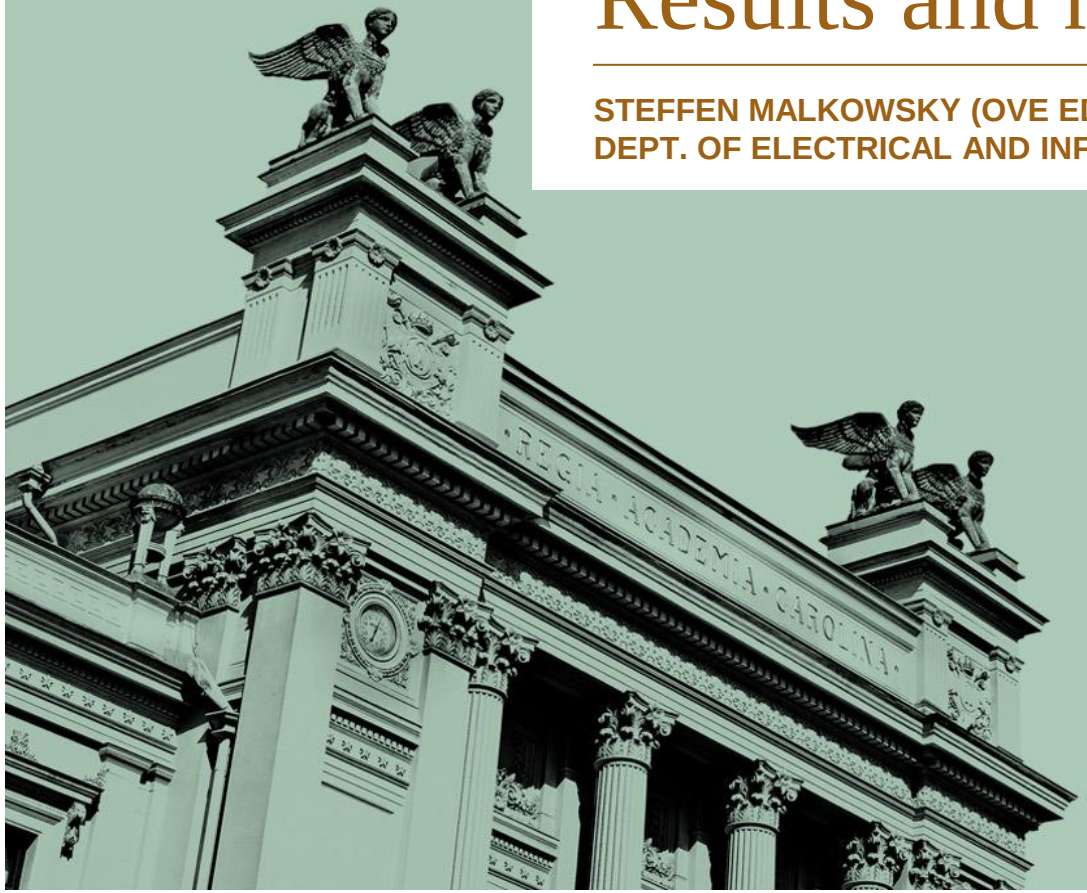
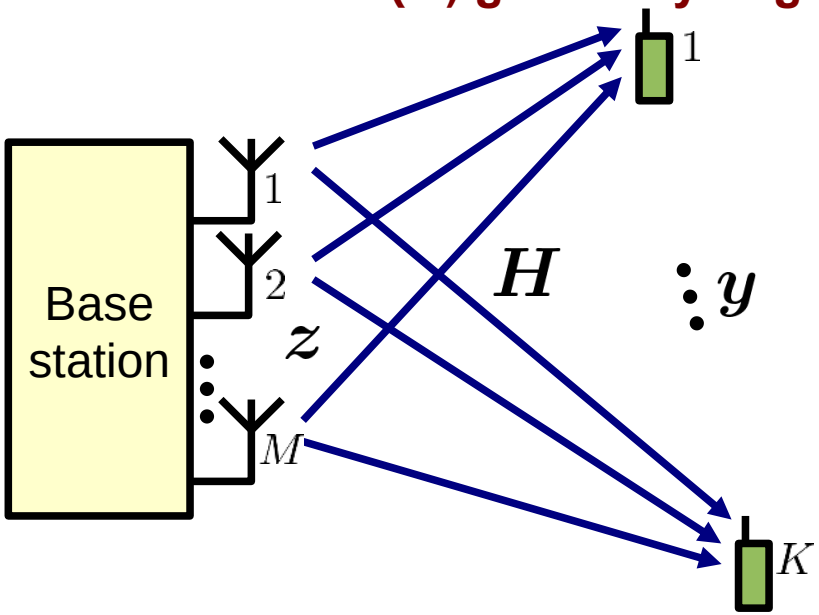
LuMaMi: Measurement Results and more…

