

**SEVENTH FRAMEWORK PROGRAMME**  
**Theme ICT-2009.1.1**  
***The network of the future***



**Deliverable D6.2**

**Work Package 6 – Exploitation and  
Dissemination**

**D6.2 Year 2 exploitation and dissemination report**

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Real-World Impact

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WP6 leader organization: Nokia Siemens Networks Denmark A/S

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### **Revision history**

Version	Author	Comments
0.1	Péter Fazekas	First draft and ToC
0.2	Péter Fazekas	Filled scientific dissemination sections
0.3	István Kovács	Industrial dissemination and exploitation sections
0.4	Biljana Badic	Industrial dissemination and exploitation sections
0.5	Guillaume Vivier	Industrial dissemination and exploitation sections
0.6	Andrea Cattoni	Scientific dissemination parts
1.0	Michael Dieudonne (PL)	Final check for submission



## EXECUTIVE SUMMARY

The document addresses the most relevant achievements of the SAMURAI project under the main dissemination topics of: *Project website creation and maintenance, Industrial exploitation of results, Standardization and Intellectual Property, Industrial Dissemination and Exploitation, Scientific Dissemination and Academic Didactic Activities.*

The *project website* has attracted significant interest from the scientific community especially in the middle of 2011 due to several dissemination activities of all project partners.

The industrial project partners plan to dedicate significant effort to incorporate the finding of the SAMURAI project into their future products, terminal equipment and algorithms, testing equipment, and radio resource management solutions.

In *standardization*, both 3GPP LTE/LTE-A and IEEE WiMax have been initially targeted especially for the carrier aggregation aspects. However, it has been concluded that the SAMURAI project has the highest impact potential in 3GPP LTE-Advanced Release 11 standardization process with possible influence also on the future LTE Release 12. In accordance with this, a contribution was submitted to 3GPP TSG RAN3, and another one is under preparation on Carrier-based ICIC topics.

In terms of *industrial dissemination* industrial partners have been showcasing the project activities in various technical seminars and workshops as part of their long term research projects.

In terms of *scientific dissemination*, the project has released 16 conference and international workshop papers, with 6 additional accepted papers for 2012 conferences. Three journal papers from the project were published in 2011 and two further papers are written and accepted, these will appear in 2012. Additionally, SAMURAI organized a tutorial workshop at FUNEMS 2011.

The timely research topics of the project have been the basis of several MSc, BSc and PhD student activities and theses at various academic partners of the consortium.



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## 1 Introduction

This deliverable summarizes the Year 2 SAMURAI dissemination and exploitation activities.

The document is structured following the main task described in the project Technical Annex. Section 2 is dedicated to the description of the SAMURAI home page. Section 3 summarizes the main industrial exploitation activities with focus on the standardization and industrial dissemination. Section 4 lists the main publications generated by the project partners, submitted and/or accepted for publication in various IEEE conference papers or journals. Finally, Section 5 contains the workshops, exhibitions and cooperative actions that took place during the reporting period.

## 2 Project website creation and maintenance

The project website has been maintained and updated periodically at the URL <http://www.ict-samurai.eu>. Figure 1 shows the updated layout of the SAMURAI portal. The website contains

- List of all partners
- Contact details
- List and short description of key achievements
- Project description
- News
- List of SAMURAI publications
- Deliverables, with download link to public ones
- Link to internal content management system (BSCW).

The website is maintained and updated by Eurecom. Usage statistics can be found in Figure 2 and Table 1.



SAMURAI is an industrially focused consortium composed of a telecommunication network equipment maker, chipset vendors, test equipment vendor and Universities. The focus of the project is to tackle the challenge of next generation telecommunication systems using multi user MIMO and aggregated spectrum techniques.

## SAMURAI

### SPECTRUM AGGREGATION AND MULTI-USER MIMO: REAL-WORLD IMPACT

SAMURAI is an industrially focused consortium composed of a telecommunication network equipment maker, chipset vendors, test equipment vendor and Universities. The focus of the project is to tackle the challenge of next generation telecommunication systems using multi user MIMO and aggregated spectrum techniques.

#### PARTNERS

1. [Agilent Technologies SANV \(B\)](#), Project coordinator
2. [Intel Mobile Communications \(D\)](#),
3. [Sequans Communications SA \(F\)](#),
4. [Institut Eurecom \(F\)](#),
5. [Aalborg Universitet \(DK\)](#),
6. [Nokia Siemens Networks Denmark A/S \(DK\)](#),
7. [Budapesti Műszaki és Gazdaságtudományi Egyetem \(HU\)](#)

#### FACTS

- **Duration:** 01/2010 - 06/2012
- **Funding scheme:** STREP
- **Total Cost:** €4.596.091,00m
- **EC Contribution:** €3.094.389,00m

#### NEWS

*Fri, 2011-06-17*  
SAMURAI at Future Network and Mobile Summit (FUNEMS) 2011

[Future Network and Mobile Summit \(FUNEMS\) 2011](#)

SAMURAI presented its first Proof-of-Concepts demonstrators for MU-MIMO and Carrier Aggregation. See the [press release](#) for further details.

