MAMMOET - Massive MIMO for Efficient Transmission

Newsletter

May 2015 - Issue 3

Message from the Coordinator

The first project year of the MAMMOET project already passed and was very successful. The progress made towards the overall goals is excellent so far: Based on the exploration of fundamental limits, a capacity gain of a factor of 50 is in sight. First assessment is reassuring on the assumption that relatively simple solutions can suffice for the transceiver hardware. All work packages initiated work and produced altogether five Deliverables (including this first Periodic Report) and two Milestones throughout the first project year. As validation is considered critical to raise the confidence level in the innovative massive MIMO technology, WP4 - "Validation and proof-of-concept" has started ahead of schedule. First experiments have been running already, both in the simulation framework as in the real-life testbed. At the beginning, major effort was put into the successful launch of the project and specifying the relevant application scenarios. The major goal was to establish a sound basis for a good and fruitful cooperation of the project partners towards the research objectives. We succeeded in realizing a quite exceptional output given the early stage of the project, demonstrating the relevance of the technology and expertise in the consortium! The progress achieved by all work packages within the first project year is in line with the initial plan. For a more detailed overview of upcoming meetings, conferences, deliverables and other dissemination material, please visit our project website: www.mammoet-project.eu.

Results of the first project year

WP1 - System approach, scenarios and requirements

The work in WP1 during the first year has set the scene for the project. The entire consortium has been involved in the definition of a minimum set of diverse and challenging 5G mobile broadband scenarios that are mostly relevant to massive MIMO. Moreover, the baseline scenarios for performance comparisons have been identified. The main operation of massive MIMO has been outlined focusing on physical layer technical functionality. The uplink and downlink signalling have been defined in a TDD-based transmission protocol and pilot-based channel estimation in the uplink has been described. The average spectral efficiencies achieved in such a system with a diverse selection of linear precoding/combining schemes have been derived. In order to be able to properly evaluate massive MIMO solutions in other WPs, the power consumption has been modelled corresponding to the achievable throughput at different system levels (per user, cell, and area). The spectral efficiencies achieved by massive MIMO in a variety of different setups have been analysed mathematically and illustrated numerically. A finite-size and asymptotic analysis has been performed first and has then been complemented by simulation results of optimized performance evaluations. The results of scaling behaviours and practical trade-offs provide fundamental limits of the massive MIMO performance and the conclusions yield a valuable first insight that will be used to steer the MAMMOET research on algorithm development around the topics of channel estimation, pilot allocation, and phase-coherent precoding/combining. Finally, channel measurements have been performed for massive MIMO with special emphasis on the crowd scenario, which is considered as one of the most challenging scenarios for today's cellular networks. Also, measurements for outdoor urban massive MIMO measurements have been characterized and work has started on an extension of the well-established COST 2100 channel model for massive MIMO scenarios.

WP2 - Efficient FE Solutions

Building the many transceiver front-ends at low cost and power is key towards an attractive deployment of Massive MIMO technology. The main focus in WP2 within the first project year was to develop a reconfigurable transmitter architecture. The transmitter for the first prototype test chip is a digital transmitter that allows an easy reconfiguration. Keeping in view the increasing speed of modern CMOS technologies, time-domain signal processing has been chosen instead of encoding information in voltage or current levels. After architecture design, the actual implementation at circuit level for the first prototype started. Also simulations have been performed on conventional I/Q, polar and digital baseband and RF – PWM concepts. Furthermore, models have been created for channel non-reciprocity impairments in order to simulate their impact on performance of MaMi systems.

WP3 - Baseband Solutions

We aim to achieve anticipated superior capacity in Massive MIMO at a drastically reduced total energy consumption. in this view, appropriate digital baseband solutions need to be conceived trading off carefully performance and complexity. The choice between single- and multi-carrier massive MIMO has been studied. There are no major differences in performance or implementation complexity. In particular, it has been identified to what extent the averaging of noise and uncorrelated distortions from hardware impairments over the different antennas allow for relaxed design constraints. The quality constraints of each individual antenna branch can be greatly relaxed. Linear and non-linear precoding techniques have been developed and studied.