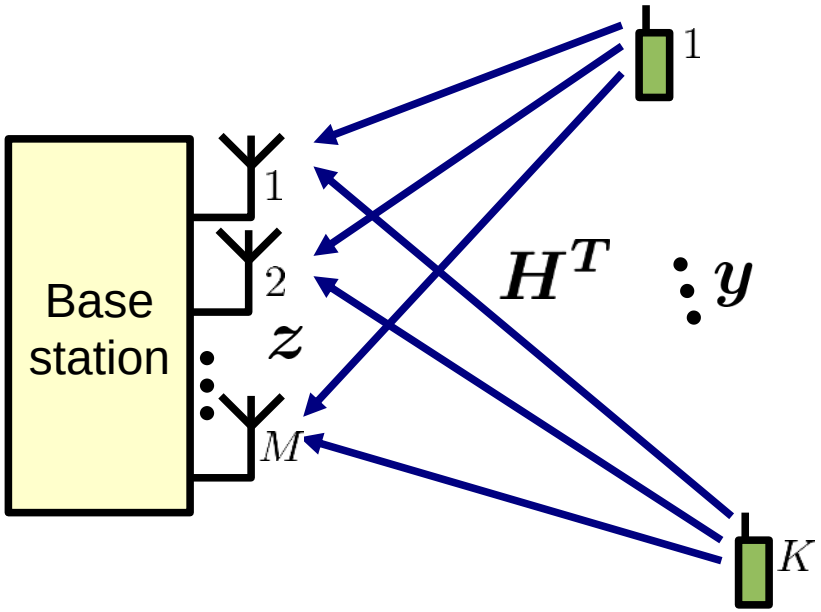
STEFFEN MALKOWSKY (OVE EDFORS),
DEPT. OF ELECTRICAL AND INFORMATION TECHNOLOGY



Massive (multi-user) MIMO in TDD

Massive MIMO implies that we let the number of base station antennas (*M*) grow very large … in the hundreds!





Down-link:

$$\boldsymbol{y} = \boldsymbol{H}\boldsymbol{z} + \boldsymbol{n}$$

Up-link:

$$\boldsymbol{z} = \boldsymbol{H}^{\boldsymbol{T}}\boldsymbol{y} + \boldsymbol{v}$$

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LUMAMI TESTBED

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LuMaMi Testbed: Parameters

- 100 BS antennas
- Serving up to 12 UEs
- 50 SDRs + 6 SDRs as UEs
- 4 FlexRIOs for centralized processing
- 3.7 GHz carrier frequency
- LTE-like parameters