Further SAMURAI organized a workshop on "Technologies for LTE-Advanced: from Theory to Practice". The presentation slides can be found [here](#).

*Tue, 2011-03-08*  
SAMURAI paper "MU-MIMO in LTE systems" accepted for publication in EURASIP Journal on Wireless Communication and Networking

The paper can be found [here](#).

*Fri, 2011-02-11*  
SAMURAI at the RAS cluster concertation meeting

The presentation given at the RAS cluster concertation meeting can be found [here](#).

*Mon, 2010-11-29*  
Third Project meeting, Sequans, Paris, France

*Thu, 2010-07-01*  
Second Project meeting, BMU, Budapest, Hungary

Figure 1: New SAMURAI webpage

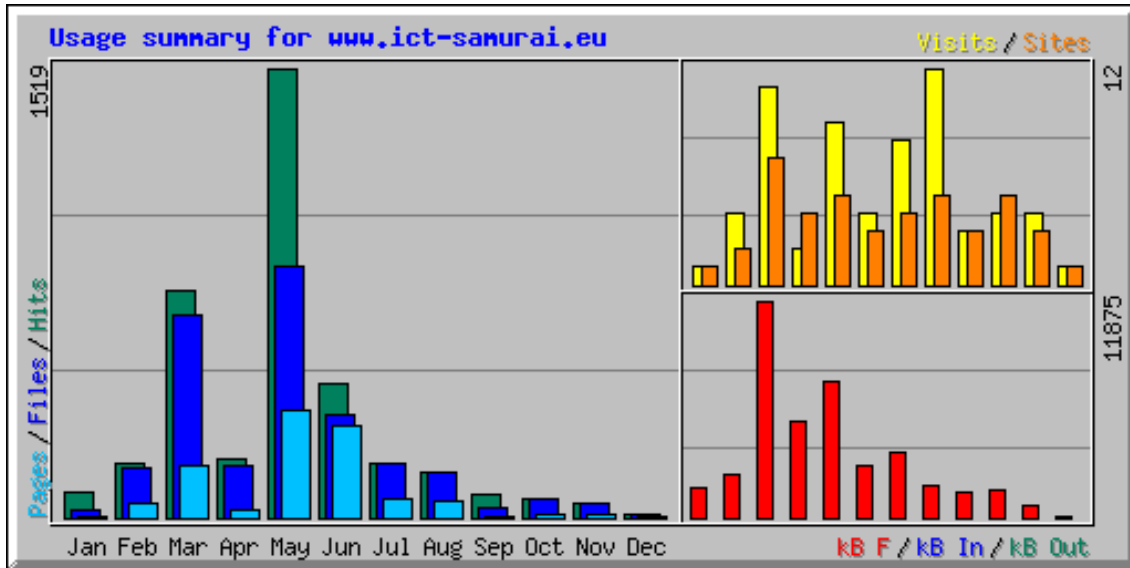


Figure 2: Usage Statistics for ict-samurai.eu

Table 1: Detailed usage statistics of ict-samurai.eu

Summary by Month													
Month	Daily Avg					Monthly Totals							
	Hits	Files	Pages	Visits	Sites	kB F	kB In	kB Out	Visits	Pages	Files	Hits	
<a href="#">Dec 2011</a>	9	9	2	1	1	69	0	0	1	2	9	9	
<a href="#">Nov 2011</a>	2	2	0	0	3	716	0	0	4	8	45	46	
<a href="#">Oct 2011</a>	3	2	0	0	5	1475	0	0	4	10	64	66	
<a href="#">Sep 2011</a>	4	1	0	0	3	1444	0	0	3	4	30	76	
<a href="#">Aug 2011</a>	5	5	1	0	5	1739	0	0	12	54	152	153	
<a href="#">Jul 2011</a>	7	7	2	0	4	3571	0	0	8	67	184	186	
<a href="#">Jun 2011</a>	16	12	11	0	3	2793	0	0	4	311	348	450	
<a href="#">May 2011</a>	72	40	17	0	5	7488	0	0	9	365	851	1519	
<a href="#">Apr 2011</a>	10	9	1	0	4	5295	0	0	2	27	173	195	
<a href="#">Mar 2011</a>	25	22	5	0	7	11875	0	0	11	177	685	768	
<a href="#">Feb 2011</a>	20	19	5	0	2	2396	0	0	4	46	172	186	
<a href="#">Jan 2011</a>	84	26	6	1	1	1679	0	0	1	6	26	84	
Totals						40535	0	0	63	1077	2739	3738	





### 3 Industrial exploitation of results

#### 3.1 Standardization and Intellectual Property

##### 3.1.1 3GPP LTE-Advanced status

The 3GPP LTE Release 11 requirements are currently being discussed by 3GPP members. The 3GPP LTE Release 11 finalization time-line is expected to follow the main steps in Figure 3.

