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Report on third-year mobility and awards

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Keywords:	Mobility grants, awards, best paper awards, young researcher award, distinguished researcher award

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Executive Summary

This deliverable reports on the activities and achievements within Work Package 3.5 "Development and valorisation of human capital", over the third year of NEWCOM# project. The aim is to facilitate the development of personal skills and the growth of professional competences in research, through funding scientific visits and awarding research works. The aims of this WP have been pursued through two tools: mobility grants and awards.

The mobility grants, of the amount of 2000 € each, consisted of seven grants provided to researchers who wish to spend at least one month in one of NEWCOM# partner premises or an external institution. The grants have been given to: Burak Cakmak (Aalborg University – Denmark), Carmine Vitiello (CNIT – UniPI – Italy), Gerhard Steinboeck (Aalborg University – Denmark), Laura Galluccio (CNIT – UniCT- Italy), Li Winjie (CNRS – Supelec – France), Quentin Bodinier (CNRS – Supelec – France), Slawomir J. Ambroziak (PUT - Poland).

In the case of awards, the recipients of second year call for N# awards were awarded during the N# Awards Ceremony that took place in Paris during the Gala Dinner of EuCNC 2015, on Wednesday 1st July 2015. Meanwhile, the recipients of the third year call for N# Awards were awarded during the N# Awards Ceremony that took place in Barcelona at the banquet of JNCW2015 (Joint NEWCOM# / COST IC1004 Workshop on Wireless Communications), on Wednesday 14th October. Each of the recipients of Best Student Paper Award (BSPA), Best Paper Award (BPA) and Distinguished Researcher Award (DRA), received 750 € paid directly by the coordinator (CNIT). The third year call for N# Awards was launched on the 12th of June and the deadline for submission was the 4th of July. The third year awardees are: Salvatore D'Oro, Laura Galluccio, Giacomo Morabito, Sergio Palazzo, Lin Chen, Fabio Martignon for the BSPA; Abdellatif Zaidi, Shlomo Shamai in case of BPA; in case of DRA, the evaluation committee decided to award: i) Raymond Knopp, ii) Adrian Kliks and Pawel Kryszkiewicz. Meanwhile the second year awardees were: Joffrey Villard, Pablo Piantanida, Shlomo Shamai for the BSPA; Achraf Mallat, Sinan Gezici, Davide Dardari, Luc Vanderdorpe for the BPA.

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Glossary

BPA	Best Paper Award
BSPA	Best Student Paper Award
DRA	Distinguished Researcher Award
WP	Work Package

1.Introduction

This deliverable reports on achievements in Work Package 3.5 “Development and valorisation of human capital” during the third year of NEWCOM#. This WP consists of two parts. The first one is the mobility grants, which aim at providing a number of actions in order to develop personal skills in research, while the awards aim at promoting and recognising excellence in the N# community. Mobility grants were awarded to PhD students, early-stage and experienced researchers to spend at least one month on a scientific visit in a foreign institution. It helps them to gain some knowledge about their field of interest. Moreover, it gives them some knowledge and skills obtained from different perspective of different research team. On the other hand, awards are given to papers and other important achievements obtained within the NoE. It is an important means to recognise hard working researchers within the network and to publicise network achievements.

The focus of this deliverable are the mobility grants and awards granted in the third year of NEWCOM#. In the next section, the steps taken in the third year regarding mobility grants are described. More in details, it explains the role of mobility grants, the process of application and reviewing, and it presents the list of applicants, awarded persons and their research topics in the mobility grant. In Section 3, N# awards are summarised. Conclusions are presented in Section 4.

2. Third year mobility grants

2.1 Introduction to mobility grants

The aim of the mobility grants is to improve the international cooperation research and career development by promoting exchanges of researchers among different institutions. The call for mobility grants was opened on 28th of February using the NEWCOM# website [1] and a mailing list. The deadlines for this call were:

- Application deadline: 30th March 2015
- Decision notification: 10th June 2015

The mobility grant winners were notified on 9th June, after reception of all the evaluations.

2.2 Rules and application process

As in the past calls, three documents were prepared: the guidelines, application form and activity report template. The guidelines (see Annex A) give the purpose of the call, which aims to enhance face-to-face cooperative research and to promote exchanges of researchers among different institutions. Eligible applicants were researchers preferably from NEWCOM# or associated partners. However, the call was open also to researchers from external institutions. Proposals showing inter-track (Trak1-2) collaboration were favoured. The grant did not cover a fix-term visit, as long as it was within NEWCOM# project duration, but priority was given to stays with duration of one month or above. Seven researchers were selected and provided 2000 €. The criteria used during the evaluation process of this call were as follows:

- Relevance to the objectives of NEWCOM# (links to WPs).
- Feasibility and clarity of the objectives.
- Integration:
    - added value to already existing liaisons;
    - new collaborations;
    - "Cross-fertilisation" (the person who moves should have complementary knowledge with respect to the one of the hosting institution in any case helpful for the research)
- Quality of applicant's CV;
- Proposals coming from NEWCOM# Institutions will be favoured
- Proposal showing inter-track (Track1-2) collaboration will be favoured
- Preference will go to female researchers *ceteris paribus*.

2.3 Third call for mobility grants

2.3.1 Evaluation process and results

The Evaluation Board, which reviewed all the applications of the third call, was composed of:

- Adrian Kliks (Poznan University)
- Jordi Perez-Romero (UPC)
- Erdal Arikan (Bilkent University)
- Allister Burr (York University)

- Jossy Sayr (University of Cambridge)

Based on the criteria in the guidelines, a review form was prepared and filled by all the members of the Evaluation Board. They evaluated the relevance of the topics to N# objectives, as well as the feasibility and clarity of the objectives. After gathering all the review reports, a discussion and decision was made on the 9th of June. For the third year call for mobility, eleven applications were received. All applications addressed interesting problems from the scientific viewpoint, and the researchers had valuable achievements justifying the high quality of future publications.

In Table 2.1, the applicants, their institution and subject of the proposal are summarised. The row in bold highlight applicants that had been granted. In this report, we would like to emphasize the relevant role of mobility grant calls within the project duration; a clear signal is that four of them had already applied for a grant in preceding calls.

Table 2.1: List of all the applicants – in boldface type the granted ones

First Name	Last Name	Sending institution / Country	Hosting institution / Country	Duration of the research stay	Subject
Slawomir Jerzy	**Ambroziak**	**Gdansk Univ. of Tech, Poland**	**IST, Portugal**	**1 month**	**Simulation research on the radio wave polarisation in Body Area Networks**
Carmine	**Vitiello**	**Cnit/UniPi, Italy**	**CNRS/ Eurecom, France**	**2 months**	**Comparison between candidate architectures for 5G Physical Layer**
Laura	**Galluccio**	**Cnit/UniCt, Italy**	**CNRS, France**	**1 month**	**On the use of combined compressive sensing and network coding in multicast sensor networks**
Paolo	Del Fiorentino	Cnit/UniCt, Italy	CTTC, Spain	1 month	Over-the-air test and validation of resource-allocation algorithm for 5G wireless communications
Burak	**Cakmak**	**Aalborg University, Denmark**	**TU Berlin, Germany**	**10 weeks**	**Dynamics and Stability of Approximate Message Passing Techniques**
Gerhard	**Steinboeck**	**Aalborg University, Denmark**	**TU Ilmenau, Germany**	**5 weeks**	**Multi-band Millimetre-Wave Channel Characterisation for 5G Systems**
Li	**Wenjie**	**CNRS/ UPSud, France**	**Cnit/UniBo , Italy**	**6 weeks**	**Distributed outlier detection in a wireless sensor network**

Quentin	**Bodinier**	**CNRS/ Supelec, France**	**CTTC, Spain**	**1 month**	**MIMO processing for 5G networks**
François	Rottemberg	UCL, Belgium	CTTC, Spain	11 weeks	Precoder and decoder design for FBMC-based Massive MIMO 5G systems
Anna	Dudnikova	Cnit/UniCt	CTTC, Spain	7 weeks	A multi–criteria greedy cell switch off algorithm for LTE heterogeneous networks
Giuseppa	Alfano	Cnit/Polito	UCL, Belgium	1 month	Statistics of realistic mimo channels: polarisation, interference correlation and clustering issues

Results were communicated to the winners by contacting them directly by mail and announced on NEWCOM# webpage.

In Annexes C – I the mobility grant reports are presented. The reports pending from the previous call are: i) Annex J: the last report related to the regular second year call for mobility; ii) Annexes K – P: the second year special call mobility grant reports.

Some statics about the mobility grant applications are shown in the following figures.

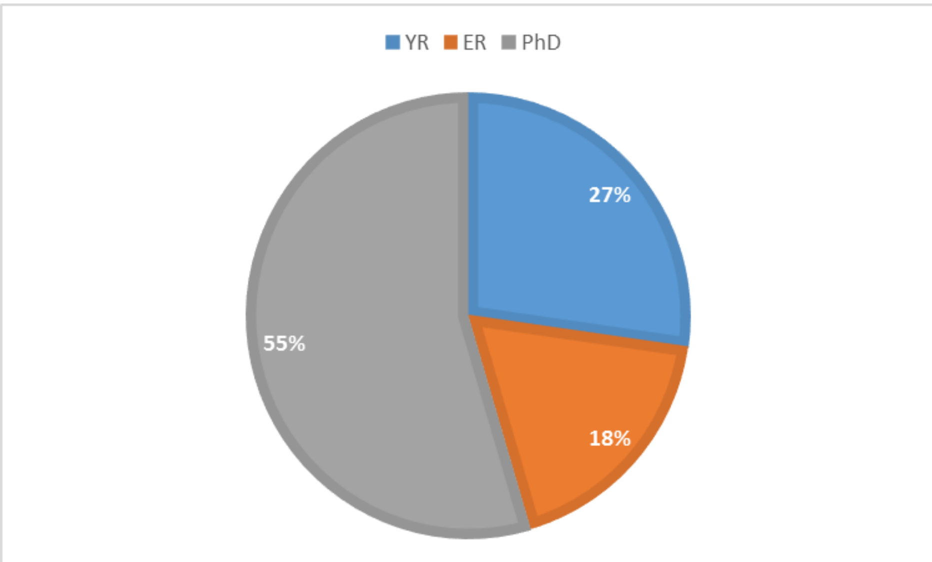

Figure 2.1: Percentage of applicants belonging to certain research seniority groups (YR = young researcher, ER = experienced researcher, PhD = PhD student).

