This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 619086.

D5.5

Updated plan and initial report on dissemination, standardization and exploitation

Project number:	619086
Project acronym:	MAMMOET
Project title:	MAMMOET: Massive MIMO for Efficient Transmission
Start date of the project:	1st January, 2014
Duration:	36 months
Programme:	FP7/2007-2013

Deliverable type:	Report
Deliverable reference number:	ICT-619086 / D5.5/ 1.0
Work package contributing to the deliverable:	WP5
Due date:	December 2015 – M24
Actual submission date:	18th January, 2016

Responsible organisation:	IFAT
Editor:	Franz Dielacher
Dissemination level:	PU
Revision:	1.0

Abstract:	This deliverable reports on the progress and future plans of the project partners for their dissemination activities, standardization and exploitation of project results.
Keywords:	Dissemination, Standardization, Exploitation, Innovation Management

Editor

Franz Dielacher, Diana V. Pop (IFAT)
Liesbet Van der Perre (KU Leuven)
Marion Buchacher, Martina Truskaller (TEC)

Contributors (ordered according to beneficiary numbers)

TEC	Technikon Forschungs- und Planungsgesellschaft mbH
Imec	Interuniversitair Micro-Electronica Centrum vzw
EAB	Ericsson AB
IFAT	Infineon Technologies Austria AG
KU Leuven	Katholieke Universiteit Leuven
ULUND	Lunds Universitet
LIU	Linköpings Universitet
TID	Telefonica Investigacion Y Desarrollo SA

Disclaimer

The research leading to these results has received funding from the European Union's Seventh Framework Programme (FP7/2007-2013) under grant agreement n° ICT-619086 (MAMMOET).

Executive Summary

This deliverable is a report describing the dissemination, standardization and exploitation activities of the consortium during the first and second project years. Furthermore, it provides a refinement of the initial plans from the project proposal stage.
The consortium is composed of strong academic and industrial partners, involved in different roles in the organization of scientific and industrial events. The impact of the project in the international scientific community working in broadband wireless in the broad sense and massive MIMO specifically, is proven by a large number of publications included in the most important journals (for example IEEE Transactions on Communications), as well as in the most important conferences of the area (specifically the IEEE communication society flag ship conferences Globecom and ICC and European events like ESSCIRC and EUCNC). Moreover, industrial partners have participated in/organized a large number of events aiming to attract interested people and to raise the public awareness of the project results.
The deliverable documents:

- Scientific publications on high-quality, international conferences and scientific events in order to provide scientific visibility
- The standardization efforts of the MAMMOET consortium
- An update overview of the project partners' plan on exploitation

To further raise the level of public awareness of the project within the scientific and industrial communities, a diversity of dissemination activities have been impelled, including a project website with blog, social media presence and presentations to well know international conferences and events.
To summarize the achievements and work towards the project goals of the first two project years for dissemination and standardisation we include: 25 presentations in conferences or organized events (workshops, winter/summer schools) with an international audience and very good feedback, 15 invited papers and 54 other events participation e.g. ICC, ISWC, EUSIPCO or ESSCIRC. The MAMMOET members took initiatives to spread MASSIVE MIMO expertise and status of the technology in the broad sense. This was achieved a.o. through the (co-) organization of 4 workshops and several tutorials on Massive MIMO in the frame of international conferences.

Contents

List of Figures

List of Tables

Chapter 1 Introduction

This deliverable presents the dissemination, standardization and exploitation activities of the MAMMOET consortium during the first and second project year. Besides the reported activities it is also a refinement of the plans from the project proposal stage.
WP5 – “Project Management including Dissemination, Standardization and Exploitation” is divided into four tasks. Task 5.1 "Administration, self-assessment and risk management", Task 5.2 "Dissemination", Task 5.3 Standardisation" and Task 5.4 "Intellectual Property Rights, Exploitation and Innovation management".
Chapter 2 describes all activities and plans related to dissemination of project results, Chapter 3 reports on MAMMOET standardisation activities and plans. The main standardization body that MAMMOET has been collaborating with is 3GPP (see subchapter 3.2.3).
All updated exploitation plans per partner and a subchapter on innovation management can be found in Chapter 4.

Chapter 2 Dissemination

This chapter provides a description of the MAMMOET dissemination strategy and activities that are coordinated within the WP5. Because dissemination is considered as a key enabler for the success of the MAMMMOET project and the adoption of Massive MIMO as a key technology for 5G, the consortium members recognized that all the performed activities are essential and pervasive actions that should be integrated within all work packages throughout the project's lifetime. The aim of all dissemination activities is to use research results in order to create value within all participating organizations, thus improving their competitive advantage. Moreover, it has aimed to raise the knowledge level on this new Massive MIMO technology in the scientific community at large. In order to promote the results of the MAMMOET project, several activities that will be presented in this chapter have been planned and realized:

- Display and promotion of public deliverables and news for access and download on the project website
- Presentations and tutorials in international conferences and workshops introducing the findings of the MAMMOET project
- High-quality papers have been submitted and published in scientific and industry conferences and journals

2.1 Dissemination strategy

The dissemination strategy describes the project's dissemination measures for the project lifecycle. It presents the key objectives, identifies the main stakeholders and how the consortium reached them. The key objectives of the dissemination strategy were to make known as widely as possible the findings and recommendations of MAMMOET specifically and Massive MIMO generally; to facilitate and enable close cooperation between different categories of stakeholders, and to strengthen the research and knowledge base of both researcher and end user. The dissemination strategy of MAMMOET consists essentially of two consecutive phases:

- The **awareness-oriented phase** which aims to create awareness and to rise public interest
- The **result-oriented phase** which involves collaboration among relevant parties to further research and promote results of the project to potentially interested parties.

Raising the public awareness involves the setting up of the basic marketing materials and awareness –raising presentations about the project and the problems it aims to tackle. The main activities of the MAMMOET consortium in this direction focused on setting up a common project design, including logo, templates, presence on social networks, leaflet, newsletters, etc. (see subchapter 2.3).

2.2 Dissemination activities in M01-M24

The MAMMOET project and its results have been disseminated by means of giving invited talks at conferences, by publications at national and international conferences (such as ISSCC, ESSCIRC, ICC, Globecom, EUCNC etc.) and by organizing technical workshops within the project. One major achievement in the MAMMOET dissemination work was the publication and distribution of the article "Resurrection of 5G – In defence of Massive MIMO" at IEEE ComSoc Technology News. Within this article the capabilities of MaMi are clarified and following the article "Dead of 5G", we got the opportunity to position the resurrection enabled by Massive MIMO: http://www.comsoc.org/ctn/resurrection-5g-defense-massive-mimo?utm_source=Real%20Magnet&utm_medium=Email&utm_campaign=88153909.
Further dissemination activities follow in the next sections in order to document the extent to which we have executed our above mentioned dissemination strategy.

2.2.1 Scientific articles and publications

The following scientific publications have been published within the MAMMOET project for the **period M01-M24**. All scientific publications are listed in an action overview list available on the project web server and are updated by all partners on a regular basis. Since the beginning of the project **24 peer-reviewed publications** have been presented in national and international events.

No	Title	Main author	Title of the periodical or the series	Publisher	Place of publication	Year of publication	Permanent identifiers[1] (if available)	Is/Will open access[2] provided to this publication?
1	MIMO Capacity under Power Amplifiers Consumed Power and Per-Antenna Radiated Power Constraints	D. Persson, E. G. Larsson, H. V. Cheng	IEEE International Workshop on Signal Processing Advances in Wireless Communications (SPAWC)	IEEE	Toronto	2014	http://dx.doi.org/10.1109/SPAWC.2014.6941397	No
2	Massive MIMO for Next Generation Wireless Systems	E. G. Larsson, O. Edfors, F. Tufvesson, T. L. Marzetta	IEEE Communications Magazine	IEEE	Not applicable	2014	http://dx.doi.org/10.1109/MCOM.2014.6736761	Yes
3	Optimizing Multi-Cell Massive MIMO for Spectral Efficiency: How Many Users	E. Björnson, E. G. Larsson, M. Debbah	IEEE Global Conference on Signal and Information Processing	IEEE	Atlanta	2014	http://dx.doi.org/10.1109/GlobalSIP.2014.7032190	Yes

[1] A permanent identifier should be a persistent link to the published version full text if open access or abstract if article is pay per view or to the final manuscript accepted for publication (link to article in repository).

[2] Open Access is defined as free of charge access for anyone via Internet. Please answer “yes“ if the open access to the publication is already established and also if the embargo period for open access is not yet over but you intend to establish open access afterwards.

No	Title	Main author	Title of the periodical or the series	Publisher	Place of publication	Year of publication	Permanent identifiers[1] (if available)	Is/Will open access[2] provided to this publication?
	Should Be Scheduled?		(GlobalSIP)					
4	On the Impact of PA-Induced In-Band Distortion in Massive MIMO	C. Mollén, E. G. Larsson, T. Eriksson	European Wireless	VDE	Barcelona	2014	https://mammoet.technikon.com/InterestingMaterial-Papers-Publications/MAMMOET-publications/	Yes
5	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	International Symposium on communications, control and signal processing	IEEE	Greece	2014	http://dx.doi.org/10.1109/isccsp.2014.6877829	Yes
6	Hardware Efficient Approximative Matrix Inversion for Linear Pre-Coding in Massive MIMO	H. Prabhu, O. Edfors, J. Rodrigues, L. Liu, F. Rusek	IEEE International Symposium on Circuits and Systems (ISCAS)	IEEE	Melbourne	2014	http://dx.doi.org/10.1109/iscas.2014.6865481	Yes
7	Large antenna array and propagation environment interaction	X. Gao, M. Zhu, F. Rusek, F. Tufvesson, O. Edfors	Asilomar Conference on Signals, Systems, and Computers	IEEE	Monterey	2014	http://dx.doi.org/10.1109/ACSSC.2014.7094530	No

No	Title	Main author	Title of the periodical or the series	Publisher	Place of publication	Year of publication	Permanent identifiers[1] (if available)	Is/Will open access[2] provided to this publication?
8	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	IEEE Globecom 2014 Workshop - Massive MIMO: From Theory to Practice	IEEE	Austin	2014	http://dx.doi.org/10.1109/GLOCOMW.2014.7063446	Yes
9	Reciprocity calibration methods for Massive MIMO based on antenna coupling	J. Vieira, F. Rusek, F. Tufvesson	IEEE Globecom 2014 - Wireless Communications Symposium	IEEE	Austin	2014	http://dx.doi.org/10.1109/glocom.2014.7037384	Yes
10	Massive MIMO with Non-Ideal Arbitrary Arrays: Hardware Scaling Laws and Circuit-Aware Design	E. Björnson, M. Matthaiou, M. Debbah	IEEE Transactions on Wireless Communications	IEEE	Stockholm	2015	http://dx.doi.org/10.1109/TWC.2015.2420095	Yes
11	Massive MIMO for Maximal Spectral Efficiency: How Many Users and Pilots Should Be Allocated?	E. Björnson, E. G. Larsson, M. Debbah	IEEE Transactions on Wireless Communications	IEEE	Not Applicable	2015	http://dx.doi.org/10.1109/TWC.2015.2488634	Yes

