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Concepts and Implementation Aspects for Massive MIMO

Liesbet Van der Perre, KU Leuven
on behalf of the MAMMOET consortium
Workshop at ESSCIRC, September 12th 2016

Workshop agenda

- 8:45 – 9:05 Workshop and project intro, Liesbet Van der Perre, KU Leuven
- 9:05 – 9:50 Communication system concepts: Massive MIMO introduction, Emil Björnson, Linköping University
- 9:50 – 10:20 Overall system complexity, L. Van der Perre, MAMMOET
- *10:20 – 10:40 Coffee Break*
- 10:40 – 11:10 Digital baseband algorithmic and architectural solutions to master complexity, Liang Liu, Lund University
- 11:10 – 11:30 ADCs for massive MIMO: low power solutions available, Jan Craninckx, imec
- 11:30 – 12:00 “Mixed Analog-Digital Pulse-Width Modulator for Massive-MIMO Transmitters” - Alexiou Nikolaos, Infineon Technologies Austria AG
- 12:00 – 12:30 Massive MIMO testbed: validation, Steffen Malkowsky, Lund University
- 12:30 – 12:40 Open Discussions and Concluding Remarks

Massive MIMO: fuelling 5G with a green MAMMOET's footprint

- 5G: the need for new fuel
- Massive MIMO: the concept (in 2 minutes)
- MAMMOET project: Massive MIMO for Efficient transmission
 - ◆ Energy efficiency: Low complexity hardware, and power savings
 - ◆ Spectral efficiency: Validation in real-life test-bed

