MAMMOET - Massive MIMO for Efficient Transmission

Newsletter

June 2016 - Issue 4

Overall progress, results and ongoing activities

During the course of the MAMMOET project, the confidence level has been raised significantly that MaMi operating with **low complexity hardware (HW)** can provide the required performance. Indeed, an obvious concern in MaMi is how the large number of antennas (and the associated transceivers and signal processing) will impact the complexity and energy consumption of the base station especially. In-depth analysis in the past year of the project confirms the spectacular promise: it is anticipated that the **overall complexity** and **energy consumption** in terms of J/bit can be **lowered by a factor** of **20 to 50** with respect to current base stations. This stunning improvement results from the fact that on the one hand, much less transmitted power is needed thanks to the coherent transceiver operation and on the other hand relatively low complexity HW can suffice. The consortium has actively disseminated these gains to the research community, for example with the article "Massive MIMO: Ten Myths and One Critical Question". During the second project year the MAMMOET team worked carefully on the following public deliverables:

D1.2 - MaMi Channel Characteristics: Measurement Results

This deliverable presents channel measurement results for the scenarios **Open exhibition** and **Crowded auditorium**. The measurement procedure and equipment are described. Massive MIMO (MaMi) channel characteristics and key parameters are extracted and used in an extended COST 2100 channel model for MaMi. The initial validation performed shows that the **model is capable** of reproducing the statistics in terms of temporal behavior of the **user separability**, **singular value spread**, **capacity** and **sum-rate** and **directional characteristics**. The model can be used for system and link level MaMi simulations.

D2.4 - Analysis of non-reciprocity impact and possible solutions

This deliverable reports on the impact study of **non-reciprocal transceivers** on the channel state acquisition, and consequently the performance of MaMi systems. Two possible mitigation approaches are introduced, which may both be adequate depending on the system set-up.

D2.5 - Description of MaMi digital modulation and architectures for efficient MaMi transmission

This deliverable describes the **digital modulator architectures**. It also presents the motivation behind time based signal processing in tandem with digital modulators and a digital modulator implementation, that is based on the needs of a transmitter for MaMi (power efficient and low-cost).

D3.2 - Distributed and centralized baseband processing algorithms, architectures, and platforms

Baseband processing and the corresponding **processing distribution** for MaMi systems are discussed. **Digital signal processing algorithms** are discussed in the context of practical deployment scenarios and in conjunction with hardware architecture, implementation cost, and power consumption.

Message from the Coordinator

The FP7 project MAMMOET is currently in its final project year. The project is progressing well to demonstrate that MaMi, operating in the **below 6 GHz spectrum**, represents a great **5G technology** without the need of new large spectral resources and with inexpensive HW. In the second year of the project, major technical progress has been made beyond the theoretical capabilities of MaMi. All in all, **15 deliverables** have been submitted and **4 milestones** have been reached so far. The 2nd Review Meeting was very successful and the project has fully achieved its objectives and technical goals for the period. According to the reviewers, MAMMOET is an **excellently "up-to-date" project** with a top level consortium. In May 2016 all partners met for a technical meeting in Stockholm/Sweden where the final upcoming partner contributions were discussed among other issues. Importantly, main industrial players have recognized the value, maybe even necessity, of **MaMi technology for 5G**. The industrial partners in the project have cooperated intensely on supporting the technology on the standardization agenda, at first in **3GPP** context. We provide a specific update on standardisation in this newsletter. Furthermore the partners prepare for several events such as the **MAMMOET workshop at ESSCIRC** in September 2016. For a more detailed project overview, please visit our project website: www.mammoet-project.eu.

Outlook for the third project year

During the first and second year of MAMMOET, good progress was made and thus a strong and solid basis for the last period could be created.

WP1 – System approach, scenarios and requirements: WP1 formally ended in M18.

WP2 – Efficient FE Solutions: The main goal is to measure and characterize the **designed test chips**. Based on the measurement results a case would be made for these architectures for integration in the **MAMMOET concept**.