No	Title	Main author	Title of the periodical or the series	Publisher	Place of publication	Year of publication	Permanent identifiers[1] (if available)	Is/Will open access[2] provided to this publication?
12	Mitigating pilot contamination by pilot reuse and power control schemes for massive MIMO systems	V. Saxena, G. Fodor, and E. Karipidis	IEEE Vehicular Technology Conference (VTC-Spring)	IEEE	Glasgow	2015	http://dx.doi.org/10.1109/VTCSpring.2015.7145932	No
13	Massive MIMO at Night: On the Operation of Massive MIMO in Low Traffic scenarios	H. V. Cheng, D. Persson, E. Björnson, E. G. Larsson	IEEE ICC 2015	IEEE	London	2015	http://dx.doi.org/10.1109/ICC.2015.7248569	No
14	On the Sum-Capacity of the Continuous-Time Constant-Envelope MIMO Broadcast Channel	C.r Mollén, E. G. Larsson	IEEE SPAWC 2015	IEEE	Stockholm	2015	https://mammoet.technikon.com/InterestingMaterial-Papers-Publications/MAMMOET-publications/	Yes
15	Multi-switch for antenna selection in massive MIMO	X. Gao, O. Edfors, F. Tufvesson, E. G. Larsson	IEEE Globecom 2015	IEEE	San Diego	2015	http://lup.lub.lu.se/luur/download?func=downloadFile&recordOId=7792574&fileOId=7792683	Yes

No	Title	Main author	Title of the periodical or the series	Publisher	Place of publication	Year of publication	Permanent identifiers[1] (if available)	Is/Will open access[2] provided to this publication?
16	Massive MIMO in Real Propagation Environments: Do All Antennas Contribute Equally?	X. Gao, O. Edfors, F. Tufvesson, E. G. Larsson	IEEE Transactions on Communication	IEEE	Not applicable	2015	http://dx.doi.org/10.1109/TCOMM.2015.2462350	No
17	Uplink Pilot and Data Power Control for Single Cell Massive MIMO Systems with MRC	H. V. Cheng, E. Björnson, E. G. Larsson	IEEE ISWCS 2015	IEEE	Brussels	2015	https://mammoet.technikon.com/InterestingMaterial-Papers-Publications/MAMMOET-publications/	Yes
18	Distributed Massive MIMO in Cellular Networks: Impact of Imperfect Hardware & Number of Oscillators	E. Björnson, M. Matthaiou, A. Pitarokoilis, E. G. Larsson	European Signal Processing Conference (EUSIPCO 2015)	EURASIP	Nice	2015	https://mammoet.technikon.com/InterestingMaterial-Papers-Publications/MAMMOET-publications/	Yes
19	Massive MIMO with Multi-cell MMSE Processing: Exploiting All Pilots for Interference Suppression	X. Li, E. Björnson, E. G. Larsson, S. Zhou, J. Wang	IEEE Transactions on Wireless Communications	IEEE	Not applicable		https://mammoet.technikon.com/InterestingMaterial-Papers-Publications/MAMMOET-publications/	Yes

No	Title	Main author	Title of the periodical or the series	Publisher	Place of publication	Year of publication	Permanent identifiers[1] (if available)	Is/Will open access[2] provided to this publication?
20	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	Globecom 2015	IEEE	San Diego, CA, USA	2015	https://mammoet.technikon.com/InterestingMaterial-Papers-Publications/MAMMOET-publications/	Yes
21	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	Globecom 2015	IEEE	San Diego, CA, USA	2015	https://mammoet.technikon.com/InterestingMaterial-Papers-Publications/MAMMOET-publications/	Yes
22	Three Practical Aspects of Massive MIMO: Intermittent User Activity, Pilot Synchronism, and Asymmetric Deployment	E. Björnson, E. G. Larsson	Globecom 2015	IEEE	San Diego, CA, USA	2015	https://mammoet.technikon.com/InterestingMaterial-Papers-Publications/MAMMOET-publications/	Yes
23	Multi-Standard Wideband OFDM RF-PWM Trnasmitter in 40nm CMOS	S. Kulkarni, I. Kazi, D. Seebacher, P. Singerl, F. Dielacher, W. Dehaene, P.	ESSCRIC 2015	IEEE	Graz, Austria	2015	http://dx.doi.org/10.1109/ESSCIRC.2015.7313835	No

No	Title	Main author	Title of the periodical or the series	Publisher	Place of publication	Year of publication	Permanent identifiers[1] (if available)	Is/Will open access[2] provided to this publication?
		Reynaert						
24	Massive MIMO: Ten Myths and One Critical Question	E. Björnson, E. G. Larsson, T. L. Marzetta	IEEE Communications Magazine	IEEE	Not applicable	2015	https://mammoet.technikon.com/InterestingMaterial-Papers-Publications/MAMMOET-publications/	Yes
25	Validation of low-accuracy quantization in massive MIMO and constellation EVM analysis	C. Desset, L. Van der Perre	2015 European Conference on Networks and Communications (EuCNC),	Not applicable	Paris	2015	http://dx.doi.org/10.1109/EuCNC.2015.7194033	No

Table 1: List of Publications

2.2.2 Presentations, workshops, conferences and other dissemination activities

The following table summarizes all presentations, workshops conferences and other MAMMOET dissemination activities, since the beginning of the project. In total 42 dissemination activities are described below.

No	Type of activities	Main leader	Title	Date			Place	Size of audience	Type and goal of the event	Countries addressed
				Day	Month	Year				
1	Press release	TEC, ALL Partners	MAMMOET Announcement Letter		*1*	*2014*	online	N/A	Press Release can be downloaded from MAMMOET website (coming soon)	International

No	Type of activities	Main leader	Title	Date			Place	Size of audience	Type and goal of the event	Countries addressed
				Day	Month	Year				
2	Flyer	TEC, ALL Partners	MAMMOET Leaflet		2	2014	online	N/A	Official project leaflet can be downloaded from the MAMMOET website (coming soon)	International
3	Presentation	LIU	Massive MIMO for next generation wireless systems	13	3	2014	Erlangen, Germany	100	Invited talk by Erik G. Larsson at 18th International ITG Workshop on Smart Antennas (WSA) 2014	International
4	Presentation	LIU	Future Wireless Communications: Keeping up with Exponential Traffic Growth	17	3	2014	Linköping, Sweden	100-150	Invited overview talk given by Emil Björnson at the Department of Electrical Engineering, LIU	National
5	Presentation	LIU	Fundamentals of massive MIMO	19	3	2014	Pisa, Italy	80	Lecture by Erik G. Larsson at Newcom# Spring School on Advanced Signal Processing Techniques for Heterogeneous Networks	International
6	Presentation	LIU	Massive MIMO: Bringing the Magic of Asymptotics to Wireless Networks	6	4	2014	Istanbul, Turkey	20-30	Invited overview talk given by Emil Björnson at the workshop "Wireless Evolution Beyond 2020", co-organized with the IEEE Wireless Communications and Networking Conference (WCNC)	International
7	Presentation	LIU	Massive MIMO: Bringing the Magic of Asymptotics to Wireless Networks	25	4	2014	Stockholm, Sweden	45	Invited "Wireless Friday seminar" given by Emil Björnson at KTH Royal Institute of Technology	National

No	Type of activities	Main leader	Title	Date			Place	Size of audience	Type and goal of the event	Countries addressed
				Day	Month	Year				
8	Presentation	LIU	On the Impact of PA-Induced In-Band Distortion in Massive MIMO	14-16	5	2014	Barcelona, Spain	N/A	Christopher Mollén presented a paper at the European Wireless conference	National
9	Presentation	LIU	Downlink waveform design for massive MIMO	25-28	5	2014	Piscadera Bay, Curacao	N/A	Erik G. Larsson gave an invited talk on downlink waveform design for massive MIMO	International
10	Presentation	LIU	Massive MIMO: Bringing the Magic of Asymptotics to Wireless Networks	26	5	2014	Stockholm, Sweden	N/A	Emil Björnson gave an invited seminar at KTH Royal Institute of Technology	National
11	Presentation	imec	IMEC Technology Form Brussels 2014 (ITF)	4-5	6	2014	Brussels, Belgium	N/A	ITF Brussels is imec's premier technology event, the imec Technology Forum. Each year, they gather experts and visionaries in a two-day event to discuss the future in technology. Liesbet van der Perre presented MAMMOET at the ITF.	International
12	Presentation	IFAT	NetWorld2020 Experts Workshop	23	6	2014	Bologna, Italy	N/A	Franz Dielacher gave an overview presentation about MAMMOET	International
13	Workshop	LIU	2014 IEEE Workshop on Signal Processing Systems (SiPS)	20	10	2014	Belfast, United Kingdom	N/A	Erik G. Larsson gave a keynote talk	International
14	Conference	LIU	2nd IEEE Global Conference on Signal and Information	3-5	12	2014	Atlanta, USA	N/A	MAMMOET partners attended to the symposia on massive MIMO on the GlobalSIP	International

No	Type of activities	Main leader	Title	Date			Place	Size of audience	Type and goal of the event	Countries addressed
				Day	Month	Year				
			Processing						conference. Emil Björnson presented the paper "Optimizing Multi-Cell Massive MIMO for Spectral Efficiency: How Many Users Should Be Scheduled?"	
15	Conference	IFAT, imec	European Conference on Networks and Communications	23-26	6	2014	Bologna, Italy	N/A	MAMMOET team members attended this conference	International
16	Presentation	LIU	Massive MIMO: Bringing the Magic of Asymptotics to Wireless Networks	11	7	2014	Bâtiment Weicker, Luxembourg	N/A	Emil Björnson gave an invited seminar at the University of Luxembourg	International
17	Presentation	ULUND	MIMO Goes Massive	5	8	2014	Austin, TX	~50	Ove Edfors presented the massive MIMO testbed at NI (National Instruments) Week.	International
18	Other	ULUND	Massive MIMO for 5G	20	8	2014	Dresden, Germany	N/A	Fredrik Tufvesson at 5G Revolution dinner event in conjunction with 3GPP meeting in Dresden.	International
19	Conference	ULUND	IEEE Global Communication Conference 2014	8-12	12	2014	Texas, USA	~80	Ove Edfors and Liesbet Van der Perre co-organized a workshop on Massive MIMO: From theory to practice	International
20	Conference	LIU	IEEE International Workshop on Computer Aided Modelling and Design of Communication	1	12	2014	Athens, Greece	N/A	Emil Björnson gave a keynote speech.	International