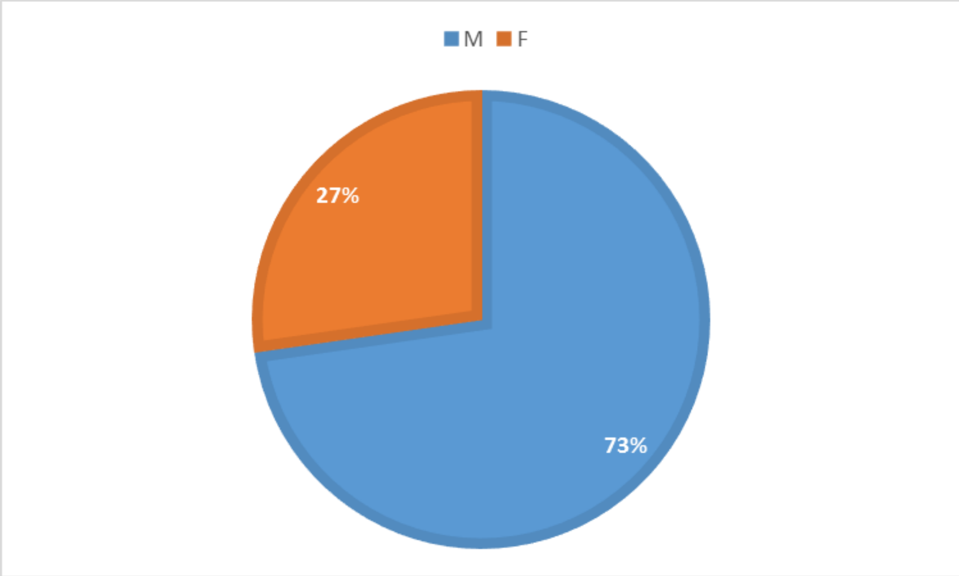

Figure 2.2: Percentage of applicants divide by gender.

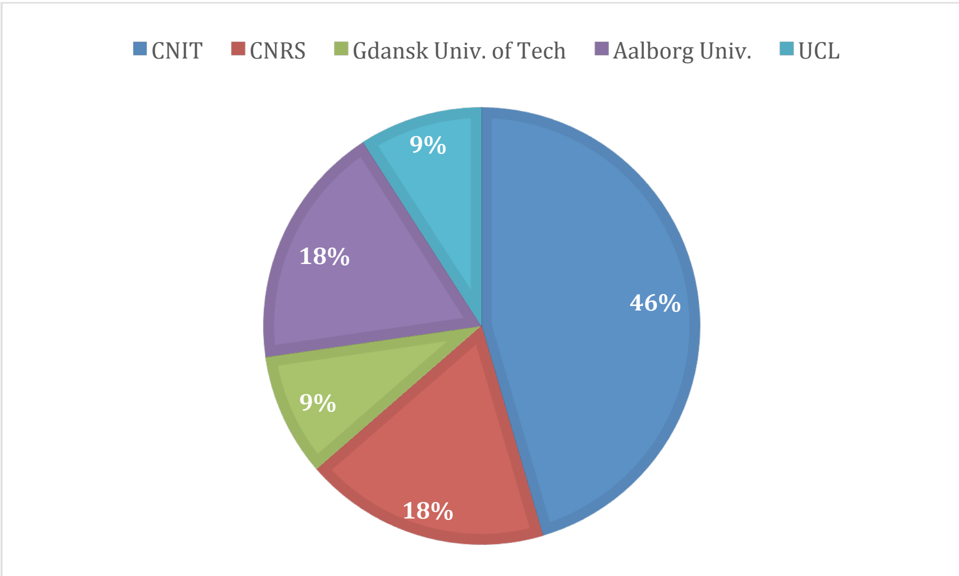

Figure 2.3: Percentage of sending institutions.

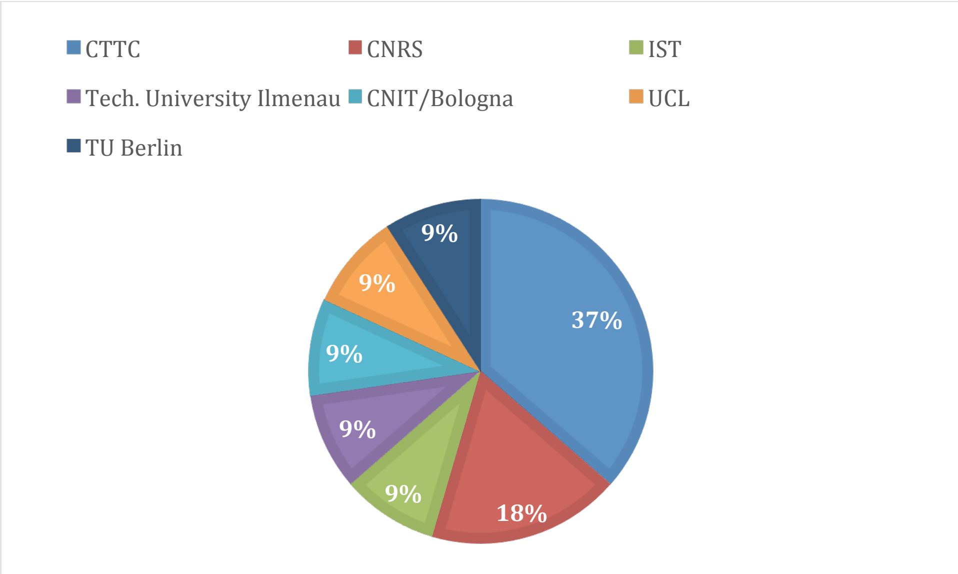

Figure 2.4: Percentage of hosting institutions.

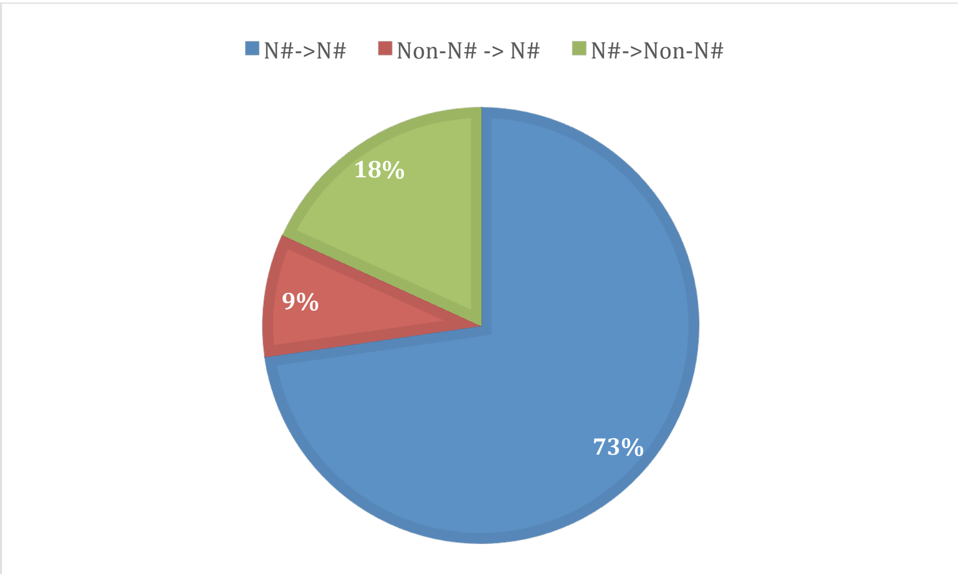

Figure 2.5: Percentage of sending/hosting institutions. Project prospective.

3. NEWCOM# awards

3.1 Introduction to third year awards

There are three kinds of awards to be granted each year in order to promote excellence in research within NEWCOM# [2]:

- The NEWCOM# Best Paper Award (BPA)
- The NEWCOM# Best Student Paper Award (BSPA)
- The NEWCOM# Distinguished Researcher Award (DRA).

Two *ad-hoc* Award Committees were created: one for BPA/BSPA evaluation and the other for DRA evaluation. Both chaired by NEWCOM# Scientific Director Marco Luise (CNIT) without voting privilege.

The call was opened on 12th of June using the NEWCOM# website [2] and a mailing list. The deadlines for this call were:

- Application deadline: 4th July 2015
- Decision notification: 31st July 2015

The winners were notified, after reception of all the evaluations.

The review committee of the BPA/BSPA was composed of:

- Vincent Poor (Princeton University)
- Helmut Bolcskei (ETH - Zurich)
- Matsumoto Tadashi (JAIST)

Meanwhile, the review committee for DRA was composed of:

- Luis M. Correia (IST - Inov)
- Bernard Fleury (Aalborg University)
- Andreas Polydoros (IASA)

3.2 Rules and application process

The rules of the awards were published on the NEWCOM# webpage and via a mailing list. The call opened on June 12th, 2015. Submission deadline was July 4th, 2015 and a final decision by the Committee was made on July 31st. Mobility Grants were available not only to NEWCOM# researchers, the awards were limited to researchers working and publishing papers within the NoE. All papers proposed for awards should have acknowledgement to the NEWCOM# project. The three awards were:

- Best Paper Award (BPA): to the best paper already published or accepted for publication by the submission deadline, and authored by NEWCOM# researchers;
- Best Student Paper Award (BSPA): to the best paper already published or accepted for publication by the submission deadline, and authored by NEWCOM# student researchers. The first author must be under 30 years of age.

- Distinguished Research Award (DRA) to a (group of) researcher(s) belonging to NEWCOM# that has achieved special results in research or dissemination resulting of his/her (their) activity in the project and during project's lifetime.

Each winner was awarded with 750 € paid by the project coordinator – CNIT. The main selection criteria were:

- Contribution to the advancement to the field of Wireless Communications;
- Relevance to the objectives of NEWCOM# (links to WPs);
- General quality, originality of research, contributions, subject matter, clarity and style of presentation;
- Priority: to papers co-authored by researchers belonging to more than one NEWCOM# partner were given special consideration in the evaluation process.
- Ceteris Paribus, preference were given to female researchers.
- The gender action, covered by the last criteria, is promised in the Description of Work to cover the DRA, though it has been decided to extend it to other awards too.

For the third year DRA, a new scheme for application was introduced: i) a candidate could propose him/herself for the award; ii) anyone could nominate a candidate for the award. In the latter case, the nominator had to produce a short document describing the reasons and the results achieved by the nominee.

The Awards were physically given during N# Awards Ceremony at JNCW 2015 (NEWCOM#'s Final Event in Barcelona).