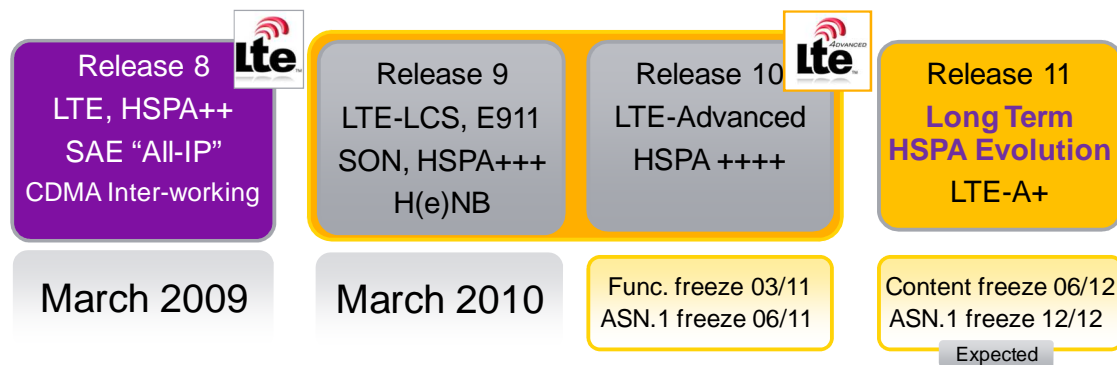


Figure 3: 3GPP Release timeline

Therefore, from 3GPP LTE standardization point of view, the potential contributions of the SAMURAI project can only target LTE Release 11 specifications. The following sections summarize the potential areas and topics which can be addressed within SAMURAI Year 3 activities.

##### 3.1.2 MU-MIMO in 3GPP

MU-MIMO topics of 3GPP are not targeted for standardization within SAMURAI. However, MU-MIMO is in key research focus of the project (e.g. implementation specific network scheduling algorithms and user equipment receiver solutions, PoC implementation, CSI imperfections, etc) but standardization inputs are not foreseen.

##### 3.1.3 Carrier Aggregation – Autonomous Component Carrier Selection in 3GPP

The 3GPP work/study items (WI/SI) for the LTE release 11 have been prioritized based on feedback from major operators and service providers [8]. It was decided that the work item on 'LTE Carrier Aggregation Enhancements' is to be continued in TSG RAN WG1, while the work item on 'Carrier based HetNet ICIC for LTE' is continuing in TSG RAN WG3.



These two work items are related to the ACCS PoC development and evaluation work addressed in SAMURAI. The initial ACCS concept was proposed and evaluated for local area scenarios with high density and un-coordinated Femto/Home eNB deployments [2][7]. In 3GPP LTE Release 11 similar mechanisms based on ACCS are under consideration for HetNet macro-pico deployment scenarios as well. Motivated by these early ACCS studies [7] (and references therein) and the newly defined LTE Release 11 (work item) WI for carrier based eICIC studies, 3GPP TSG RAN 3 has highlighted recently the need for "new terminologies for various types of carriers in the context of the carrier-based ICIC". Their proposal is to use the terminology of *Base Carrier* (BC) and *Auxiliary Carrier* (AC) as described in [9]:

- A *BC* is a carrier deployed mainly for purpose of ensuring reliable coverage and seamless mobility services;
- An *AC* is a carrier deployed only for providing maximized capacity, which can be useful in for instance data-demanded applications, premium services, etc.

This terminology is equivalent with the previously employed ACCS terminology throughout the SAMURAI documents and deliverables, with:

- *Base Component Carrier* (BCC) = *Base Carrier* (BC), and
- *Supplementary Component Carrier* (SCC) = *Auxiliary Carrier* (AC).

In 3GPP TSG RAN3 a further distinction is proposed to be made between open- and closed-mode access eNBs (macro, pico or femto). The initial ACCS concept was targeted for closed-mode femto cell operation and, for these "[...] there is a slight difference in the application of the BC/AC concepts. Usually, close-mode HeNBs are *Customer Premises Equipment (CPE)* to be manually deployed by end users without usual network planning. In addition, users have sole discretion in turning on and off their close-mode HeNBs. From the moment when a close-mode HeNB is switched on until it is turned off, at least one cell will be powered on, which may be considered as a BC. On the other hand, if a cell's powered on/off is controlled by the closed HeNB for premium or dedicated services, the cell is considered as an AC." [9].