No	Type of activities	Main leader	Title	Date			Place	Size of audience	Type and goal of the event	Countries addressed
				Day	Month	Year				
			Links and Networks (CAMAD)							
21	Conference	ULUND	International Solid-State Circuits Conference (ISSCC)	24	2	2015	San Francicso, USA	N/A	Fredrik Tufvesson presents the lessons learned from the test bed implementation: "More Bits via the Same Spectrum - Massive MIMO Opportunities"	International
22	Presentation	ULUND, imec, KU Leuven	Wireless communication going massive	1	12	2014	Leuven, Belgium	35	Ove Edfors gave a seminar on the Massive MIMO concept and testbed	International
23	Workshop	ULUND	Mobile communications going massive	15	12	2014	Gothenburg, Sweden	30	Ove Edfors, Emil Björnson and Erik G. Larsson gave talk at Annual Swedish Workshop on Wireless Systems	National
24	Presentation	ULUND	Mobile communications going massive	21	10	2014	Lund, Sweden	20	Ove Edfors gave a talk at the Mobile Heights Center opening in Lund	National
25	Workshop	ULUND	LuMaMi – A flexible 100-antenna Testbed for Massive MIMO	19	11	2014	Stockholm, Sweden	~50	Ove Edfors presented the Massive MIMO testbed at the European workshop on testbed based wireless research in Stockholm	International
26	Conference	ULUND	A low-complex peak-to-average power reduction scheme for OFDM based massive MIMO systems	21	5	2014	Athens, Greece	~30	Hemanth Prabhu presented a new precoding scheme at the IEEE International Symposium on communications, control and signal processing	International

No	Type of activities	Main leader	Title	Date			Place	Size of audience	Type and goal of the event	Countries addressed
				Day	Month	Year				
27	Conference	ULUND	Hardware Efficient Approximative Matrix Inversion for Linear Pre-Coding in Massive MIMO	1	6	2014	Melbourne, Australia	N/A	Hemanth Prabhu presented a n efficient matrix inversion implementation for massive MIMO at IEEE International Symposium on Circuits and Systems	International
28	Conference	ULUND, LIU	Large Antenna Array and Propagation Environment Interaction	23-26	11	2014	Monterey, California	~40	Erik G. Larsson organized a special session on massive MIMO at the 48th Asilomar Conference on Signals, Systems and Computers. Ove Edfors gave a talk in this session.	International
29	Conference	IFAT	2015 IEEE Radio&Wireless Week (RWW)	25-28	1	2015	San Diego, California	N/A	RWW's multidisciplinary events bring together innovations that are happening across the broad wireless spectrum and dedicated 5G workshop, Countries: international	International
30	Presentation	imec, ULUND	5G: Challenges, opportunities… and more challenges	26	2	2015	Xilinx, California	N/A	Presentation and meeting with Xilinx executives on 5G including Mammoet and Massive MIMO (Liesbet Van der Perre and Viktor Owall)	International
31	Workshop	IFAT	Terahertz band: Next frontier for wireless communications	17-22	5	2015	Phoenix, USA	N/A	In this talk, an in-depth view of THz-band communication networks is presented.	International
32	Workshop	LIU	Massive MIMO for 5G: Fundamentals and	8	6	2015	London, UK	~100	Overview presentation of the basic properties and latest	International

No	Type of activities	Main leader	Title	Date			Place	Size of audience	Type and goal of the event	Countries addressed
				Day	Month	Year				
			Recent Theory						communication theoretic developments on Massive MIMO, given by Erik G. Larsson and Emil Björnson	
33	Presentation	LIU	Massive MIMO at Night: On the Operation of Massive MIMO in Low Traffic Scenarios	42317	6	2015	London, UK	N/A	Hei Victor Cheng presented a paper at the IEEE ICC	International
34	Workshop	LIU	Massive MIMO for 5G: Fundamentals and Recent Theory	29	6	2015	Stockholm, Sweden	~60	Overview presentation of the basic properties and latest communication theoretic developments on Massive MIMO, given by Erik G. Larsson and Emil Björnson	International
35	Presentation	LIU	On the Sum-Capacity of the Continuous-Time Constant-Envelope MIMO Broadcast Channel	30	6	2015	Stockholm, Sweden	N/A	Christopher Mollén presented a paper at the IEEE SPAWC	International
36	Presentation	EAB	Bringing Massive MIMO to reality	29	6	2015	Paris, France	N/A	Keynote in Massive MIMO WS of EuCNC	International
37	Presentation	EAB	Bringing Massive MIMO to reality	9-10	6	2015	Brooklyn, USA	N/A	Invited talk	International
38	Workshop	IFAT	Massive MIMO&mm-wafe frequencies for 5G wireless	9	6	2015	Vienna, Austria	N/A	Presentation and Discussion (invited)	National
39	Presentation	LIU	Massive MIMO: Myths and Realities	25-28	8	2015	Brussels, Belgium	N/A	Erik G. Larsson gave a keynote talk at the IEEE ISWCS	International

No	Type of activities	Main leader	Title	Date			Place	Size of audience	Type and goal of the event	Countries addressed
				Day	Month	Year				
40	Presentation	LIU	Uplink Pilot and Data Power Control for Single Cell Massive MIMO Systems with MRC	25-28	8	2015	Brussels, Belgium	N/A	Hei Victor Cheng presented a paper at the IEEE ISWCS	International
41	Presentation	LIU	Distributed Massive MIMO in Cellular Networks: Impact of Imperfect Hardware & Number of Oscillators	4	9	2015	Nice, France	N/A	Antonios Pitarokoilis presented a paper at the EUSIPCO conference	International
42	Workshop	IFAT	EuMIC-2015, Workshop organizer, "RF Technologies on the Move"	6-11	9	2015	Paris, France	N/A	Workshop organizer	International
43	Conference	IFAT	Massive MIMO & mm-wafe frequencies for 5G wireless; MIDEM conference Slovenia	23-25	9	2015	Bled, Slovenia	N/A	Presentation and Discussion	International
44	Conference	LIU	Massive MIMO: Myths and Realities	15	10	2015	Nanjing, China	~300	Keynote talk in the WCSP conference by E.G. Larsson	International
45	Workshop	LIU	Cell free Massive MIMO	7	10	2015	Munich, Germany	~40	Invited one-hour talk in a workshop on Massive MIMO at TU Munich, by E.G. Larsson	National
46	Other	LiU	Massive MIMO tutorial	8	10	2015	Stuttgart, Germany	~40	Tutorial on Massive MIMO by E.G. Larsson	National
47	Workshop	imec	Complexity assessment: keeping the Massive MIMO low power preomise	29	6	2015	Paris, France	~25	Contribution to MAMMOET Massive MIMO workshop	International

No	Type of activities	Main leader	Title	Date			Place	Size of audience	Type and goal of the event	Countries addressed
				Day	Month	Year				
48	Presentation	imec	MAMMOET FP7 PROJECT: Massive MIMO for Efficient Transmission	29	6	2015	Paris, France	~ 25	Mammoet summary in RAS cluster meeting	International
49	Workshop	imec, ULUND	Characterizing the channel: measurements and models	29	6	2015	Paris, France	~ 25	Contribution to MAMMOET Massive MIMO workshop	International
50	Workshop	IFAT	Massive MIMO & mm-Wave for 5G Wireless	9	07	2015	Vienna, Austria	N/A	Keynote Speaker F. Dielacher- Photonics as a Key Enabler modern broadband technology	National
51	Other	Imec/ KU Leuven	Massive MIMO introduction	29	7	2015	Bejing China	125	Introduce Massive MIMO technology to Professionals and Academia of China an neighbouring countries	International
52	Workshop	Imec / KU Leuven / ULund	Massive MIMO: from fascinating theory to amazing proven concept	30	6	2015	Paris, France	20	Workshop ate European Conference on Networks and Communications (EuCNC) 2015	International
53	Workshop	ULund, imec/KU Leuven	Massive MIMO: From theory to practice	8	12	2014	Austin, Texas, USA	~30	Workshop at IEEE Globecom 2014	International
54	Workshop	ULund, imec/KU Leuven	Massive MIMO: From theory to practice	6	12	2015	San Diego, USA	~30	Workshop at IEEE Globecom 2015	International
55	Other	All	Resurrection of 5G: In defense of Massive MIMO	12	01	2016	Online	N/A	This article aims to clarify the capabilities of MaMi.	International

Table 2: Presentations, Conferences and Workshops

2.3 Details on other dissemination activities

Deliverable D5.1 "Project quality plan and internal IT communication infrastructure including project website" (submitted in M03) describes the MAMMOET website (http://mammoet-project.eu/) and its functionality. It also describes the tools provided within the IT infrastructure to facilitate the project cooperation as well as coordination. Further, the project quality plan constitutes a set of project templates, instruction on the management process within MAMMOET, the review process of deliverables, quality checks and various matters regarding the organisation of meetings.
The following subsections provide some details on the project website (the current status of the massive MIMO info point, and the MAMMOET website statistics). For collecting this data, Technikon makes use of the “AwStats” tool.

2.3.1 MAMMOET project website

2.3.1.1 Massive MIMO info point

On the MAMMOET project website, the link "Beyond The Project" guides the visitors to the Massive MIMO Info Point: http://massivemimo.eu/.
This info point is based on a research library and offers the possibility to request a paper already published within the project and available under the Research Library tab.
On this page we provide lists of research papers and maintain a research library in the emerging area of very large MIMO systems. The result is a broad and up to date inventory of key papers that address different research problems that appear in massive MIMO, clearly organized in categories. These lists might serve as an accessible entry-point for those who want to study this field. This massive MIMO info-point has grown out from a literature survey website originally created and hosted by the communication systems group at Linköping University. The page is now maintained by the FP7-MAMMOET project.
Currently the library comprises about 360 publications in 13 categories and is maintained and updated by the FP7-MAMMMOET project on a regular basis.

Figure 1: Extract of massive MIMO Info Point webpage

A statistical analysis of access of the second project period for the Massive MIMO website has been created with the AWStats statistical tool. The analysis was carried out to reveal the number of unique visitors (the number of distinct individuals requesting the Massive MIMO website during the year 2015, regardless of how often they visit) and the total number of all visits (the total number of requests (visits) on the webpage).
A graphical representation of the figures is presented below. In the year 2015 there were 37.119 unique visitors from all around the world and 64.330 total visits on the webpage. These numbers reflect the growing popularity of the massive MIMO topic.

