

SHARING

SELF-ORGANIZED HETEROGENEOUS ADVANCED RADIO NETWORKS GENERATION

Deliverable D2.3

Dissemination and exploitation report

Date of delivery	23/02/2016
Contractual date of delivery	29/02/2016
Project number	C2012/1-8
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Dissemination level	PU/RE/CO
Work package	2
Version	V1.1
Total number of pages	41

Abstract:

This deliverable gives an overview of all public documents (deliverables, publications, presentations, press releases) generated by the project; as well as an insight on the dissemination effort and exploitation activities. For more details you can refer to the exploitation and dissemination plan deliverable D2.1 released in October 2013.

Keywords: dissemination, exploitation

Document Revision History

Version	Date	Author	Summary of main changes
0.1	17/11/2015	Antti Ratilainen (ERICSSON)	Initial draft
1.0	12/02/2016	Antti Ratilainen (ERICSSON)	First complete version

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1 INTRODUCTION

SHARING project will contribute, through the dissemination and promotion of project results, to the medium-to-long term evolution of future mobile networks. Many partners of the consortium are active in different standardization bodies and research fora; their collaborative work in SHARING will contribute to inspire a coherent and consolidated development of system specifications.

Dissemination

SHARING will use different means to leverage the dissemination and promotion of the project results:

- Project web site
- Press releases
- Contributions to international conferences and journals
- Organization or participation to international workshops and events
- Contributions to standards

Exploitation of the project results

The SHARING consortium comprises industry partners (comprising operators, manufacturers and SMEs) and academic partners (universities, engineering schools and a public R&D center). For each category, the exploitation strategy will be targeted to address specific needs:

Network operators involved in the SHARING project are well aware that standards will continue to play a crucial role in market development strategies. Operators will take advantage of the project's results to help standards and regulation bodies to specify appropriate system requirements and solutions, in collaboration with the NGMN initiative when suitable.

The main objective of manufacturers and SMEs involved in SHARING is to benefit from the know-how acquired during the project to be ahead from their competitors when technologies dealt within the project come to real life. As a consequence of their contribution to early system specifications and thanks to their IPRs, manufacturers and SMEs will be in the position to exploit the project results by addressing the market with competitive products at the appropriate time.

Academic partners participating in the SHARING consortium are naturally interested in building on and further developing their existing research achievements and know how in radio communications. Their participation will allow them to keep track of the industrial realities, and therefore to address the relevant challenges in a realistic way.

The management of knowledge, intellectual property and other aspects of innovation will be handled in the Consortium Agreement. After the necessary steps for ensuring the protection of IPRs have been made, information will be disseminated within the project and to external bodies, in the form of publications and presentations to regulatory and standards bodies.

For more details you can refer to the exploitation and dissemination plan deliverable D2.1 released in October 2013.

2 EXPLOITATION AND DISSEMINATION

2.1 Overall description

2.1.1 Operators

Operator participation in SHARING has been mainly based on skill development, internal and external dissemination as well as pre-integration technology development through a demonstration platform. The individual exploitation and dissemination activities of the two operators of the project are detailed below:

FT-Orange (FT – T, France)

During the first year of the project, FT-Orange has developed/enhanced its capabilities and know-how on a large variety of topics such as flexible interference management, multi-node coordination, advanced receivers, next generation SON functionalities and environment-aware radio resource management for intra-LTE heterogeneous networks, device-to-device communications and the corresponding architectural impacts. This know-how serves the operator in multiple ways: (1) helps better determine/steer the Group's standardization strategy in accordance with its mid-term interests, (2) provides input to internal studies/work which supplies the Group affiliates with recommendations on the deployment of new LTE-A features, (3) training of the Group employees on new LTE-A features in order for them to develop new skills/knowledge on the upcoming technologies, and (4) provides input to discussions with the vendors which take place within the context of Request for Proposals (RFPs) or (pre-deployment) trials.

One very important dissemination event for Orange has been the annual Orange Labs Research Exhibition (OLRE) which took place in November 2014. A SHARING-sponsored demonstration has been presented in this important event. The demonstration included the presentation of the concept of Virtual Small Cells (VSC), which is studied/explored within SHARING (Task 4.1 – D4.2). The VSC demonstration shows the effectiveness of VSCs on increasing the network capacity, making networks greener, with a more flexible infrastructure, all this at a lower CApital Expenditures (CAPEX). The demo was well attended and considerable interest was shown by participants. We were visited by a very diverse public coming from different Orange entities as well as numerous VIP and Executive Committee members. Also, more than 30 companies, universities and research centers attended the demonstration. The demonstration showed that VSCs, when reconfigured according to traffic fluctuation, can provide a 50% throughput increase and reduce the global network consumed power in a 27% compared to an only-macro-cell deployment in a dense urban scenario and full buffer traffic mode.

FT-Orange has also led/participated to the organization of SHARING-related workshops and special sessions as part of project dissemination. More details on these workshops and special sessions can be found below in section 2.3.3.

AVEA (AVEA – T, Turkey)

As being one of the major telecom operators in Turkey, AVEA has been experiencing rapid growth in its data traffic due to growing number of subscribers. Big portion of this traffic stems from multimedia applications such as video, high definition contents, etc. In observance of this fact, AVEA has been seeking alternative solutions as means to offload most of its data traffic to alternative networks such as Wi-Fi, especially in major meeting/crowding locations, such as the airports, concerts or stadiums.

As of 2015 Q3, AVEA has nearly 17 million subscribers and more than 5000 Wi-Fi access points deployed all over Turkey. AVEA is interested in using Wi-Fi Offload platform being developed in SHARING project to open up new opportunities for coverage and capacity improvements as well as instantiating new services and business models.

In that regard, SHARING project has directed AVEA to develop innovative offloading solutions to alternative technologies by developing a Wi-Fi based solution on a multi-operator (fixed and mobile network operators) environment platform that can support AVEA's drive towards improved capacity. A proof-of-concept implementation of an intelligent integrated offloading platform is developed and presented in several dissemination events. This new integrated Wi-Fi Offload approach – that AVEA plans to incorporate to their own infrastructure – will add a key competitive advantage over other mobile operators operating in the same region.

2.1.2 Manufacturers

Manufacturer participation in SHARING includes inputs to related standardization forums, patenting, different kinds of prototyping and demonstration efforts, as well as contributions to various conferences and workshops. Furthermore, the work in SHARING is expected to provide valuable inputs to the development of future products and services. The individual exploitation and dissemination activities of the three manufacturers and six SMEs are detailed below.

Mitsubishi Electric R&D Centre Europe (MER - M, France)

In 1995, Mitsubishi Electric, a leading company in electronics and telecommunication, created a research laboratory in France, formerly named ITE/TCL (Information Technology Europe - Telecommunication Lab) focused on future generations of wireless communication systems. This laboratory recently evolved to include technologies related to energy and environment, and is now named Mitsubishi Electric R&D Centre France (MERCE-France). This laboratory employs today about 25 engineers. Current activities in the telecommunication field cover short-term studies and developments addressing the fiber optic (EPON and evolutions) development in France and advanced research on future cellular systems (B3G 3GPP/LTE, 4G IMT-Advanced). MERCE has participated to various European and French RNRT projects, and is taking active part to relevant standardization bodies (SMG/3GPP, ETSIBRAN, IEEE, etc.). Moreover, direct collaborations with European universities and research laboratories are established.

In the field of mobile communications, MERCE developed an expertise that encompasses advanced architecture for mobile communication networks, digital communications (modulation, channel coding, equalization, smart antennas, space-time codes, etc.), protocols (multiple access protocols, error detection and correction, resource allocation, handover, etc.), implementation (hardware and software architecture and technologies). In particular, MERCE has participated in numerous national and European collaborative projects related to digital communications all of them targeting B3G and 4G cellular systems and based on MIMO and multicarrier technologies.

MERCE is mainly active in SHARING WP4 by providing a complete set of radio resources management algorithms for heterogeneous networks (HetNet) deployment scenarios and setting and leading task 4.4 on spectrum allocation for heterogeneous networks. The other major contribution of MERCE is on energy saving techniques for HetNets as described in WP4 task4.3.

As a research laboratory of Mitsubishi Electric, MERCE will disseminate the SHARING project results and follow standardization of 3GPP RAN WG2 and RAN WG3 on small cells within the framework of release 12, 13 and beyond. More precisely MERCE will follow the discussions of the standardization on small cells enhancement and energy saving.

MERCE is also planning to disseminate the most advanced results of SHARING project in relevant academic conferences.

Thales Communications & Security (TCS - M, France)

Thales Communications & Security (TCS) is one of the few companies in the world to address all telecommunications segments. TCS is a major branch of the Thales Group. The Thales Group revenues total €12.7 billion, half from the civilian businesses and half in the defense domains. TCS division revenues reached €2.8 Billion employing 13,000 people in 20 countries. The division addresses all the segments of the telecommunications market: radio-communications, IP networks, satellite communication, network administration and security.

TCS has a long experience in mission critical Information Systems and secure infrastructures for systems and networks, including Internet and Intranets. R&D investment is realized by over 10,000 engineers, including 4,200 researchers and concretized by more than 1,500 patents filed. Within Thales Communications and Security (TCS), the R&D Signal Processing & Multimedia team performs advanced studies on signal and antenna processing techniques, digital wireless communication, cross layer optimization and cognitive radio. Platforms are developed for feasibility studies. The team maintains close links with the French administration, SMEs, University laboratories and European research actors.

In SHARING, TCS is mainly involved in WP3 "Flexible air interface", and WP5 "Advanced relaying and D2D solutions". In WP3, TCS studies advanced MIMO schemes and flexible interference concept. In WP5 TCS focuses on advanced relaying techniques and resource allocation especially for multi-hop scenarios in mesh deployments.

TCS has strong experience in taking part to industrial and cooperative international projects, and more especially to projects related to MIMO and relaying techniques. Through SHARING, TCS targets the following business segments:

- Radio communication products (aeronautic use, surveillance,...);
- Private radio communication products (police, firefighters,...);
- Spectrum monitoring products (for spectrum surveillance, signal and interference analysis).

PMR solutions are used by public safety officials such as the police, fire-fighters, medical professionals, or local government authorities who need to rely upon dedicated networks for day-to-day missions as well as crisis or special event management. Over the past ten years, PMR systems used by public safety and law enforcement professionals all over the world are mainly focus on voice, text messaging and low data rate services. In addition to voice and text, PMR users have emerging needs driven by the fast changing technological environment: now a PMR system needs to offer rich multimedia services such as images, video, face recognition and database access. TCS has been proposing PMR solutions for a long time, with its TETRA networks called Digicom25, and also with proprietary solutions based on WiMAX. Recently TCS extended his offer of PMR systems by revealing NEXIUM Wireless which is the first LTE-based solution adapted to civil and security forces' mission-critical applications. It offers high speed data services (based on LTE 4G international standard), including broadband video applications, while still providing existing PMR services. This offer also includes a new professional smartphone, TeSquad, delivering broadband mission-critical applications in a ruggedized form-factor and enabling secured communications. TeSquad integrates a solution "push-to-talk" enriching NEXIUM Wireless by offering professional services (group communication, conference, emergency calls) to protection forces. Finally, Thales launched in 2014 a MVNO offer: Eiji. It is a suite of secure mobile telecommunications services for professional.

TCS will promote the exploitation of the results of SHARING in its product portfolio and more specifically regarding its activities linked with the next generation of high data rate professional mobile radios (PMR) based on LTE-A, i.e. the Wireless NEXIUM line. The exploitation plan for the possible integration of SHARING innovations into NEXIUM is to foster innovation transfer by regular dissemination of the project results to the business line in charge of this product. Also there will be a regular synchronization and exchange of information about the most interesting standardization activities involving the SHARING consortium members. Finally, SHARING work will help TCS to strengthen its position within the PMR market which is estimated to grow by 40% each year between 2017 and 2023.