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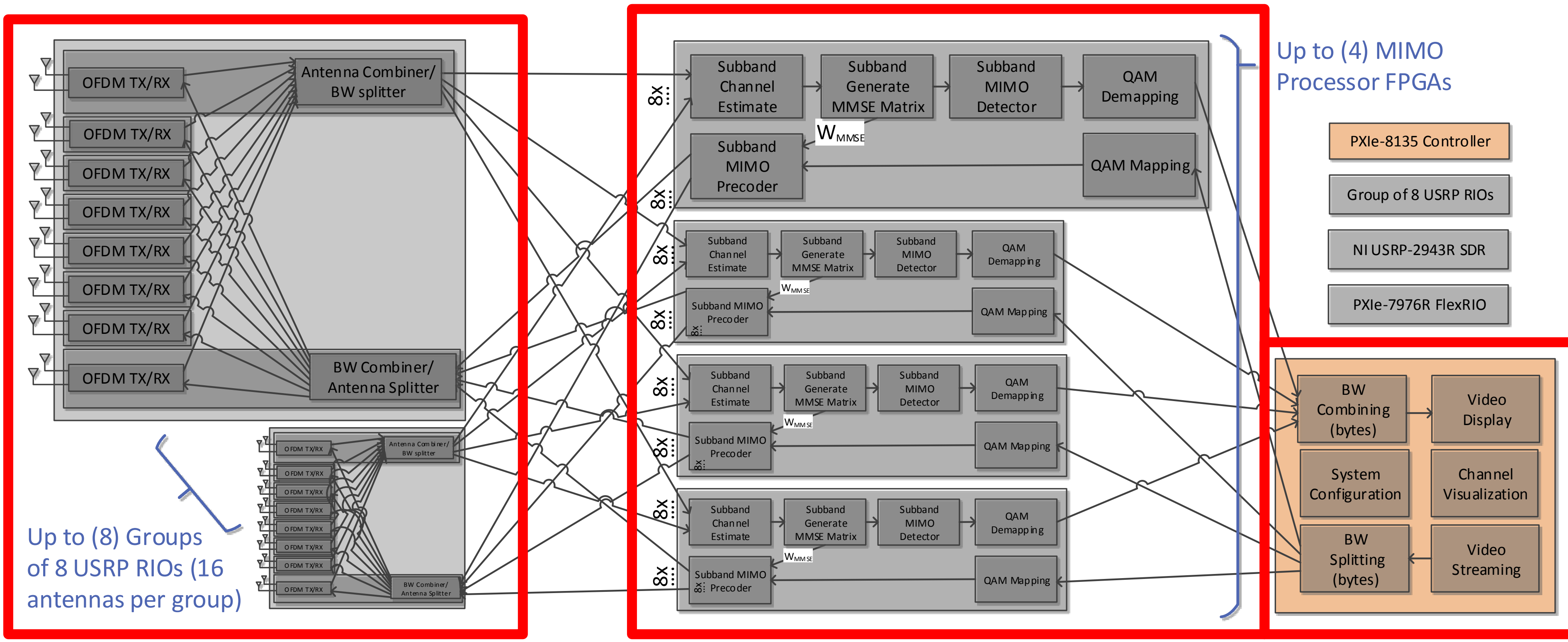
LuMaMi Testbed: Processing



- ➢ Per antenna (OFDM) processing on each USRP SDR
- ➢ Data of groups of 8 USRPs combined and send to centralized processing
- ➢ Centralized processing distributed over 4 units, each working on 1/4 bandwidth
- ➢ 3 detector types implemented: MRC/MRT, ZF and regularized ZF
- ➢ A standard (Windows) computer to control the complete system
- ➢ Configures system
- ➢ Visualizes system parameters, e.g. channel impulse response and acts as source and sink for video streams

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THREE TESTS

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Indoor Measurements

- Serving 12 users in groups of 4 on UL and DL in a lecture hall
- Record BERs while sweeping amplifier gains (0-30 dB)
  - UL: Sweep the gain of the UEs transmitter
  - DL: Sweep the gain of the BS transmitters
- 18 Million bits transmitted per step
- Compare performance of MRC/MRT vs. ZF