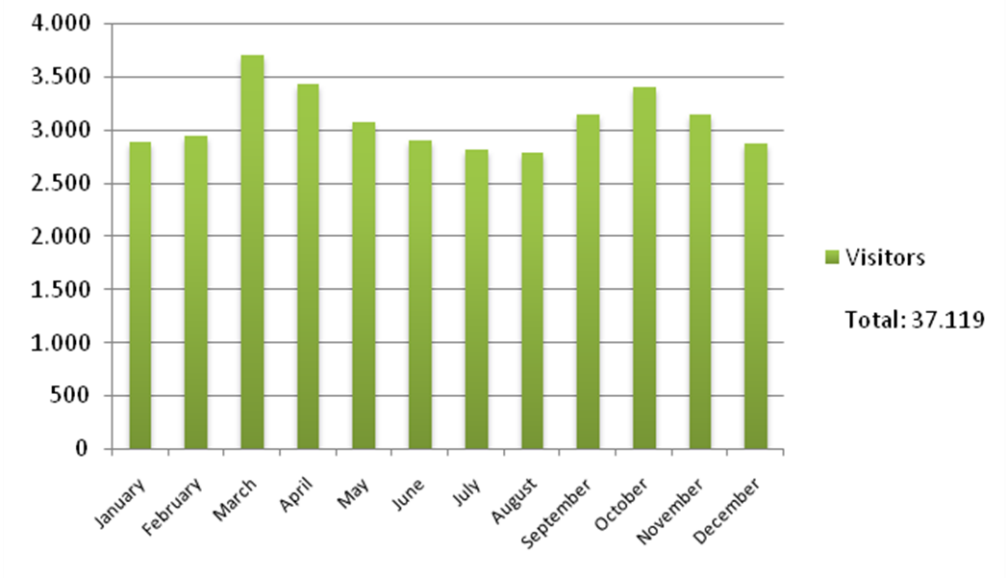

Figure 2: Massive MIMO website statistic of unique visitors

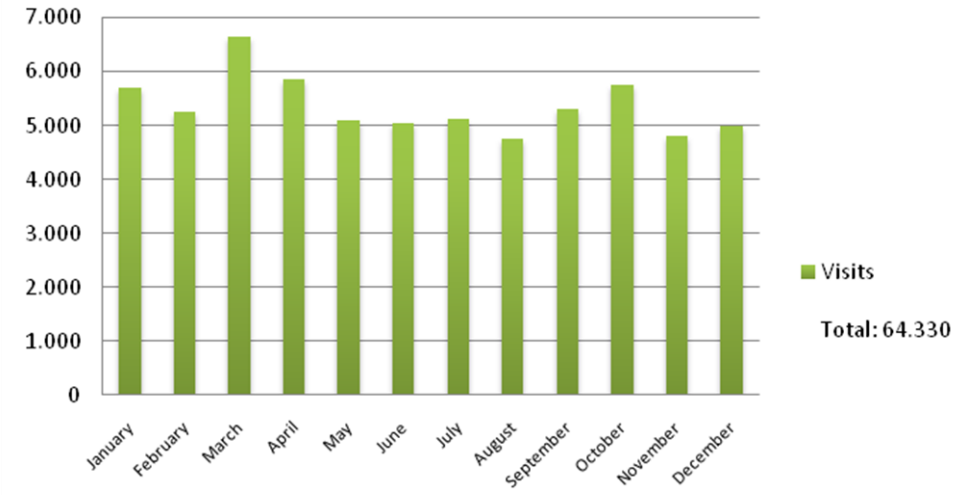

Figure 3: Massive MIMO website statistic of all visits

2.3.1.2 The number of unique visitors

A statistical analysis of access (both unique visitors and overall visits) to the MAMMOET project website (graphical visualisation) has been created which can be found below. In order to obtain these figures, we used two different statistical tools (Google Analytics and AWStats).

The following figures give attention to the second project period from the 1st of January 2015 to the end of November 2015. However, these statistics were generated at the end of November, so the last month of the second project period will not appear in the following figures. The two illustrations below provide an overview of the number of unique visitors and the total number of requests (visits). While the visitors are counted just for the first time of their website visit, visits are counted for each request of the website.

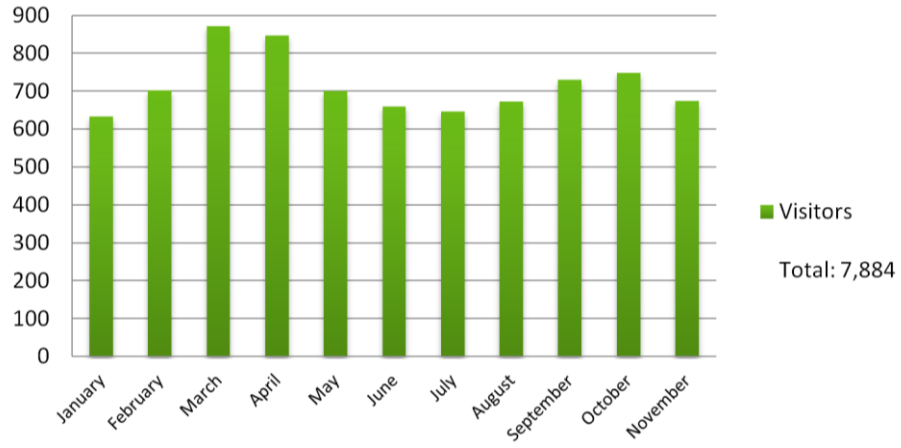

Figure 4: MAMMOET website statistic of unique visitors

2.3.1.3 The number of total visits

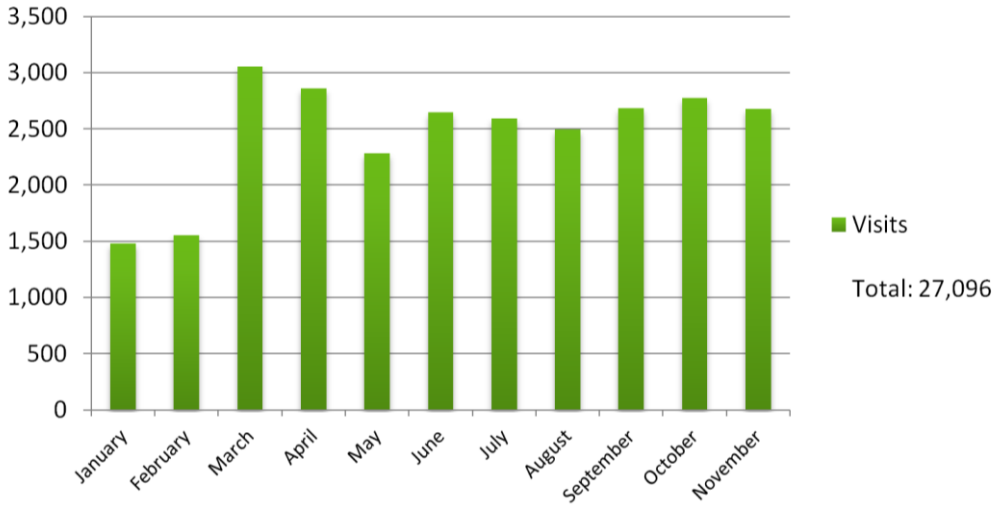

Figure 5: MAMMOET website statistic of non-unique visits

During the second project period the MAMMOET website has been visited 27,096 times in total by 7,884 unique visitors. These numbers reflect the growing popularity of the MAMMOET project. In year one the website was visited by 5,321 visitors which imply a considerable increase of 46%.

2.3.1.4 Top 20 downloads

The following table represents the most frequently viewed/downloaded documents, which are accessible over the MAMMOET project website during the project's lifetime. As can be seen the Hits are direct proportionate with the time when the specific document was uploaded.

Document	Hits
Announcement Letter	**2,451**
Newsletter (Issue 2, November 2014)	**2,378**
MIMO Capacity under Power Amplifiers Consumed Power and Per-Antenna Radiated Power Constraints (Paper)	**824**
D3.1 – First assessment of baseband processing requirements for MaMi systems	**698**
Leaflet	**684**
Newsletter (Issue 1, May 2014)	**632**
D1.1 – System scenarios and requirements specifications	**564**

Document	Hits
Poster	**520**
D5.2 – Publishable Summary	**476**
D5.1 – Project quality plan and internal IT communication infrastructure including project website	**436**
Massive MIMO: 10 Myths and One Grand Question (Paper)	**414**
Roll-Up	**380**
Massive MIMO with Multi-cell MMSE Processing: Exploiting All Pilots for Interference Suppression (Paper)	**324**
Massive MIMO with Non-Ideal Arbitrary Arrays: Hardware Scaling Laws and Circuit-Aware Design (Paper)	**316**
Newsletter (Issue 3, May 2015)	**296**
Mitigating Pilot Contamination by Pilot Reuse and Power Control Schemes for Massive MIMO Systems	**264**
Massive MIMO for 5G: From Theory to Practice (Tutorial)	**230**
Massive MIMO for 5G: Fundamentals and Recent Theory (Tutorial)	**218**
D2.2 – Prototype test chips 1st run	**20**

Table 3: Top 20 downloads

2.3.1.5 The geographical distribution of the visitors' locations

The following website statistic (Figure 6) illustrates the geographical distribution of the visitor's location. More than a third of the visitors were from Europe and almost one third is represented by America (Northern, South and Central America and the Caribbean). The remaining percentage is spread over Asia, Africa and Oceania (Australia, New Zealand and New Guinea). However, the location of the visitor is not always known, so there is a small percentage called "Other" which represents these users. This shows that during the past project period the major interest in this European research project lies of course within Europe, but it must be also highlighted that the project raises considerable interest in America. This might be due to the presentation of MAMMOET at conferences in the US, such as the IEEE GLOBECOM conference, the IEEE Radio & Wireless Week (RWW) 2015 in San Diego (CA) and several workshops.

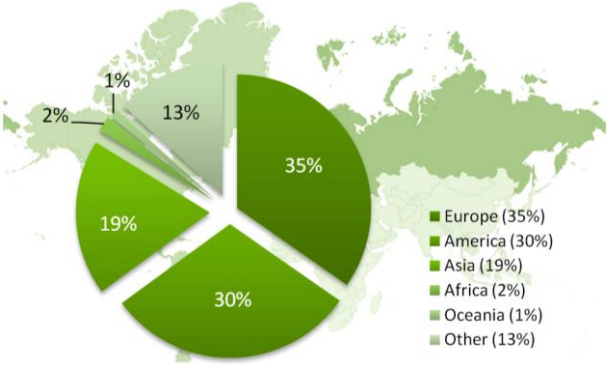

Figure 6: MAMMOET website statistic of the geographical distribution of visitor's location

2.3.1.6 The ratio between new and returning visitors

With respect to the following statistic (Figure 7), it has to be pointed out that in the second project period of MAMMOET, the website has been able to attract a considerable amount of new visitors, representing almost 84% of the overall visitors.