50 billion connected devices BY 2020



Smart connected systems: going massive, with a great diversity



1000 TIMES



INCREASING WIRELESS CAPACITY

90%



SAVING ENERGY

7 TRILLION



CONNECTING THINGS

20 BILLION HUMAN-ORIENTED TERMINAL



CONNECTING ALL PEOPLE

0 LATENCY



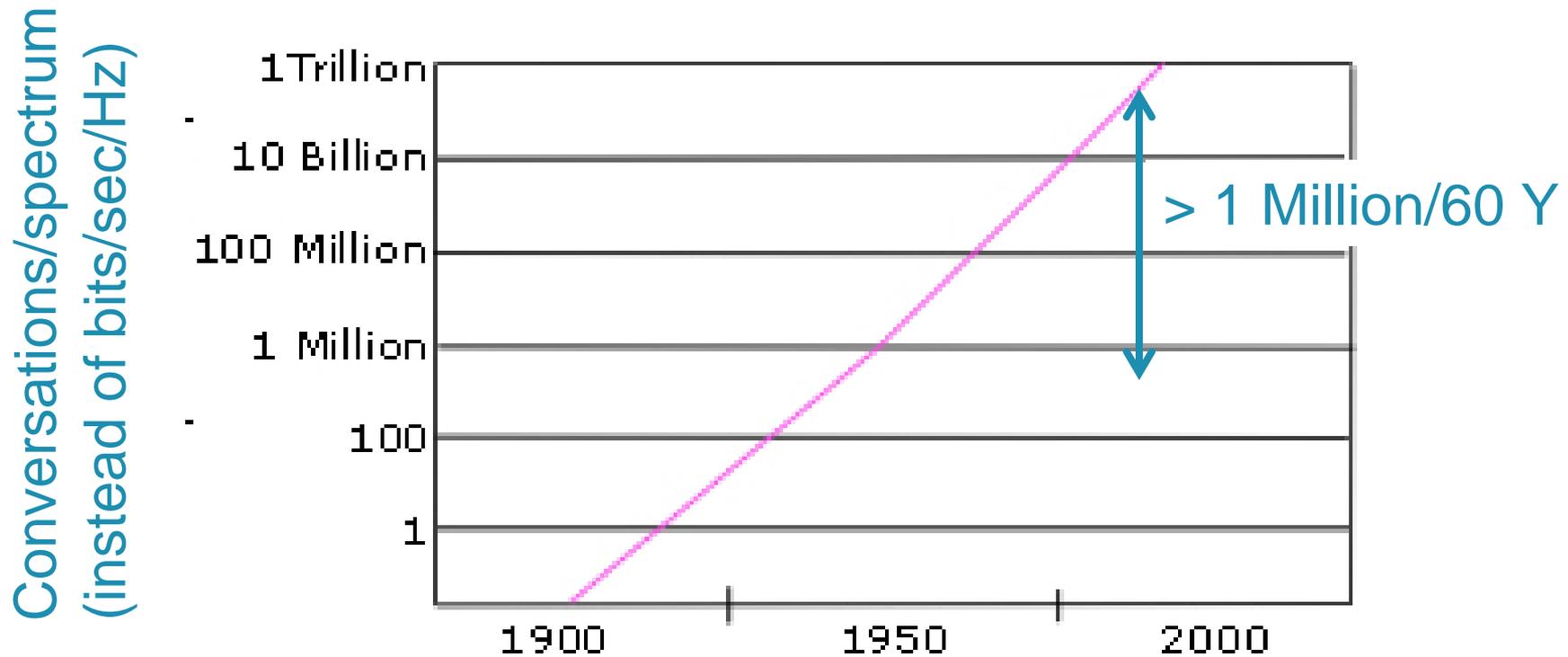
LOW LATENCY

99.999%



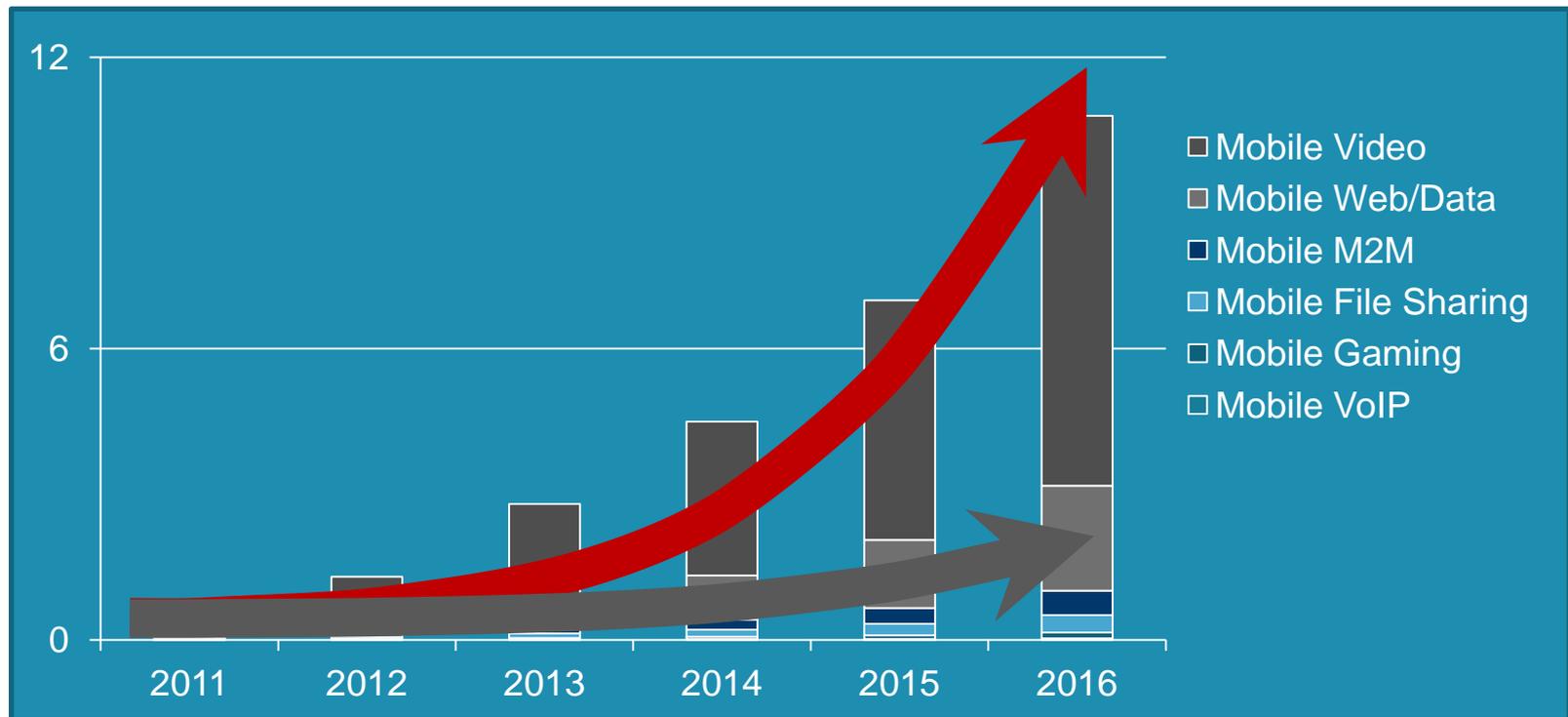
RELIABILITY

Cooper's law: Spectrum utilization has doubled every 30 months last > 100 years



Mobile Network Capacity Crunch

- Cooper's law gives us factor 4!
- Factor **18 is needed**



How was it done?

**Link
Capacity**

5X

Closing the gap with
Shannon's bound

**More
Bands**

25X

Conquering the spectrum

**Spatial
reuse**

1600X

Densifying the network

**Frequency
Division**

5X

Improving the hardware



5G

comsoc.org/CTN

The Death of 5G?

WILL DENSIFICATION BE THE DEATH OF 5G?

September 12th, 2016

MAMMOET – Massive MIMO for Efficient
Transmission

IEEE ComSoc Technology News, May 5th 2015

.... a vast majority of capacity increases has been enabled by ever denser and denser cell deployment.
Will this law continue to get us towards the promised land of 5G data rates or will it end up in a messy patchwork?



physical limits:
interference



traffic constraints:
scheduling complexity

Telefonica Sept 2015: “The small cell debate”

Theoretical research: small cells best to increase area capacity (bps/Hz/km²), they are hardly seen.

Reasons: mixture of technical, economic, spectrum & deployment

5G

IEEE ComSoc Technology News, January 2016

comsoc.org/CTN

After our doom-laden "death of 5G" series we did get some letters. In particular, the good people of the MAMMOET project in Europe managed to hit several points at once. So to start 2016 on an upbeat, we have a positive look at massive MIMO covering both the throughput and the implementation for sub 6GHz. We hope this makes you feel just a little bit better about wireless in 2016. - Alan Gatherer, Editor-in-chief