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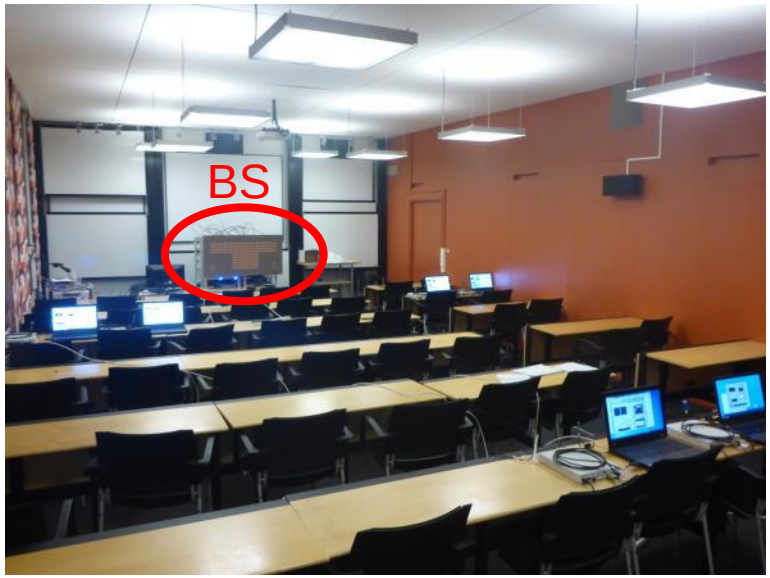
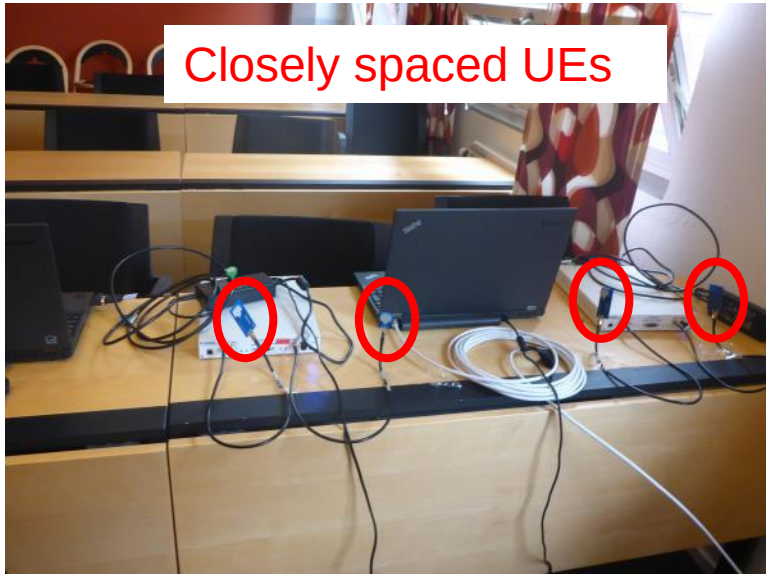
Setup



Base station placed at the front of the lecture hall



Users are distributed in groups of 4 with close spacing inside each group

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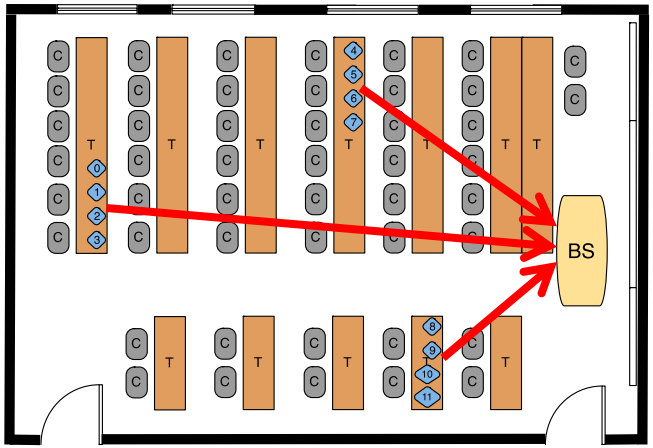
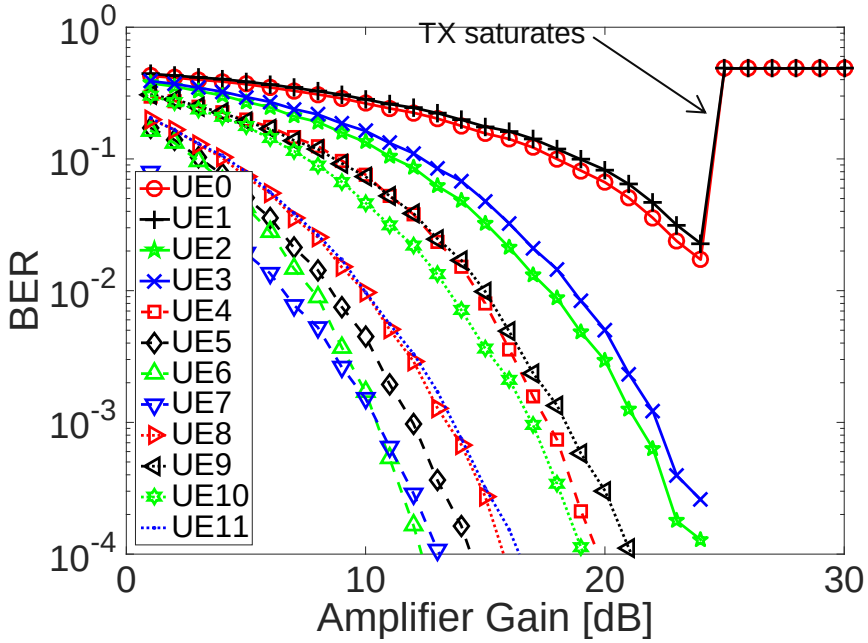
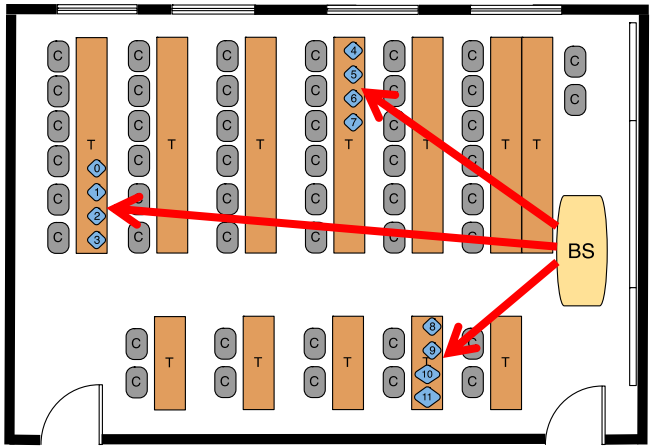
Uplink BERs (QPSK)