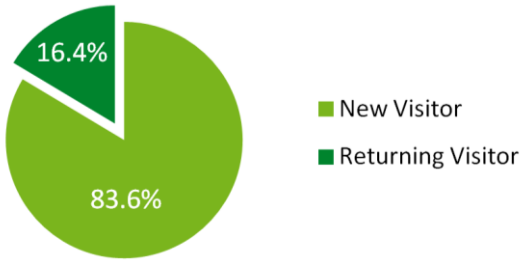

Figure 7: MAMMOET website statistic of the distribution of the type of the visitors

2.3.2 Project leaflet

The official MAMMOET leaflet is a four page informative and graphically appealing A4 flyer, highlighting the objectives and the work programme of MAMMOET. It is used for distribution at conferences or certain other events in order to provide further visibility to the MAMMOETA project. Technikon was mainly responsible for the content and design of the leaflet and distributed it to all partners after finalisation. An electronic version of the leaflet is available on the MAMMOET website following the link:
http://mammoet-project.eu/downloads/leaftlet/Mammoet_leaflet_web.pdf

2.3.3 Project newsletters

Until now three project newsletters have been launched in order to address MAMMOET project related news:

- The *1st newsletter* had been issued in May 2014 intending to open a new communication channel in order to provide news on the project progress and discuss ongoing topics relevant to MAMMOET for both internal and external project partners, stakeholders and all other interested bodies.
  Link: http://www.mammoet-project.eu/downloads/newsletter/MAMMOET-Newsletter-Issue1-May2014.pdf
- The *2nd newsletter* had been issued in November 2014 in which results of the first year were presented and an outlook for the second MAMMOET project year was provided.
  Link: http://www.mammoet-project.eu/downloads/newsletter/MAMMOET-Newsletter-Issue2-Nov2014.pdf
- The *3rd newsletter* was issued in May 2015 and the public was informed that the progress made towards the overall goals is considered as excellent so far: Based on the exploration of fundamental limits, a capacity gain of a factor of 50 is in sight. Results of the 1st project year have been presented by work packages, an overview of the submitted deliverables has been provided, events at which MAMMOET was present, publications of the partners, honours and awards of the consortium members have been highlighted and last but not least the upcoming meetings and events have been mentioned.
  Link: http://www.mammoet-project.eu/downloads/newsletter/MAMMOET-Newsletter-Issue3-May2015.pdf

2.3.4 Social media

Making use of the advantages of social media helps spreading project information to a large audience. As a consequence, they are valuable means to disseminate project ideas and results.
LinkedIn is a business-oriented social networking service and allows the formation of interest groups. Within the MAMMOET group, called "*FP7 MAMMOET Friends*", a discussion area, moderated by the group owner will allow interested, connected parties to easily discuss relevant topics. The MAMMOET group is a closed group with currently 41 members. This ensures that only people who have been approved by the manager or admin can see the content of the group. It can be accessed via https://www.linkedin.com/groups/7451662.

Twitter is a micro-blogging social media service. Social media have changed the way people communicate as it is no longer a one-way direction communication. Social media enables its users to share their ideas in an interactive way and to connect each other in networks. Twitter is not only a service that allows users to connect with their "followers" (those who signed up to follow their updates), but it gives users the possibility to interact with each other on the basis of topics and themes they are interested in. The MAMMOET project on Twitter, can be followed on "*FP7_MAMMOET*". So far we have tweeted 28 entries. We will continue with monthly tweets to inform the interested community about the latest project news and increase the number of followers. At the next conferences, presentations and given talks we will continue to inform the audience to follow us on Twitter: https://twitter.com/FP7_MAMMOET.
The success of the dissemination activities related to the social media can be measured by reporting as so called "key performance indicators" (KPI) the "number of contacts" and the "number of posts/messages" as shown in the table below. The first KPI, related to the number of contacts (or followers for Twitter) has been overcome for the LinkedIn group. As regards the number of posts, whose threshold has been set 1-2 per month for a total of 23 posts/messages, we register that the number of tweets is sufficient.
To improve the use of social media channels, we revised our strategy and decided to augment the number of messages requesting a more active participation of the partners in increasing the number of followers/contacts and the number of posted messages. We plan to better report project's activities by having at least 2 messages per month. This strategy could allow a better diffusion of project's activities over these channels.

2.3.5 Cooperation activities with other projects

As part of MAMMOET project management and dissemination activities, further projects in the same area have been identified and the coordinator provided them with the most important project information on a regular basis (e.g. exchange of newsletters, social media).

Since the beginning of the project, we are linked with the following projects:

- FP7 project METIS
- ERC project AMIMOS
- FP7 project DUPLO
- FP7 project 5GNOW
- FP7 project DRAGON
- FP7 project MULTI-BASE
- H2020 project M3TERA

Specifically, the METIS results have been built upon extensively in WP1 as a starting point for the scenario definition. In the RAS cluster meetings and at the EUCNC conferences the results of MAMMOET have been presented to the community, and there have been interactions with representatives of the running 5G projects. As a result for example, the potential new 5G waveforms (as investigated by 5GNOW) are being assessed in conjunction with Massive MIMO.

See also MAMMOET website: http://www.mammoet-project.eu/links

Chapter 3 Standardization

3.1 MAMMOET standardization

Standardization is a key activity to avoid closed systems that cannot inter-operate and to ensure a market size that yields economies of scale. Furthermore, standardization is more and more important to ensure that the technologies developed within a research project are widely accepted and available in general. For MAMMOET especially the inclusion of Massive MIMO as a technology in 5G standards is crucial to the success of the potential exploitation of the results. The standardization strategy of MAMMOET consists essentially of two consecutive phases:

- The **message identification** phase whose aim was to identify the key outcomes of the project which could be promoted for their development in a standard.
- The **standardization promotion** phase whose goal was to write contributions, based on the key outcomes identified in the previous phase, and present them to the target standardization bodies.

At this phase in the project, the message that Massive MIMO has a great potential for 5G has been spread by MAMMOET extensively, and the great progress towards the proof of concept and efficient implementation has raised the confidence level of its relevance significantly. Also progress has been made towards the standardization promotion.

3.2 Standardization activities

5G is the next step in the evolution of mobile communication. It will be a key component of the Network Society and will help realize the vision of essentially unlimited access to information and sharing of data anywhere and anytime for anyone and anything.

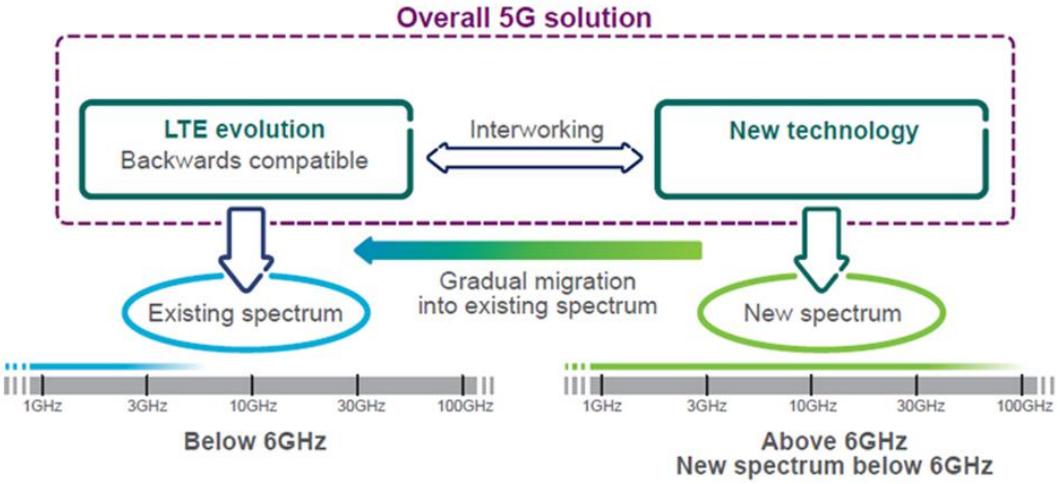

Figure 8: 5G Radio Access - Technology and Capabilities[3]

LTE will continue to develop in a backwards-compatible way and will be an important part of the 5G wireless-access solutions for frequency bands below 6GHz. Around 2020, there will be massive deployment of LTE providing services to an enormous number of devices in these bands. In parallel, new radio-access technology (RAT) without backwards-capability requirements will emerge, at least initially targeting new spectrum for which backwards capability is not relevant. In the, long-term perspective, the new-backwards-capable technology may also migrate into existing spectrum. In order to enable connectivity for a very wide range of applications, the capabilities of 5G wireless access must extend far beyond those of previous generation of mobile communication:

[3] https://twitter.com/ericsson/status/565084455828996096

- **Massive system capacity** – traffic demands for mobile-communication system are predicted to increase dramatically. In order to support such traffic in an affordable way 5G networks must be able to deliver data with much lower cost per bit compared with the networks today and on a lower energy consumption per delivered bit.
- **Very high data rates everywhere** – 5G should be able to provide data rates exceeding 10Gbps in specific scenarios such as indoor and dense outdoor environments, data rates of several 100Mbps should be achievable in urban and suburban environments and last but not least data rates of at least 10MBps should be achievable everywhere.
- **Very low latency** – because 5G targets high data rates, this in itself targets lower latency. However, lower latency will also be driven by the support for new applications.
- **Ultra-high reliability and availability** - for critical services such as control of critical infrastructure or traffic safety, connectivity has to be always available with essentially no deviation.
- **Very low device cost and energy consumption** – it should be possible for the 5G devices to be available at very low cost and with a battery life of several years without recharging.

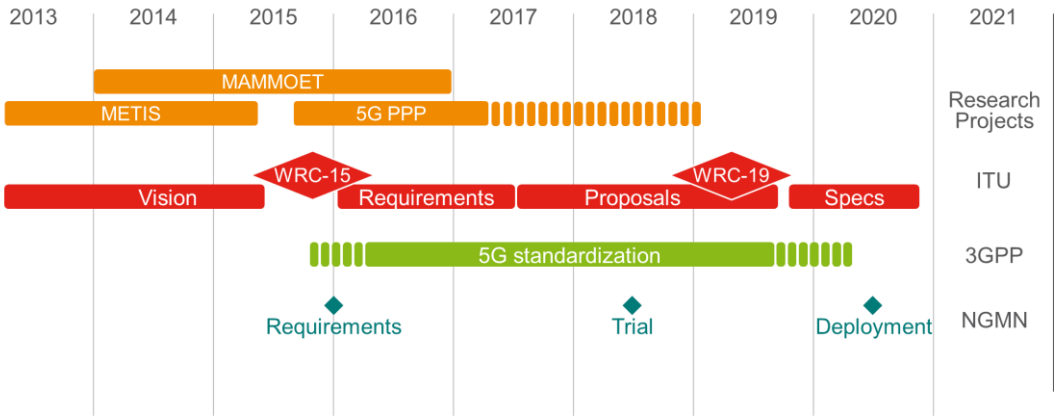

Figure 9: New Radio Access Technology Standardization

Figure 9 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.