WP3 – Baseband Solutions: The third period will focus on consolidating and refining recommendations for **HW-aware baseband processing**. With a fully functional **LuMaMi testbed**, we also increase our capacity to perform investigations in **real propagation environments**.

WP4 – Validation and proof-of-concept: The channel models coming from the measurements in WP1 will be connected to the simulator of WP4. Innovation from WP3 at the algorithmic level will also be integrated where needed. **Final tests of MaMi scenarios** will be run on the testbed and concluded, providing **real-life validation** of the MaMi concept. Designed hardware components (power-efficient modulator from WP2) will be measured and reported.

WP5 – Project Management including Dissemination, Standardisation and Exploitation: WP5 will further foster good **cooperation between the consortium members and the EC** and continue with dissemination, exploitation and standardization activities.

Start Date: 1 January 2014
End Date: 31 December 2016
Duration: 36 months
Project Reference: 619086
Project Costs: € 4.384.904
Project Funding: € 3.047.000

Consortium: 8 partners (4 countries)

Project Coordinator: Dr. Klaus-Michael Koch
coordination@mammoet-project.eu

Technical Leader: Dr. Franz Dielacher
franz.dielacher@infineon.com

Scientific Leader: Dr. Liesbet van der Perre
Liesbet.VanderPerre@esat.kuleuven.be

Project Website: www.mammoet-project.eu

https://twitter.com/FP7_MAMMOET

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MAMMOET standardisation activities

Status of 5G standardization

3GPP has started the Study Item (SI) on a new RAT (currently called "NR", for "New Radio"), whose official name and acronym have not yet been decided (but most likely NR will be the de-facto name). The new SI will develop new Technical Reports (TRs) from all Working Groups (TR 38.8XX), and one from the plenary (TR38.9XX):

- RAN 1: TR for Study on New Radio Access Technology Physical Layer Aspects
- RAN 2: TR for Study on New Radio Access Technology Radio Interface Protocol Aspects
- RAN 3: TR for Study on New Radio Access Technology: Radio Access Architecture and Interface
- RAN 4: TR for Study on New Radio Access Technology: RF and co-existence aspects
- RAN Plenary: TR for Study on New Radio Access Technology

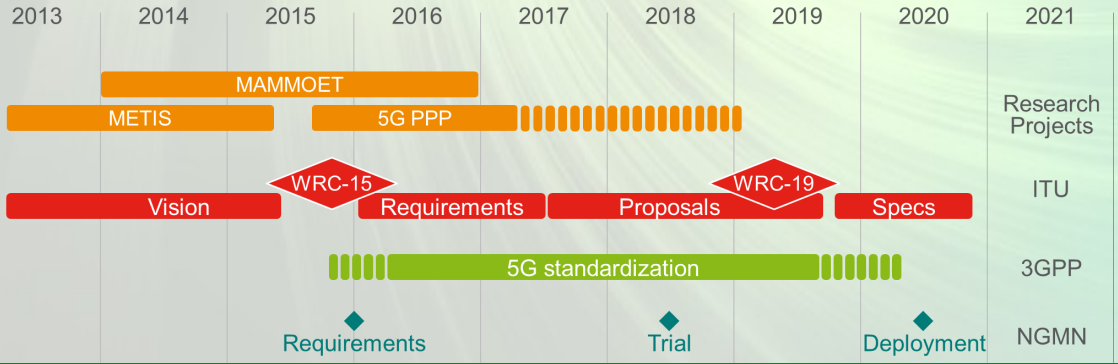
Currently the plan is to end these SIs by June, 2017.
3GPP will submit to IMT 2020 (the official name for 5G) the following two technologies:

- The currently under study NR
- Next years' evolution of "LTE-Advanced Pro" (official name of the evolution of LTE-Advanced including the features of current Release 13)