3.2.1 BPA/BSPA: Evaluation process and results

The Awards Committee, which reviewed all the applications of the third call, was composed of:

- Vincent Poor (Princeton University)
- Helmut Bolcskei (ETH - Zurich)
- Matsumoto Tadashi (JAIST)

They evaluated the relevance of the topics to N# objectives, as well as the feasibility and clarity of the objectives. After gathering all the review reports, a discussion and decision was made on the 9th of June.

In the tables below, the applicants, their institution and title of the scientific paper they proposed.

Table 3.1 List of all the applicants for BSPA – in boldface type the granted ones.

First Name	Last Name	Institution	Country	Paper Title
Salvatore	D'Oro	Cnit/UniCt	Italy	Cost-Efficient Throughput Maximisation in Multi-Carrier Cognitive Radio Systems
Salvatore	D'Oro	Cnit/UniCt	Italy	On the trade-off between delivery delay and power consumption in opportunistic scenarios
Salvatore	D'Oro	Cnit/UniCt	Italy	Adaptive Transmit Policies for Cost-Efficient Power Allocation in Multi-Carrier Systems
Salvatore	**D'Oro**	**Cnit/UniCt**	**Italy**	**Defeating Jamming With the Power of Silence: A Game-Theoretic Analysis**
Stefan	Mijovic	Cnit/UniBo	Italy	Optimal Design of Energy-Efficient

				Cooperative WSNs: How Many Sensors Are Needed?
Jeroen	Van Hecke	UCL	Belgium	Goodput-maximising Resource Allocation in Cognitive Radio BIC-OFDM systems with DF Relay Selection

Table 3.2: List of all the applicants for BPA – in boldface type the granted ones.

First Name	Last Name	Institution	Country	Paper Title
Veronica	Belmega	CNRS	France	Energy-Aware Competitive Power Allocation for Heterogeneous Networks Under QoS Constraints
Petar	Djuric	Stony Brook University	USA	Indoor Tracking: Theory, Methods, and Technologies
Luca	Sanguinetti	Cnit/UniPi	Italy	Interference Management in 5G Reverse TDD HetNets With Wireless Backhaul: A Large System Analysis
Ana	Moragrega	CTTC	Spain	Potential Game for Energy-Efficient RSS-Based Positioning in Wireless Sensor Networks
Ivan	Stupia	UCL	Belgium	Power Control in Networks With Heterogeneous Users: A Quasi-Variational Inequality Approach
Abdellatif	**Zaidi**	**Universite Paris-Est Marne-La-Vallee**	**France**	**On Cooperative Multiple Access Channels With Delayed CSI at Transmitters**

The review committee decided to award:

- For the BSPA the paper “Defeating Jamming With the Power of Silence: A Game-Theoretic Analysis” - Salvatore D'Oro, Laura Galluccio, Giacomo Morabito, Sergio Palazzo, Lin Chen, Fabio Martignon;
- For the BPA the paper “On Cooperative Multiple Access Channels With Delayed CSI at Transmitters”- Abdellatif Zaidi, Shlomo Shamai

3.2.2 DRA: Evaluation process and results

The Awards Committee, which reviewed all the applications of the third call, was composed of:

- Luis M. Correia (IST- INOV)
- Andreas Polydoros (IASA)
- Bernard H. Fleury (Aalborg University)

The number of the received applications was three. In particular, two were self-nominated while a third person nominated the other.

In the table below, the applicants and their institution are shown.

Table 3.3: List of all the applicants for DRA – in bold the granted once

First Name	Last Name	Institution	Country
Raymond H.	**Knopp**	**EURECOM**	**France**
Adrian	**Kliks**	**Poznan TU**	**Poland**
Pau	Closas	CTTC	Spain

Due to the fact that during second year of the project no DRA was assigned, it was decided to assign two awards during the third year.

3.2.3 BPA/BSPA: second year results

The second year BPA/BSPA were presented during the N# Awards Ceremony that took place in Paris during the Gala Dinner of EUCNC 2015, on Wednesday 1st July 2015.

The awarded researchers were:

- For BSPA: Dr. Villard, Prof. Piantanida, Prof. Shamai
- For BPA: Dr. Mallat, Prof. Gezici, Prof. Dardari, Prof. Vanderdorpe

4. Conclusion

During the third year of NEWCOM#, a call for mobility grants and a call for project awards were launched. There were eleven applications for mobility grants. The large number of applicants shows that the cooperation between partners became more mature. Moreover, the fact that four researchers applied for the second or third time demonstrates the success of this tool to expose young researchers to the international research community on one hand. On the other hand, it justifies the need for this tool.

A satisfying result was achieved also in case of BSPA and BPA. In fact, there were six applications for the BSPA and six for the BPA. The origin of the received papers (best international journals and conferences) showed a good development of researchers' skills and coherence between topics investigated within the NoE and worldwide trends.

In case of DRA, three applications were received. The evaluation committee decided to assign two DRA this year; this decision was made taking into account the fact that during the second year no DRA was assigned.

Considering all the actions that have been taken, the amount of applications and generally cooperation between the partners, we can conclude that the aims of this WP have been fulfilled.

5.References

[1] NEWCOM#, http://www.newcom-project.eu/index.php?option=com_content&view=article&id=149&Itemid=208, Date of access: 28/10/2015

[2] NEWCOM#, http://www.newcom-project.eu/images/N_Awards_Call%20for%20submission.pdf, Date of access: 28/10/2015

6. Annex A: Third year call for mobility grants

Seventh Framework Programme

MOBILITY GRANTS

Call for applications and guidelines – Third year

Opening of the call: 28th February 2015

Project acronym: NEWCOM#
Type of contract: NETWORK OF EXCELLENCE.
Contract N°: 318306
Project URL: http://www.newcom-project.eu/

GENERAL ASPECTS	
Purpose	The aim of the mobility grants is to enhance face-to-face cooperative research and to promote exchanges of researchers among different institutions.
Participants	Young researchers (typically early stage researchers) preferably from N# beneficiaries or associate partners, not excluding external institutions.
Duration	The duration of the research stay is not fixed, as long as it is within NEWCOM# duration. Priority will be given to stays with a duration of 1 month or above.
Budget	The total budget allocated for each grant is € 2.000,00.
Number of grants	The maximum number of grants to be issued in the third year is six.
Claim and Proof	The grant will be directly paid to the winner by the coordinator CNIT. Within 60 days from the end of the stay the researcher will send to the project Office a short activity report as well as a certification by the hosting institution with starting and ending date of the stay.
EVALUATION OF PROPOSALS	
Criteria	• Relevance to the objectives of NEWCOM# (links to WPs). • Feasibility and clarity of the objectives. • Integration: o added value to already existing liaisons; o new collaborations; o "Cross-fertilisation" (The person who moves should have complementary knowledge with respect to the one of the hosting institution in any case helpful for the research) • Quality of applicant's CV; • Proposals coming from N# Institutions will be favoured • Proposals showing inter-track (Track1-2) collaboration will be favoured • Preference will go to female researchers *ceteris paribus*.
Procedure	Each project will be evaluated by the Mobility Panel to be appointed by the Executive Board. In case of conflicts of interest, the corresponding member(s) of the Panel will be replaced by a person chosen by the Executive Board.
Supporting Documentation	Application Form and Applicant's CV

SCHEDULE

- Proposal Submission: 28th February 2015
- Application Deadline: 30th March 2015
- Decision Notification: 10th June 2015.

APPLICATION FORM AND SUBMISSION INSTRUCTIONS

The applicants should send the Proposals to the NEWCOM# Office project_office@newcom-project.eu

The application form can be found at: http://www.newcom-project.eu under the 'Mobility' section.

7. Annex B: Call for Awards

Seventh Framework Programme

3rd BEST PAPER, BEST STUDENTE PAPER and DISTINGUISHED RESEARCHER AWARDS

Call for submissions

Opening/Closure of the call: June 12/July 4, 2015

Project acronym: NEWCOM#

Type of contract: NETWORK OF EXCELLENCE

Contract N°: 318306

Project URL: http://www.newcom-project.eu/

GENERAL ASPECTS	
Purpose	The aim of the awards is to encourage (especially, young) researchers to publish their research work and to promote a healthy competition among researchers and institutions.
Participants	The papers must have originated from NEWCOM# researchers and contain the acknowledgement of NEWCOM# support.
Budget	The budget allocated to each award is 750 euro. Three awards will be issued during the third year of NEWCOM#: • 3rd Best Paper Award (BPA): to the best paper already published or accepted for publication by the submission deadline, and authored by NEWCOM# researchers; • 3rd Best Student Paper Award (BSPA): to the best paper already published or accepted for publication by the submission deadline, and authored by NEWCOM# researchers. The first author must be under 30 years of age. • 3rd Distinguished Research Award (DRA) to a (group of) researcher(s) belonging to NEWCOM# that has achieved special results in research or dissemination resulting of his/her/their activity in the project and during project's lifetime
Prize-giving	The prize will be issued to the winner by the coordinator (CNIT)
EVALUATION	
Criteria	✓ Contribution to the advancement to the field of Wireless Communications; ✓ Relevance to the objectives of NEWCOM# (links to WPs); ✓ General quality, originality of research, contributions, subject matter, clarity and style of presentation; ✓ Priority: papers co-authored by researchers belonging to more than one NEWCOM# partner will be given special consideration in the evaluation process. ✓ *Ceteris Paribus*, preference will be given to female researchers
Procedure	Two committee will evaluate the submissions: ✓ Each paper will be evaluated by the BPA/BSPA Committee, formed by external distinguished experts.

	✓ The Distinguished Research Award will be evaluated by a sub-committee of the Executive Board Both Committees will be chaired, without voting privilege, by the NEWCOM# Scientific Director.
Schedule and Documentation	✓ For the BPA and BSPA, the applicants must send a PDF version of their paper(s) to the NEWCOM# Office at project_office@newcom-project.eu by the submission deadline indicated below. ✓ For the DRA, instead, the applicants must provide a short document (max. 1 page) describing the achievements as a result of his/her/their involvement in the project plus CV(s). ✓ For the DRA, this year, anyone can nominate a candidate for the award. In this case, the nominator must provide a short document (max. 1 page) describing the reasons and the results achieved by the nominee emphasising his/her/their involvement in the project. **Submission deadline: July 4, 2015** **Notification of the ranking: July 31, 2015.**

8. Annex C: Report of Burak Cakmak

MOBILITY GRANT
Report

Guest name: Burak Cakmak
Guest institution: Aalborg University, Denmark

Host name: Professor Manfred Opper
Host institution: Technical University of Berlin, Germany

Research topic: Dynamics and Stability of Approximate Message Passing Techniques

Starting date: 06. April 2015
Ending date: 05. August 2015

1. Scope of Work
Building a theoretical framework to solve TAP equations iteratively.

2. Motivations
Promising, low-complexity and near optimum solutions for compressed sensing, detection problems in Massive MIMO and the iterative receiver design techniques as well.