3.2.1 Identified standardization activities where MAMMOET contributes or plans to contribute:

- **Study of 3D channel models and 3D beamforming**
    - Two study Items are devoted to in within 3GPP
        - FS_LTE_3D_channel "Study on 3D-channel model for Elevation Beamforming and FD-MIMO studies for LTE", already completed in Release 12.
        - "Study on Elevation Beamforming/Full-Dimension (FD) MIMO (FD-MIMO)", as a continuation of the above in Release 13. – **Future Activity**
- **Extension of COST2100 channel model**, a geometry based stochastic channel model (GSCM) that can reproduce the stochastic properties of MIMO channels over time, frequency, and space. In contrast to other popular GSCMs, the COST 2100

approach is generic and flexible, making it suitable to model multi-user or distributed MIMO scenarios.

- **MaMi specific hardware impairment models and hardware complexity estimates**

3.2.2 IEEE802.11 and IEEE802.15.3

IEEE 802 – WNG (Wireless Next Generation) Imec has attended the March 2015 IEEE802 standardization meeting in Berlin. Massive MIMO is a candidate technique in the new standardization activity called "High Efficiency Wi-Fi" (802.11ax). Hence, most of the attendance was devoted to this Task Group. Imec attended, as well, the September 2015 IEEE802 standardization meeting in Bangkok. Most of the focus was on the 802.11 Working Group, especially 802.11ax and 802.11ay, which are the most active Task Groups (i.e. groups working towards new draft amendments). Although MIMO will be leveraged in 802.11ax/ay, Massive MIMO will not be used as such in these amendments. It is possible that Massive MIMO will be used in later developments within IEEE802.11 (post 11ax and 11ay).

3.2.3 3GPP-LTE

3GPP is the key Standards Development Organization that produces the technical specifications concerning 2G, 3G and 4G cellular systems widely deployed everywhere. On September, 17th-18th 2015 3GPP organized a workshop on 5G Radio Access Networks, so that all interested companies could present their views on 5G and receive feedback. TID presented a contribution on such workshop containing high-level views on 5G, and including key thoughts and findings regarding massive MIMO on behalf of the MAMMOET Consortium. The presentation can be publicly downloaded from: http://www.3gpp.org/ftp/workshop/2015-09-17_18_RAN_5G/Docs/RWS-150005.zip

The feedback received from partners at the workshop was very useful for the project. On one hand, there was consensus in that MaMi should be a key element as part of the foreseen 5G physical layer techniques. On the other hand, most companies were interested in exploring MaMi at current cellular frequencies (below 6 GHz) because of the greater chances to perform spatial multiplexing of users, as compared to the relatively less known frequencies beyond 6 GHz. There was an interest in looking at both beamforming and spatial multiplexing techniques beyond 6 GHz to overcome pathloss effects, but at short term the pure spatial multiplexing approach was the preferred one (as in MAMMOET). As a result of the workshop, we could confirm the interest in developing MaMi for the immediate standardization work in TDD systems, while FDD deployments would have to wait some time so as to circumvent fundamental issues related to channel acquisition and estimation. This is also in line with the project's findings. Additionally, the preference expressed by most companies was that broadcast control signalling and related aspects could rely on additional access nodes (e.g. an existing LTE coverage layer), in dual-connectivity mode, to avoid any issues in common control and coverage with the new 5G air interface. This was also the approach taken in MaMi, by which common control procedures were decided to remain out of the scope of the project. MAMMOET will keep tracking 3GPP progress for 5G standardization and pushing for incorporation of MaMi techniques throughout 2016.

3.2.4 European Telecommunications Standards Institute (ETSI)

ETSI is the European Telecommunications Standards Institute, produces globally-applicable standards for Information and Communications Technologies (ICT), including fixed, mobile, radio, converged, broadcast and Internet technologies. ETSI has currently more than 750 members worldwide, from 63 countries and all of them are recognized as the world's leading companies and innovative R&D organizations. Ericsson, Telefonica and Infineon are ETSI member and are actively involved and contributing to ETSI. The discussion about 5G and new air interfaces is initiated and there will be a "Workshop on Future Radio Technologies: Air Interfaces" on January 27-28 2016 and the "5G: Forum Myth to Reality" on April 21, 2016. MAMMOET is keeping track on all the Massive-MIMO related discussion and will submit contributions in the future.

Chapter 4 MAMMOET exploitation

Beside the dissemination of the project results and contribution to standards, the exploitation of the achievements of MAMMOET is of crucial importance for the consortium.
It can clearly be distinguished between:

- Public exploitation, not directly interested in commercial revenue but focusing on benefits at the level of the society, and
- Business exploitation with clear commercial motives

Exploitation was recognised as the key element for the success of MAMMOET as underpinned by its significant industrial participation. Exploitation is specifically targeted at potential clients of the MAMMOET project. For the research partners in the consortium extension of their R&D activities and partnerships is considered a successful exploitation.
The MAMMOET business exploitation strategy was based only the fact that the wireless infrastructure market which experienced modest growth between 2003 and 2011 is entering a time of considerable change, the telecommunication services revenue is projected to grow at an average growth rate of 5,3% by 2017 and according to several studies the most growth is expected to come from broadband services, with wireless 3G and 4G broadband services.[4]
Each partner has a quite different exploitation strategy in the relative business domain, and all steps towards commercialization of the new technology have been carefully aligned between all partners.
MAMMOET partners have tackled exploitation in different directions:

- Internally, all partners have been expanding and sharing their knowledge on the emerging massive MIMO technology;
- Relevant scenarios were identified, where this disruptive technology can be applied;
- New solutions and IP have been created, paving the way to actual MaMi products and deployment;
- Early insights for future 5G networks were given to business partners and customers.

4.1 Main exploitation plan

An exploitation plan was developed in the first year of the MAMMOET project on both partner and consortium level. Exploitation activities are not only focused on the preparation of actual commercial exploitation but aim to reach the overall goal to widely exploit the project outcome. Depending on the organization type (industry / SME / university) the exploitation strategies and activities are focusing on different aspects:

- New telecommunication services level especially for metro areas (city hot zone; large venue)
- Mobile and wireless network infrastructure equipment ranging from antenna to software for radio resource management
- Highly efficient RF devices
- Industrial partnetrship programs, IP transfer and licensing

The consortium differentiated from the very beginning between public exploitation, not directly interested in commercial revenue but focusing on benefits at the level of the society, and business exploitation with clear commercial motives.
Specific planned activities include:

- Exploitation-oriented upgrade of the project website, including optimisation for search engines and optional registration for specific keywords.
- Commercialised products and /or services incorporating the findings of the project.

[4] http://bizmology.hoovers.com/2012/01/17/healthy-growth-forecast-for-telecom-industry

- Management of IPR to enable partners to exploit and re-use MAMMOET outputs and license key MAMMOET technologies.

The detailed per-partner plans towards exploitation activities as well as the update exploitation plan after 2nd project year including stakeholder is provided in Sub-chapter 4.2

4.2 Exploitation plans per partner

Every Partner has provided an update of their initial exploitation plan as specified in part B of the Description of Work (DoW) - B5.2 - Planned Standardization Activities. Furthermore, they included an initial report on the performed exploitation activities within the project.

Partner 1: Technikon Forschungs- und Planungsgesellschaft mbH (TEC) – Austria	
Exploitation plan according to Annex I	For the last 14 years, our business has been to provide both general and engineering services for technology-related challenges. Our general services focus on feasibility studies, the creation of business plans and the planning and management of industrial research activities. Our core customers are early adopters of new technologies and we will use the knowledge created within the project to strengthen our image as technology scout and spearhead. Participation in this project leads to the early identification of novel technology, which is a prime asset for our business success. Our requirement engineers will sharpen their expertise while working together with some of the world's leading industrial scientists in this project. As an emerging SME, the reputation gained from the project will positively influence our future acquisition activities. TEC's "Trusted knowledge Suite", a workflow based management support system, has highly benefited from its employment in European research projects. Critical project users have constantly triggered improvements and the introduction of new features which elevated the market position of our IT tool.
Updated exploitation plan after 2nd project year including stakeholder	Our project involvement strengthens our knowledge on intrinsic security features of MIMO and MaMi technologies. This experienced gained will be funnelled into our industrial services on requirement engineering for telecommunication solutions. We will highly profit from the project approach of solving complex problems on gateway levels and deriving system solutions for industrial driven use cases. As an emerging SME, the reputation gained from the project is positively influencing our acquisition activities. New costumers, like Kathrein, have been identified. Our research results fostered our security engineering research services and pave the way for additional activity fields. We will continue to sharpen our industrial service profile with hardware entangled security business solutions well suited for small enterprises. Practical experience from carrying out the project will trigger improvements of TEC's "Trusted knowledge Suite" and verify its integration and usability with mobile devices and commodity clouds. Novelties demanded and consequently introduced will elevate the market position of our IT tools.
Partner 2: Interuniversitair Micro-Electronica Centrum VZW (imec) - Belgium	
Exploitation plan according to Annex I	Imec is a research institute that realises exploitation of its R&D results to industry via 'Industrial Affiliation Programs', bilateral projects, IP transfer and licensing, and occasionally the creation of spin-off companies. In the affiliation program, imec teams up with leading companies across the value chain of the wireless market, in which they get early access in new radio technologies and can use imec's know-how and prototypes to accelerate the development of

	their next-generation ICs. Spin-offs launched in the wireless domain have focused a.o. on satellite communications, positioning systems, analogue design and reconfigurable transceivers.
Updated exploitation plan after 2nd project year including stakeholder	Imec is a research institute that realises exploitation of its R&D results to industry via 'Industrial Affiliation Programs', bilateral projects, IP transfer and licensing, and occasionally the creation of spin-off companies. Massive MIMO is becoming one of the central elements of our 5G research offering. The exploration achieved within MAMMOET enables us to improve our understanding of this technology. Specific results from imec will help Massive MIMO investigation towards our future partners, for example building on Matlab baseband simulations or power modelling, and validating the concept under realistic scenarios. The results of MAMMOET also guide our internal roadmap in order to design specific hardware components solving Massive MIMO issues. Next to industrial exploitation, publications are also important to recognize our scientific leadership; one publication was presented at EuCNC 2015 and two have been submitted.
Partner 3: Ericsson (EAB) - Sweden	
Exploitation plan according to Annex I	The findings of MAMMOET will give important guidance and provide input to updates of technology roadmaps. Results will be incorporated into standardisation efforts and support discussions on deployment solutions with customers. In particular EAB will specifically emphasize project results that can be implemented in products and services, providing a competitive edge, e.g. in terms of energy efficiency and meeting future demands on capacity per cost. Also, the research outcome on hardware aspects of MaMi and its impact on baseband algorithms, architecture and system design will complement MIMO activities in the FP7 IP project METIS which focuses on aligning the industry view on wireless networks for 2020 and beyond. It is also expected that the MAMMOET research will be a basis for future research and development at EAB and may in many aspects very well have significant impact on how tomorrow's wireless networks are designed and deployed, not least in relation to environmental aspects and energy consumption.
Updated exploitation plan after 2nd project year including stakeholder	Research results from MAMMOET project complement and enhance EAB's ongoing intense activities that are paving the way to the 5th generation mobile communication system (5G), since they provide valuable insight on one of the most promising technologies for 5G. The results will be exploited to maintain and further widen EAB's lead in 3GPP standardization. Moreover, the research on massive MIMO hardware design will be used to update the technology roadmaps of the beyond 2020 products. During the first year, by participation to the project, EAB has further increased its expertise in massive MIMO. Also, EAB has efficiently collaborated with the consortium to identify the scenarios where the massive MIMO technology has larger real-world exploitation potential. This is crucial knowledge, especially in the ongoing interactions with customers, in particular on setting the requirements for 5G.
Partner 4: Infineon Technologies Austria AG (IFAT) - Austria	
Exploitation plan according to	Infineon Technologies Austria AG will exploit and sell all the relevant results of the MAMMOET project through the mother company