TCS also provides a complete set of spectrum monitoring solutions worldwide for regulation and spectrum monitoring authorities. With the deployment of LTE/LTE-A, new spectrum monitoring tools will be needed and adapted to the different LTE deployment configurations (macro/micro/femto/pico cells, and next evolutions). The work in SHARING will help to accelerate the implementation of the required evolutions in the current spectrum monitoring products, and especially with a special focus on the configurations where multiple antennas are used.

The objective of the team involved in the project is to bring state-of-the-art innovations to the products. It makes the bridge between fundamental R&D and TCS products; its activities reach the maximum TRL (Technical Readiness Level) of 5. Through the project, TCS team reinforces its skills in advanced MIMO antenna processing and develops new receivers with interference mitigation capabilities (TRL 2 to 4).

Finally, TCS expects to reinforce its skills and Intellectual Property Rights in signal and antenna processing in interference cancellation digital techniques.

Oy LM Ericsson Ab (ERICSSON - M, Finland)

Ericsson is a world leading provider of telecommunications equipment and related services to mobile and fixed network operators. Ericsson systems handle about 40 percent of the world's mobile traffic. Oy LM Ericsson AB (Ericsson Finland) represents Ericsson in the SHARING project. Ericsson Finland has a long history of R&D in the telecommunication area and is currently focusing on 3G/4G and core network products. The research department at Ericsson Finland has an extensive experience in concept development, IPR creation and standardization, especially in 3GPP and IETF.

In SHARING, Ericsson Finland is involved in WP2 and in WP4. A clear majority of the work is in WP4, where Ericsson Finland has contributed to HetNet mobility (HSPA connected cell, and uplink/downlink split within a heterogeneous LTE-A network deployment) and energy efficiency (utilizing eNodeB sleep mode and fast cell DTX within a heterogeneous LTE network deployment).

The obtained results related to energy efficiency have been partially presented in one conference paper and in one workshop paper. Furthermore, part of the results has been published as part of one doctoral dissertation. The work on HetNet mobility has been related to the discussions within 3GPP aiming to standardize Release-12 HSPA and LTE technologies. Furthermore, the work on uplink/downlink traffic split has been published as one conference paper and as one master's thesis.

Sequans Communications (SEQ - S, France)

SEQUANS Communications is a French SME, world-leading 4G chipmaker, supplying LTE and WiMAX chips to equipment manufacturers and mobile operators globally. Founded in 2003 to address the WiMAX technology for which it is now a global leader, SEQUANS expanded in 2009 to address the LTE market. SEQUANS' chips are inside the world's leading WiMAX networks and will soon be inside LTE networks. SEQUANS is based in Paris, with additional offices throughout the world, including USA, United Kingdom, Israel, Hong Kong, Singapore, and Taiwan.

In SHARING, SEQUANS is mostly involved in WP3 through the development of advanced MIMO receivers for next generation LTE products. The know-how gained during the project will help to optimize the complexity/performance ratio of embedded algorithms (both hardware and software) of next generation chipsets. Moreover, SEQUANS has contributed to an exploratory work towards 5G, by evaluating the promises of a new modulation scheme, namely, enhanced spatial modulation. The work performed by SEQUANS in SHARING has also been disseminated through publications and a patent filing.

IDATE Consulting and Research (IDATE - S, France)

IDATE has established itself over the years as one of the leading centres for exchange and analysis in Europe, specializing in the Telecommunications, Internet and Media Industries and markets.

IDATE's vocation is to lead a number of original initiatives, a European Forum furthering the debate of ideas and the exchange of experiences between the players in these domains.

Highly reputed teams of consultants and analysts conduct numerous reports and consultancy missions and participate in the continual investment in a worldwide observatory on the markets and strategies of those players in the Information Technology and Communication sectors.

In SHARING, IDATE is involved in WP2 and in WP4 with a majority of the effort focused on market studies (WP2).

As a market research company, IDATE will take advantage of SHARING research to enhance its future market reports and seminars related to femto cells, Wi-Fi, D2, relay mode and HetNets with specific focus on market forecasts. Those reports will be used by all stakeholders involved in the industry to design future sustainable access networks. The SHARING project will help strengthen IDATE position as a reference in international centre of excellence for mobile and wireless markets.

SIRADEL (SIRADEL - S, France)

SIRADEL (<http://www.siradel.com>) is a high-tech company (Small Medium Enterprise) created in 1994 based in France, China (Hong-Kong) and Canada (Toronto). SIRADEL provides Products and Services for the ICT Industry and the Wireless Telecommunications in particular. The portfolio of the company is composed of:

- Data: digital geographical 3D representation of environments, accurate and reliable RF measurements.
- Software: edition and licensing of leading Scientific Tools (Volcano, VolcanoLab) to simulate the EM wave propagation (Radio Coverage of Wireless networks) and realistic channel models (System performances of radio access network and equipment).
- Consulting: technology (coverage analysis, emerging wireless systems) and management (organizational management) to optimize the wireless networks deployment and equipment design.

More than 50 people work at SIRADEL across the world and serve more than 250 Customers in about 50 countries. SIRADEL's solution brings more reliable and realistic assessments of wireless network and wireless equipment performances. SIRADEL's customers profile encompass: wireless carriers, radio access equipment manufacturers, regulation bodies and consultants.

SIRADEL has been participating, as Task and Work Package Leader, in more than 30 funded research projects. SIRADEL's teams have a strong background and expertise in scientific simulations, signal processing, field experimentation, complex system analysis of radio-wave and optical wave propagation. SIRADEL has a background at the research frontier in advanced wireless system and propagation computations. Experimentations and investigations are required to obtain highly reliable software and expertise, the recent research focus is on energy and spectrum efficient networks, as well as on heterogeneous wireless networks, and Smart City Data Infrastructure.

SIRADEL is involved in WP2, WP3 and WP4 for the elaboration of a realistic environment simulation framework using 3D map data and a ray-based propagation model. MIMO

technologies, interference reduction schemes and 4G heterogeneous network performance can then be assessed considering realistic macro- and small-cell deployments. The exploitation plan can be outlined as follows:

- Development of an industrial solution for realistic MIMO channel modeling, plugged into dynamic system simulation and / or radio-planning tools.
- Enhancement of our system simulation tools related to:
 - Small-cell backhaul – Industrial and commercial stand-alone product;
 - Heterogeneous networks (realistic network and resource allocation, along with inter- and intra-system offloading) – Advanced simulation tools dedicated to expertise studies (i.e. evaluation of new topologies and techniques) and network design.
- Development of engineering services for the deployment of advanced features of LTE-A and wireless small-cell backhauling.

TTI Norte, S.L. (TTI - S, Spain)

TTI has focused its efforts in WP3 and WP7 in the study and development of a hardware prototype for carrier aggregation. The study has evaluated the requirements of a reconfigurable power amplifier to support intra-band carrier aggregation providing energy savings versus a conventional power amplifier. A hardware prototype was developed to evaluate the proposed reconfigurable solution. Additionally, the prototype also enables inter-band carrier aggregation. The obtained results related to reconfigurable power amplifier have been presented in one conference paper. TTI has acquired wide experience on this topic performing LTE lab measurements. This knowledge will increase the expertise of TTI and it would extend its business on RF products for 4G cellular systems and future 5G cellular systems. Moreover, the development of reconfigurable RF products provides to TTI a strong competitive asset.

Furthermore, different transistor technologies such as LDMOS and GaN have been evaluated to perform real-time tuning to optimize the power consumption. This knowledge will be exploited in future power amplifiers developments for cellular communications and satellite communications which is one of main TTI business.

Finally, in WP4 TTI has also studied several enhancements regarding protocols and algorithms able to improve and increase the flexibility and QoS of the radio access network. This is achieved by providing mechanisms to autonomously reconfigure the cells according to their current traffic load, and proposing management schemes and procedures in order to efficiently handle the number of active cells inside the network. Through the creation of an innovative middleware, entities in the network will be well aware of the surrounding conditions and thus be capable of exchange useful information, in their way to improve the overall network performance. In addition, a network planning tool has been developed to simulate different LTE scenarios where the aforementioned ideas can be translated to a close to real life situation allowing in this way to assess the benefits of the proposed solutions. Through all these activities, TTI is consolidating its software development capabilities.

European Communications Engineering Ltd (ECE - S, Finland)

ECE is a Finnish SME company, providing network planning, optimization, and cloud software services. In SHARING, ECE participates in WP6, exploiting performance evolution of small cells as well as antenna smart grid solutions for outdoor DAS. The work so far has resulted in co-operation and contribution with Magister solutions on smartphones measurements for locations based services verifications; as well as a contribution in form of six academic papers and submissions in the research areas of Antenna Smart Grid and Smart Phones. ECE will

continue to enhance, develop and research its novel SPMA "Single Path Multiple Access" concept with further simulations in higher frequency bands suitable for 5G evolution.

Magister Solutions Ltd (MAGISTER - S, Finland)

Magister Solutions has exploited the SHARING project results to further develop its know-how on various aspects on LTE network architecture. With this know-how we have developed novel enhancement to LTE Minimization of Drive Tests functionality to address the problems that were recently arisen e.g., in 3GPP LTE/WLAN Interworking and 3GPP Minimization of Drive Tests studies. We have already obtained scientific visibility with 8 conference papers and successfully demonstrated the benefits of the developed concept in urban environment. Our goal is to find industrial partners for further developing the proposed *Generalized MDT* (GMDT) concept in a hardware demonstration in live LTE-A network with MDT capable UEs.

2.1.3 Universities

Academic partners participating in the SHARING consortium are naturally interested in building on and further developing their existing research achievements and know-how in radio communications. Their participation will allow them to keep track of the industrial realities, and therefore to address the relevant challenges in a realistic way. SHARING's academic partners already have long standing records of contributions in the field of mobile communications, as well as numerous collaborations with the industry in this field. Their expertise, enriched by the project, will permeate into the daily university life and will be exploited within academia education, especially at Masters and PhD students' level, contributing in this way to better educate future European mobile communication experts.

University of Oulu (UOULU – U, Finland)

So far, UOULU has exploited and disseminated its outstanding innovations to top IEEE conferences, journal submissions, as well as workshop organizations, books, awards and tutorials. Through SHARING project, UOULU was to build further on our expertise in the field of Heterogeneous and small cell networks. UOULU has already given eight tutorials, and is thus planning to continue this trend in the coming years. Likewise, UOULU has organized four workshops on HetNets. A book on recent advances on small cell networks has been published in December 2015, at Cambridge University Press. Looking ahead UOULU is planning to leverage this outstanding track record fostered during the lifetime of SHARING for upcoming EU H2020 and CELTIC collaborations.

Institut Eurecom (EUR – U/I, France)

EURECOM is a Graduate school and Research Centre in Communication Systems located in the Sophia Antipolis technology park (French Riviera), a major European place for telecommunications activities. It was founded in 1991 in a consortium form [GIE]¹ that allowed EURECOM to build a large network of renowned academic and industrial partners. The "Institut Mines Telecom" is a founding member of EURECOM consortium. EURECOM research teams are made up of international experts, recruited at the highest level, whose work is

¹**Current members of EURECOM consortium :**

SFR, Orange, ST Microelectronics, BMW Group Research & Technology, Symantec, Monaco Telecom, SAP, IABG, Telecom ParisTech, Aalto University (Helsinki), Politecnico di Torino, Technische Universität München (TUM), Norwegian University of Science and Technology (NTNU), Vietnam National University Ho Chi Minh Ville (VNU). Principality of Monaco

regularly honored and has earned international recognition. EURECOM is particularly active in research in its areas of excellence while also training a large number of doctoral candidates. Its contractual research is recognized across Europe and contributes largely to its budget. Projects are at the heart of EURECOM's research activity [around a 100 contracts managed each year], one of their many benefits is the wealth resulting from the collaborative work with partners.