3. Objectives
Developing a theoretical framework that allows us to design and analyze algorithms for solving TAP-like equations with general invariant random matrices.

4. Meetings
During my visit I have had bilateral meetings with Professor Opper. These meetings have taken place 4 times (roughly) a week.

5. Activities
During the stay Professor Opper , Mr. Cakmak and Professor Winther (from DTU) have built a new theoretical framework for the objectives mentioned above. Moreover we have written a journal paper.

6. Results
We have developed an analysis of iterative algorithms using a dynamical functional approach that in the thermodynamic limit yields an effective dynamics of a single variable trajectory. We have submitted the corresponding paper "A Theory of Solving TAP Equations for Ising Models with General Invariant Random Matrices", to Journal of Physics: Mathematical and Theoretical. See also arXiv version at http://arxiv.org/pdf/1509.01229.pdf .

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7. Plans for Follow-up

We have presented a theoretical approach to the design of iterative algorithms for solving the TAP equations for Ising models with random couplings drawn from general invariant ensembles. Using dynamical functional theory we have shown that in such a way, memory terms can be canceled and one arrives at a Gaussian distributed field, which eventually converges to the cavity field provided that a stability condition is fulfilled. We have presented a specific method which we have called the 'Single Step Memory Construction'. Our approach may be extended in several ways. For example other subtraction methods are possible. One might design an alternative scheme, where the response function is required to be zero after one time step leading to a somewhat different algorithm and we will give details elsewhere. It would be interesting to see in which cases the explicit memory terms in the subtraction method can be simplified by introducing auxiliary variables as is possible for the Hopfield model. Other extensions of our method would be to more general probabilistic models beyond the simple Ising case. This would include continuous random variables and other forms of interactions. An application to models of compressed sensing would be interesting where certain random matrix ensembles (such as the random orthogonal ones) might be natural models for the observation matrix. We will discuss details in a forthcoming publication. Finally, it would be important to address a drawback of our method which prevents an application to probabilistic inference problems with arbitrary data. Our subtraction scheme depends explicitly on the random matrix ensemble of couplings which may not be known in practice. Hence it would be interesting to develop schemes which adapt to the concrete data which would then achieve convergence to 'adaptive TAP equations', providing possible alternatives to the currently applied message passing algorithms like expectation propagation.

8. Attachments

The corresponding paper can be downloaded from http://arxiv.org/pdf/1509.01229.pdf !

Signature

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9. Annex D: Report of Carmine Vitiello

MOBILITY GRANT
Report

Guest name: Carmine Vitiello
Guest institution: CNIT – University of Pisa

Host name: Raymond Knopp
Host institution: CNRS - Eurecom

Research topic: Comparison between candidate architectures for 5G Physical Layer

Starting date: 15/09/2015
Ending date: 15/10/2015

1. Scope of Work

This activity follows the experimental activity conducted in the past and supported by NEWCOM# mobility grant, about the development of UFMC (Universal Filtered Multi-Carrier) waveform. Starting from the result of last activity, we target analysing and implementing different waveforms under consideration for 5G Physical Layer, such as GFDM (Generalized Frequency Division Multiplexing).

2. Motivations

UFMC, GFDM and conventional OFDM are the best candidate multicarrier waveforms for the air interface of newest 5G system. We investigated about efficiency of this architectures especially in case of joint transmission/reception of broadband multimedia traffic and bursty machine-type communications (e.g. car-to-car or health monitoring applications) in order to prove the best features of each waveform in this scenario.

3. Objectives

The main objective of the mobility action is to continue a long-term collaboration among the partners in the field of Software-Defined Radio applied to 5G technologies which also allows collaboration to continue beyond NEWCOM#.
This visit focused on developing GFDM waveform and improving UFMC waveform from adding to OpenAirInterface.org library in order to enlarge its potentiality. The GFDM waveform blocks will be added to the existing real-time software libraries from OpenAirInterface.org and tested with the USRP B210 and ExpressMIMO2 platforms at EURECOM. In the testing phase we focused on the waveform behaviour in case of imperfect synchronization, evaluating out-of-band emission and time-frequency efficiency. We will also evaluate the efficiency of turbo-coded transmission of short block-length packets in conjunction with the new waveforms.

4. Meetings

- **01/09/2015:** Research activity was planned in details thanks by Skype meeting. Starting from literature, we established basic architecture scheme of GFDM waveform and we discussed what aspects can be improved. We decided to investigate on several structures of transmitters, for example applying classic “superimposition” scheme or using “modulation matrix” or exploiting the capabilities of Fourier transform. We planned to simulate GFDM waveform by Matlab and porting the code on real system using by OpenAirInterface after architecture optimization. Attendees: Prof.Raymond Knopp and Carmine Vitiello
- **Eurecom (Sophia-Antipolis) - 15/09/2015:** In the initial meeting we discussed some former results obtained by Matlab simulations and their impacts on development of GFDM waveform. We decided to implement “superimposition” scheme by using upsampling in order to computationally simplify the operation at the transmitter. Attendees: Prof.Raymond Knopp and Carmine Vitiello
- **Eurecom (Sophia-Antipolis) - 16/09/2015–14/10/2015:** Several meeting have been done thanks by Prof.Knopp availability when a problem occured. Side-by-side work guaranteed constant development of the GFDM waverform and comparison with UFMC and classical OFDM, via Matlab simulations and C code implementation on OpenAirInterface. Attendees: Prof.Raymond Knopp and Carmine Vitiello
- **Eurecom (Sophia-Antipolis) - 15/10/2015:** Final meeting has been done at the end of Mr.Vitiello visit. Achieved results have been discussed particularly emphasizing the potentially uses of the waveform, for testing and development of future applications. We also delineated future plans in order to exploit UFMC and GFDM and the joint collaboration between Eurecom and UniPi. Attendees: Prof.Raymond Knopp and Carmine Vitiello

5. Activities

UNIPI and EURECOM activity focused on developing GFDM waveform, testing it on real scenario in order to evaluate its features in comparing with classical CP-OFDM and new UFMC waveform peculiarities. As done in the previous visit, we decided to implement GFDM on a real-system, such as LTE. Given that UFMC and OFMD are already implemented on OpenAirInterface, we continued to use this tool for developing and testing waveforms. OpenAirInterface is based on SDR hardware, therefore we are able to modify the digital signal processing of the system devices, from baseband to radio frequency domain. Furthermore it implements LTE eNB with release 10 and LTE UE with release 8. Starting from this point, we decided to work on LTE uplink level, modifying transmitter modulator, based on OFDMA or SC-FDMA, and adapting standard receiver. In according with literature and supposing we work on 10MHz band, we adapt our waveform to the following OFDM features:

- FFT size = 1024;
- Cyclic prefix length = 72 or 80 (depends to time domain symbol);
- Number of subcarrier per multicarrier symbol= 12B where B is PRB number and 12 is the number of resource element per PRB (in number of subcarriers).

UFMC waveform exploits same FFT size, taking into account real FFT size and upsampling operation, a filter length of 73 or 81 coefficients and the same subcarrier number of OFDM system. Before to set the right setting to GFDM waveform, it’s better to explain its structures, starting from the most intuitive transmitter scheme, called superimposition scheme. Supposing to transmit vector $\boldsymbol{d}=(d_0, d_1, \dots, d_{N-1})^T$ composed by N complex symbols, already mapped into a constellation. GFDM modulator divides N symbols into K subcarriers and M subsymbols,

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The latter approach instead exploits the Fourier transform deduced from the initial transmitter. Here the transmitter signal can be written as:

$$\boldsymbol{x} = \frac{1}{N}\boldsymbol{W}_N^H \sum_{k=0}^{K-1} \boldsymbol{P}^{(k)}\boldsymbol{G}\boldsymbol{R}^{(K,M)}\boldsymbol{W}_M\boldsymbol{d}_k$$

where $\boldsymbol{d}_k$ represents transmit data on *k*-th subcarrier (*M* subsymbols), $\boldsymbol{W}_M$ is Fourier matrix with size M, $\boldsymbol{R}^{(K,M)}$ is repetition matrix, $\boldsymbol{G}$ is the diagonal filter matrix in frequency domain, $\boldsymbol{P}^{(k)}$is the circular shift matrix of the *k*-th subcarrier. This scheme can be directly exploited in frequency domain working on subsymbols taking data on *m*-th subsymbol (*K* subcarriers) as follows:

$$\boldsymbol{x} = \sum_{m=0}^{M-1} \boldsymbol{P}^{(m)}\boldsymbol{g}\boldsymbol{R}^{(M,K)}\boldsymbol{W}_K^H\boldsymbol{d}_m$$

where $\boldsymbol{g}$ is diagonal filter matrix in time domain. In this contest we choice to work with traditional scheme because it shows better features in terms of parallelization and larger degree of freedom for future modifications. Indeed circular filtering with relative frequency shifting results really easy to implement in C, thus in OAI, maximizing the exploiting of parallel programming. In order to maintain the same receiver changing as little as possible without rebuild a specific structure for every waveform, we use classical FFT scheme to demodulate the incoming signals. In order to evaluate the performance of the system using short packet, the configuration used in the testing phase occupy only 3 PRBs, from 21st to 23rd, removing the 7.5KHz offset usually applied in standard communications. Comparison from different spectrum are depicted in Fig. 2.

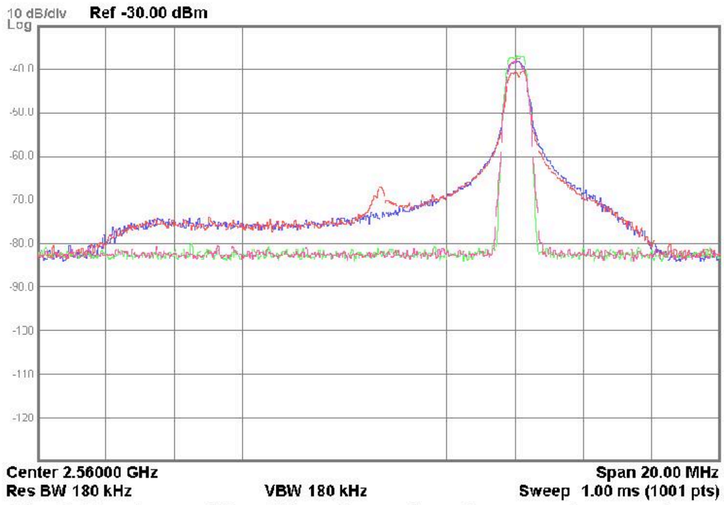

Fig. 2- Spectrum of the different waveform from spectrum analyzer

It is possible to see the best behaviour in terms of OOB emission from UFMC(lower red line) and GFDM(green line), than SC-FDMA(blue line) and OFDM(upper red line). Considering more or less the same occupied bandwidth, UFMC is computationally lighter than GFDM.