As a final note, a general framework for *Operational Carrier Selection* has been proposed in 3GPP [10] related to the WI on "Carrier Based HetNet ICIC". Under this framework, the ACCS for femto cell operation as addressed in SAMURAI can be considered to be part of the more general *Autonomous Operational Carrier Selection (AOCS)* mechanisms proposed recently for HetNet scenarios.



### **3.1.4 SAMURAI contributions**

During Year 2, there has been one 3GPP TSG RAN 3 contribution on the ACCS topic from NSN. This contribution is R3-113008, "Autonomous Operational Carrier Selection Proposals", presented at 3GPP TSG-RAN WG3 Meeting #74, San Francisco, USA, November 14-18, 2011. [11]

For the Year 3 of the SAMURAI project, partner NSNDA and AAU plan to continue the work on the ACCS concept and generate potential contributions to 3GPP LTE Release 11 standardization process. Therefore another 3GPP contribution is currently under preparation, which is foreseen to be submitted at the first quarter of 2012.

### **3.1.5 MU-MIMO and CA in IEEE**

Although WiMAX standardisation and commercial deployment were active when the SAMURAI project was defined and build, and to some extent during the first year, it appears now that the WiMAX ecosystem is running at a slower pace now.

The WiMAX2 definition (corresponding more or less to LTE Rel. 10) is frozen, including MU-MIMO and CA. However, little traction from the market is seen to upgrade the existing WiMAX network to WiMAX2 (except possibly in Japan where the regulation could be technology specific).

Therefore, SAMURAI didn't put too much effort to contribute to IEEE or WiMAX forum, but still monitor what was on-going in these bodies.

## **3.2 Industrial dissemination**

### **3.2.1 Nokia Siemens Networks**

Internally in Nokia Siemens Networks, the SAMURAI project is part of the general framework of long-term research projects. Regular internal project meetings have been organized where the SAMURAI results and status have been shared with other research groups with the company. Additionally, the SAMURAI work has been also presented as part of two technical seminars, for local Aalborg University and Nokia Siemens Networks Denmark and for global Nokia Siemens Networks audience.

In Year 3 Nokia Siemens Networks will continue to disseminate and raise awareness on the SAMURAI work in these types of internal technical seminars. Several internal demonstrations and presentations



of the ACCS PoC developed in WP5 are planned in the first half of 2012 in order to get feedback from radio and standardization experts. The final ACCS PoC demonstration to be presented in the final SAMURAI technical project review to the European Commission will be aligned as much as possible with the 3GPP LTE-Advanced Release 11 "Carrier Based HetNet ICIC" assumptions.

### **3.2.2 Agile Technologies**

The SAMURAI project is part of a general framework for long-term research within Agilent Technologies. Regular internal project meetings were conducted where the results and status of SAMURAI were shared with other research technical staff members within the company. Additionally, the SAMURAI work has been presented as part of technical seminar to the Agilent Research group in Aalborg, Denmark and in the Rotselaar, Belgium facility.

In Year 3 Agilent Technologies will continue to disseminate and raise awareness on the SAMURAI work both in internal as well as external technical seminars.

### **3.2.3 IMC**

At IMC, regular internal project meetings and discussions have organized where the SAMURAI results and status have been shared with other groups within the company. The SAMURAI work has been also presented as part of a several internal LTE workshops. IMC will continue to disseminate and raise awareness on the SAMURAI work in internal technical seminars and workshops.

## **3.3 Industrial Exploitation**

### **3.3.1 Sequans**

Sequans Communications is a SME having the goal to deliver to the market innovative chipset solutions to enable 4G mobile systems. The outcome of SAMURAI project are planned to be exploited in future products, such as for instance within the SQN3110 family (LTE chipsets).

During the second year, SEQ pursued the activity related to feedback generation in the user terminal, to support close-loop MIMO. The outcome of this activity will be exploited internally to specify the CQI/PMI/RI report generation for next generation LTE UE chipsets.

An activity related to spur mitigation was conducted in the framework of WP4, in which the support of carrier aggregation may conduct to



the use of non-ideal RF components that could generate spurs in the receiver chain. Beyond spurs, the aggregation of contiguous band could not be perfect and as such include interference from the transmit part or from the environment. The technique developed in WP4 to mitigate those spurs was implemented and prototyped on a WiMAX terminal. It is planned to include such functionalities in current LTE chipset, to anticipate the transition to next gen product supporting carrier aggregation.