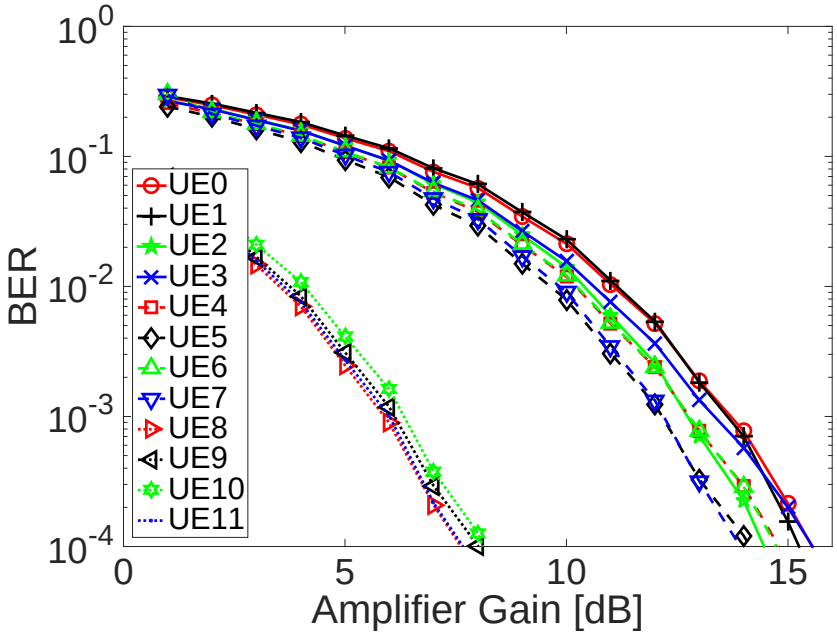




- ZF detector
- Close by users (UE8-11) show best BERs
- Far users (UE0-UE3) show worst performance
- UE0/1 interference limited
  - Bad performance at full power close to saturation