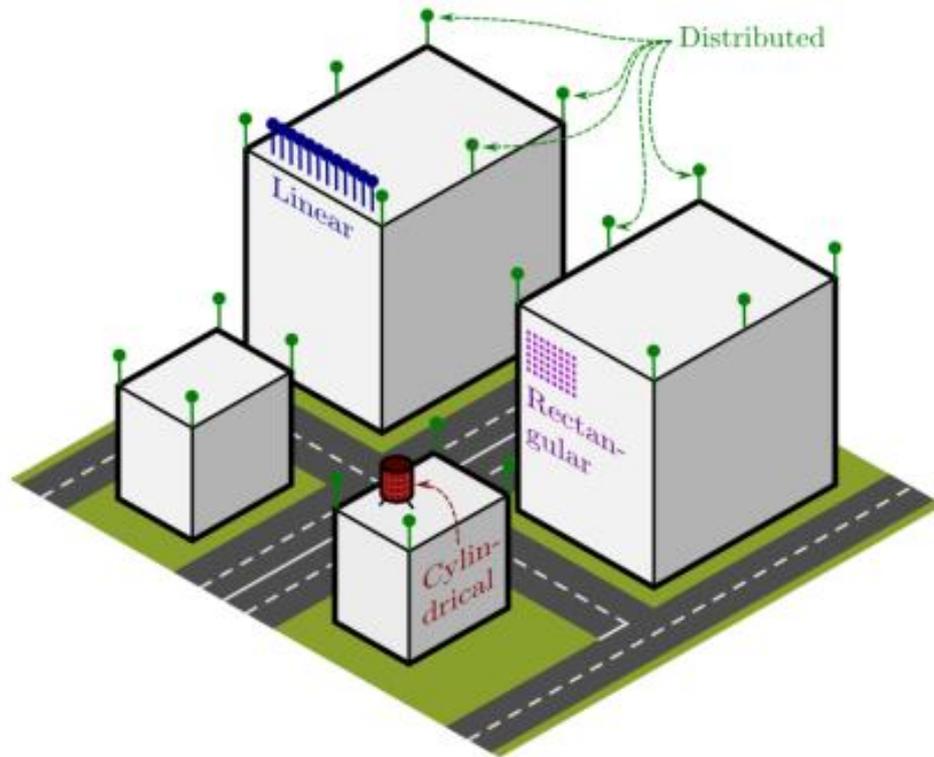
September 12th, 2016

MAMMOET – Massive MiMO for Efficient
Transmission

Key idea: exploit the unique multipath signatures constructively



Massive MIMO: the set-up

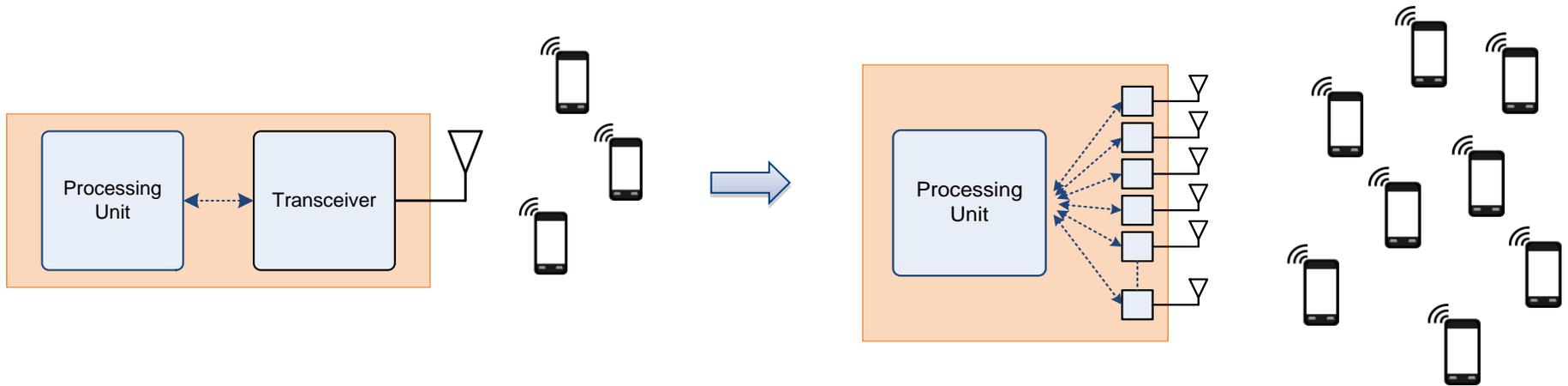


Massive BS arrays
with orders of magnitude
more antenna elements

**Simple single-antenna
terminals**

Massive MIMO boosts spectral efficiency

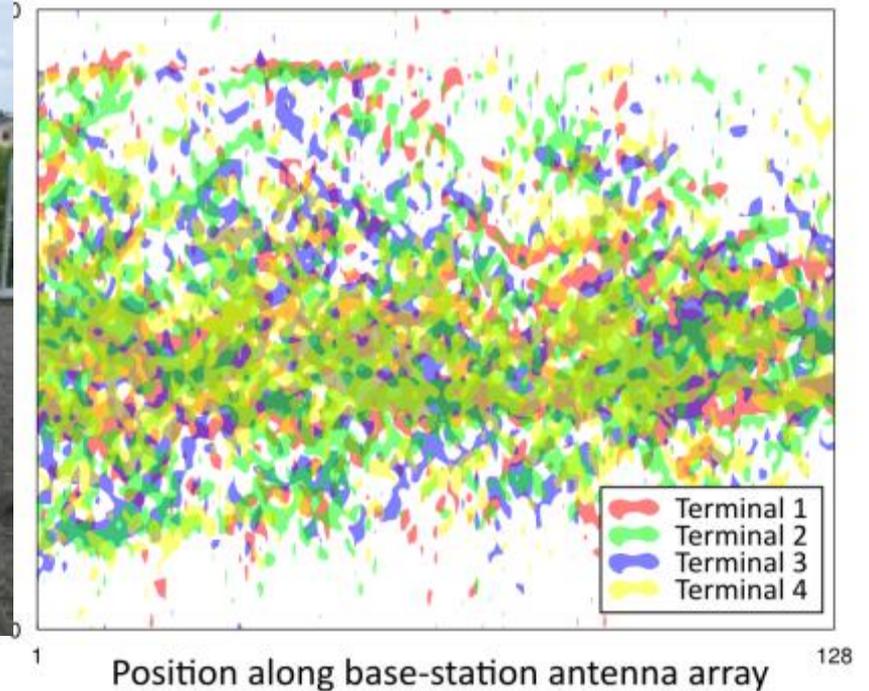
- MU-MIMO with more antennas and users
- All users benefit from the whole bandwidth simultaneously