Although the demonstration of CA able receiver on existing WiMAX board did not conclude as expected, the lessons learned from this development will be exploited for the future LTE development of a CA able receiver.

### **3.3.2 IMC**

One of IMC's major competencies is Mobile Phone Platforms. In addition to baseband processors, radio frequency transceivers and power management chips as the classical semiconductor components, the know-how spectrum covers platforms for mobile phones, including software solutions. Thus, the outcome of SAMURAI project are planned to be exploited in future products.

During the second year, final feasibility study of selected MU-MIMO receiver algorithms was carried out as a part of WP3. Algorithm implementation in fixed point C for optimal performance was completed and transferred to Proof-of-Concept in WP5 where further investigation and optimization has been carried out. In the framework of WP2, IMC has supported activities related to feedback generation. The impact of MU-MIMO CQI estimation schemes on MU-MIMO receiver algorithms has been demonstrated. IMC also actively participates in standardization/regulation bodies like ETSI (European Telecommunications Standards Institute), 3GPP, IEEE, ITU, and in WP4, IMC provided support identification of spectrum aggregation deployment scenarios in particular with regards to 3GPP standardization activities.

### **3.3.3 Agilent Technologies**

One of the important goals of Agilent technologies within the Samurai project is to deliver to the market innovative test and measurement solutions for 4G mobile communication systems. The outcome of SAMURAI project will be exploited in both the current and future feature products that are designed to accommodate both carrier aggregation and multi-user MIMO scenarios. One such product is



Agilent's PXB which is also considered for proof of concept demonstration within the SAMURAI project.

In WP4, technical enablers to support carrier aggregation were under investigation and should be included in the future test and measurement products as soon as market requirements are more clearly known.

### **3.3.4 Nokia Siemens Networks**

The carrier aggregation feature is an important building block in LTE-Advanced (Release 10-12). Nokia Siemens Networks aims to provide advanced LTE network optimization and radio resource management solutions which take full advantage of carrier aggregation transmission schemes in both downlink and uplink while minimizing the required radio signaling and user equipment energy consumption. Traffic management and load balancing mechanisms are envisioned to utilize the carrier aggregation schemes as an overall enabling feature.

Specifically targeting the large scale small-cell deployments, as part of the foreseen heterogeneous networks (HetNet) deployments, the carrier based ICIC schemes will be further developed and promoted by Nokia Siemens Networks. The learning from the SAMURAI ACCS studies and PoC development will be used as references for the newly proposed schemes and solutions in 3GPP LTE.



## 4 Scientific Dissemination

### 4.1 Publications

#### 4.1.1 Conference papers

##### 4.1.1.1 Papers in proceedings, presented at conference

Rizwan Ghaffar; Raymond Knopp, "Interference Sensitivity for Multi-user MIMO in LTE", IEEE International Workshop on Signal Processing Advances in Wireless Communications (SPAWC 2011), San Francisco, USA, June 2011.

R. Ghaffar and R. Knopp, "Mixed CSIT DL Channel: Gains with Interference Aware Receivers", European Wireless Conference, Vienna, Austria, April 2011.

Imran Latif, Florian Kaltenberger, Rizwan Ghaffar, Raymond Knopp, Dominique Nussbaum, Hervé Callegaert, and Gael Scot, "Performance of LTE in rural areas - benefits of opportunistic Multi-User MIMO," *IEEE Personal Indoor Mobile Radio Communications (PIMRC 2011 - WACC)*, Toronto, Canada, September 2011.

Nguyen, Hung Tuan; Kovács, István; Wang, Yuanye; Pedersen, Klaus "Downlink Performance of a Multi-Carrier MIMO System in a Bursty Traffic Cellular Network", *IEEE International Conference on Communications (ICC2011)*, Kyoto, Japan, June 2011.

Nguyen, Hung Tuan; Kovács, István Z.; Wang, Yuanye ; Pedersen, Klaus "Feedback Compression Schemes for Downlink Carrier Aggregation in LTE-Advanced", *IEEE Vehicular Technology Conference (VTC Fall)*, San Francisco, USA, CA, September 2011

Vivier, Guillaume ; Badic, Biljana ; Cattoni, Andrea Fabio ; Choi, Hyung-Nam ; Duplity, Jonathan ; Kaltenberger, Florian ; Kovacs, István Z.; Nguyen, Hung Tuan ; Sezginer, Serdar "Spectrum Aggregation: initial outcomes from SAMURAI project", *Future Networks and Mobile Summit (FUNEMS 2011)*, Warsaw, Poland, June 2011.