Annex I	Infineon Technologies AG based in Munich/Germany. Infineon already offers an extensive component portfolio for radio-base-stations and wireless infrastructure equipment. All the knowledge and building blocks developed in MAMMOET will provide a trust of innovation for the whole portfolio for next generation systems by achieving: • MaMi capability • Significantly reduced power consumption of base station and wireless access point transmitters. • Reduced cost through higher integration • Improved reliability and features on re-configurability and flexibility MaMi is seen as a game changing technology for telecom infrastructure. Due to that the exploitation strategy has to be carefully planned and continuously adjusted according to the results achieved and specifications aligned with the system manufacturers. A major requirement will be to replace high performance extremely linear and high-output-power single-channel solutions by highly integrated multi-channel transceivers with less stringent performance requirements and significantly reduced output power.
Updated exploitation plan after 2nd project year including stakeholder	It is most important to achieve progress in the standardization because this will be the basis for the ramp-up and exploitation of the new technology. It is expect that the agreement in the standard will be on the World Congress in 2019 and the start of the deployment of the 5G is expected to happen from 2020 onwards. Through MAMMOET we are involved in the standardization activities and technology development and this, directly relates to all the performed work in the feasibility of chip design and involvement in the technology demonstration. All this effort will be most important to finally achieve not just a 5G standard in 2019 but also to achieve a specification for our products ready by that date when the standard is decided. IFAT is involved in the testbeds and prototyping which in our case refers to the chip implementation feasibility studies. Thus, by the time when the standard is decided we should have the first products ready for the deployment.
Partner 5: Katholieke Universiteit Leuven (KU Leuven) – Belgium	
Exploitation plan according to Annex I	The main exploitation for a university like KU Leuven lies in the communication of the results on several top conferences and publication of the results in international top journals (see list above). After the project KU Leuven will based on the MAMMOET result more direct, bilateral, cooperation with major industrial players. This will enable these industrial partners to commercialise these result on one hand. It will allow the university to further develop and refine the scientific results. Leading to even more PHDs level engineers and international publications.
Updated exploitation plan after 2nd project year including stakeholder after 2nd project year including	The main exploitation for a university like KU Leuven lies in the communication of the results on several top conferences and publication of the results in international top journals (see list above). After the project KU Leuven will based on the MAMMOET result more direct, bilateral, cooperation with major industrial players. This will enable these industrial partners to commercialise these result on one hand. It will allow the university to further develop and refine the

stakeholder	scientific results. Leading to even more PHDs level engineers and international publications. As of November 30th 2015, there has been one conference publication in ESSCIRC 2015 and joined publications and workshop with other partners. As a result of the cooperation in MAMMOET, the knowledge on MASSIVE MIMO has increased significantly at KU Leuven. Other R&D initiatives have resulted, including establishment of a Massive MIMO testbed (HERCULES funding, co-promotor L. Van der Perre) and new PhD projects complementary to MAMMOET..
Partner 6: Lunds Universitet (ULUND) - Sweden	
Exploitation plan according to Annex I	ULUND hosts research centres in the fields of circuit design as well as wireless systems. Those will be used as the major path for industrial exploitation of the results, as those provide already established frameworks for cooperation with industry in the area of telecommunications. Lund University has agreements with these companies for technology transfer and, as a consequence, the exploitation and commercialization is most efficiently done through them. When those agreements are not applicable, technology transfer is pursued on a case-by-case basis. Results and know-how from this project will also be used to improve research and education practices, on both graduate and undergraduate levels. The involved researchers have a proven track record of patent applications and various forms of licensing results to our industrial partners as well as a track record of establishing start-ups based on our research results.
Updated exploitation plan after 2nd project year including stakeholder	Exploitation plans remain largely the same as in Annex I, with some updates due to the larger than expected interest in massive MIMO. The most important change, beyond this, is the bilateral agreement between ULUND and EAB where EAB acquires all patentable inventions made by ULUND research in MAMMOET. Knowledge from the MAMMOET project has been used to develop education on undergraduate and graduate levels. Over 10 events in behave of MAMMOET have been attended because the main exploitation for a university like ULUND lies in the communication of the results on several top conferences and publication of the results in international top journals (see Table 2: Presentations, Conferences and Workshops).
Partner 7: Linköpings Universitet (LIU) - Sweden	
Exploitation plan according to Annex I	LIU, as a university, will primarily exploit the results in the form of new publications and course material, see Sec. 3.2.1. The researchers at LIU involved in MAMMOET also have a history of successful technology transfer in form of patent rights acquired by industry. In MAMMOET, technology transfer will be handled on a case-by-case basis, and LIU has an innovation office that can assist with this.
Updated exploitation plan after 2nd project year including stakeholder	LIU, as a university, exploits MAMMOET results in the form of new publications and course material, see Sec. 3.2.1. The researchers at LIU involved in MAMMOET also have a history of successful technology transfer in form of patent rights acquired by industry. In MAMMOET, a bilateral agreement has been signed between LIU and one of the MAMMOET industrial partners (Ericsson). Under this agreement, Ericsson acquires the rights to inventions made by LIU

	researchers within the MAMMOET project. As of November 2015, three patent applications with LIU co-inventors (PCT/SE2014/051163, PCT/EP2015/053737 and PCT/SE2015/050754) have been filed under this agreement and assigned to Ericsson.
Partner 8: Telefonica Investigación y Desarrollo SA (TID) - Spain	
Exploitation plan according to Annex I	TID plans to use the knowledge acquired in the scope of the project in the definition of the future network architectures, with the focus on provisioning novel wireless services. More specifically, the most important exploitation points for Telefónica are the implementation of MaMi solutions in HetNets, improved network efficiency and energy saving strategies, and identification of network requisites for future mobile networks. TID plans to involve its industrial partners and stakeholders in the design of technically feasible and scalable commercial products from the project concepts and cooperate in the transfer process to the industry by means of several Telefónica Group entrepreneurship initiatives, such as Wayra (http://wayra.org/), promoting the availability of the MaMi concept to a wide number of technological start-ups.
Updated exploitation plan after 2nd project year including stakeholder	As a result of the activities in the first half of the project, the Consortium now has a clearer view of the massive MIMO potential and benefits. In order to assess the benefits of MaMi compared to other, more traditional solutions for capacity enhancement (like e.g. small cells), TID conducted a thorough assessment of practical deployment aspects that should be taken into consideration in any realistic exploitation. A comparison with some of the issues in small cell was made in order to highlight the benefits of MaMi, therefore suggesting a clear alternative to heterogeneous networks that would overcome most of the current issues with small cells. The pros and cons of TDD deployments were also evaluated, as a pre-requisite of current MaMi approach, as well as some key points in terms of unwanted emissions, RF device impairments, synchronization, CQI estimation, and power control. These aspects were analysed and shared with the other partners, and the result of such discussions will lead to a clearer position towards how to deploy massive MIMO as an alternative for area capacity boost in 4G/5G networks. In addition, a 5G research centre was launched, namely 5TONIC (5G Telefonica Open Network Innovation Centre), where Telefonica is one of the founding members (see http://tinyurl.com/oqwfawe). Technologies like massive MIMO are among the selected candidates for real testing, as a first step towards future ambitious massive MIMO deployments.

Table 4: Exploitation plans per partner

To sum up, the MAMMOET consortium has tackled exploitation in different directions. All partners have been expanding and sharing their knowledge of the emerging massive MIMO technology. This expertise is beneficial towards our other business partners/customers, by giving them early insights in a key technology for future 5G networks. Relevant scenarios were also identified, where this disruptive technology can be applied. Externally, a number of scientific publications were written in order to disseminate the most important results of our research and fruitful the scientific exploitation plans.

In the last year, we will continue to target many scientific publications and demonstrate our leadership in massive MIMO research at specific events. More tangible results will also become available for our industrial customers outside of the MAMMOET consortium. As the

project proceeds closer to the practical side, including testbed results and implementation including tape-out, the industrial exploitation towards products will become more relevant.
Imec pursues and active strategy to protect its crucial innovation by patents. This strategy is crucial to IMEC's business models and industrial exploitation of the results. In the broadband wireless domain, imec has built up a portfolio of 70 patent families (300 patents and patent applications). Many of them relate to efficient implementation of emerging mobile systems. Some examples relevant to the MAMMOET project are imec's patents on IQ mismatch compensation and calibration, and methods to cope with non-reciprocal front-ends.
Given the focus of the project which will address challenges for which currently no solutions exist, and IMEC's specific expertise (e.g. in calibration and compensation solutions for non-ideal front-ends), it was from the beginning quite sure that new and patentable results will be generated in the frame of MAMMOET. All filled patents during the project intended to protect and create licensing opportunities. Within MAMMOET the patents are filled in by the industrial partner but exception can occur if KU Leuven wants to promote a spinoff company with the MAMMOET results.
Until this point in time the consortium filled three patents:

- PCT/SE2014/051163 – Methods, network node and communication devices for transmitting data – Application of E.G. Larsson, P. Frenger and E. Eriksson
- PCT/EP2015/053737 – Technique for assessing pilot signals to user equipment – Application of E. Björnson and E.G. Larsson
- PCT/SE2015/050754 – A wireless device, a radio network node and methods therein – Application of M. Hessler, E.G. Larsson, E. Björnson and H. V. Cheng

4.3 Innovation management

Massive MIMO proposes utilizing a very high number of antennas to multiplex messages for several devices on each time-frequency resources, focusing the radiated energy towards the intended directions while minimizing intra and intercell interfaces. They require as well major architectural changes, particularly in the design of macro base stations, and it may also lead to new types of deployments. In a publication from 2015, several companies used the Henderson-Clark model to classify the impact of several disruptive technologies directions for 5G. They argued that in the context of Henderson-Clark framework, massive MIMO has a disruptive potential for 5G.
What this means:

- At a node level it is a scalable technology (this is in contract with 4G which in many respects it is not scalable, like there is limited space for bulky azimuthally directive antennas ore there is an inevitable angle spread of the propagation)
- It enables new deployments and architectures

While very promising, massive MIMMO still presents research challenges. The adoption of massive MIMO for 5G represents a leap with respect to today's state of the art in system and component design.
Within the MAMMOET project, based on the Henderson-Clark model the theory presented above was proved to be true. Considering the industry trends and the DG CONNECT Innovation Questionnaire used as a first innovation activity within the project, the consortium claims that massive MIMO is a disruptive technology direction for 5G. Therefore, they can lead to fundamental changes in the design of cellular networks.