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each according to $\boldsymbol{d}$=$(\boldsymbol{d}_0^T, \boldsymbol{d}_1^T, \dots, \boldsymbol{d}_{M-1}^T)^T$ where $\boldsymbol{d}_m$=$(d_{0,m}, d_{1,m}, \dots, d_{K-1,m})^T$ and N=MK. Data can be expressed by the block:

$$\boldsymbol{d} = \begin{pmatrix} d_0 \\ d_1 \\ \vdots \\ d_{N-1} \end{pmatrix} = \begin{pmatrix} d_{0,0} & \cdots & d_{0,M-1} \\ \vdots & \ddots & \vdots \\ d_{K-1,0} & \cdots & d_{K-1,M-1} \end{pmatrix}$$

Afterwards the generic element $d_{k,m}$ corresponds to the data transmitted on the *k-th* subcarrier and in the *m-th* subsymbol of the block. Circular pulse shaping filter $\boldsymbol{g}$ is applied to each subsymbol on the *k-th* subcarrier and then pulse shaped symbol is up converted by $e^{-j2\pi\frac{k}{K}n}$. The corresponding pulse shape of generic $d_{k,m}$ at time *n* can be written as:

$$g_{k,m}[n] = g[(n - mK) mod N] \cdot e^{-j2\pi\frac{k}{K}n}$$

The transmitted signal $\boldsymbol{x}$ can be obtained by the superimposition of each symbols as follows:

$$x[n] = \sum_{k=0}^{K-1}\sum_{m=0}^{M-1} g_{k,m}[n] d_{k,m}$$

The structure of the GFDM transmitter is depicted in the followed picture.

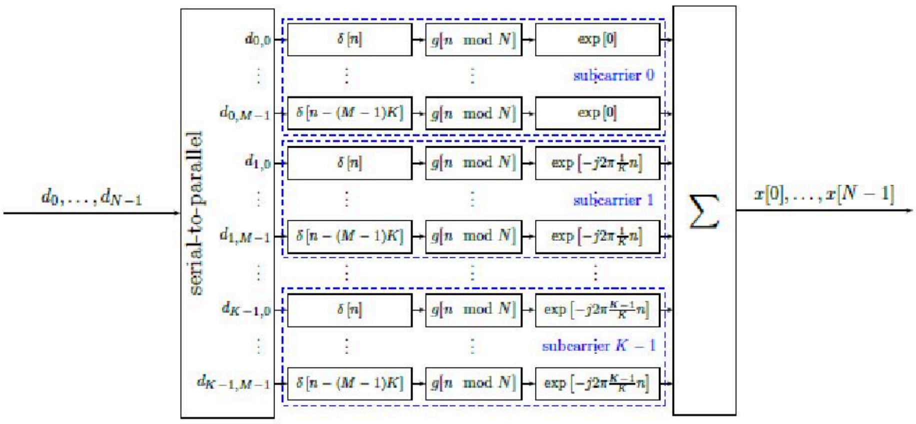

Fig. 1- GFDM transmitted system model

To make GFDM compatible to the LTE framing, we set the number of used subcarrier to K=12B, the number of subsymbols to M=12 plus one subsymbol for the cyclic prefix. Further we add two guard symbols at the start and at the end of the block in order to reduce OOB emissions. These guard symbols could potentially be used as pilot symbols. Raised cosine filter with a roll-off factor equal to *0* has been applied. In our work we also evaluated other approach about transmitter structure such as modulation matrix and by using Fourier transform. The former approach exploits the linear property of the classic modulation compressing each operation of the transmitter into only one matrix called *A*. So the transmitted symbols can be represented as:

$$\boldsymbol{x} = \boldsymbol{Ad} = \begin{pmatrix} a_{0,0} & \cdots & a_{0,N-1} \\ \vdots & \ddots & \vdots \\ a_{N-1,0} & \cdots & a_{N-1,N-1} \end{pmatrix} \begin{pmatrix} d_0 \\ \vdots \\ d_{N-1} \end{pmatrix}$$

- 3/5 -

6. Results

a. Scientific results

Mainly this activity is addressed to implement a new branch on OpenAirInterface tool in order to give new possibilities of experimentation, evaluating impacts of GFDM on real system and in real scenarios. Thanks by this implementation, we started to evaluate the behavior of GFDM and UFMC on real scenario. We have shown through real-time experiments the benefits of UFMC and GFDM over OFDM and SC-FDMA in the uplink communications of LTE systems, testing new waveforms on UEs with small burst of traffic. Both UFMC and GFDM have a much lower adjacent channel leakage ratio, even when it operates without time or frequency synchronization to the primary system, facilitating dynamic spectrum access and decreasing interference between adjacent signals that access to contiguous resources. UFMC shows more or less same OOB emissions and the same bandwidth of GFDM but saving a lot of computational resources.

b. Collaboration results

The visit of Carmine Vitiello allowed the continuation of collaboration started thanks to previous NEWCOM# mobility grant between involved institutions, Eurecom and University of Pisa. Furthermore it represents an inter-track activity between Track 1 and Track 2: in particular it assumes relevance on work packages WP1.3 Energy and Bandwidth - Efficient Communications and Networking, Task 1.3.2 Low-interference, low-emission, radio interfaces and WP2.1 Radio Interfaces for next-generation wireless systems, Task 2.1.2 Low-energy-consumption and low-emission radio interfaces. After this visit UniPi is joint into OAI Alliance.

c. Dissemination

All of the results, both numerical and drawn theoretical conclusions, will be presented as papers, journals and conference talks.

7. Plans for Follow-up

Frequency and timing misalignments are still under study as well as the coexistence between OFDMA or SC-FMDA and new proposal waveforms, such as GFDM and UFMC, highlighting new benefits of the latter architecture to its employment on 5G. Furthermore we are planning to perform several tests in order to evaluate GFDM and UFMC behaviour with IoT-based traffic. We are also planning to implement SCMA waveform on OAI.

Signature

Carmine Vitiello

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10. Annex E: Report of Gerhard Steinboeck

MOBILITY GRANT
Report

Guest name: Gerhard Steinboeck
Guest institution: Aalborg University, Denmark

Host name: Prof. Dr.-Ing. habil. Reiner S. Thomä
Host institution: Technical University Ilmenau, Germany

Research topic: Multi-band Millimeter-Wave Channel Characterization for 5G Systems

Starting date: 17. August 2015
Ending date: 11. September 2015

1. Scope of Work
For 5G channel modelling purposes we conducted channel measurements in two frequency bands, namely 3.4 to 10.1 GHz (FCC band) and 30.4 to 37.1 GHz (mm-wave band). The purpose of the multi-band measurements is three fold, i) investigation of the similarity of multiband channel characteristics, ii) investigation of the reverberation effect, and iii) calibration of stochastic channel models.

2. Motivations
Knowledge of the radio channel, in particular the development of appropriate channel models, is a basic building stone to develop the 5G transceiver architecture. Thus currently there are many activities in channel measurements and modelling for mm-wave bands. These activities consider typically just a single frequency band. But results are often compared to previous <6 GHz measurements. These investigations typically compare extracted channel parameters from the single band measurements. However, comparisons are done between frequency bands and different environments. This makes it virtually impossible to discern what creates observed differences, the environment or the frequency bands. Thus we would like to conduct multi-band measurements that allow for a more direct comparison of the results.

3. Objectives
Conduct channel measurements and start an informal collaboration between Technical University Ilmenau and Aalborg University to process the measurements and publish the results.

4. Meetings
Multiple phone / skype meetings were held prior to the visit in order to plan the measurement campaign, get an overview of available equipment like positioning devices, antennas, etc. These meetings were held between Gerhard Steinboeck (AAU) and Robert Mueller (TU Ilmenau).

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At AAU we held as well meetings to discuss the different proposals of experiments. We prepared a document describing the experiments. This document was the basis for our skype meetings with Robert Mueller. Later during conducting the actual measurement campaign this document was used too and formed the basis for the documentation of the measurement campaign.

5. Activities

During the stay Robert Mueller (TU Ilmenau), Stephan Haefner (TU Ilmenau) and Gerhard Steinboeck (AAU) built the multi-band measurement setup for the FCC and mm-wave bands. Extensions of the sounder control software to use the linear positioning device in combination with the spherical positioners.
Documenting the environment (measurements of the rooms geometry, photos, etcs.), the sounder setup and finally conducting the measurements.

6. Results

a. Scientific results

A set of measurement data which is the basis for currently ongoing research and (informal) collaboration between TU Ilmenau and AAU with respect to channel modeling.

b. Collaboration results

Multi-band measurement setup at TU Ilmenau.
Documentation of the measurement campaign.
Measurement data itself.

c. Dissemination

Gerhard Steinboeck held a talk on: "Modelling of Reverberation Effects for Radio Communications".
Preparation of Temporary document for Joint NEWCOM/COST Workshop on Wireless Communications in Barcelona.

7. Plans for Follow-up

We consider to have at least one joint publication on each of the purposes of the multi-band measurements; i) similarity of multiband channel characteristics, ii) the reverberation effect, and iii) calibration of stochastic channel models.

Intentions for a future visit to conduct another multi-band measurement campaign for outdoor environments.

8. Attachments

A temporary document for Joint NEWCOM/COST Workshop on Wireless Communications, 14^{th} to 15^{th} October, in Barcelona.

Signature

11. Annex F: Report of Laura Galluccio

MOBILITY GRANT
Report

Guest name: LAURA GALLUCCIO
Guest institution: CNIT CATANIA

Host name: MICHEL KIEFFER
Host institution: CNRS UNIPS

Research topic: MODELING OF OUTLIER DETECTION PROTOCOLS IN DELAY TOLERANT NETWORKS

Starting date: AUGUST 20, 2015
Ending date: SEPTEMBER 21, 2015

1. Scope of Work

The scope of this research activity has been to develop new collaborations between CNIT-CT and CNRS/UniPS. This will be facilitated by the complementary competences and background of the two research teams in terms of opportunistic networks design (CNIT-CT) and outlier detection schemes (CNRS/UniPS).