Based on the close ties it has developed with industry, EURECOM can direct an essential part of its research activities towards areas of interest for its industrial partners. One of our challenges is to fill the gap between fundamental research and the more business oriented one in our partner companies. From the beginning, the main objective set by our members was excellence on an international level. In research this excellence results in a high number of publications and patents, in the active participation to international scientific events and organizations and of course in getting many important European contracts in the European framework. Given its size, EURECOM chose to focus its research activities on three main areas: networking and security, multimedia communications and mobile communications.

In addition to contributing to academic exploitation of results through scientific publications in the highest-level conference proceedings and journals, through SHARING EURECOM is continuing to promote the use of open-architecture, and in particular, open-source radio systems. The equipment and software developed by EURECOM SHARING's context is made available to the public-domain for future use in collaborative initiatives. In particular, the software generated during the project contributes to the OpenAirInterface Software Alliance (OSA) making its use possible in future collaborative projects and by industry and academia around the world. EURECOM will also promote the development in SHARING through official communications in the context of the OSA events and publications. OSA (www.openairinterface.org) is a non-profit consortium to develop ecosystem for open source software/hardware development for the core network (EPC) and access-network (EUTRAN) of 3GPP cellular networks. The Alliance sponsors the initial work of [EURECOM](#) to create OpenAirInterface™ towards development of 5G Cellular Stack on commercial off-the-shelf (COTS) hardware.

Supelec - Ecole Supérieure d'Electricité (SUP - U, France)

Supelec is one of the leading engineering schools in France. Its wide spectrum covers electrical engineering, telecommunications, computer science, signal processing, control systems and power engineering. Supelec has a three-fold mission: Basic curriculum leading to the engineering degree (Master of Science level), fundamental and applied research, and continuing education. Research teams work in close cooperation with industry through bilateral research contracts or collaborative European or French national projects.

Supelec has been participating in SHARING project in WP2, 3, 4 and 7. So far, Supelec has exploited the results obtained in SHARING through publications in top conference proceedings and journals (7 journal papers and 15 conference papers), new projects applications (French ANR, upcoming European H2020 call). Supelec has also given three tutorials in IEEE conferences. As a consequence, SHARING's results give SUPELEC the opportunity to promote new ideas on advanced HetNets, relaying, distributed strategic learning in heterogeneous networks and strategies for power amplifier energy savings.

2.1.4 Research Centres

Commissariat à l'Énergie Atomique et aux Énergies Alternatives (CEA - I, France)

One of CEA-LETI main vocations is to help companies to increase their competitiveness through innovation and research-to-industry technological transfer. Therefore, one goal of CEA-LETI in SHARING is to enlarge its portfolio of know-how in order to increase its potential clients range.

CEA-LETI is mainly involved in WP3, WP5 and WP7. In WP3, Three topics have been investigated: an interference aware receiver, an interference map and a miniature dual-band frequency agile antenna. In WP5, power allocation for irregular LDPC codes for relay channels has been investigated. In WP7, an implementation study of the interference aware receiver has been conducted, and on the other hand, the miniature antenna studied in WP3 has been prototype, and later on, connected to TTI wideband RF.

To date, five papers have been published in conferences/workshops, and four others have been submitted. The results that have been thus disseminated are concerned with: the interference aware receiver, the interference map, the miniature dual-band frequency agile antenna, and the LDPC codes. A demonstration of the miniature antenna took place at the Vienna Celtic Event (April 27-28th 2015), another one at the "Pôle Images et Réseaux 10-th Anniversary Day" in Nantes, France September 24-th 2015, and lastly, will be demonstrated at the CROWNCOM conference, Grenoble, France, 30-th May- 1st June 2016. -

In addition, the miniature antenna is viewed as a key building block for future frequency agile antennas that will be designed and customized to fulfill the needs of CEA-LETI clients. It is to be noted that the same concept of frequency agility applied to narrow band is of great interest for miniature antenna of IoT communicating electronic devices.

2.2 Exploitation report

2.2.1 Standardisation

Below, you can find the short description of relevant standardization bodies (3GPP, IEEE), other fora/alliances (NGMN, Small Cell Forum, Wireless World Research Forum ...) and their relevance to SHARING.

3rd Generation Partnership Project (3GPP)

The purpose of the 3GPP is to unite six telecommunications standard development organizations to provide an environment to produce reports and specifications that define 3GPP technologies such as GSM, WCDMA, HSPA and LTE/LTE-A. Since the completion of the first LTE and the Evolved Packet Core specifications (EPC), 3GPP has become the focal point for mobile systems beyond 3G. The 3GPP organization consists of four technical specification groups being Radio Access Networks (RAN), Service & Systems Aspects (SA), Core Network & Terminals (CT) and GSM EDGE Radio Access Networks (GERAN). Each of the four groups has a set of working groups focusing on different areas of the technology and meeting regularly several times a year to discuss and define the technological aspects of the developed system.

During the SHARING project the focus in 3GPP has been on Release 12 finalization and the initiation of the Release 13 specifications of LTE-Advanced systems. Some of technical specifications/reports that are the most relevant to SHARING project are listed below as well as the corresponding SHARING research topics:

Device to device communications:

- RP-140518: LTE Device to Device Proximity Services. The related technical report is TR 36.843 (RAN1/RAN4)
- RP-140518: LTE Device to Device Proximity Services. The related technical document is TR 36.877 (RAN4)

Interworking between LTE and WLAN:

- RP-132086: Multi- RAT joint coordination, the related technical document is TR 36.870 (RAN3)

- RP-132101:WLAN/3GPP radio interworking at RAN2, the related technical document is TR 37.834(RAN2)

ON/OFF energy savings:

- RP-122035: Study on energy saving enhancement for E-UTRAN, the related technical document is TR 36.887 (RAN3)

Small cells:

- RP-122033: Study on small cell enhancement for E-UTRA and E-UTRAN higher layer aspects. The related technical document is 3GPP TR36.842 (RAN2).
- RP-122032: Study on small cell enhancement for E-UTRA and E-UTRAN physical layer aspects. The related technical document is 3GPP TR36.872 (RAN1).
- RP-121418: Scenarios and requirements of LTE enhancement of small cells. The related technical document is 3GPP TR36.932 (RAN2).

The technical contributions that are related to the innovations of SHARING and that were presented in 3GPP standardization are summarized in Table 1.

Table 1: Sharing contributions in 3GPP

Contribution	3GPP technical group	SHARING partner, date
R1-144242, Deployment scenarios for LAA-LTE and simulation assumptions for coexistence evaluation	RAN1	Orange, October 2014
R1-143358, Results for 3D Channel Model Calibration Phase 2	RAN1	Orange, August 2014
R1-141623, Impact of D2D on cellular traffic - Necessary further evaluation	RAN1	Orange, April 2014
R1-140781, Network control and flexible resource sharing between cellular and D2D communication within network coverage	RAN1	Orange, February 2014
R1-135548, Text Proposal for turbo-CWIC receivers System Level Modeling Methodology	RAN1	Orange, November 2013
R1-135549, Initial results for 3D Channel Model Phase 2 and different UE attachment options	RAN1	Orange, November 2013
R1-135550, Shadow fading modeling for microcell scenario based on a measurement campaign	RAN1	Orange, November 2013
R1-134818, Scenarios and requirements for Public Safety an related TP to 36.843	RAN1	Orange, October 2013

R1-133671, Results for 3D Channel UMa Calibration Case 1	RAN1	Orange, October 2013
R1-133722, Physical layer abstraction for turbo-CWIC receivers	RAN1	Orange, August 2013, [resubmitted at RAN1#74bis as R1-134799]
R1-133720, Initial results for 3D Channel Model UMa Calibration Case 3	RAN1	Orange, August 2013
R1-133719, Initial results for 3D Channel Model UMa Calibration Case 1	RAN1	Orange, August 2013
R2-131678, Further discussions on UL-DL split	RAN2	Ericsson, May 2013
R1-131596, Literature review on user antenna height correction factor for 3D-channel model	RAN1	Orange, April 2013
R1-131633, Views on network-assisted interference cancellation and suppression	RAN1	Orange, April 2013
R1-131594, Scenarios for network-assisted interference cancellation and suppression	RAN1	Orange, April 2013
R2-131381, Improving offloading potential with UL DL split	RAN2	Ericsson, April 2013
R2-130416, Small cell challenges and benefits of dual connectivity	RAN2	Ericsson, January-February 2013
R3-130393, Summary of offline discussions of clarifications of use cases and requirements for non-overlapping energy saving	RAN3	MERCE, January 2013
R3-131901, Optimized distributed TX power control for LTE coverage layer	RAN3	MERCE, October 2013
R3-131863, Evaluation method and metrics for ES solutions	RAN3	MERCE, October 2013
R3-131922, TP on ES evaluation criteria	RAN3	MERCE, October 2013
R3-132174, Further clarification on optimized distributed TX power setting for LTE coverage layer	RAN3	MERCE, November 2013
R3-140408, Overlaid coverage scenario showcase, performance and solution requirements	RAN3	MERCE, February 2014
R3-140428, Energy saving TR: technical annexes on potential ES gains	RAN3	MERCE, February 2014
R3-140784, Energy saving TR: technical annexes on potential ES gains	RAN3	MERCE, April 2014

R3-140901, ES solution evaluation for TX power optimization scenario	RAN3	MERCE, April 2014
R3-140915, Evaluation of the need for switch ON mechanism enhancement	RAN3	MERCE, April 2014
R3-140876, ES solution evaluation for switch ON enhancement.	RAN3	MERCE, April 2014

Specifics in relation with 3GPP standardisation effort

Magister Solutions goal is to propose an enhancement to 3GPP MDT functionality to support user-plane GMDT as part of the Release 13 work if a proper work/study items are active in 2015. One option is the foreseen study item for enhancing indoor positioning in Release 13.

IEEE 802.11

Wi-Fi is a very efficient technology, which can provide high throughput with a good reliability in certain conditions like in a home environment. In addition, current products are far from using the highest possible throughput. But Wi-Fi can become the victim of its own success, as its important growth and market adoption will lead, in the coming years, to the transformation of almost all environments into dense environments, subject to interference. This will be even truer for typical operator deployments. In order to prevent this situation and make Wi-Fi robust enough for its new usages in the long term, Orange has identified the main weaknesses of 802.11 standards and has pushed, with success, for the creation of a new group in 802.11, called High Efficiency WLAN (HEW), which is now expected to become the next Wi-Fi generation.

The issues related to the offload of the LTE traffic through Wi-Fi identified in SHARING fall in the same line with those improvement directions identified in the new IEEE 802.11 HEW standardization group. With Orange being an active member of this standardization group, SHARING foresees a significant impact on it.

NGMN

The Next Generation Mobile Networks (NGMN) Alliance (www.ngmn.org) is a mobile telecommunications association predominantly consisting of operators, which acts as a pre-standardization forum by providing operator-oriented input to standardization bodies, and also to the mobile networks industry community within the scope of LTE and EPC (Evolved Packet Core). This input includes requirements, use cases, performance targets, guidelines on equipment, and deployment preferences for a cost-effective network evolution through raised awareness on high customer benefit. NGMN achieves these tasks through liaison statements, organized workshops with related standardization and regulatory bodies as well as industrial stakeholders.

The relevance of NGMN on SHARING activities is mainly related to use cases and architecture requirements on Self-Organizing Network functionalities for next generation advanced cellular networks. The work carried on WP4 and the interaction of WP6 with WP4 has potential outputs which can be disseminated in NGMN through the project operator partners².

Small Cell Forum (formerly Femto Forum)

²It has to be noted however that the SON activity is on standby in NGMN for the moment.