Chapter 5 Strategic impact of MAMMOET

The MAMMOET project develops key technologies for radio access networks, which holds the potential to increase the capacity 10 times or more and simultaneously, improve the energy-efficiency in the order of 1000 times or more. As presented in Annex 1 Part B MAMMOET impact related to the work program is as can be seen in Table 5.

ICT-2013.1.1	MAMMOET impact
Developing key enabling technologies for the future generations of the European high-speed broadband and mobile network infrastructure (factor of 10 overall capacity increase, plus factor of 10 radio efficiency increase)	Going to massive numbers of antenna elements on the base stations can substantially enhance data rates, while the required transmit power can be decreased by several orders of magnitude compared to today's systems. To prove that MaMi is a strong candidate for future mobile networks, MAMMOET will develop new essential functionality and attractive integration, which together can achieve exceptional radio efficiency (10-fold capacity increase together with 100-fold reduction in radiated energy). The gain will come from combining heavy beamforming with high-efficiency low-power radio components.
Improved flexibility and economic, spectral and energy efficiency of access/transport infrastructures (factor of 4 reduction in watts/bit)	MAMMOET pursues a next generation system with much higher spectral and energy efficiency compared to current systems. The increased capacity is achieved by aggressive spatial multiplexing. The improvement in energy efficiency stems from power (array) gain of the massive array, as well as the introduction of low-power amplifiers with much better efficiencies. Moreover, the large number of antennas offers a large flexibility towards reduction of interference between cells exploiting the same frequency band. The project concentrates on low energy solutions, not only for the transmitted (radiated) power, but also for the **total** energy consumption including digital baseband, RF front-end and power amplifier.
Strengthened positioning of European industry in the fields of Future Internet technologies, mobile and wireless broadband systems, optical networks, and network management technologies	The MAMMOET consortium has main European industrial players on board, which through the project will be able to acquire relevant technological innovation to strengthen their position. Moreover, the consortium will promote its results especially in Europe. The outcome will also be injected into other European projects that the partners are involved in and be important input to product plans for mobile, wireless, networks and its convergence with IT.
Contributions to standards and regulation as well as the related IPR	MAMMOET has concrete plans to contribute to standards, as detailed in section B3.2.2 from Part B of the DOW. Appropriate IPR measures and plans will be put in place, as specified in B3.2.4 of Part B, of the DOW.
Adoption by network operators of integrated all-optical networks and of spectrum-flexible broadband wireless systems (by 2020)	The MAMMOET consortium has an operator on board, namely Telefonica. This operator has an ambitious strategy, and is looking forward to investigate the potential of upgrading its network radically building on the promising MaMi technology through this project.

Table 5: MAMMOET impact related to the work programme

During the first two project years MAMMOET brought about the impacts described above through appropriate focus and objectives, pursued by a well-placed team and the plan to promote the results beyond the project.
The work-plan of the project has been established to ensure all main hurdles towards an efficient realisation of MaMi, those hurdles were addressed through cooperative research activities. The MAMMOET partners cover all important experience and expertise required to

successfully execute the project. Through the industrial partners, Infineon AG, Ericsson AB and Telefonica, project results in the mobile network standardization as well as dissemination of project results have been guaranteed for industrial and business relevance. The project had from the beginning the ambition to share the findings and promote the results outside the consortium and beyond the duration of the project. Specially, the industrial partners have been really active in dissemination, standardization and exploitation activities (See Chapter 2, Chapter 3 and Chapter 4).

From early stage of the project the consortium agreed that establishing from an early phase of the project a close cooperation between experts spanning from theoretical specialists to implementation experts and industrial partners, including network operators, equipment makers and silicon providers is essential. The combination of this variety of expertise requires collaboration on the European level.

The ambitious targets of the MAMMOET project are only feasible due to the fact that the project can leverage on already successful and on-going other research activities. The MAMMOET is in line with the long term vision and R&D strategy of its partners, and thereby can profit from significant expertise and IP that has been built up and will be further extended in internal R&D activities and cooperative projects.

Collaboration with projects like METIS (where 5G requirements and scenarios have been established), MULTIBASE (where partners acquired essential know-how on architecture algorithm co-design for reconfigurable baseband, and power efficiency transmitters), Greentouch association (which initiated target 100x improvement in energy efficiency for ICT networks), EARTH project (where partners improved energy efficiency by innovative hardware, network deployment and management mechanisms building on traditional base stations), DRAGON project (where essential known-how on reconfigurable, highly energy efficiency and extremely miniaturized RF-front could be build up) and many other projects inspired and helped the MAMMOET consortium.

The progress of the broadband wireless networks allows numerous new and better services, which can bring great value for Europe's society by offering mobile multimedia services, as well as enabling many new wireless applications (machine-to-machine communication, eHealth, and traffic safety improvement, to name just a few). In the last years, there's a tendency to growing agreement between industry and end-users that minimal energy consumption is equally crucial because of ecological and because it can extend the autonomy and usability of mobile products with wireless interfaces. MAMMOET through the realization of its objective combined both societal aspirations, to progress broadband wireless networks while saving energy.

The project focuses on a quite disruptive transmission scheme, and its actual deployment will depend on its adoption in relevant standards. The partners firmly believed and proved that MaMi makes a great candidate for future broadband wireless, and actively contributed to that.

5.1 Expected impact of MAMMOET

Given the outstanding capacity and energy efficiency potential of this technology, the progress towards convincing proof of concept can stimulate the take up by standards. Eventually, MAMMOET results will then end up in 5G networks and (hardware) systems.

Specifically, through a widespread dissemination of the project expertise and progress, both broad and in-depth knowledge of Massive MIMO technology is raised. Indeed the quite exceptional dissemination results, illustrate the timeliness of the project and recognizes the expertise available in the consortium. Particular project results can also be used beyond the Massive MIMO focus, as for example the channel characterisation and the power efficient transmitters. The positive reactions on the presentations made in the context of standardization initiatives, is promising for a long-lasting impact of MAMMOET.

Chapter 6 Conclusion

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 as early as M02 (D5.1; www.mammoet-project.eu) 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. Three newsletters have been published and distributed. 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 list of dissemination activities has been compiled and updated periodically. A first impression of all activities done within the first project year have been presented in the 1st Periodic Report. An important topic in terms of exploitation is the standardization work within the MAMMOET. This is seen as promotion of the exploitation of the project's foreground.

In the standardization the R&D lines between 4G and 5G are blurred and technologies that are likely to end up in the 5G standards like the Massive-MIMO technology are already being considered as part of the evolution of LTE. In the standardization 3GPP is the key Standards Development Organization that produces the technical specifications concerning 2G, 3G and 4G cellular systems. Just recently in 'September 2015 3GPP started to discuss 5G and it was decided to establish a study group for this topic. There are many open issues to be solved like: technologies-research (Massive-MIMO, dense networks, 5G waveforms and mm-Wave technology), free up spectrum and achieve agreement on specifications (3GPP and ITU-R) in order to have a solution that can be deployed by the operators. Therefore, it is very likely that 5G will be standardized in two phases. The specifications for the first phase are expected to be finalized in late 2018 and mainly targeting conventional sub-6 GHz spectrum bands. Those will be followed by a second phase, which will consider new bands, such as millimeter wave, and more abstruse technologies.

As for the commercial 5G roll-outs agreed specifications and standards are a mandatory requirement, it is expected that the deployment will start in 2020 (see Figure 10).

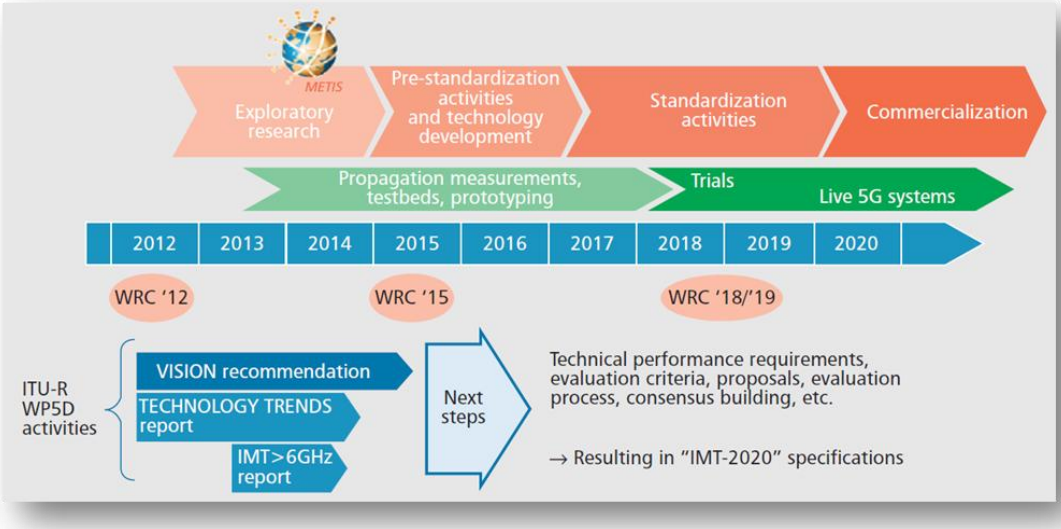

Figure 10: Live 5G Systems Timeline

Chapter 7 List of abbreviations

MaMi	Massive MIMO
MIMO	Multipe Input Multiple Output
ICC	International Communication Conference
3GPP	3rd Generation Partnership Project
IEEE	Institute of Electrical and Electronics Engineers
ESSCIRC	European Solid-State Circuits Conference
EUCNC	European Conference on Network and Communications
ISWC	International Semantic Web Conference
EUSIPCO	European Signal Processing Conference
ISSCC	International Solid-State Circuits Conference
RWW	Radio Wireless Week
KPI	Key Performance Indicators
5GNOW	5th Generation Non-Orthogonal Waveforms for Asynchronous Signalling
RAT	Radio-Access Technology
LTE	Long-Term Evolution
FDD	Frequency Division Duplex
TDD	Time Division Duplex
ETSI	European Telecommunications Standards Institute
ICT	Information and Communications Technologies
R&D	Research and Development
5G	5th Generation
SME	Small Medium Sized Enterprise
IPR	Intellectual Property Rights
RF	Radio Frequency
DoW	Description of Work
ITU-R	International Telecommunication Union Radiocommunication Sector