It is for later discussion whether there will be a single or two Radio Interface Technologies (RITs) as formal submissions to the ITU, as well as the evaluation process organization. The first SIs for RAN on NR have been approved for Release 14, in which only Technical Reports will be delivered. The normative work will really begin on Release 15, officially the first "5G Release". One of the most important topics already ongoing in the RAN group is the definition of the scenarios and requirements for Next Generation Access Technology. The associated Technical Report is TR 38.913, which will be part of Release 14. Such work is planned to be completed by June 2016, and is being built upon the 3GPP SMARTER study that led to TR 22.891 "Feasibility Study on New Services and Markets Technology Enabler (Stage 1, Rel-14)". As part of the RAN 1 Technology Study, a fundamental agreement has been reached on waveforms, multiple access, and channel coding. The baseline agreement for the waveform is to start with an OFDM numerology that scales with carrier frequency, where the subcarrier width follows the rule N x 15 kHz, in which N is a power-of-two integer ($N = 2^n$). This scaling enable wider subcarriers at higher frequencies, and hence shorter OFDM symbol lengths and higher robustness against phase noise. One of the most controversial points, actually to be agreed in the June 2016 RAN plenary, is the proposal to "speed up" the standardization process so as to fulfil the requirements of some operators (mostly Asian and North-American based). The proposal is to deliver a first, limited version of 5G by end of 2017, focused on enhanced Mobile Broadband with non-standalone operation (where 5G base stations are anchored by LTE base stations, and making use of current 4G core network). Having this preliminary version under 3GPP avoids the risk of some operators releasing their own "flavors" of 5G that could compromise interoperability in the long term.

Status of Release-14 Full-Dimension MIMO (FD-MIMO) in LTE

FD-MIMO is the official name given by 3GPP to utilizing massive antenna arrays for throughput enhancements in LTE. The approach however is not reciprocity-based as in MAMMOET: it rather extends the codebook-based approach of previous MIMO works towards three dimensions, with the subsequent limitations. In Release 14 however it was agreed that channel state information (CSI) reporting could be selected between codebook based approach and non-codebook, with uplink physical channel enhancements (also known as analog feedback). The latter would be more robust to realistic deployments, as well as follow more closely the reciprocity-based scheme considered in MAMMOET. We can therefore acknowledge the interest in the industry towards more accurate acquisition of CSI at the base station, hence closer to MAMMOET approach. These works will pave the way towards full usage of MaMi potential in 5G.
The figure below provides the new radio technology standardization timeline with a 2021 forecast. The World Radio Congress may not decide until as late as 2019 how to allocate spectrum above 6 GHz for 5G services. The timing of MAMMOET, leveraging on METIS, is also shown.



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MAMMOET present at past events

- The Twelfth International Symposium on Wireless Communication Systems (ISWCS), 25-28th August 2015, Brussels/Belgium
  E.G. Larsson and H.V. Cheng (LIU) gave a talk and presented a paper
- EUSIPCO Conference, 4th September 2015, Nice/France
  A. Pitarokoilis (LIU) presented a paper
- European Microwave Week (EuMIC), 6-11th September 2015, Paris/France
  Partner IFAT organized a workshop "RF Technologies on the Move"
- IEEE 802 Wireless Interim Meeting, 11-18th September 2015, Bangkok/Thailand
  Partner imec participated in this meeting
- International Wireless Industry Consortium, 15-17th September 2015, Warsaw/Russia
  Partner imec participated in the workshop "Radio Access Networks - Active Antenna Evolution"
- International Conference on Microelectronics, Devices and Materials (MIDEM), 23rd-25th September 2015, Bled/Slovenia
  Partner IFAT gave a presentation on Massive MIMO & mm-wave frequencies for 5G wireless
- RAN 5G Radio Access Networks workshop, 17-18th September 2015, Phoenix/USA
  Partner TID participated in this meeting
- 7th International Conference on Wireless Communications and Signal Processing (WCSP), 15th October 2016, Nanjing/China
  E.G. Larsson (LIU) gave a keynote talk on Massive MIMO: Myths and Realities
- ICT 2015 Innovate, Connect, Transform, 20th-22nd October 2015, Lisbon/Portugal
  MAMMOET was represented at the ICT 2015
- Global Communications Conference, 6-10th December 2015, San Diego/USA
  E.G. Larsson (LIU) gave a keynote on "Massive MIMO: the road ahead". E. Björnson (LIU) presented several papers.
- Workshop 5G for Cyber Physical Systems, 9th December 2015, Vienna/Austria
  MAMMOET partners participated in this workshop
- IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP 2016), 20-25th March 2016, Shanghai/China
  T. Marzetta (MAMMOET scientific advisor) and E. G. Larsson (LiU) gave a tutorial on Fundamentals of Massive MIMO
- 20th International ITG Workshop on Smart Antennas, 9-11th March 2016, Munich/Germany
  MAMMOET partners participated in this conference
- IEEE International symposium on circuits and systems (ISCAS 2016), 22nd-25th May 2016, Montreal/Canada
  MAMMOET partners participated in this conference
- IEEE International Conference on Communications (ICC 2016), 23rd-27th May 2016, Lumpur/Malaysia
  MAMMOET partners participated in this conference