The Small Cell Forum - formerly the Femto Forum - supports, promotes and helps driving the wide-scale adoption of small cell technologies to improve coverage, capacity and services delivered by mobile networks.

The Small Cell Forum is directed by an Executive Board which comprises the Chair and the Executive Board Members. The Chair is elected by the Members for one year and can be the representative of a Member or an independent non-Member. The Executive Board consists of a minimum of four Executive Board Members and a maximum of 15 Executive Board Members plus the Chair. Up to three Board positions are reserved for large system integrators/OEM (Original Equipment Manufacturers) from the mobile industry and up to three for licensed holders of spectrum.

Further information about the Small Cell Forum can be found on their website (www.smallcellforum.org).

2.3 Dissemination report

As mentioned in **Erreur ! Source du renvoi introuvable.**, the project planned to publish its results in prestigious journal and magazines, such as IEEE Transactions, EURASIP Journal on Wireless communications and networking, and IEEE Communications Magazine. This was done with a special focus on IEEE Transactions on Wireless Communications (8 papers), IEEE Transactions on Information Theory (6 papers), EURASIP Journal on Wireless communications and networking (2 papers), and IEEE Communications Magazine (3 papers). Targeted conferences listed in **Erreur ! Source du renvoi introuvable.** were renowned IEEE Conferences, as well as EUCAP (European Conference on Antennas and Propagation). They have been covered with a focus on IEEE Vehicular Technology Conference (8 contributions), EUCAP (7 contributions), Personal, Indoor and Mobility Radio Conference PIMRC (6 contributions). In addition, 11 papers were contributed to a conference which was not listed in [2], IEEE international Symposium on Wireless Communication Systems (ISWCS). In addition, several books/book chapters have been contributed with SHARING results, three Doctorate dissertations and one Master thesis have been defended, three patents have been filed, three SHARING-related workshops and two SHARING special sessions have been organized and one more workshop is planned after the end of the project.

A website <http://www-sharing.cea.fr/> is maintained with the list of publications and of public deliverables.

2.3.1 Publications

In the following the list of SHARING publications can be found:

- Journal Papers (33)
- Conference papers (78)
- Workshop papers (11)
- Book (1),
- Book chapters (3)
- Doctorate thesis (3), Master Thesis (1)
- Paper awards (2)
- Tutorials (6)

Journal Papers

Reported after MTR:

Y. Gu, W. Saad, M. Bennis and M. Debbah, "Matching Theory for Future Wireless Networks: Fundamentals and Applications," IEEE Communications Magazine, Special Issue on Emerging Applications, Services, and Engineering for Cellular Cognitive Systems, 2015.

E. Baştuğ, M. Bennis, E. Zeydan, M. Abdel Kader, A. Karatepe, A. Salih Er, and M. Debbah, "Big Data Meets Telcos: A Proactive Caching Perspective", to appear on Journal of Communications and Networks, Special Issue on Big Data Networking-Challenges and Applications, December 2015.

S. Samarakoon, M. Bennis, W. Saad, M. Debbah, and M. Latva-aho, Ultra Dense Small Cell Networks: Turning Density into Energy Efficiency," IEEE Journal on Selected Areas in Communications - Series on Green Communications and Networking, Accepted with major revision, Dec. 2015.

S. Samarakoon, M. Bennis, W. Saad and M. Latva-aho, Dynamic Clustering and Sleep Mode Strategies for Wireless Small Cell Networks," IEEE Trans. in Wireless Communications, accepted, to appear, Dec. 2015.

A. Destounis, M. Assaad, M. Debbah, B. Sayadi and A. Feki, "On Queue-Aware Power Control in Interfering Wireless Links: Heavy Traffic Asymptotic Modelling and Application in QoS Provisioning", IEEE Transactions on Mobile Computing, Vol 13 No. 10, pp. 2345-2356, 2014.

Reported before MTR:

S. Lakshminaryana, M. Assaad and M. Debbah, "Energy Efficient Cross Layer Design in MIMO Multi-cell Systems", IEEE Journal on Selected Areas in Communications (JSAC), to appear, October 2015.

M. Simsek, M. Bennis, and I. Guvenc, "Learning Based Mobility Management Enhancements in HetNets: A Reinforcement Learning Approach," EURASIP Journal on Wireless Communications and Networking, to appear, August 2015.

Subhash Lakshminarayana, Mohamad Assaad and Merouane Debbah "Asymptotic Analysis of Distributed Multi-cell Beamforming", IEEE Transactions on Information Theory, to appear, July 2015.

A. Destounis, M. Assaad, M. Debbah and B. Sayadi, "Traffic-Aware Training and Scheduling in MISO Downlink Systems", IEEE Transactions on Information Theory, to appear, June 2015.

O. Semiari, W. Saad, S. Valentin, M. Bennis, and H. V. Poor, "Context-Aware Resource Allocation in Small Cell Networks: How Social improves Wireless," IEEE Transaction in Wireless Communications, March 2015.

M. Simsek, M. Bennis, and I. Guvenc, "Learning Based Frequency- and Time-Domain Inter-Cell Interference Coordination in HetNets", IEEE Transaction in Vehicular Technology, March 2015.

E. Bastug, M. Bennis, M. Kountouris and M. Debbah, "Cache-enabled Small Cell Networks: Modeling and Tradeoffs", EURASIP Journal on Wireless Communications and Networking, March 2015.

Hana Baili and Mohamad Assaad, "Optimal Scheduling and Power Allocation in Wireless Networks with Heavy Traffic", Mathematical Modelling of Dynamical Systems Journal, March 2015.

Chien-Chun Cheng, Serdar Sezginer, Hikmet Sari, and Yu T. Su, "Linear Interference Suppression with Covariance Mismatches in MIMO-OFDM Systems," Wireless Communications, IEEE Transactions on. IEEE Transactions on Wireless Communications Vol. 13, no. 12, December 2014.

E. Bastug, M. Bennis, and M. Debbah, "Living on The Edge: On the Role of Proactive Caching in 5G Wireless Networks", IEEE Communication Magazine, Special Issue on Context Awareness, vol. 52, no. 8, pp. 82-89, November 2014.

- A. Destounis, M. Assaad, M. Debbah, B. Sayadi and A. Feki, "On Queue-Aware Power Control in Interfering Wireless Links: Heavy Traffic Asymptotic Modelling and Application in QoS Provisioning", IEEE Transactions on Mobile Computing, Vol 13 No. 10, pp. 2345-2356, 2014
- M.U. Sheikh, J. Sae and J. Lempiäinen, "Arguments of Innovative Antenna Design and Centralized Macro Sites for 5G", Springer International Journal of Electronics and Communications (Status: Submitted October 2014 and currently under review).
- M.U. Sheikh, J. Sae and J. Lempiäinen, "Evaluation of SPMA and Higher Order Sectorization for Homogeneous SIR through Macro Sites", Springer Journal on Wireless Networks (Status: Submitted October 2014 and currently under review).
- M.U. Sheikh, and J. Lempiäinen, "Will New Antenna Material Enable Single Path Multiple Access (SPMA)?", Springer Journal on Wireless Personal Communications, vol. 78, no. 2, pp. 979-994, September 2014.
- K. Hamidouche, E. Baştuğ, M. Bennis, and M. Debbah, "Le caching proactif dans les réseaux cellulaires 5G", La Revue de l'Electricité et de l'Electronique (REE), vol. 4, 2014.
- P. de Kerret and D. Gesbert, "Spatial CSIT Allocation Policies for Network MIMO Channels", IEEE Trans. on Information Theory, vol. 60, no. 7, pp.4158-4169, July 2014.
- M. Cardone, D. Tuninetti, R. Knopp, and U. Salim "Gaussian Half-Duplex Relay Networks: Improved Constant Gap and Connections with the Assignment Problem" IEEE Trans. on Information Theory, Vol. 60, n°6, June 2014.
- M. Cardone, D. Tuninetti, R. Knopp, and U. Salim, "On the Gaussian Half-Duplex Relay Channel", IEEE Transactions on Information Theory, Vol 60, n°5, May 2014.
- P. de Kerret and D. Gesbert, "Interference Alignment with Incomplete CSIT Sharing", IEEE Trans. on Wireless Communication, vol. 13, no. 5, pp. 2563-2573, May 2014.
- F. Pantisano, M. Bennis, W. Saad, M. Debbah, M. Latva-aho: Improving Macro cell - Small Cell Coexistence Through Adaptive Interference Draining. IEEE Transactions on Wireless Communications vol. 13, no.2, pp. 942-955, February 2014.
- X. Yi, S. Yang, D. Gesbert, and M. Kobayashi, "The degrees of freedom region of temporally-correlated MIMO networks with delayed CSIT", IEEE Trans. on Information Theory, vol. 60, no. 1, pp. 594-614, January 2014.
- N. Ul Hassan, M. Assaad and H. Tembine, "Robust Power Control in Arbitrary Wireless Networks", IEEE Communication Letters, Vol. 17, issue 6, pp. 1124-1127, 2013.
- S. Samarakoon, M. Bennis, W. Saad and M. Latva-aho, "Backhaul-Aware Interference Management in the Uplink of Wireless Small Cell Networks," IEEE Transactions on Wireless Communications, vol. 12, no. 11, pp. 5813-5825, November 2013.
- S. Gurucharya, D. Niyato, M. Bennis, and D. Kim, "Dynamic Coalition Formation for Network MIMO in Small Cell Networks," IEEE Transactions on Wireless Communications, vol. 12, no. 10, pp. 5360-5372, September 2013.
- M. Bennis, M. Simsek, W. Saad, S. Valentin, M. Debbah and A. Czylik, "When Cellular Meets WiFi in Wireless Small Cell Networks", IEEE Communication Magazine, Special Issue in HetNets, Vol. 51, no. 6, June 2013. ***** Featured among top 10 most accessed online papers in IEEE Comsoc for June 2013 and July 2013 - Awarded with the 2015 Fred W. Ellersick Prize *****
- D. Feng, L. Lu, Y. Yuan-Wu, G. Li, G. Feng and S. Li, "Device-to-device communications underlying cellular networks," IEEE Trans. Commun. vol.61, no. 8, pp. 3541-3551, Aug. 2013.
- Chien-Chun Cheng, Serdar Sezginer, Hikmet Sari, and Yu T. Su, "Robust MIMO Detection Under Imperfect CSI Based on Bayesian Model Selection," Wireless Communications Letters, IEEE, vol.2, no.4, pp. 375-378, August 2013.

X. Yi and D. Gesbert, "Precoding methods for the MISO broadcast channel with delayed CSIT", IEEE Trans. on Wireless Communications, vol. 12, no. 5, pp. 2344-2354, May 2013.

Conference papers

Reported after MTR:

Gougeon, G.; Corre, Y.; De Domenico, A.; Clemente, A.; Kaddour, A.S.; Bories, S & Lostanlen, Y. "LTE System-Level Evaluation of Directive Compact Antennas for Small-Cell Networks", 10th European Conference on Antennas and Propagation (EuCAP 2016), Davos, Switzerland.

Letourneux, F.; Gougeon, G.; Brau, M.; Corre, Y. & Lostanlen, Y. "Small-Cell Wireless Backhaul and Access Networks: Realistic Modeling and Holistic Analysis", 10th European Conference on Antennas and Propagation (EuCAP 2016), Davos, Switzerland.

Cyril Jouanlanne Christophe Delaveaud "Dual Resonant Compact Frequency Agile Microstrip Antenna", accepted to 10-th European Conference on Antennas and Propagation, EUCAP 2016, April 2016, Davos, Switzerland

T. Hiltunen, J. Turkka, R. Mondal and T. Ristaniemi, Performance Evaluation of LTE Radio Fingerprint Positioning with Timing Advancing, The 10th International Conference on Information, Communications and Signal Processing, ICICS 2015, December 2015, Singapore.