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)

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The non-linear precoding is aimed at bringing lower power variations on individual antennas relaxing power amplifier requirements. The algorithmic complexity is in the same range as with linear precoding, but the implementation complexity will be studied in more detail for final conclusions. An overview of different hardware platforms for massive MIMO baseband processing has been compiled. A critical part of realizing massive MIMO is related to reducing the amount of data that needs to be exchanged between different processing nodes when using distributed processing.

WP4 - Validation and proof-of-concept

As overall validation work package, WP4 needs to be connected to WP1 where scenario definition takes place, in order to ensure the possibility to validate at least some of the selected scenarios in WP4. This was considered for both simulator-based and test-bed-based validation. For the simulation-based validation, the high-level structure of the simulation framework was created and discussed within the consortium, in order to clarify both the usage of the simulator and the possibilities for contributions on specific components. A number of elements have been aligned within the consortium, such as the frame structure (uplink/downlink switches), channel models (time-varying options, integration of measurements) or inclusion of specific extensions (constant-envelope precoding, digital modulator, multi-antenna terminals). The actual development of the simulator has started for ideal scenarios. For the test-bed-based validation, the assembly of the LuMaMi test-bed has been completed, including selection of components, mechanical design and assembly. This has enabled first real-environment tests, that have shown a successful proof of concept. Scenario parameters were harmonized between the physical test-bed and the simulation-based framework.

WP5 - Project management including Dissemination, Standardisation and Exploitation

WP5 consists of two parts. The project management part was responsible for the effective organization of the project and covered all relevant management components. Some of the main achievements so far have been: the organization of meetings (e.g. Kick-Off and GA Meeting), the implementation of monthly EB Telcos, monitoring of work plan (Interim Management Reporting), supporting partners in everyday issues (handling day2day requests), etc. For the Dissemination, Standardisation and Exploitation part, a robust IT infrastructure (web site, SVN repository including web access, mailing lists including mailing list archives) was established and regularly updated since. MAMMOET has also been advertised by web pages and press releases. Hardcopies of the MAMMOET project flyers have been distributed by partners at various events. The project is also visible on Twitter and LinkedIn. Dissemination activities are announced via http://www.mammoet-project.eu/news. In terms of dissemination management, to ease communication on publications, a mailing list for publication proposals has been established. A great number of published papers, presentations, and workshops originated from MAMMOET already in the first project year. A list of dissemination activities has been compiled and updated periodically.

The following public deliverables have been developed during the first MAMMOET project year and are available on our official project website:
http://mammoet-project.eu/publications-deliverables

D1.1 - System scenarios and requirements specifications

Key 5G mobile broadband scenarios, for which massive MIMO is mostly relevant, are described. The envisioned operation of a massive MIMO system is outlined, focusing on PHY technical functionality. The total BS power consumption is modelled, the main performance metrics of spectral and energy efficiency are elaborated and several tradeoffs are discussed.

D3.1 - First assessment of baseband processing requirements for MaMi systems

Base-band processing requirements for massive MIMO systems are discussed and outlined. Alternative transmission and reception strategies for massive MIMO are discussed in conjunction with associated processing requirements and hardware platform/implementation options.

D5.1 - Project quality plan and internal IT communication infrastructure including project website

This deliverable briefly describes the website and its functionality. Further it describes the tools provided within the IT infrastructure to facilitate cooperation and coordination.

Massive MIMO Info Point

The first European wide technology platform was developed by the MAMMOET consortium and is available on the following link: http://massivemimo.eu/.
On this website we provide lists of research papers in the emerging area of very large MIMO systems.

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MAMMOET present at past events