Spatial finger prints distinguished



SPATIAL FINGER PRINTS FROM FOUR TERMINALS



- Use **hundred(s)** of base-station antennas
- Serve **ten(s)** of terminals simultaneously

A 2-minute movie to illustrate the concept

Massive MIMO: Precise "beamforming" to terminals

IMPROVEMENTS

ENERGY EFFICIENCY
by transmitting only in directions where signals actually reach intended terminal.

SPECTRAL EFFICIENCY
by transmitting to many terminals simultaneously, since interference is low.

ic1 Ove Edfors, 2015

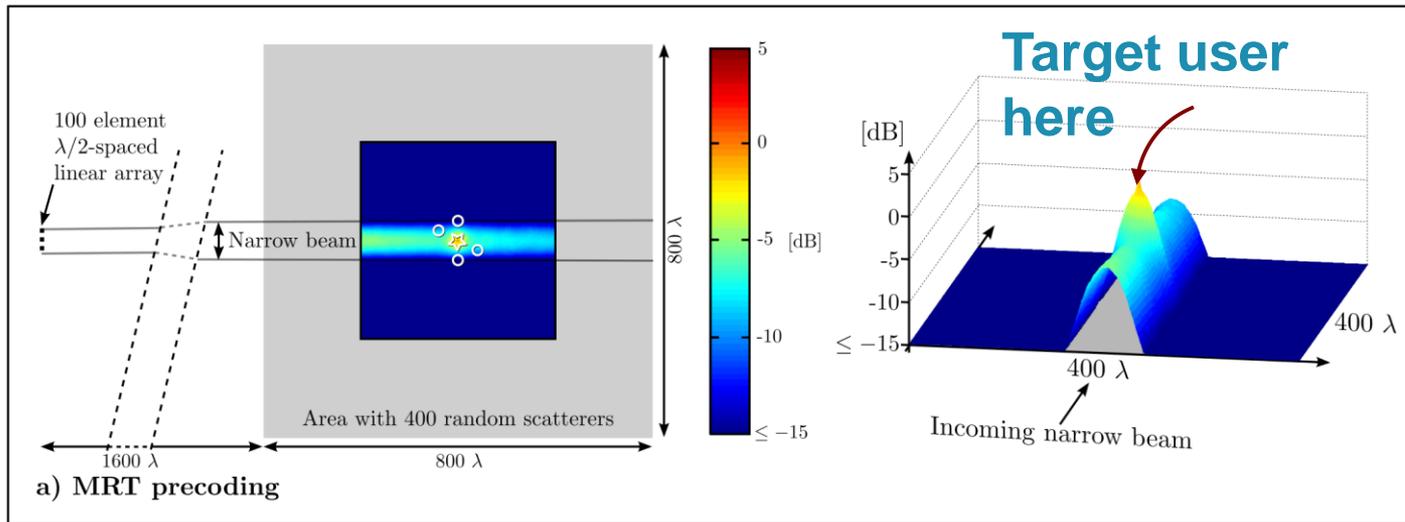
September 12th, 2016 MAMMOET – Massive MIMO for Efficient Transmission 17