R. Mondal, J. Turkka, and T. Ristaniemi, Cluster-Based RF Fingerprint Positioning Using LTE and WLAN Outdoor Signals, The 10th International Conference on Information, Communications and Signal Processing, ICICS 2015, December 2015, Singapore.

M. Abdel Kader, E. Baştuğ, M. Bennis, E. Zeydan, A. Karatepe, A. Salih Er, and M. Debbah, "Leveraging Big Data Analytics for Cache-Enabled Wireless Networks", IEEE Global Communications Conference (GLOBECOM) Workshop, San Diego, CA, USA, 2015

M.U. Sheikh, S. Naghdian and J. Lempiainen, "SPMA An Innovative Solution for Future Smart Networks in Macrocellular Suburban Environment," 11th International Conference on Innovations in Information Technology (IIT'15) , pp.110-115, 1-3 Nov. 2015

T. Hiltunen, R. Mondal, J. Turkka and T. Ristaniemi, Generic Architecture for Minimizing Drive Tests in Heterogeneous Networks, IEEE Vehicular Technology Conference, VTC Fall, September 2015, Boston United States.

Is. Maaz, J.M. Conrat, J.C. Cousin, "Channel Model Validation for the Relay-Mobile Link in Microcell Environment", VTC2015-Fall, September 2015, Boston, USA.

A. Ratilainen, V. Virkki, S. Wager, K. Hiltunen, "Protocol Performance of UL/DL Separation in LTE Heterogeneous Networks", in Proc. of International Symposium on Wireless Communication Systems (ISWCS) 2015, Brussels, Belgium, August 2015

Engin Zeydan, A. Serdar Tan, I. Alper Karatepe, A. Salih Er, Gozde Ozcan, "Connectivity Management Using Multiple Attribute Decision Making in Heterogeneous Networks", Twelfth International Symposium on Wireless Communication Systems, ISWCS'15, Brussels, Belgium, August 2015.

J. Turkka, T. Hiltunen, R. Mondal and T. Ristaniemi, Performance Evaluation of LTE Radio Fingerprinting using Field Measurements, International Symposium on Wireless Communication Systems, ISWCS'15, August 2015, Brussels, Belgium.

C. Jouanlanne, C. Delaveaud "Compact dual-band frequency agile antenna designed for carrier aggregation LTE small cells", 12-th International Symposium on Wireless Communications Systems ISWCS 2015, 25-28-th August, Brussels, Belgium

N. Cassiau, S. Mayrargue, M. Laugeois, T. Cattelain, V. Berg "Performance of interference aware receivers in the downlink of LTE" 12-th International Symposium on Wireless Communications Systems ISWCS 2015, 25-28-th August, Brussels, Belgium

R. Mondal, J. Turkka and T. Ristaniemi, An Efficient Cluster-based Outdoor User positioning using LTE and WLAN Signal Strengths, IEEE International Symposium on Personal, Indoor and Mobile Radio Communications, (PIMRC), August 2015, Hong Kong.

C. Jouanlanne, C. Delaveaud "LTE small cell dual-band frequency agile antenna design optimized for carrier aggregation" EUCNC 2015, 29th June-2nd July Paris, France.

F. Z. Kaddour, B. Denis, D. Ktenas, "Downlink Interference Analytical Predictions under Shadowing within Irregular Multi-Cell Deployments" in Proc. of IEEE International Conference on Communications, 8-12 June 2015, London (UK).

N. Abbas, T. Bonald, B. Sayrac, "Opportunistic Gains of Mobility in Cellular Data Networks", accepted in the 13th International Symposium on Modeling and Optimization in Mobile, Ad Hoc and Wireless Networks (WiOpt 2015), 25-29 May, 2015.

Gougeon, G.; Brau, M.; Corre, Y. & Lostanlen, Y. "Impact of Wireless NLOS Backhaul Design On Small-Cells Deployment and End-user Experience", 9th European Conference on Antennas and Propagation (EuCAP 2015), April 2015 Lisbon, Portugal.

J. Sæe, J. Lempiäinen, "User Guided Energy and Capacity Optimization in UMTS Mobile Networks", IEEE PIMRC 2014

A Bagayoko, D. Panaitopol and C. Mouton, "On the Feasibility of Cellular Resource Reuse for Device-to-Device Communication under 3GPP Network Constraints", Proc. of IEEE 20th European Wireless Conference 2014, EW'2014, Barcelona, Spain, May 2014. ***** European Wireless 2014 Best Paper Award *****

O. Abel Gouba, Y. Louët, "A joint approach for PAPR reduction and predistortion by adding signal in Cognitive Radio", Crowncom 2013, Washington, United States, July 2013.

O. Abel Gouba, Y. Louët, "Digital Predistortion Expressed as an Adding Signal Technique in OFDM Context", IEEE NewCas 2013, Paris, France, June 2013

Reported before MTR:

A. Destounis, M. Assaad, M. Debbah and B. Sayadi, « A Threshold-Based Approach for Joint Active User Selection and Feedback in MISO Downlink Systems », in proc. of IEEE ICC, June 2015.

M. Deghel, M. Assaad and M. Debbah, "System Performance of Interference Alignment under TDD Mode with Limited Backhaul", in proc. of IEEE ICC, June 2015.

M. Simsek, M. Bennis, I. Guvenc, "Context-Aware Mobility Management in HetNets: A Reinforcement Learning Approach," in Proc. of the IEEE WCNC 2015, New Orleans, USA, March 2015.

F. Pantisano, M. Bennis, W. Saad, and M. Debbah, "In-Network Caching and Content Placement in Cooperative Small Cell Networks", in Proc. of the 1st International Conference on 5G for Ubiquitous Connectivity, Levi, Finland, November 2014.

Chien-Chun Cheng, Hikmet Sari, Serdar Sezginer, and Yu T. Su, "Enhanced Spatial Modulation with Multiple Constellations and Two Active Antennas", Latin-American Conference on Communications (LATINCOM), 2014 IEEE 6th, 5-7 November, 2014.

P. de Kerret, M. C. Filippou, and D. Gesbert, "Statistically coordinated precoding for the MISO cognitive radio channel" in proc. IEEE ASILOMAR, California, USA, Nov. 2014.

I. Maaz, J-M. Conrat, J.Ch. Cousin, « Path Loss Models in NLOS Conditions for Relay Mobile Channels", VTC Fall, Vancouver, Canada, Sept 2014.

M.S. ElBamby, M. Bennis, W. Saad and M. Latva-aho, "Content-Aware User Clustering and Caching in Wireless Small Cell Networks," in Proc. 11th International Symposium on Wireless Communication Systems (ISWCS), Barcelona, Spain, August 2014.

- M.S. ElBamby, M. Bennis, W. Saad and M. Latva-aho, "Dynamic Caching Strategies for Dense Small Cell Networks," invited paper, in Proc. of the 11th International Symposium on Wireless Communication Systems (ISWCS), Barcelona, Spain, August 2014.
- M.S. ElBamby, M. Bennis, W. Saad and M. Latva-aho, "Dynamic Uplink-Downlink Optimization in TDD-based Small Cell Networks," in Proc. of the 11th International Symposium on Wireless Communication Systems (ISWCS), Barcelona, Spain, August 2014.
- S. Samarakoon, M. Bennis, W. Saad and M. Latva-aho, "Dynamic Clustering and Sleep Mode Strategies for Small Cell Networks," in Proc. of the IEEE ISWCS, special issue on Advanced Small Cells for Future Systems 5G, Barcelona, Spain, Aug. 2014.
- E. Bastug, M. Bennis and M. Debbah, "Cache-enabled Small Cell Networks: Modelling and Tradeoffs", 11th International Symposium on Wireless Communication Systems (ISWCS), Barcelona, Spain, August 2014.
- X. Yi and D. Gesbert, "Topological interference management with transmitter cooperation", in proc. of IEEE International Symposium on Information Theory (ISIT), Hawaii, USA, July 2014.
- A. Destounis, M. Assaad, M. Debbah and B. Sayadi, «Traffic-Aware Training and Scheduling for the 2-user MISO Broadcast Channel », in IEEE Symposium on Information Theory, Hawaii, USA, 28 June - 2 July, 2014.
- R. Mondal, J. Turkka, T. Ristaniemi "An Efficient Grid-based RF Fingerprint Positioning Algorithm for User Location Estimation in Heterogeneous Small Cell Networks" International Conference on Localization and GNSS, Helsinki, Finland, June 24-26, 2014.
- S. Samarakoon, M. Bennis, W. Saad and M. Latva-aho, "Opportunistic Sleep Mode Strategies for Wireless Small Cell Networks," in Proc. IEEE ICC 2014, Sydney, Australia, June 2014.
- Chien-Chun Cheng, Serdar Sezginer, Hikmet Sari, and Yu T. Su, "Linear Interference Suppression with Covariance Mismatches in MIMO-OFDM Downlink," Communications (ICC), 2014 IEEE International Conference on, 10-14 June 2014.
- Chien-Chun Cheng, Hikmet Sari, Serdar Sezginer, and Yu T. Su, "Enhanced Spatial Modulation with Multiple Constellations," Black Sea Conference on Communications and Networking (BlackSeaCom), 2014 IEEE 2nd, 27-30 May, 2014.
- Chien-Chun Cheng, Serdar Sezginer, Hikmet Sari, and Yu T. Su, "SINR Enhancement of Interference Rejection Combining for the MIMO Interference Channel," Vehicular Technology Conference (VTC Spring), 2014 IEEE 79th, 18-21 May 2014.
- Chien-Chun Cheng, Serdar Sezginer, Hikmet Sari, and Yu T. Su, "Moving-Average Based Interference Suppression on Frequency Selective SIMO Channels," Vehicular Technology Conference (VTC Spring), 2014 IEEE 79th, 18-21 May 2014.
- F. Pantisano, M. Bennis, W. Saad and M. Debbah, "Cache-aware User Association in Backhaul-Constrained Small Cell Networks ," in Proc. IEEE WiOpt, Tunisia, May 2014.
- S. Kottath, D. Gesbert, H. Khanfir, and E. Hardouin "Broadcast Channel Feedback in Multiple-Antenna Transmitter Cooperation Networks: Accuracy or Consistency?", Proc. of IEEE 20th European Wireless Conference 2014, EW'2014, Barcelona, Spain, May 2014.
- A. Karatepe, and E. Zeydan, "Anomaly Detection in Cellular Network Data Using Big Data Analytics", Proc. of IEEE 20th European Wireless Conference 2014, EW'2014, Barcelona, Spain, May 2014.
- Khan, Y.; Sayrac, B.; Moulines, E., "Centralized Self-Optimization Performance of eICIC and AAS in LTE-A: A Comparison," Proceedings of 20th European Wireless Conference, pp.1, 6, 14-16 May 2014.
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- Issam Maaz, Jean-Marc Conrat, Jean-Christophe Cousin, "Path Loss Models in LOS Conditions for Relay Mobile Channels", EUCAP, The Hague, Netherlands, April 2014.
- Jean-Marc Conrat, Quang Hien Chu, Issam Maaz, Jean-Christophe Cousin, "Path Loss Model Comparison for LTE-Advanced Relay Backhaul Link in Urban Environment", EUCAP, The Hague, Netherlands, April 2014.
- G. Gougeon, M. Brau, Y. Corre, T. Tenoux, and Y. Lostanlen, "3D Ray-Based Propagation Channel Modelling for Multi-Layer Wireless Network Performance Simulation: Focus on the MIMO Channel Rank", EUCAP, The Hague, Netherlands, April 2014.
- M.S. ElBamby, M. Bennis and M. Latva-aho, "Decentralized Caching Strategies in Wireless Small Cell Networks", WWRF 32, Morocco, April 2014.
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M. Abdel Kader, E. Baştuğ, M. Bennis, Engin Zeydan, A. Karatepe, A. Salih Er and M. Debbah "Leveraging Big Data Analytics for Cache-Enabled Wireless Networks", in Proc. of IEEE Global Communications Conference (GLOBECOM) Workshop on 5G & Beyond - Enabling Technologies and Application, December 2015, San Diego, US.