- Mobile Heights Center opening, 21st October 2014, Lund/Sweden
  Ove Edfors gave a talk on Mobile communications going massive
- Asilomar Conference on Signals, Systems and Computers, 23rd-26th November 2014, Monterey/California
  E. G. Larsson organized a special session on massive MIMO and O. Edfors gave a talk in this session: Large Antenna Array and Propagation Environment Interaction
- IEEE International Workshop on Computer Adided Modeling and Design of Commincations Links and Networkds (CAMAD), 1st December 2014, Athens/Greece
  E. Björnson gave a keynote speech
- Wireless communication going massive, 1st December 2014, Leuven/Belgium
  O. Edfors gave a seminar on the Massive MIMO concept and testbed
- 2nd IEEE Global Conference on Signal and Information Processing, 3rd-5th December 2014, Atlanta/USA
  MAMMOET partners co-organized the symposia on Massive MIMO on the GlobalSIP conference
- IEEE Global Communication Conference (Globecom), 8th-12th December 2014, Austin Texas/USA
  MAMMOET members co-organized a workshop on Massive MIMO: From theory to practice (MassMIMO)
- Annual Swedish Workshop on Wireless Systems, 15th December 2014, Gothenburg/Sweden
  O. Edfors, E. Björnson and E. G. Larsson gave talks on Mobile communications going massive
- IEEE Radio & Wireless Week (RWW), 25th-28th January 2015, San Diego/USA
  IFAT participated to learn more about innovations that are happening across the broad wireless spectrum and dedicated 5G workshop
- International Solid-State Circuits Conference (ISSCC), 24th February 2015, San Francisco/USA
  F. Tufvesson presented the lessons learned from the test bed implementation: "More Bits via the Same Spectrum - Massive MIMO Opportunities"

MAMMOET publications

- Optimizing Multi-Cell Massive MIMO for Spectral Efficiency: How Many Users Should Be Scheduled?
  E. Björnson, E. G. Larsson, M. Debbah
- Massive MIMO with Non-Ideal Arbitrary Arrays: Hardware Scaling Laws and Circuit-Aware Design
  E. Björnson, M. Matthaiou, M. Debbah
- Massive MIMO for Maximal Spectral Efficiency: How Many Users and Pilots Should Be Allocated?
  E. Björnson, E. G. Larsson, M. Debbah
- MIMO Capacity under Power Amplifiers Consumed Power and Per-Antenna Radiated Power Constraints
  D. Persson, E. G. Larsson, H. V. Cheng
- Massive MIMO for Next Generation Wireless Systems
  E. G. Larsson, O. Edfors, F. Tufvesson, T. L. Marzetta
- On the Impact of PA-Induced In-Band Distortion in Massive MIMO
  C. Mollén, E. G. Larsson, T. Eriksson
- A low-complex peak-to-average power reduction scheme for OFDM based massive MIMO systems
  H. Prabhu, O. Edfors, J. Rodrigues, L. Liu, F. Rusek
- Hardware Efficient Approximative Matrix Inversion for Linear Pre-Coding in Massive MIMO
  H. Prabhu, O. Edfors, J. Rodrigues, L. Liu, F. Rusek
- Large antenna array and propagation environment interaction
  X. Gao, M. Zhu, F. Rusek, F. Tufvesson, O. Edfors
- A flexible 100-antenna testbed for Massive MIMO
  J. Vieira, S. Malkowsky, K. Nieman, Z. Miers, N. Kundargi, L. Liu, I. Wong, V. Öwall, O. Edfors, F. Tufvesson
- Reciprocity calibration methods for Massive MIMO based on antenna coupling
  J. Vieira, F. Rusek, F. Tufvesson
- Massive MIMO: 10 Myths and One Grand Question
  E. Björnson, E. G. Larsson, T. L. Marzetta

Upcoming Meetings & Events

- IEEE International Conference on Communications (ICC2015), 8th-12th June 2015, London/UK
  MAMMOET partners are organizing two tutorials
- IEEE International Workshop on Signal Processing Advances in Wireless Communications (SPAWC), 28th June - 1st July 2015, Stockholm/Sweden
  E. G. Larsson and E. Björnson will give a MaMi tutorial and intend present several papers
- European Conference on Networks and Communications (EUCNC), 29th June - 2nd July 2015, Paris/France
  MAMMOET partners will organize a workshop

Honors and Awards

- **Prof. Liesbet Van der Perre**, Scientific Leader of the MAMMOET project, received an **honorary doctorate from Lund University** in May 2015
- **Dr. Thomas Marzetta**, member of the MAMMOET international Advisory Board, received an **honorary doctorate from Linköping University** in May 2015
- **H. Ngo, E. G. Larsson and T. Marzetta** won the **2015 Stephen O. Rice Prize Paper Award** in the Field of Communications Systems for their paper "Energy and Spectral Efficiency of Very Large Multiuser MIMO Systems", IEEE Transactions on Communications, Vol. 61, No. 4, April 2013, pp. 1436-1449

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