LuMaMi – A flexible testbed for massive MIMO

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Massive MIMO research topics

- Propagation studies and channel modeling
- Antenna and antenna array design
- Baseband processing algorithms
- Baseband processing hardware
- System design and performance evaluations

We need a testbed to take the next step towards realizing massive MIMO.
Challenges

• Coherency
  – the channel has to be constant between uplink and downlink
  – The 100 RF tranceivers have to be coherent and synchronous

• Reciprocity
  – The channel has to be reciprocal, including uplink and downlink tranceiver chains

• Data shuffling
  – 100 parallell RF chains generate data streams that have to be managed

• Baseband processing architecture
  – A combination of centralized and distributed processing.
System architecture

- Based on Star-Architecture
- Central Controlling Unit
  - Link Evaluation
  - Upper layer protocols
  - Logging data
  - Baseband Proc.
- Switches
  - Routing data
- SDR
  - Baseband Proc.
  - RF-Front End
System components

USR P 2943R

OctoClock-G

Printed antenna array

PXle-1085 chassis

PXle-8135 Controller

Flex RIO FPGA
System components - SDR

USRP RIO 2953R (Universal Software Radio Peripheral)

- 2 RF chains
- Xilinx Kintex-7 FPGA
- ~800 MBps bidirectional data streaming
- ~135 MBps baseband data
- Center frequency from 1.2 to 6 GHz
System components – FPGA coprocessor

**FlexRIO 7976R (Flexible Reconfigurable Input Output)**

- Xilinx Kintex-7 FPGA
- Up to 3.2 GBps data streaming
- Customizable I/O
- Up to 32 simultaneous high throughput connection to other FPGAs
- Used for centralized co-processing
System components – Antenna Array

- Designed at the department for $f_c = 3.7$ GHz
- 10dB bandwidth of 183 MHz
- Average antenna match -28 dB.
- 160 dual polarized patch antenna array elements
- Allows different configurations
  - 4 x 25
  - 10 x 10
  - 5 x 10 dual pol.
  - etc …

In-house design at Lund University
Assembly of ”mobile” base station

19” Rack 1
24 U

19” Rack 2
24 U

Antenna array
160 dual polarized patch antennas
(100 of 320 ports connected)

Width: 1.2 m
Depth: 0.8 m
Height: 1.5 m
BS hardware setup: side-view

Up to 800 MB/s/direction

2.8 GB/s bidirectional

Time and Freq. synchronization network
Assembly of the base station
User-equipment
PXIe and OctoClock
Simplified processing block diagram
1st ver.: LTE-like OFDM-based TRX

NI RMC-8354

NI FlexRIO 7976

Centralized processing
Basic frame structure

One radio frame $T_f = 10\text{ms}$

Subframe #0  Subframe #1  Subframe #2  Subframe #3  Subframe #4  Subframe #9

One subframe $T_{sf} = 1\text{ms}$

One slot $T_{slot} = 0.5\text{ms}$

ULPilot  ULData  ULData  Switch Guard  DLData  DLData  Switch Guard

Time to calculate down-link precoder
Initial results I

Capabilities of the RF front ends:

- Requirement: stable frequency response of RF-chains to achieve reciprocity calibration
- Transmit signal by one SDR and split into 4 other signals
- Fig. shows the phases of the received signals
- Only a few degrees of phase drift after warming up
Initial results II

Capabilities of the RF front ends:

- 30.72 MHz i.i.d. Gaussian sequence transmitted by single antenna
- 25 x 4 Rx antenna array with roughly same distance to Tx
- Strong LOS channel to verify sampling synchronization capabilities;
- Distinctive planar wavefront with a small delay spread;
- The received samples are time aligned within one 40 MS/s sample
Initial results

Received signal constellations – LOS & four users 2 m separation
Initial results

Received signal constellations – LOS & four users 2 m separation
Initial results

Received signal constellations – NLOS & four users in 15 cm radius
Initial results

Received signal constellations – NLOS & four users in 15 cm radius

User 1 – ZF detector

User 2 – ZF detector
Summary

- 100 coherent RF chains
- Flexible architecture based on NI platform and software radios
- Supports 10 simultaneous single antenna users in the same time-frequency resource block
- Real time operation in the 3.7 GHz band, 20 MHz bandwidth
- Taking Massive MIMO from the lab to reality.