E. Zeydan, A. Serdar Tan, I. Alper Karatepe, A. Salih Er and G. Özcan "Connectivity Management Using Multiple Attribute Decision Making in Heterogeneous Networks" in Proc. of International Symposium on Wireless Communication Systems (ISWCS 2015), August 2015, Brussels, Belgium.

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F. Z. Kaddour, B. Denis, D. Ktenas "Accuracy of Location-Dependent Inter-Cell Interference Stochastic Model with Ranging Errors" in Proc. of IEEE Vehicular Technology Conference, VTC Spring 2015, workshop on Intelligent Design and performance evaluation of LTE-Advanced Networks, 11-14 May 2015, Glasgow, Scotland.

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E. Bastug, M. Bennis and M. Debbah, "Social and Spatial Proactive Caching for Mobile Data Offloading," in Proc. of the IEEE International Conference on Communications, workshop on Small Cell and 5G Networks, Sydney, Australia, June 2014.

F. A. Tuzunkan, C. Gungor, E. Zeydan, O. Ileri and S. Ergut, "Seamless Mobile Data Offloading in Heterogeneous Wireless Networks based on IEEE 802.21 and User Experience", in Proc. of Self Organizing Networks (SONETs) Workshop, IEEE Wireless Communications and Networking Conference (WCNC'14), Istanbul, Turkey, April 2014.

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P. de Kerret, J. Hoydis, and D. Gesbert, "Rate loss analysis of transmitter cooperation with distributed CSIT", in proc. IEEE 14th Workshop on Signal Processing Advances in Wireless Communications (SPAWC), Workshop, June 2013

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Reported before MTR:

A. Anpalagan, M. Bennis, and R. Vannithamby, "Design and Deployment of Small Cell Networks", Cambridge University Press, Spring 2015

Book Chapters

E. Baştuğ, M. Bennis and M. Debbah, "Think Before Reacting: Proactive Caching in 5G Small Cell Networks", Towards 5G: Applications, Requirements and Candidate Technologies", Wiley, 2015

M. Simsek, M. Bennis, and I. Guvenc, "Time and Frequency Domain e-ICIC with Carrier Aggregation in HetNets", book chapter in Design and Deployment of Small Cell Networks, Cambridge University Press, 2014

Y. Khan, B. Sayrac, E. Moulines, "Centralized self-optimization of Interference management in LTE-A HetNets", book chapter in Design and Deployment of Small Cell Networks, Cambridge University Press, 2014

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Reported after MTR:

Y. Khan "Automated optimization of radio resource management in 4th generation cellular radio networks", PhD dissertation, Telecom ParisTech, Feb. 2015

J. Turkka, "Aspects of Knowledge Mining on Minimizing Drive Tests in Self-organizing Cellular Networks ", Doctoral Dissertation, Tampere University of Technology, publication 1229, 2014.

Reported before MTR:

K. Hiltunen "The Performance of Dense and Heterogeneous LTE Network Deployments within an Urban Environment", Doctoral Dissertations 51/2014 Aalto University publication series.

A. Ratilainen, "Protocol Performance of Uplink/Downlink Separation in LTE Heterogeneous Networks", Master's thesis, Aalto University, School of Electrical Engineering, 2014.

2.3.2 Presentations

Two presentations have been made:

1. Presentation of the SHARING vision at the 1stFP7 SEMAFOUR interim workshop, September 25 2014, Braunschweig/Germany (in conjunction with the ITG/VDE Future Networks 2014 Conference).

Title: Self-Organized Heterogeneous Radio Access for Future Wireless Networks: SHARING vision

Abstract — Considered as a major economic driver, wireless broadband industry is facing increasing challenges due to the vast growth in data traffic demand together with the scarcity and high cost of (radio) resources. This challenge sets strong requirements on coverage, capacity and cost improvements of mobile networks in the horizon of 5 to 10 years. Therefore, it is vital to define highly spectral-, energy- and cost-efficient mobile broadband systems to satisfy these impending requirements. In parallel, considering emerging services and new spectrum regimes, offloading solutions also need to be strongly improved as an important leverage to avoid the saturation of future mobile networks. This paper presents the vision of the Celtic-Plus project SHARING (Self-organized Heterogeneous Advanced RadIo Networks Generation) whose aim is to address these challenges. To this end, SHARING focuses on Heterogeneous Networks (HetNets), including innovative concepts such as advanced relaying and Device-to-Device (D2D) communications. HetNets is a concept which has been introduced as a promising solution to the foreseen massive traffic overload over the horizon of 2020. Consisting of a wide area coverage layer of high-powered macro cells together with a layer of short range, low-powered small cells (micro/pico/femto cells and Wi-Fi access points), HetNets push for densification of the cellular networks towards smaller and smaller cells whilst offloading part of the traffic overload burden from macro cells: 1-towards micro and pico cells in outdoor environments, and 2-towards femto cells and Wi-Fi hotspots in indoor (residential, corporate etc.) environments (indoor small cells also enhance indoor coverage). Calling for a substantial increase in the number of network nodes, this densification necessitates the development of automated operation and management solutions to avoid the related increase in costs. Therefore, self-organization of operation and management tasks is an inevitable component of the HetNet solution for future radio access networks. Combined with the breakthroughs in radio link spectral efficiency (transmitter cooperation, advanced receivers, link-level interference management techniques) and mature solutions such as D2D communications (allowing higher data rates, power saving and better resource utilization due to shorter radio path), self-

organized HetNets constitutes the most promising and viable solution to face the forthcoming capacity crunch.

2. Project presentation to the Advisory Board (AB), telephone meeting, March 17 2015.

The presentation contains a general overview of the project vision and objectives, as well as a detailed presentation of selected technical innovations of the project such as intra-cell offloading, multi-node cooperation schemes and device-to-device communications.

2.3.3 Workshops

Three SHARING related workshops and two SHARING special sessions were organized in 2014 and 2015:

1. **The 1st IEEE International Workshop on Self-Organizing Networks (SONETs)**, in conjunction with IEEE WCNC 2014, April 6th 2014, Istanbul, Turkey.
<http://open-innovation.alcatel-lucent.com/www/sohnets/index.html>
 - Full-day workshop.
 - 30-40 attendees.
 - Keynotes: Colin Willcock, Ismail Guvenc.
 - 12 papers in 4 technical sessions.
2. **The 2nd International Workshop on Small Cell Wireless Networks (SmallNets)**, in conjunction with IEEE ICC 2013, June 9th 2013, Budapest, Hungary.
<http://www.cwc oulu.fi/smallnets2013/program.php>
 - Full-day workshop.
 - 40-50 attendees.
 - Keynotes: Satoshi Nagata, Amitava Ghosh and Holger Claussen, Gerhard Fettweis.
 - 22 papers in 4 technical sessions.
3. **SHARING project special session within European Wireless 2014 (EW'14)**, May 14th 2014, Barcelona, Spain.
<http://www.ew2014.org/workshop-program.html#A1>
 - Half-day session.
 - 15-20 attendees.
 - Four papers from SHARING authors.

The SHARING paper "*On the Feasibility of Cellular Resource Reuse for Device-to-Device Communication under 3GPP Network Constraints*" by Abdoulaye Bagayoko (NEC Technologies, France); Dorin Panaitopol (NEC Technologies, France); Christian Mouton (NEC Technologies, France) was awarded with the ***best paper award*** (among all the papers of the conference EW'14).
4. **The 1st International Workshop on Intelligent Design and Performance Evaluation of LTE-Advanced Networks**, in conjunction with VTC2015-Spring, May 11th 2015, Glasgow, Ireland.
<http://www.ieeevtc.org/vtc2015spring/final-program.pdf>
 - Half-day session
 - 35-45 attendees
 - 2 papers from SHARING authors
5. **SHARING project special session within ISWCS 2015 (ISWCS'15)**, August 27th 2015, Brussels, Belgium.
http://www.iswcs2015.org/images/ISWCSFiles/FinalProgram_ISWCS2015.pdf
 - Half-day session
 - 10-20 attendees
 - 8 papers from SHARING authors

A final dissemination event will be organized after the end of the project, under the form of a workshop in the **CROWNCOM 2016 conference** (<http://crowncom.org/2016/show/home>), May 30th – June 01st 2016, Grenoble.

2.3.4 Demonstrations

Several demonstrations in four different contexts have already been or will be carried out:

Project mid-term review demonstrations (April 15th 2015, Paris)

Demo 1: Connectivity Management Platform Using Multiple Attribute Decision Making in Heterogeneous Networks (AVEA)

Mobile operators are thus looking for cost-effective solutions to overcome the capacity bottlenecks especially in high contention traffic scenarios. Offloading a portion of the mobile data traffic to Wi-Fi networks is a promising solution to overcome the capacity bottleneck. However, thereby Wi-Fi networks may get easily congested as well. A centralized connectivity management mechanism can be used to solve this dilemma. In this demo, a novel centrally controlled Wi-Fi offloading platform for heterogeneous wireless networks is presented. For a given user, a centralized management server collects information regarding the quality of service and experience from all accessible data networks, then selects the data network that maximizes the overall system performance, finally the decision is sent to the application on the mobile phone for execution. The intelligent decision process uses an algorithm that is shown to be robust and also flexible to adapt to the needs of different mobile operators.

Demo 2: Radio fingerprint positioning demo (MAGISTER / ECE)

Coverage measurements with detailed location information are an important asset in self-optimization of wireless networks. When correlating location and coverage 3G/LTE measurements with coverage WLAN measurements i) the positioning accuracy can be significantly improved and ii) knowledge about joint coverage of heterogeneous 3G/4G/WLAN networks can be obtained. However, currently, there exists no standardized method to combine 3G/4G measurements with WLAN measurements. In this demo, LTE and WLAN radio fingerprint positioning accuracy is visualized utilizing field measurements from commercial LTE network. The demo tracks several mobile users showing their exact and estimated location on top of a map utilizing novel architecture that enables combining MDT 3G/4G and WLAN fingerprint measurements. Applications: In addition to provides a convenient and novel way of visualizing the content of MDT 3G/4G trace records, this approach is valuable for network vendors and operators who are keen on automating the collection of radio coverage measurements for improving their radio fingerprint positioning capabilities.

Demo 3: Dual band / dual access antenna exhibit (CEA)

Integration of small cell base stations to urban environment requires a miniaturization effort compared to regular base stations. In addition, increasing base stations capacity is a hot topic that can be handled thanks to Carrier Aggregation (CA) which consists in simultaneously using several carriers (within the same band or not). CEA active dual band / dual access antenna design, covering 2100 and 800 MHz LTE bands, has been optimized to take into account these requirements. Since the antenna size increases with its bandwidth, the antenna system bandwidth has been reduced as far as possible, to only cover the required bandwidth for a given CA configuration. Frequency agility has been introduced to make the antenna system compatible with a subset of CA configurations recommended by the standards. This bandwidth reduction has led to a miniaturization of the antenna system without degrading its performance.

2015 Celtic Event demonstration (April 28th-29th 2015, Vienna)

Demos 1, 2 and 3 were presented in 2015 Celtic Event.

Partner Eurecom also demonstrated its OpenAirInterface platform, showing a standard compliant LTE eNB software radio implementation capable of communicating with commercial UEs.

Loading the Future Trophées (September 24th 2015, Nantes)

Demo 3 was presented in this event.