This collaboration will be useful also to complement the ongoing research activities carried out by researchers both in CNIT-CT and in CNRS UNIPS.

The mobility action will allow to achieve tangible results in terms of joint submissions to conferences and journals. Indeed, by working in strict contact with the researchers in CNRS/UniPS, a more effective interaction between the two research teams will be possible. Indeed it is well known how the face-to-face interaction represents the best way to work together and finalize the joint research by obtaining significant results in short time.

2. Motivations

Outliers detection is a critical problem in wireless sensor networks because it can be used to diagnose potential faulty nodes which insert into the network faulty measurements which can alter the sink elaboration. However in opportunistic scenarios where users move around and exchange information it is important to identify users which unconsciously exchange unreliable data. Accordingly in this work we want to address this aspect which is relevant also in social communities and can help to model belief propagation in social scenarios. In particular we want to study how, depending on the initial density of users which have a certain belief/opinion,

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the population of users evolves towards possible regime belief states depending on the statistics of intercontacts among users.

3. Objectives

- The mobility action will be aimed at developing new collaborations between CNIT-CT and CNRS/UniPS by exploiting the complementary knowhow of the two research groups.
- This activity is also relevant to WP 1.3, T1.3.2 on energy-efficient techniques for data collection in sensor networks.
- The mobility action allows to achieve tangible results in terms of joint submissions to conferences and journals.
- Indeed it is well known how the face-to-face interaction represents the best way to work together and finalize the joint research by obtaining significant results in short time.

4. Meetings

- Work set up and logistics -24 August 2015, 8.30 am, Prof. Kieffer's office, L. Galluccio, M. Kieffer, W. Li
- Discussion on background – 26 August 2015, 9.30am, Prof. Kieffer's office, L. Galluccio, M. Kieffer, W. Li
- Presentation of research knowhow – 2 September 2015, 10.30am, Prof. Kieffer's office, L. Galluccio, M. Kieffer, W. Li
- Presentation of research knowhow – 4 September 2015, 10.30am, Prof. Kieffer's office, L. Galluccio, M. Kieffer, W. Li, F. Bassi
- Definition of research framework – 7 September 2015, 14.30am, Prof. Kieffer's office, L. Galluccio, M. Kieffer, W. Li, F. Bassi
- Definition of the analytical model – 10 September 2015, 12.30am, Prof. Kieffer's office, L. Galluccio, M. Kieffer, W. Li, F. Bassi
- Refinement of the analytical model – 11 September 2015, 12.30am, Prof. Kieffer's office, L. Galluccio, M. Kieffer, W. Li, F. Bassi
- Extension of the analytical model – 14 September 2015, 10.30am, Prof. Kieffer's office, L. Galluccio, M. Kieffer, W. Li, F. Bassi
- Definition of the ODE equations – 17 September 2015, 10.30am, Prof. Kieffer's office, L. Galluccio, M. Kieffer, W. Li, F. Bassi
- Revision of the ODE equations – 18 September 2015, 10.30am, Prof. Kieffer's office, L. Galluccio, M. Kieffer, W. Li, F. Bassi

5. Activities

The activities carried out during the one-month stay were different:

- face-to-face meetings during which the idea was discussed and the draft elaborated (above we reported only the longest face-to-face meetings)
- individual research activity during which researchers worked on the framework/code individually to prepare the common discussion
- email exchange during which the elaborated and updated draft was exchanged

6. Results

a. Scientific results

In spite of the limited time for the visit, a joint draft document was elaborated. This will be used as the basis for a joint paper to be submitted shortly.

b. Collaboration results

After an initial "training phase" during which researchers have discussed on the individual background and on their going-on research, they have identified a common interest topic which, in spite of being different from the one agreed during the preparation of the proposal for collaboration, seemed more in line with the current research interests of the participating groups.

c. Dissemination

Researchers will keep working to a common joint paper to be shortly submitted to a conference/journal and, in case of acceptance, will present the results of the joint activity to disseminate the contribution of their research.

7. Plans for Follow-up

Reseachers have agreed a common plan of actions:

- Refine and polish the elaborated draft
- Add simulation results after debug of the code that was developed during the stay
- Elaborate a conference paper and submit it shortly (in 2 months)
- Add in the framework the consideration of an agenda of contacts to refine the framework and possibly update the outlier detection scheme.
- Elaborate on the new framework and refine a new draft
- Submit a journal paper by 6 months

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8. Attachments

We are attaching a draft that was elaborated during the visit

Signature

12. Annex G: Report of Li Wenjie

MOBILITY GRANT
Report

Guest name: Wenjie Li
Guest institution: CNRS/UPsud

Host name: Prof. Davide Dardari
Host institution: CNIT/Bologna

Research topic: Distributed outlier detection in a wireless sensor network

Starting date: June 15th, 2014
Ending date: July 24th, 2014

1. Scope of Work

This work is related to two tasks: one belonging to Track 1, the second to Track 2, and hence it is an inter-track joint research activity. The experimental activities helped us in characterizing the impact of the MAC on our outlier detection mechanism in real scenarios.

Task 1.2.3: Energy-efficient data collection in sensor networks.

Task 2.2.2: Large-scale wireless sensor networks: routing protocols, network topologies and cooperative localization.

2. Motivations

Distributed fault detection (DFD) is essential to the correct functioning of wireless sensor networks (WSN) applications [1]. A sensor is defined as faulty when it produces outliers, *i.e.*, off-scale readings which cannot be justified by the statistics of the measurement noise [2]. Outliers are harmful to the estimation accuracy of the WSN. Moreover, the transmission of the outliers among the nodes is a burden in energy-limited networks. The aim of a DFD algorithm is to identify the nodes equipped with a defective sensors that produce outliers, to the aim of removing them from the sensing operations of the WSN.

Recently, we have proposed a DFD algorithm for large WSN in [3] with a random network topology. Each node broadcasts its own local measurements to its neighbors, collects the measurements from its neighbors, and performs some *local outlier detection test* (LODT), only able to determine the *presence* of outliers in a set of measurements. The outcomes of the LODT are exchanged within the neighborhood. Finally, each node makes a decision on the

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status (good or defective) of its own sensor based on the results of the LODT in the whole neighborhood. The LODT considered in [3] is simple and effective even using only as few as two or three measurements. For this reasons, the DFD algorithm in [3], differently from the classical solutions, *e.g.*, [4-7], does not need to manage a table of neighbors. Moreover, it has low complexity, low communication costs, low delay, and good performance in terms of non-detection rate (NDR) and false alarm rate (FAR).

The results presented in [3] assume ideal communication conditions between the nodes: collision avoidance mechanisms are ideal and packet losses are neglected. In this work, we aim to verify the behavior of the proposed algorithm in a real context. Since it is not enough to propose an algorithm and simulate it in an ideal case for the lower layers of the network.

[1] Y. Zhang, N. Meratnia, and P. Havinga, "Outlier detection techniques for wireless sensor networks: A survey," IEEE Communications Surveys & Tutorials, vol. 12, no. 2, pp. 159–170, 2010.
[2] V. Barnett and T. Lewis, Outliers in statistical data, vol. 3, Wiley New York, 1994.
[3] W. Li, F. Bassi, D. Dardari, M. Kieffer, and G. Pasolini, "Low-complexity distributed fault detection for wireless sensor networks," in Proc. IEEE ICC, London, United Kingdom, June 2015.
[4] J. Chen, S. Kher, and A. Somani, "Distributed fault detection of wireless sensor networks," in ProcWorkshop DIWANS, New York, NY, 2006, pp. 65 – 72.
[5] S. Ji, S.-F. Yuan, T.-H. Ma, and C. Tan, "Distributed fault detection for wireless sensor based on weighted average," in Proc NSWCTC, Wuhan, China, 2010, pp. 57 – 60.
[6] J. W Branch, C. Giannella, B. Szymanski, R. Wolff, and H. Kargupta, "In-network outlier detection in wireless sensor networks," Knowledge and information systems, vol. 34, no. 1, pp. 23–54, 2013.
[7] A. De Paola, S. Gaglio, G.L. Re, F. Milazzo, and M. Ortolani, "Adaptive distributed outlier detection for wsns," Cybernetics, IEEE Transactions on, vol. 45, no. 5, pp. 888–899, May 2015.

3. Objectives

The objective of my visit is to deploy the outlier detection technique on the EuWIn@CNIT/Bologna platform DATASENS to evaluate the performance of the proposed DFD algorithm in real situations. Time constraints should be considered to see the impact of the MAC layer on the performance of the DFD algorithm. We need to consider a fully random network topology. A large number of experimentations are essential to validate the results.
These experiments will provide us some insights to extend our theoretical work [3] by considering the impact of the MAC layer. When sensor nodes are broadcasting their packets, collisions may happen in the real situation. Therefore, it would be interesting to investigate in a theoretical and practical way the robustness of our proposed algorithm against the packet losses.

4. Meetings (meeting purpose, dates, location, attendance)

Physical meeting (in Bologna) on 1st July, 2015
Attendances: Davide Dardari (DD), Gianni Pasolini (GP), Alex Calisti (AC), Wenjie Li (WL)
Purpose: Discussion on the plan of the experimental activities of WL, time constraint is very important to be considered in the experiments.

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Virtual meeting (Skype) on 9th July, 2015
Attendances: DD, GP, Michel Kieffer (MK), Francesca Bassi (FB), AC, WL
Purpose: Discussion on the interest of the preliminary results obtained by WL, as well as the possible extension of the current work. The next step is to reduce the transmission power of the wireless sensor nodes to build a network which is not fully connected.

Virtual meeting (Skype) on 21st July, 2015
Attendances: DD, GP, MK, AC, WL
Purpose: Discussion on the improvement that should be done based on the obtained results.

5. Activities

I used the EuWln@CNIT/BO Datasens platform to implement the proposed DFD algorithm. In a first set of experiments, all the nodes are closely located and can receive packets from all other nodes. However, each node is assigned a random virtual location to create its set of neighbors. An interesting problem is to compare the performance of the algorithm (in terms of the non-detection rate (NDR) and the false alarm rate (FAR)) with different number of initial round K_1 and final round K_2 as a function of total execution time T_e. Independent experiments have been repeated 1000 times for all the cases to obtain the average performance of the algorithm.