Berardinelli, Gilberto; Zetterberg, Per; Tonelli, Oscar; Cattoni, Andrea Fabio; Sørensen, Troels Bundgaard; Mogensen, Preben "An SDR architecture for OFDM transmission over USRP2 boards", *Asilomar*



*Conference on Signals, Systems and Computers, Pacific Grove, USA, November 2011*

Tonelli, Oscar; Berardinelli, Gilberto; Cattoni, Andrea Fabio; Sorensen, Troels Bundgaard; Mogensen, Preben "Software Architecture Design for a Dynamic Spectrum Allocation-Enabled Cognitive Radio Testbed", *European Signal Processing Conference (EUSIPCO 2011)*, Barcelona, Spain, August-September 2011.

Albert Mraz and Peter Fazekas, "Effect of Imperfect Channel Estimation on LTE MU-MIMO Performance", *Future Networks and Mobile Summit (FUNEMS 2011)*, Warsaw, Poland, June 2011

Zijian Bai, Biljana Badic, Stanislaus Iwelski, Tobias Scholand, Rajarajan Balraj, Guido Bruck, Peter Jung "On the Receiver Performance in MU-MIMO Transmission in LTE", *International Conference on Wireless and Mobile Communications (ICWMC 2011)*, Luxembourg, June 2011

Zijian Bai; Iwelski, S.; Bruck, G.; Jung, P.; Badic, B.; Scholand, T.; Balraj, R." Receiver performance-complexity tradeoff in LTE MU-MIMO transmission", *IEEE International Workshop on Mobile Computing and Networking Technologies (WMCNT 2011)*, Budapest, Hungary, October 2011

Albert Mraz and Peter Fazekas, "Analysis of Channel Estimation Imperfections Within the 3GPP LTE Physical Layer", *IEEE International Conference on the Network of the Future (NOF 2011)*, Paris, France, November, 2011

Filippi, Morris; Cattoni, Andrea Fabio; Le Moullec, Yannick; Sacchi, Claudio "SDR Implementation of a Low Complexity and Interference-resilient Space-Time Block Decoder for MIMO-OFDM Systems", *4th International Workshop on Multiple Access Communications (MACOM 2011)*, Trento, Italy, September 2011. In: *Lecture Notes in Computer Science*, 2011, Volume 6886/2011, Springer

#### **4.1.1.2 Accepted conference papers (submission in 2011)**

Cattoni, Andrea Fabio; Nguyen, Hung Tuan; Duplicy, Jonathan; Tandur, Deepaknat; Badic, Biljana; Balraj, R.; Kaltenberger, Florian; Latif, Imran; Bhamri, Ankitt; Vivier, Guillaume; Kovacs, Istvan; Horvat,





Peter "Multi-User MIMO and Carrier Aggregation in 4G Systems: the SAMURAI Approach", *IEEE Wireless Communications and Networking Conference (WCNC 2012)*, Paris, France, April 2012. Workshop on 4G Mobile Radio Access Networks.

Wang, Hua; Nguyen, Hung Tuan; Rosa, Claudio; Pedersen, Klaus "Uplink Multi-Cluster Scheduling with MU-MIMO for LTE-Advanced with Carrier Aggregation", *IEEE Wireless Communications and Networking Conference (WCNC 2012)*, Paris, France, April 2012

Biljana Badic Rajarajan Balraj, Tobias Scholand, Zijian Bai, Stanislaus Iwelski "Impact of Feedback and User Pairing Schemes on Receiver Performance in MU-MIMO LTE Systems", *IEEE Wireless Communications and Networking Conference (WCNC 2012)*, Paris, France, April 2012

Imran Latif, Florian Kaltenberger, Raymond Knopp "Link Abstraction for Multi-User MIMO in LTE using Interference-Aware Receiver", *IEEE Wireless Communications and Networking Conference (WCNC 2012)*, Paris, France, April 2012

Biljana Badic Rajarajan Balraj, Tobias Scholand, Zijian Bai, Stanislaus Iwelski "Analysis of CQI prediction for MU-MIMO in LTE Systems", *IEEE Vehicular Technology Conference (VTC2012-Spring)*, Yokohama, Japan, May, 2012

Nguyen, Hung Tuan; Kovács, István Z. "Downlink Radio Resource Management for LTE-Advanced System with Combined MU-MIMO and Carrier Aggregation Features", *IEEE Vehicular Technology Conference (VTC2012-Spring)*, Yokohama, Japan, May, 2012

#### **4.1.1.3 Papers presented at COST workshops**

Johansen, Jeppe; Enevoldsen, Sune; Pucci, Vincent; Tonelli, Oscar; Cattoni, Andrea Fabio; Le Moullec, Yannick "Analysis of the USRP2 Firmware: system architecture overview" International Workshop of the COST Action IC0902 *Cognitive Radio and Networking for Cooperative Coexistence of Heterogeneous Wireless Networks*, Barcelona, Spain, October, 2011