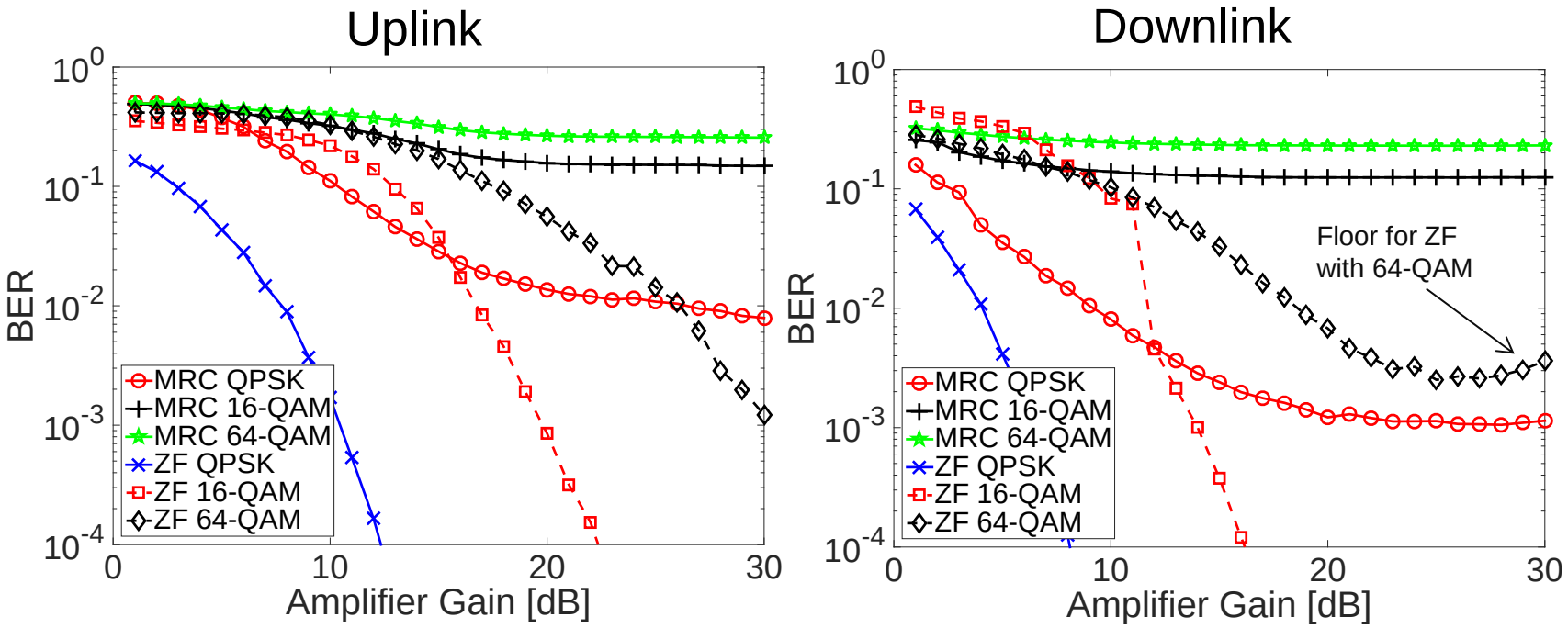
Downlink BERs (QPSK)





- ZF precoder
- Close by users (UE8-11) shows best BERs
- Other users (UE0-7) show similar performance
- High performance difference between UE8-11 and the UE0-7

ZF vs. MRC/MRT



- MRC/MRT showing significant error floors
  - Usable in practical systems?
- ZF far superior in real-life channels

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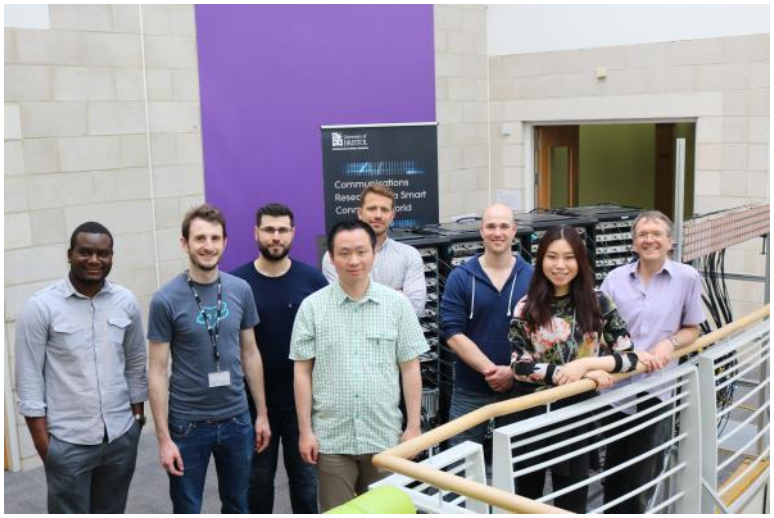
Collaborative Measurements in Bristol