Project Final Review demonstrations (March 03rd 2015, Sophia Antipolis)Demo4: RF front end system with green power amplifier and miniature antenna

TTI has developed a proof-of-concept demonstrator for carrier aggregation to validate the WP3 study on the topic of reconfigurable power amplifiers. The prototype supports intra-band contiguous and intra-band non-contiguous carrier aggregation providing energy savings versus a conventional power amplifier and it also supports inter-band carrier aggregation. The demonstrator operates in LTE-A band 7 for intra-band carrier aggregation and in LTE band 20 and band 7 for inter-band carrier aggregation. The prototype is focused on a downlink LTE-A transmitter for a small cell scenario. The power amplifier is configured using different operating points to fulfill 3GPP specifications associated to different carrier aggregation modes and provides energy savings compared to conventional amplifiers.

This hardware demonstrator is combined with a dual band antenna system developed by CEA. This antenna system is composed of a first antenna covering the whole band 7 and of a second antenna covering one channel (Rx/Tx) of band 20 at a time. Frequency agility is used to make this second antenna cover the whole band 20 by tuning the antenna frequency according to the selected band 20 channel. This antenna system can cover all possible intra-band and inter-band carrier aggregation configurations. This technique enables miniaturization of the band 20 antenna without jeopardizing the whole system radiated performance.

A demo video was prepared in order to show the validation results of both prototypes.

Demo5: eMBMS relaying

We consider the demonstration scenario described in Figure 1. These scenarios are described in more detail in WP7 deliverables D7.2 and D7.3. The eMBMS relaying scenario corresponds to the case of a macro-cell eMBMS transmission which is relayed on a secondary component carrier to the region around the relay. The relays derive time and frequency synchronization from the macro-cell eNodeBs and have transmit-only functionality. The relay is a decode-and-forward relay made up of a standard eMBMS-aware UE and the eMBMS TX-path of an eNodeB. These ensure coverage of the primary eMBMS carrier in difficulty to reach areas such as large underground zones or heavily shadowed zones, which would limit the global eMBMS throughput if covered by the macro-cell eNodeB only. The primary target is to serve the MBSFN-area with a very high-spectral efficiency from the macro-cell eNodeBs which are received by the great majority of locations and add the TX-only relay to cover the difficult-to-reach zones.

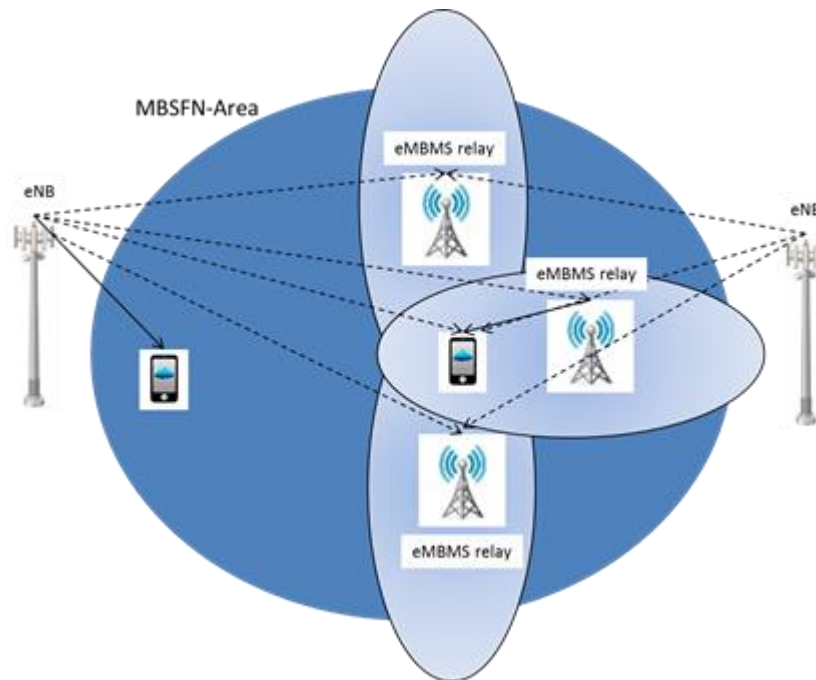


Figure 1: eMBMS Relay (dual-carrier)

CROWNCOM conference (May 30th-June 1st)

Demo 4 will be presented in this event.

Partner EURECOM will also demonstrate in this event a variant of demo 5 illustrating Carrier Aggregation.

2.3.5 Press release

The project launch was promoted with the publication of the press release shown in the appendix. A project conclusion press release is under preparation.

2.3.6 Web site

SHARING website URL is <http://www-sharing.cea.fr/>. There can be found the summary and objectives of the project, the consortium description, the list of events (workshops, etc.), the list of publications (which is regularly updated), the list of deliverables, with links to already published deliverables.

2.3.7 Public deliverables

The list of completed deliverables is shown in the Table 2.

Table 2: List of completed SHARING deliverables

	Deliverable	Month
	BEFORE MTR	
D2.1	Dissemination and exploitation plan	Oct-2012
D2.2	Scenarios, KPIs and Evaluation Methodology for Advanced Cellular Systems	Jan-2013
D2.3 V0	Dissemination and exploitation report	Feb-2015
D2.4 V0	Market analysis and performance targets	Sep-2014

D3.1	New opportunities, challenges and innovative concepts candidates for Multi-point transmission and reception	Jul-2014
D3.2	Multi-point cooperation schemes at the transmitter: innovative concepts and performance evaluation	Jan-2015
D3.3	Advanced Transceivers and interference cancellation schemes at the receiver: innovative concepts and performance evaluation	Feb-2015
D3.4	Flexible interference management concept: innovative concepts and performance evaluation	Jan-2015
D3.5	Progress in RF Front-End, Antenna Design	Jan-2015
D4.1	New opportunities, challenges and innovative concepts candidates for SON/Heterogeneous Networks	Jun-2014
D4.2	Intra-system offloading: innovative concepts and performance evaluation	Dec-2014
D4.3	Inter-system offloading: innovative concepts and performance evaluation	Dec-2014
D4.4	Power control: innovative concepts and performance evaluation	Feb-2015
D4.5	Spectrum allocation: innovative concepts and performance evaluation	Jan-2015
D5.1	Advanced Relays: innovative concepts and performance evaluation	Dec-2014
D5.2	Device-to-device communications: innovative concepts and performance evaluation	Dec-2014
D6.1	Requirements and progress on architecture issues	Sept-2014
D6.2	Architecture aspects for multi-layer, multi-RAT heterogeneous network including D2D implementations	Feb-2015
D6.3	Localization architecture for multi-layer, multi-RAT heterogeneous network	Feb-2015
D7.1	Selection of scenarios for proof of concept test-beds, specifications and recommendations on key building blocks for implementation	Mar-2014
D7.2	Selection of key algorithms and technologies with Integration into platforms	Feb-2015
	AFTER MTR	
D2.3	Dissemination and exploitation report	Feb-2016
D2.4	Market analysis and performance targets	Jan-2016
D3.6	Performance assessments of the most promising Multi-point transmission and reception techniques	Feb-2016
D4.6	Performance assessment and comparison of the most promising techniques in cooperative networks	Feb-2016
D5.2	Device-to-device communications: innovative concepts and performance evaluation	Feb-2016
D5.3	Performance assessment and comparison of the most promising techniques in relay-aided networks	Feb-2016
D6.2	Architecture aspects for multi-layer, multi-RAT heterogeneous network including D2D implementations	In progress
D6.4	Final conclusions on RAN architecture	Jan-2016
D7.3	Integration of selected algorithms into platforms & interfaces finalisation	Dec-2015
D7.4	Final proof of concept validation, results and analysis	Feb-2016

2.3.8 Patent applications

The patents listed in this section were submitted during the project up to the current date of delivery.

Reported after MTR:

Patent: Operator Supported Decision Making Method for Internet Connection Management in Heterogeneous Networks

- Inventors: Engin Zeydan, Alper Karatepe
- Title: Operator Supported Decision Making Method for Internet Connection Management in Heterogeneous Networks
- Assignee: Avea Iletisim Hizmetleri A.S.
- Nationality: Turkey
- Patent number: 2015/04874
- Filing date: 04.05.2015
- Granting date: N/A
- Publication date: N/A
- Abstract: The invention is on a decision making method realized by a decision making system to manage the user devices based on operator control in heterogeneous networks.

Reported before MTR:

Patent: Multi User Multi Attribute Decision Making Method for Wireless Network Access

- Authors: Engin Zeydan, Ahmet Serdar Tan, Omer Ileri, Salih Ergut, Fazil Aykut Tuzunkan, Cagri Gungor
- Title: Multi User Multi Attribute Decision Making Method for Wireless Network Access
- Assignee: Avea Iletisim Hizmetleri A.S.
- Nationality: Turkey
- Patent number: 2014/09831
- Filing date: 21.08.2014
- Granting date: N/A
- Publication date: N/A
- Abstract of the patent: The invention is on a multi user multi attribute decision making method proving the user equipment of operators to choose a network to connect in an area with heterogeneous wireless network access.

Patent: Method of combining user reported information with Minimization of Drive Tests trace records.

- Inventor: Jussi Turkka, Magister Solutions Ltd.
- Assignee: Magister Solutions Ltd.
- Nationality: Finland
- Patent document number: 20150058
- Filing date: 20.02.2015
- Granting date: N/A
- Publication date: N/A

- Abstract: A method for collecting and correlating Minimization of Drive Test trace records with other types UE reported performance measurements e.g., WLAN radio measurements, is disclosed in this patent to better support network operation and optimization in next generation heterogeneous cellular networks.

3 INNOVATIONS IN SHARING AND ASSOCIATED MARKET POTENTIAL

In this chapter, we analyze the market potential associated with SHARING' innovations:

- Improved offload capability
- Device-to-device
- Relay mode
- Carrier aggregation
- COMP and MU-MIMO
- FPGA
- Caching
- SON

3.1 Improved offload capability

3.1.1 Offloading benefits for MNOs

Two deliverables deal with offloading: D4.2 for intra system offloading and D4.3 for inter system offloading.

In the case of intra-system offloading, the benefits are an increased capacity resulting from the increased collaboration between cells. Thanks to the Self Organizing Technique, operating costs are reduced and cells can adapt themselves dynamically to the nature of traffic and to the mobility of users, which also provide increased throughputs at the edge of the cell

In the case of inter-system offloading, the benefits are an increased capacity available on the cellular network, reduced cost of data transportation and the possibility to set up operator effective offloading strategies/policies. It has an impact first on the Radio Access Network and on the backhaul. This however probably increase signaling and controlling traffic since the user has to be managed on the offloaded network but this increased signaling traffic affect more the core network than the RAN.

Indeed, MNOs need to retain control on the offloaded user and provide him a secure access to the core network. In the case of degraded experience on the offloaded network, the user must be onloaded back to the cellular network. With improvement proposed in D4.3, the user is dynamically offloaded and onloaded depending on multiple criterions which enable the operator to define offloading strategies

3.1.2 Market potential for improved offloading

Improved offload capability between 3GPP and non 3GPP network is of strategic importance for players with both fixed and mobile assets and where WiFi access points can be leveraged to successfully improve coverage and capacity. Up to now, the main issues have been connecting the user seamlessly to an access point while being able to still retain control on the user and steer it dynamically depending on network conditions and the users' subscription status. We see then a lot of potential in the short to mid-term for those kinds of innovation. This is an effective way of decreasing CapEx and OpEx while improving the user experience.

The potential for those innovations might be limited by the success of LTE-U/LAA among operators in the long term but given the large penetration of WiFi devices, this potential should remain untouched at least in the short/mid-term.

Table 3: Evaluation of improved offloading market potential

Innovation	Scenario	The market today	Market potential (2018-2020)	Market players
Improved 3GPP/WiFi offloading	2.4.1, 2.4.2, 2.4.3	Offload: On the WiFi side: HotSpot 2.0/Passpoint (not standardized by IEEE)	++ for 3GPP standardization (but LTE-U is coming) the use of unlicensed bands by 3GPP-type technologies)	For MNOs, decrease CAPEX & OPEX Other players: Tower companies & facility managers (& urban furniture managers): SCaaS, Offloading as a Service CableCos: decrease reliance on MVNO agreement?