Berardinelli, Gilberto; Zetterberg, Per; Tonelli, Oscar; Cattoni, Andrea Fabio; Sørensen, Troels Bundgaard; Mogensen, Preben "An SDR



Architecture for OFDM Transmission Over USRP2 Boards”, International Workshop of the COST Action IC0902 *Cognitive Radio and Networking for Cooperative Coexistence of Heterogeneous Wireless Networks*, Barcelona, Spain, October, 2011

Tonelli, Oscar; Berardinelli, Gilberto; Tavares, Fernando Menezes Leitão; Cattoni, Andrea Fabio; Da Silva, Luiz A “Coexistence Issues in multi-system Cognitive Radios”, International Workshop of the COST Action IC0902 *Cognitive Radio and Networking for Cooperative Coexistence of Heterogeneous Wireless Networks*, Barcelona, Spain, October, 2011

#### **4.1.1.4 Papers with pending acceptance notification (preparation in 2011)**

Nguyen, Hung Tuan; Kovács, István Z. “A MU-MIMO CQI estimation method for MU-MIMO UEs in LTE systems” submitted to IEEE VTC Fall 2012, Québec City, Canada, September 2012

### **4.1.2 Journal papers**

#### **4.1.2.1 Published journal papers**

Duplicy, Jonathan; Badic, Biljana; Balraj, Rajarajan; Ghaffar, Rizwan; Horvath, Peter; Kaltenberger, Florian; Knopp, Raymond; Kovács, István Z.; Nguyen, Hung Tuan; Tandur, Deepaknath; Vivier, Guillaume “MU-MIMO in LTE Systems”, *EURASIP Journal on Wireless Communications and Networking*, March, 2011.

Rizwan Ghaffar and Raymond Knopp “Interference-aware receiver structure for multi-user MIMO and LTE” *EURASIP Journal on Wireless Communications and Networking*, Volume 2011:40, July, 2011

Zijian Bai; Badic, B.; Iwelski, S.; Scholand, T.; Balraj, R.; Bruck, G.; Jung, P. “On the Equivalence of MMSE and IRC Receiver in MU-MIMO Systems” *IEEE Communications Letters*, Volume: 15 Issue:12, December 2011

#### **4.1.2.2 Accepted journal papers (submission in 2011)**

Garcia, Luis Guilherme Uzeda; Kovács, István Z.; Pedersen, Klaus; Da Costa, Gustavo Wagner Oliveira; Mogensen, Preben “Autonomous



Component Carrier Selection for 4G Femtocells: A fresh look at an old problem”, *IEEE Journal on Selected Areas in Communications (JSAC)*, to appear in April 2012.

Lajos Nagy “Modified MIMO Cube for Enhanced Channel Capacity”, *International Journal on Antennas and Propagation*, to appear in 2012

## **4.2 Academic Didactic Activities**

### **4.2.1 Student projects**

- BME M.Sc.E.E. student Levente Nika finished MSc thesis in SAMURAI topic related to channel estimation imperfections in MU-MIMO systems.
- BME BSc student Gergely Kasrácsony finished his thesis on the effect of CSI imperfections on MU-MIMO, using Matlab simulator.
- EURECOM masters student project for Eric Foti-Meli. The goal of this project is to evaluate the PHY performance of LTE in high speed scenarios using the OpenAirInterface evaluation platform. This involves
  - review of channel models and their implementations for high speed scenarios
  - selection of the best suited channel model and its implementation on the OpenAirInterface platform
  - Definition of test-cases and performance evaluation
- EURECOM masters student project for Sandip Gangakhedkar. The goal of this project is to scrutinize the OpenAirInterface LTE software and write a technical specification of how to implement carrier aggregation on OpenAirInterface.
- At partner AAU, an MSc thesis project related to the design of a TxRx within the USRP FPGA platform is currently ongoing.
- At AAU, there is also a semester student project on the analysis of the USRP Firmware and the feasibility of FFT/IFFT insertion on the FPGA, and the analysis of requirements and design in FPGA of turbo coder/encoder.