In a second set of experiments, the DFD tests are performed in a more realistic situation where the network is not fully connected. The network topology is shown in Figure 1, where 41 nodes are randomly deployed over the right side of WiLab. The position of nodes remains unchanged, each node has a given probability to be defective in each test. In our tests, the defective probability is set to be 15%, the DOD is performed with $K_1 = 5$ and $K_2 = 1$. The tests have also been repeated 1000 times.
All the results are shown in Section 6(a).

6. Results

a. Scientific results

The results of the first set of experiments are presented in Figure 2(a), where different number of defective sensor nodes N_d are also considered. As expected, less packet collision occurs as T_e increases and thus the performance of the algorithm becomes better. In both cases where N_d = 1 and N_d = 3, both NDR and FAR become smaller as the number of initial rounds K_1 increases, considering the same T_e.

Figure 2(b) illustrates the average performance of DOD in different areas and using different transmission power (TxP), in the second set of experiments. The results show that the nodes in the center have lower NDR and FAR than those at sides, considering the same TxP. As the testbed has a limited space, the performance of DOD suffers from boundary affects. Three different TxP are considered with their values $P_1 > P_2 > P_3$. Comparing the average NDR and

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FAR of the nodes in the center, the results highlight that NDR converges faster as TxP decreases, whereas the variation of FAR is not significant.

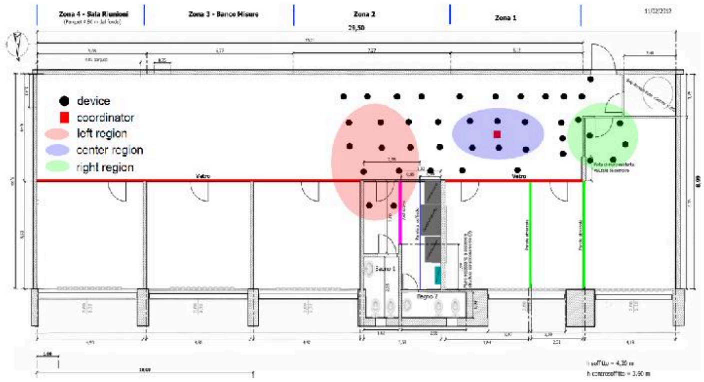

Figure 1. Node distribution in WiLab

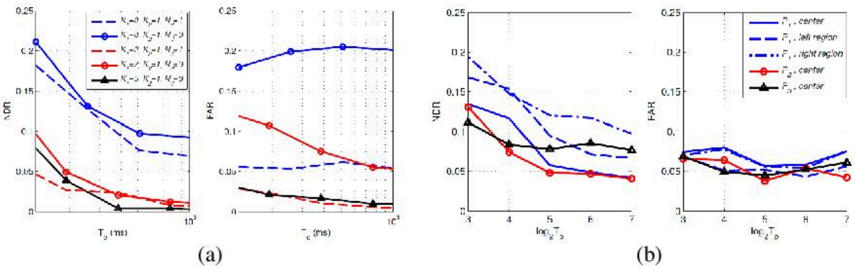

Figure 1. NDR and FAR as functions of execution time for different DFD algorithms

b. Collaboration results

The experiments are performed in collaboration between CNIT/Bologna and CNRS/UPsud. I have deeply benefitted from the experience of CNIT/Bologna in wireless sensor networks. The collaboration will continue in the future.

c. Dissemination

This work has presented in

(a) Special technical session on "Advanced techniques for energy- and bandwidth-efficient communications" @ EuCNC Bologna, 2014
(b) NEWCOM# Track1-Track2 meeting, Athens, 2015.
(c) IEEE ICC, London, UK, 2015

It will also be presented in

(d) Joint NEWCOM/COST Workshop on Wireless Communications JNCW, Barcelona 2015

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(e) IEEE CDC, Osaka, Japan, 2015

7. Plans for Follow-up

We are working on the journal paper submitted to IEEE Transactions on Signal and Information Processing over Networks. We have submitted the major revision and now we are waiting for the feedback.

8. Attachments

(draft of papers/papers, slides of presentations etc.....)

Signature

13. Annex H: Report of Quentin Bodinier

MOBILITY GRANT
Report

Guest name: Quentin BODINIER
Guest institution: CentraleSupélec

Host name: Prof. Ana I. Perez Neira
Host institution: CTTC

Research topic: Filter Bank Approaches for 5G: A common approach for capacity analysis

Starting date: 18/06/2015
Ending date: 10/07/2015

1. Scope of Work

At the beginning of this collaboration, two working tracks were studied: on one hand, we wanted to theoretically study filter bank based waveforms proposed for 5G. On the other hand, we had mutual interest in some resource allocation problems for opportunistic networks. However, due to the amount of time that we disposed of, we decided to focus our work on the former problem. The basis for a common work on resource allocation have however been laid out.

2. Motivations

In the last few years, a lot of research has been going on the design of filter bank based waveforms for 5G. It has become difficult to see clearly among the different proposed waveforms, and we feel that there is a need to unify the different proposed solutions under a common mathematical framework in order to properly and fairly compare them.

3. Objectives

The objectives of the study we led were threefold:

- Propose a generic filter bank mathematical model encompassing different
- Proposed waveforms to express their theoretical capacity.
- Analyse the intrinsic interference of filter bank models.
- Study the feasibility and theoretical benefits of exploiting the said interference.

4. Meetings

- Kick-off meeting : in presence of Dr. Marius Caus, Dr. Musbah Shaat and Pr. Ana Perez. Decision was made to focus on the analysis of the capacity of filter banks and leave the collaboration with Dr. Shaat on resource allocation for further work.
- We had meetings every 1 or 2 days with Dr. Caus to progress on our common work on filter banks capacity.
- Meeting with Dr. Shaat, at the end of my stay, in order to lay down the basis for our future collaboration.
- Ending meeting: in presence of Dr. Caus and Pr. Perez, to sum up our works and start dissemination plans.

5. Activities

6. Results

a. Scientific results

A thorough analysis of the capacity of Generic Filter Banks systems has been led. Interesting results have been found and may be sent for publication.

b. Collaboration results

This mobility mission has started collaboration between Quentin Bodinier (CentraleSupélec, France) and Dr. Marius Caus as well as Dr. Musbah Shaat (CTTC, Spain)

c. Dissemination

Dissemination of the led research activities will be achieved by publication in the coming conferences. Details are still to be decided.

7. Plans for Follow-up

As told in the section before, the work that has been led is still under progress and will lead to common work in the coming months.

14. Annex I: Report of Slawomir Ambroziak

MOBILITY GRANT
Report

Guest name: Slawomir Jerzy Ambroziak
Guest institution: Gdansk University of Technology, Poland

Host name: Luís M. Correia
Host institution: Instituto Superior Técnico (IST), University of Lisbon, Portugal

Research topic:
Simulation research on the radio wave polarisation in Body Area Networks

Starting date: 02.09.2015
Ending date: 30.09.2015

1. Scope of Work

Measurements for off-body links had been done at GUT, but there was the need to perform a comprehensive analysis of the results, and to perform simulations in the corresponding environment, so that a model is established. Taking above into account the scope of work was as follows:

- processing of previously collected measurements of radio wave polarisation;
- integration of the antenna patterns gain characteristics of the patch antenna used during measurements, and simulations for different body postures, locations, and antenna placements;
- analysis of the results for various configurations, comparative analysis between simulations and measurements, and establishment of the new channel model for BANs.

The scenario was an indoor multipath environment with dimensions 7×5×3 m^3, and a receiving dual polarisation antenna (installed in the middle of the wall, in front of the body) at 1.4 m high. The following three transmitting antenna placements were analysed: front side of the torso (TO_F), left side of the head (HE_L), and right side of the arm (AB_R). Five static scenarios were investigated: TO_F, HE_L, and AB_R in standing position, AB_R in sitting position with hands based on the armrest, and with hands in reading position. Six distances between the body and the receiving antenna were studied, from 1 to 6 m. In each point, a full rotation of the body was performed, with a step of 45° (counter clockwise). Moreover, two dynamic scenarios were analysed: AB_R in walking in fixed place, and TO_F in real walking.

Since the most common antenna type is a vertically polarised one, one of the metrics used in the analysis is the cross-polarisation discrimination, XPD, calculated as a ratio of the vertically polarised to the horizontally polarised received powers.

2. Motivations

Body Area Networks (BANs) will play a very important role in the next generation of wireless systems, as they will allow for the integration of wearable or handheld devices with the surrounding infrastructure. An important challenge is to increase the connection reliability of these off-body links. In order to boost system performance, a good understanding of the radio channel in BANs is required. A very important effect that should be considered in BANs, especially in indoor environments, is the depolarisation of radio waves during the propagation process, due to the many reflections on walls and floors, and to the existence of many scatterers in the environment. In off-body channels, when there is an on-body transmitting antenna and a fixed receiving one, a polarisation mismatch can be expected.

3. Objectives

The objectives of the research were:

- to compare and analyse results of simulations and measurements in a real indoor scenario;
- to develop the new channel model for off-body communications in indoor environments, taking depolarisation effects into account.

Additional objectives and added value of the mobility:

- the applicant from GUT, and the team in which he is working, will gain experience in the simulations of Off-Body Area Networks channels;
- the team in IST will be able to compare results of simulations with empirical ones from the measurements obtained by the GUT team in previous research work;
- the cooperation and collaboration in between the GUT and IST teams working in channel modelling in BANs, which has been initiated within the COST IC1004 Action, will be continued and reinforced.

Finally, it is worthwhile to notice that results of this mobility grant will be shared between both institutions, and will be made available to both the NEWCOM# and COST communities.

4. Meetings

Date	Location	Meeting purpose	Attendance
04.09.2015	IST	– discussion on the measurements results; – distribution of tasks;	3 people
10.09.2015	IST	– presentation of first results of the analysis; – discussion;	3 people
14.09.2015	IST	– presentation of the current state of work; – discussion on the paper for EuCAP 2016; – discussion;	3 people

Date	Location	Meeting purpose	Attendance
14.09.2015	IST	– seminar: *Description of measurements of path loss in body-to-body communication* (Appendix 1); – discussion;	9 people
18.09.2015	IST	– discussion on the TD for Joint NEWCOM/COST Workshop on Wireless Communications JNCW 2015 (Appendix 2);	3 people
21.09.2015	IST	– discussion on draft of joint journal paper; – discussion on the project of future measurement research of the depolarisation phenomenon in BANs channels;	3 people
23.09.2015	IST	– discussion on draft of joint journal paper;	3 people
28.09.2015	IST	– seminar: *Fading Modelling in Dynamic Off-Body Channels* (Appendix 3); – discussion;	10 people
29.09.2015	IST	– summary of realized task; – discussion on the obtained results and future collaboration;	2 people

5. Activities

Activities carried out:
- processing of previously collected measurements of radio wave polarisation;
- integration of the antenna patterns gain characteristics of the patch antenna used during measurements;
- simulations for different body postures, locations, and antenna placements;
- analysis of the results for various configurations;
- comparative analysis between results obtained for vertical and horizontal polarisation;
- analysis of appropriate statistical distributions;
- establishment of the new channel model for BANs for vertical and horizontal polarisations.