Upcoming Meetings & Events

- European Conference on Networks and Communications (EuCNC 2016), 27-30th June 2016, Athens/Greece
  MAMMOET partners will participate in this conference
- ESSCIRC - ESSDERC 2016, 12-15th September 2016, Lausanne/Switzerland
  Partners organized a MAMMOET workshop
- European Microwave Week 2016, 3rd-7th October 2016, London/UK
  Partners will participate in this event
- Global Communications Conference, 4-8th December 2016, Washington D.C.
  Partners will organize a tutorial on Massive MIMO.

MAMMOET publications

- Uplink Pilot and Data Power Control for Single Cell Massive MIMO Systems with MRC
  H. V. Cheng, E. Björnson, E. G. Larsson
- Distributed Massive MIMO in Cellular Networks: Impact of Imperfect Hardware and Number of Oscillators
  E. Björnson, M. Matthaiou, A. Pitarokoilis, E. G. Larsson
- Mitigating pilot contamination by pilot reuse and power control schemes for massive MIMO systems
  V. Saxena, G. Fodor, E. Karipidis
- Massive MIMO at Night: On the Operation of Massive MIMO in Low Traffic scenarios
  H. V. Cheng, D. Persson, E. Björnson, E. G. Larsson
- On the Sum-Capacity of the Continuous-Time Constant-Envelope MIMO Broadcast Channel
  C. Mollén, E. G. Larsson
- Multi-switch for antenna selection in massive MIMO
  X. Gao, O. Edfors, F. Tufvesson, E. G. Larsson
- Massive MIMO in Real Propagation Environments: Do All Antennas Contribute Equally?
  X. Gao, O. Edfors, F. Tufvesson, E. G. Larsson
- A Multi-cell MMSE Detector for Massive MIMO Systems and New Large System Analysis
  X. Li, E. Björnson, E. G. Larsson, S. Zhou, J. Wang
- A Multi-cell MMSE Precoder for Massive MIMO Systems and New Large System Analysis
  X. Li, E. Björnson, E. G. Larsson, S. Zhou, J. Wang
- Three Practical Aspects of Massive MIMO: Intermittent User Activity, Pilot Synchronism, and Asymmetric Deployment
  E. Björnson, E. G. Larsson
- Multi-Standard Wideband OFDM RF-PWM Transmitter in 40nm CMOS
  S. Kulkarni, I. Kazi, D. Seebacher, P. Singerl, F. Dielacher, W. Dehaene, P. Reynaert
- Massive MIMO: Ten Myths and One Critical Question
  E. Björnson, E. G. Larsson, T. L. Marzetta
- Validation of low-accuracy quantization in massive MIMO and constellation EVM analysis
  C. Desset, L. Van der Perre

Contact:

MAMMOET Project Coordination Team
Dr. Klaus-Michael Koch
Technikon Forschungs – und Planungsgesellschaft mbH
Burgplatz 3a, A-9500 Villach
Tel.: +43 4242 23355 - 71
Fax.: +43 4242 23355 - 77
E-Mail: coordination@mammoet-project.eu
Website: www.mammoet-project.eu