- First joint measurement campaign with Lund University and University of Bristol in May 2016
- Based on Bristol MaMi system with 128 antennas
- How many users can be served simultaneously?
- What spectral efficiency can be achieved?



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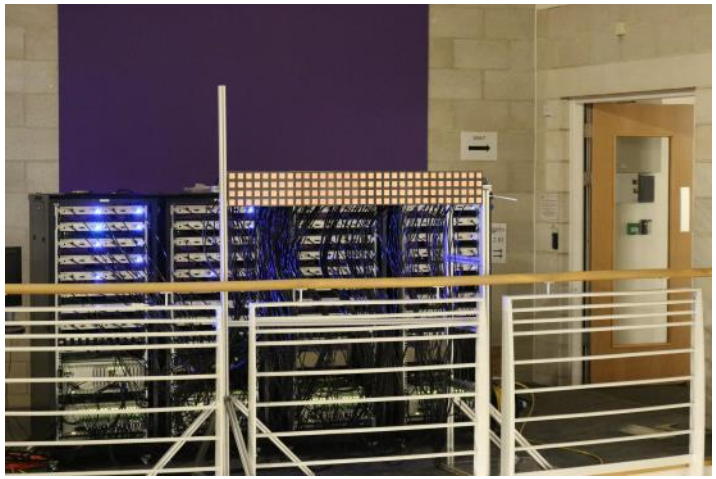
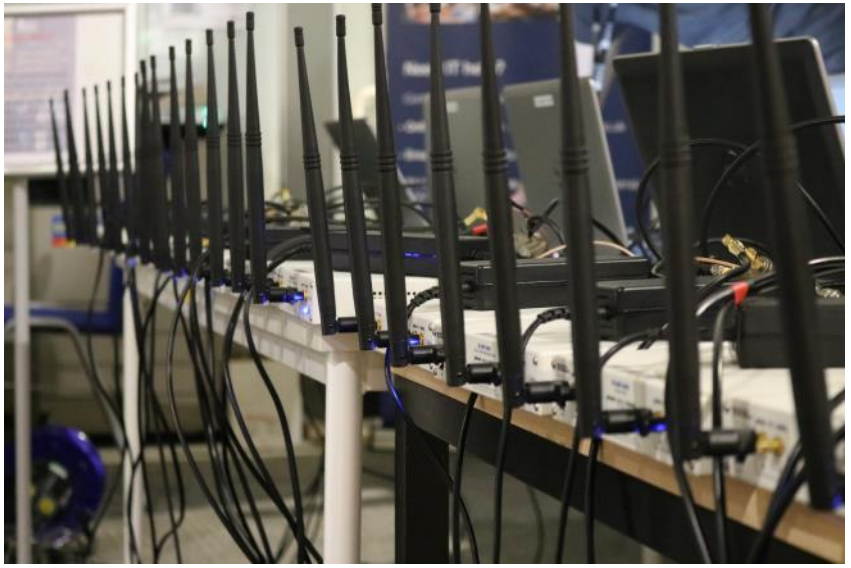
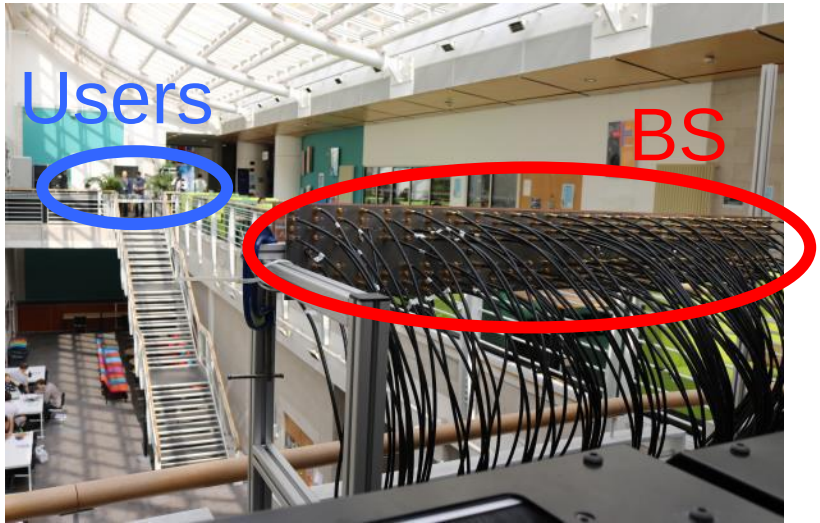
Setup