#### 4.2.2 PhD Student projects

- Ankit Bhamri joined Eurecom as a PhD student in January 2011. The topic of his PhD thesis is "MU-MIMO Algorithms: Design, Validation and Implementation for LTE/LTE-A"
- Imran Latif who has been a PhD student at Eurecom since 2010, successfully completed his midterm defense in 2011 in the topic "Physical Layer Design for Next Generation Wireless Communication".
- BME involved PhD student Zoltán Jakó in SAMURAI research topic on effect of imperfect CSI on MU-MIMO scheduler performance.
- At partner AAU, several PhD students were contributing to SAMURAI in the reporting period. Two of them have specific SAMURAI topics:
  - defense of Luis Garcia, the PhD student who created his PhD thesis on ACCS and was main author of corresponding journal paper
  - PhD student Oscar Tonelli who was the initiator and is main developer of the ASGARD platform and he is continuously contributing to SAMURAI deliverables



## **5 Workshops, exhibitions, demonstrations, liaisons**

### **5.1 Workshops/special sessions in 2011**

#### **5.1.1 Workshop at Future Networks and Mobile Summit (FUNEMS)**

The project organized the workshop entitled "Technologies for LTE-Advanced: from Theory to Practice", that was held on 17<sup>th</sup> June in Warsaw, as part of the FUNEMS 2011 conference. The workshop consisted of five talks, from recognised international experts of their fields. The participation was high, therefore the workshop is considered as a success.

The program of the workshop contained the following presentations:

- "3GPP LTE / LTE-A Standardization: Status and Overview of Technologies", Deepaknath Tandur, Agilent Technologies, Belgium
- "Design and Challenges for UE with Carrier Aggregation Capability", Guillaume Vivier, Sequans Communications, France
- "Carrier Aggregation: From Physical Layer to Upper Layers", Istvan Zsolt Kovacs, Nokia Siemens Networks, Denmark
- "Recent Advances in Relaying Technology", Jacek Gora, Nokia Siemens Networks Sp. z o.o., Poland
- "MU-MIMO in LTE/LTE-A: Performance Analysis", Rizwan Ghaffar, EURECOM, France

### **5.2 Accepted workshop proposals for 2012 events**

#### **5.2.1 Joint workshop at WCNC 2012**

The SAMURAI consortium organizes jointly with the EU ICT projects BUNGEE, WHERE2 and ARTIST4G the "Workshop on 4G Mobile Radio Access Networks." The workshop takes place on Sunday, 1 April 2012 at WCNC 2012 in Paris. Although this is an event outside the reporting period, its organization, with related invited paper as well as liaison activities with mentioned EC projects were carried out in 2011.

### **5.3 Public demonstrations**

The main demonstration opportunity of the SAMURAI project was the FUNEMS 2011 event. Therefore a booth was set up and used jointly together with LOLA project. The booth featured a set of posters presenting the results achieved as well as live demos obtained in the



project's framework. Both carrier aggregation and multi-user MIMO concepts were presented as demonstrations to the audience. The attendance was quite satisfactory. The live demos were well appreciated by the audience and every visitor got a share of it. The booth was also visited by the project officer and other EU commission officers. Good contacts from both the industry and the academic worlds were established. SAMURAI leaflets were distributed as well as a significant number of company leaflets.

The physical demo setup in particular contained the following items:

- Agilent MXA signal analyzer platform
- Sequans receiver platform
- Aalborg University software radio based platform for automatic component carrier selection (ACCS) demonstration
- EURECOM OpenAirInterface demonstrator setup for MU-MIMO

Further public demonstration of the ASGARD hardware/software platform developed in SAMURAI took place in COST IC0902 Second International Workshop, see below.





Figure 4: Demo booth at FUNEMS 2011

## **5.4 Collaborations with other research activities**

### **5.4.1 COST IC0902**

The SAMURAI consortium presented its topics and some particular research and developments towards COST IC0902 project, through massive presence at its Second International Workshop in October 2011, Barcelona. Here several contributions related to the analysis of the USRP firmware and the design of multicarrier OFDM PHY based on USRP boards were presented. Besides technical presentations, spectrum coexistence experimental demonstration was held. This was a good opportunity for dissemination of SAMURAI results towards a wide audience from more than 60 different institutions. This also set the base for further project level cooperations.

### **5.4.2 LOLA project**

SAMURAI project was cooperating with LOLA project through the common booth at FUNEMS 2011. Through the common partner Eurecom, and the common platform used by both projects, the cooperation is continuous.



### **5.4.3 CREW project**

The SAMURAI-developed ASGARD software platform and the basic ACCS/BCC selection concept was the fundamental basis for a spectrum coexistence experiment in cooperation with Trinity College Dublin and the CREW EU FP7 project.

### **5.4.4 Joint workshop**

As described above, a joint workshop with ARTIST4G, BUNGEE and WHERE2 projects was organized, to be held in 2012. This is an opportunity to learn about each project and to harmonize activities and set up further joint actions.

### **5.4.5 EU coordination events**

SAMURAI took part and presented its topics at the EU RAS cluster concertation meeting in January, 2011. Furthermore, consortium members participated in the RAS cluster meeting which was held in conjunction with the FUNEMS event.





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