3.2 Device to Device (D2D)

Relay and D2D features have been initially developed for Public Safety users but will find other usage outside this specific group of users.

Relay and D2D features do not offer much optimization and improvement in the efficiency of network but enable new services to be provided.

3.2.1 D2D benefits

Device to device communications will bring the following benefits:

Relay mode and D2D communications will enable:

- The offload of some part of the traffic from the cell and the backhaul by enabling the data to be transferred without passing through the eNodeB. The control plane would continue to go through the eNodeB. D2D extends the offload strategy and reduces the cost per bit for very specific kinds of data transfer
- In case where both devices are not close enough for D2D, the data plane can go through the eNodeB and be routed locally, which offloads both the backhaul and possibly the backbone
- The discovery process and the direct communication between the devices are managed by the operator who can bill this feature to application developers through the use of network APIs, enabling large scale discovery (contrary to competing existing technologies such as Bluetooth and WiFi)
- D2D and device discovery could be the basis for other Location Based Services for operators, especially relying on low power geofencing

D2D is expected to play a major role in V2V communications in the automotive sector and for connected cars applications.

New D2D features for wearables are also under development and will enable connection from multiple devices to a hub such as a smart phone using 3GPP technology instead of short range technology such as BLE for instance.

3.2.2 Market potential for D2D

Device to Device applications will most exclusively grab interest from the PPDR market in the short to mid-term. Indeed, the specification and standardization within 3GPP has been mainly driven for public safety usage and business model for commercial use is not there yet as other competing technologies are already on the market with no proof that consumers and/or 3rd party developers will be ready to pay for.

Commercial use of D2D features will thus begin more probably after 2020 if an ecosystem and an underlying business model exist. At that time, use of D2D for Vehicle to Vehicle (or infrastructure) communication is, in our view, more likely to grab interest and therefore hold more potential than B2C applications.

Table 4: Evaluation of D2D market potential

Innovation	Scenario	The market today	Market potential (2018-2020)	Market players
D2D with open air interface	2.5.2, 2.6.1, 2.5.1	D2D: supported by PMR-type technologies (2G and 2.5 G such as TETRA do not support MBB)	In 2020, the D2D market should represent less than 10 million users worldwide. Public safety will represent the bulk of the market	MNOs: potential new market for MNOs but PMR networks are by definition private and so are PPDR network, which give little place for MNOs for this market (but UK example with use of commercial LTE networks) Equipment vendors: new market with PPDR and PMR players

3.3 Relay mode

3.3.1 Relay mode benefits

Even though relay mode is not expected to be implemented in the near future, it will bring the following benefits:

- Relay mode will enable a specific User Equipment to act as a Relay at the edge of the cell to easily extend the coverage in uncovered areas, either indoor or outdoor. This would be useful in temporary situation, for instance in cases where temporary additional coverage is required.
- Relay mode could be used as a complement to eMBMS to broadcast a message outside of a network through a mesh network, for instance to broadcast the existence of a danger on the road from car to car (Vehicle to Vehicle communication)

3.3.2 Relay mode potential

The adoption of LTE by public safety will drive the deployment of Relay features (impact for equipment manufacturers mostly). Indoor coverage may in certain situation be solved by relays deployment. In complex urban or natural field with many obstacles, relay may improve signal quality in shadowed areas.

Relay features within 3GPP have been mainly developed for the public safety market in order to be able to quickly bring coverage to areas of operation where no coverage is available. It should also grab minimal interest from Mobile Network Operators as it will provide more flexibility when extending their network, may this extension be temporary or not. This case however should be rather limited in terms of occurrence. In the long term, the use of relay feature for M2M/IoT purpose (in addition to the use of the broadcast mode) could have a significant potential.

In a far longer term (2025?), User Equipment such as smartphones could act as relay devices to opportunistically provide coverage to other users/objects/things at the edge of the network. This would require those devices to be energy autonomous or wireless communication to have limited impact on the users' device battery life.

Table 5: Evaluation of Relay mode market potential

Innovation	Scenario	The market today	Market potential (2018-2020)	Market players
Relay with open air interface	2.5.4, 2.6.2, 2.6.3	Relay: transportable base stations « tactical transportable areas» for Defense users	Relay: long term potential, MNOs reluctant? eMBMS coverage extension looks promising but the eMBMS market has not yet taken-off. In 2020, the relay market should not represent significant figures with only some trials around the world.	MNOs: address new market with M2M and IoT and offload some part of the traffic (especially for D2D broadcast)

3.4 Carrier aggregation

The fragmented spectrum assets of operators play in favor of CA deployment. Carrier aggregation brings both increased peak performance as well as increased average throughput, something that operators need to differentiate their network. Improvement on the RF side on mobile device (envelope tracking, antenna sharing...) make the support of a wide range of frequency bands possible (e.g. iPhone 6s and 6s plus support 23 different bands) with reduced impact on battery life. Furthermore, carrier aggregation may marginally improve battery life. The further development of User Generated Content puts a stress on the uplink and carrier aggregation in the uplink is one solution for this.

Carrier aggregation potential is already a reality and doesn't have to be demonstrated. This potential will maintain in the future as more and more frequency bands will be available. Frequencies above 6 GHz will notably provide higher capacity and throughputs. LTE Rel-13 should allow the aggregation of up to 32 different Carrier Components. The main driver to the aggregation of so many frequencies could however be the increased energy consumption that powering more antennas would imply.

Table 6: Evaluation of carrier aggregation market potential

Innovation	Scenario	The market today	Market potential (2018-2020)	Market players
Carrier aggregation	2.3.7 2.7.1 & 2.7.2, 2.7.3, 2.7.4	OK, already in use (but enhancements to come)	+++ CA is part of LTE-A and widely adopted by MNOs	MNOs : leverage their fragmented spectrum assets to provide increased network performance

3.5 COMP and MU-MIMO

COMP and MU-MIMO will be essential when densification of the network will be effective in order to mitigate interferences. Since the densification of networks is something for granted in the coming years, the potential is sizeable in the short to mid-term, although the market today is quite limited. The potential for the combination of COMP and MU-MIMO TM5 to limit resource usage will depend on the perceived efficiency of CoMP by MNOs.

Table 7: Evaluation of COMP and MU-MIMO market potential

Innovation	Scenario	The market today	Market potential (2018-2020)	Market players
COMP and MU-MIMO	2.1.1, 2.1.2, 2.1.3, 2.1.5, 2.1.6, 2.7.3	Limited	++: It will be essential when densification of the network will have started to improve interferences management	For MNOs, decrease CAPEX&OPEX while maintaining/improving service quality

3.6 FPGA

Innovations based on Field Programmable Gate Array could foster the number of aggregated Component Carriers within devices such as smartphones or even femtocells by notably enabling antenna to cover more bands with a smaller footprint. In the short term, the potential seems limited but could find its interest when higher order carrier aggregation will be requirement for Mobile Network Operators.

Table 8: Evaluation of FPGA market potential

Innovation	Scenario	The market today	Market potential (2018-2020)	Market players
FPGA	2.7.1 &2.7.2	?	Limited to research and development or testing of technology? Only use for filter bank implementation	MNOs: better cell-edge coverage thanks to the ability to more easily aggregate several frequency bands with the same RF Front End, especially low frequency bands. Reconfigurable RFFE & smaller antennas for femtocell will increase network densification penetration and facilitate installation

3.7 Caching

Caching and more generally Mobile Edge Computing will have its big interest in very densely populated area where a lot of people will download the same kind of content, application. Caching will primarily reduce the constraint on backhauling, which is of primary importance in the context of small cell deployment and heterogeneous network. This will help drive backhaul OpEx down.

Table 9: Evaluation of caching mode market potential

Innovation	Scenario	The market today	Market potential (2018-2020)	Market players
Caching	2.3.9	No market	Potential in densely populated areas and at sites with limited backhaul capacity	MNOs: reduce backhaul bottleneck and improve service by caching popular content at the cell site. May reduce backhaul OpEx

3.8 SON

The innovations regarding Self Organizing Network (SON) will have a very strong potential in the context of an ultra densified network. Indeed, in order for small cells to be economically viable, CapEx and OpEx need to be contained. OpEx will be reduced because less operation will be required to operate the small cell network and because it will enable energy savings. Also from a time to market perspective, the possibility to quickly deploy its small cell network is particularly important.

Table 10: Evaluation of SON market potential

Innovation	Scenario	The market today	Market potential (2018-2020)	Market players
SON	2.3.3, 2.3.4, 2.3.8, 2.3.10	Limited	+++ The densification of networks with small cell, although based on low power nodes will benefit from even more important energy savings with such optimization of power	MNOs: decrease in OpEx resulting from decreased overall network consumption without involving physical intervention
SON	2.3.12	Limited		MNO: will ease radio configuration and collaboration between cells depending on the user's position

4 CONCLUSION

This document summarizes all the dissemination and exploitations efforts achieved during the project. SHARING has advanced the evolution of future mobile networks via numerous contributions in several prestigious journals, magazines and conferences. In total, SHARING has published 33 journal papers and 89 conference papers, 1 book and several book chapters. In addition, SHARING has organized 5 workshops/special sessions and prepared several demonstrations. With 39 3GPP contributions, SHARING has impacted the standardization bodies alike.

APPENDIX

Celtic-Plus SHARING project – Press Release

The collaborative research project SHARING – Self-organized Heterogeneous Advanced Radio Networks Generation – opens up new perspectives for the improvement of user experience in 4G networks

Paris, November 2013

The SHARING project, launched by the Celtic-Plus European research initiative in September 2013, aims to stimulate the evolution of 4G mobile network standards by developing innovative technologies designed to improve network performance and user experience. The project follows other European industry-driven schemes led by initiatives such as FP7 and Celtic, including WINNER, WINNER+, ARTIST4G and BeFemto. These have all successfully leveraged European expertise on mobile technologies and the impact of technological developments on mobile network standards.

Due to the increased use of smartphones and tablets, the market is currently experiencing unprecedented growth in wireless traffic. To efficiently address this challenge, a consensus has now emerged that, given the current scarcity of spectrum, future wireless networks will need to be built across heterogeneous access (macro, micro, pico and femto cells) that incorporate multiple technologies (cellular and WiFi access points). Clearly, managing and optimizing such networks will be highly complex, particularly due to the interference caused by numerous neighbouring and overlapping cells. SHARING will seek to provide spectrally and energy efficient solutions for such heterogeneous networks, thereby helping to ensure that future wireless networks are able to offer the highest possible levels of quality and performance.

To this end, SHARING will explore new concepts with a special focus on the following areas: interference management; cost-power efficient small cell deployments; LTE-A / WiFi convergence; network controlled device-to-device communications; meshed relay-assisted networks; Self-Organized Network (SON) features and architecture evolutions for heterogeneous networks.

The project aims to develop solutions that will improve the overall user experience based on enhanced network performance (improved capacity, spectral efficiency and cooperation of different technologies and network layers).

SHARING brings together major actors from the mobile industry and the academic world to build consensus on standards development and the design of future wireless networks. The project partners are: Antenna Systems Solutions (Spain), Avea Iletisim Hizmetleri (Turkey), Commissariat à l'Énergie Atomique et aux Énergies Alternatives (France), Ericsson Finland (Finland), Eurecom (France), European Communication Engineering (Finland), Orange (France, project coordinator), IDATE Consulting and Research (France), Imperial College London (UK), Magister Solutions (Finland), Mitsubishi Electric R&D Centre Europe (France), NEC Technologies (France), Sequans Communications (France), Siradel (France), Supelec (France), Thales Communications and Security (France), TTI Norte (Spain) and the University of Oulu (Finland). The project will be completed in February 2016.