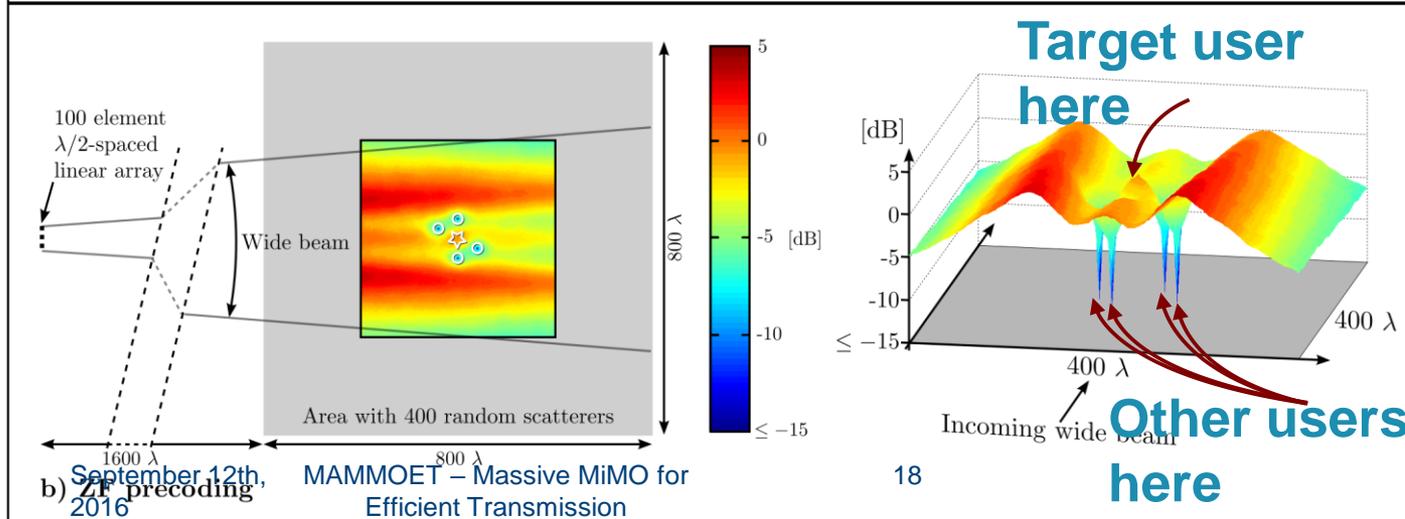
LUND
UNIVERSITY

KU LEUVEN

Result: Focusing of the energy



Field strength concentrated in TWO spatial dimensions: Angle and depth!



EU FP7 MAMMOET project (2014-2016)



MAMMOET = MASSive MiMO for Efficient Transmission

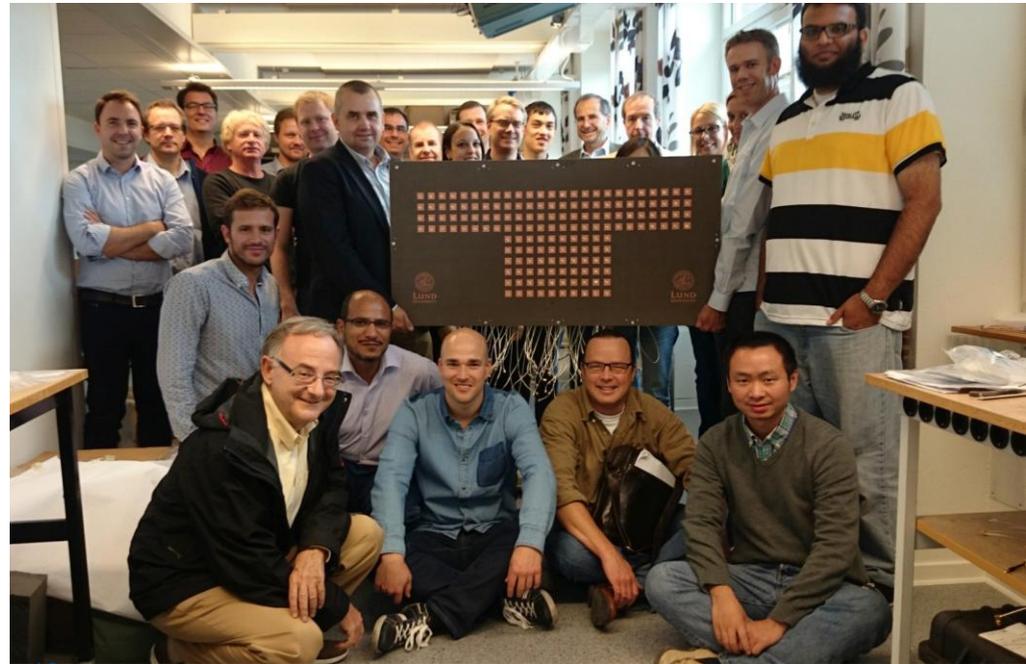
Mission: Enable mobile and ubiquitous access to gigabytes of information with significantly improved energy efficiency and reduced emitted RF-power by progressing Massive MIMO technology