Base station



Closely spaced users





Overall setup from base station view

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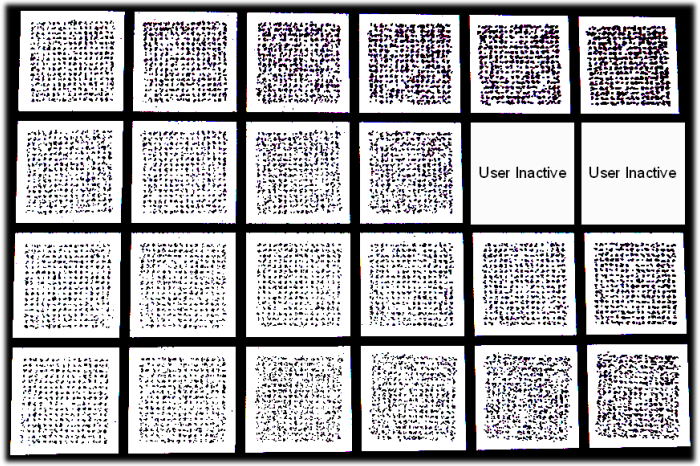
Results

- 22 users served simultaneously using 256-QAM
- Uncoded transmission
- Equating a spectral efficiency of 145 b/s/Hz



World record spectral efficiency

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NI Engineering Impact Awards 2016

- 5 Awards go to Bristol and Lund for the paper “Setting a World Record in 5G Wireless Spectrum efficiency With Massive MIMO”

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Joint Mobility Trials in Lund

- Together with a team from University of Bristol we performed the first mobility test using the LuMaMi testbed
- Goal was to analyze how well massive MIMO works in dynamic environments
- Tests were performed with up to 10 users, 4 mounted on cars (up to 40 km/h) and 6 mounted on cycle carts (walking speed)
- Uplink channel data, BERs and LabVIEW front panels were recorded

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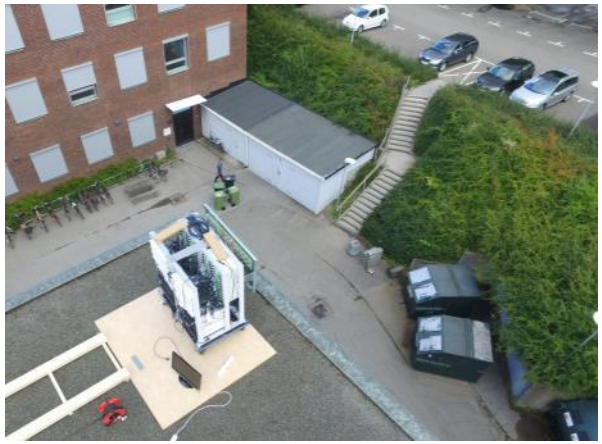
Setup I

Base station deployed on rooftop



Users mounted on cycle cart

Users mounted on cars

10 user mobility test

VIDEO ...

Conclusions

- The LuMaMi testbed is fully functional and working for UL and DL transmission
- In a joint campaign Lund University and University of Bristol achieved a new world record for spectral efficiency
- Indoor measurements showed that even with 100 antennas at the BS, MRC/MRT show significantly worse performance than ZF
- Mobility measurements showed that massive MIMO works for moving users with relatively good BER performance on UL and DL (more analysis to be performed)

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