Partners:

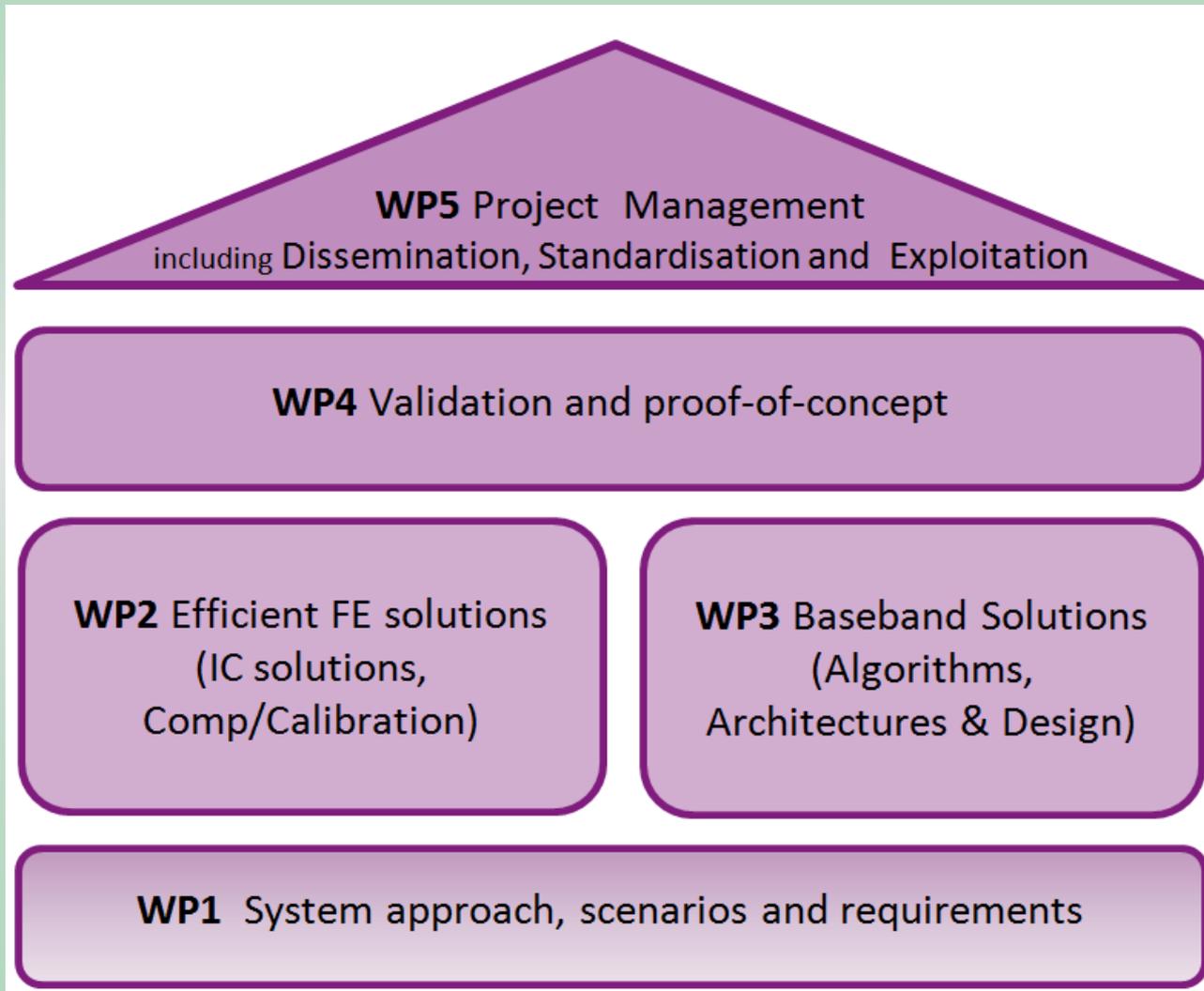
Infineon, Ericsson,
Telefonica, Technikon
Lund Univ., Linköping Univ.,
imec, KU Leuven

Scientific Advisory Board:

Tom Marzetta (Bell Labs),
Jan Rabaey (Berkeley),
Piet Demeester (UGent)



MAMMOET Work plan



MAMMOET Grant Agreement No. 619086

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