6. Results

a. Scientific results

At the end of this NEWCOM# Mobility Grant, the results have been discussed and analysed. Statistical analysis of the results for both polarisations of receiving antenna have been realized, including mean path loss values, distributions of body shadowing and fast fading, as well as the cross polarisation discrimination values. The difference between the vertical and horizontal components of the received radio signal were analysed. The best results have been obtained for scenarios with a vertical polarised transmitting antenna, especially for the case when the maximum gain of the transmitting antenna is directed towards the receiving one.

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The results of these analysis will be presented at the Joint NEWCOM/COST Workshop on Wireless Communications – JNCW 2015 in October 14- 15, 2015 in Barcelona (Spain), and at the 10th European Conference on Antennas and Propagation – EuCAP 2016, in Davos, Switzerland, on 11-15 April 2016.

b. Collaboration results

As a result of this NEWCOM# Mobility Grant, both institutions GUT and IST have strongly enhanced their existing cooperation. On the one hand, GUT gained experience in the simulations of BAN channels. On the other hand, IST enhanced the experience in such simulations and was able to compare results of simulations with empirical ones from the measurements. In general, this Mobility Grant confirmed that present and future cooperation between GUT and IST in the field of BAN channel modelling has a solid base. Both institutions have a firm plan to further develop the measurements platform for BANs, e.g., including multiple wearable antennas, and analysis of antenna orientation and position during measurements. Moreover, a further analysis of channel depolarisation in BANs will be jointly performed.

c. Dissemination

The following publications are expected:

- joint TD on the Joint NEWCOM/COST Workshop on Wireless Communications – JNCW 2015 in October 14-15, 2015 in Barcelona (Spain), entitled: *Fading Modelling in Dynamic Off-Body Channels* (Appendix 2);
- joint journal paper, entitled: *Off-Body Channel Model for Body Area Networks in Indoor Environment* – already submitted to IEEE Transactions on Antennas and Propagation (awaiting decision);
- joint journal paper, entitled: *Influence of radio wave polarisation on the off body channel characteristics*;
- joint conference publications (*e.g.*, at EuCAP 2016 and URSI AP-RASC 2016) on simulation and measurements of the radio wave polarisation in off-body communications.

7. Plans for Follow-up

Plans for future joint research in the area of Body Area Networks are connected with new COST Action: *Inclusive Radio Communication Networks for 5G and beyond* – IRACON, which is currently under review.

Apart from this, both institutions are going to deepen their research in the field of Body Area Networks with an emphasis on depolarization in radio channel, and to exchange results of these research within researchers from *i.a.* European Association for Communications & Networking (EURACON).

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8. Attachments

- **Appendix 1**:
  Description of path loss measurements in body-to-body communication – slides of presentation;
- **Appendix 2**:
  Slawomir J. Ambroziak, Kenan Turbic, Carla Oliveira, Luís M. Correia, Ryszard J. Katulski: *Fading Modelling in Dynamic Off-Body Channels* – Joint NEWCOM/COST Workshop on Wireless Communications – JNCW 2015 in October 14-15, 2015 in Barcelona (Spain);
- **Appendix 3**:
  Fading Modelling in Dynamic Off-Body Channels – slides of presentation.

Signature

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15. Annex J: Report of Giuseppina Alfano (Y2)

MOBILITY GRANT
Report

Guest name: Giusi Alfano
Guest institution: PoliTO

Host name: Prof. E. A. Jorswieck
Host institution: TUD

Research topic: ENERGY EFFICIENT Massive MIMO communications

Starting date: 09/06/2014-26/06/2014
Ending date: 11-14/05/2015

1. Scope of Work

The scope of this mobility has been to begin the introduction of resource allocation algorithms to optimize the EE of massive MIMO systems, fully accounting for the lack of perfect CSI, as a consequence of channel estimation errors, quantisation noise, and phase noise. This last impairment has been the main focus of the mobility period, while the impact of other mentioned causes of imperfect CSI will be studied later, in the framework of a collaboration which is kept at least as far as Newcom# ends.

2. Motivations

Present cellular networks are optimized to maximize throughput for fast and reliable communications. However, this comes at the expense of significant energy consumptions, for both signal transmission and terminal operations. Recent estimates ascribe 5% of the global world energy consumption and CO2 emissions to cellular communications, and this percentage is rapidly growing due to the exponential increase of connected devices and infrastructure nodes. It is foreseen that the number of connected nodes will reach 50 billion by 2020 and that the energy demand will soon become unmanageable. Moreover, the resulting greenhouse gas emissions and electromagnetic pollution will exceed safety thresholds. As a result, a paradigm shift from throughput-optimized to energy-efficiency optimized cellular networks is required to successfully tackle these societal challenges.

The fifth generation of wireless networks shall be designed so as to maximize the efficiency with which each Joule of energy is used to communicate information, rather than using all available energy to maximize the throughput. This leads to the introduction of new, fractional performance functions, measured in bit/Joule, which are able to strike a balance between the contrasting needs of achieving high throughputs and saving energy. Being aware of this scenario, the EU has recently funded the 5G-PPP (http://5g-ppp.eu/) association and activated the new HORIZON 2020 funding program, which both identify energy efficiency as a key societal challenge to tackle and aim at increasing the energy efficiency of 5G wireless networks by a factor 1000 compared to state-of- the art systems. The same objective is

pursued by the Green Touch consortium (http://www.greentouch.org), formed by leading telecommunication companies.

Since antenna densification represents a promising technique for 5G networks, it is planned to replace conventional arrays with few antennas, fed by bulky and expensive hardware, by hundreds of small antennas fed by low-cost amplifiers and circuitry. The motivation for this approach is that, by virtue of the law of large numbers, using many antennas has the potential to average out multiuser interference. Moreover, energy can be focused in a specific direction with greater precision than with conventional MIMO, thus avoiding radiating power in unintended directions. Although these features are attractive from an energy-efficient perspective, Massive MIMO suffers from several limiting factors, among which a relevant one is the channel estimation complexity. Indeed, employing many antennas requires the estimation of large channel matrices, which in turn causes a significant signalling overhead. Furthermore, since much more circuitry is necessary to feed hundreds of antennas, a massive MIMO system must use low-cost circuitry. This leads to heavy hardware impairments such as quantisation noise, that further degrades channel estimates, and phase noise, which is another cause for channel uncertainty and jeopardizes coherent data detection.

3. Objectives

To carry out an extensive performance analysis (from the energy-efficiency point of view) of current massive-MIMO solutions in presence of phase-noise. To possibly particularize the findings to LOS MIMO systems (even not massive) for wireless backhaul. To move a step toward the ultimate performance limit evaluation for multiple-antenna systems impaired by phase noise, at least via implicit, fixed point characterisation of the achievable mutual information.

4. Meetings

17.06.2014, half mobility summary and future activities plan, E. A. Jorswieck, A. Zappone, and G. Alfano
12.05.2015 final meeting, E. A. Jorswieck, A. Zappone, and G. Alfano.

5. Activities

During the first phase of the mobility stay, a thorough analysis of the literature on MIMO Broadcast transmission has been carried out. Currently, the formulation of a suitable model of phase-noise impaired broadcast channel is under study. The main goal of this activity is the analytical evaluation of quantities related to the rate region, and the subsequent study of energy efficiency of the phase-noise impaired BC. The activity is mathematically very challenging.

The second week of the mobility has been partially devoted to attend a mini-course on Energy-efficiency in wireless channels, which is the extended version of the ISWCS tutorial by the hosts, E. A. Jorswieck and Alessio Zappone. This course lasted 6 hours.

The third week has been devoted to the preparation of the camera-ready version of the paper *Mutual Information of Phase-Noise Impaired Wireless Networks*, by G. Alfano, A. Zappone, E. Jorswieck and G. Montorsi, presented at ISWCS, Barcelona, August 26-29, 2014, and partly spent in Bologna, at EuCNC conference, for the presentation of the poster *Energy-efficiency of phase-noise impaired* *wireless networks* by the same authors, containing preliminary results of ISWCS abovementioned paper.

During last week, the possible structure of a joint contribution (to be submitted as journal paper) PoliTO-TUD has been formulated. The activity is detailed in Section 7.
On May 13th, a seminar entitled "*A unifying analysis of error exponents for MIMO channels with application to multiple-scattering"* was given.

6. Results

a. Scientific results

Two conference papers (detailed in previous section) and a perspective journal paper.

b. Collaboration results

The activities led to strengthening the ongoing collaboration with TUD.

c. Dissemination

Results were presented at a top-level conference, usually attended by N# institutions researchers.

7. Plans for Follow-up

Joint activity will be articulated as follows: first the energy-efficiency of a sub-optimum multiuser uplink policy (the adopted model comes from the seminal paper Antonios Pitarokoilis, Saif Khan Mohammed, Erik G. Larsson, "**Uplink Performance of Time-Reversal MRC in Massive MIMO Systems subject to Phase Noise**", *IEEE Transactions on Wireless Communications,* **14**: *711-723*, 2015.) will be evaluated; then, starting from the very same scenario, a resource allocation policy possibly improving the already proposed one will be devised. Upon availability of further analytical results on the spectrum of a block-random matrix embodying phase noise into the channel model, either in presence or absence of time-selectivity, communication performance both from the point of view of the spectral as well as of the energy efficiency will be characterized.

8. Attachments

G. Alfano, A. Zappone, E. Jorswieck, G. Montorsi, *Mutual Information of Phase-Noise Impaired Wireless Networks,* **ISCWS 2014**, Barcelona.

Signature

16. Annex K: Report of Carmine Vitiello (Y2)

MOBILITY GRANT
Report

Guest name: Carmine Vitiello
Guest institution: CNIT – University of Pisa

Host name: Prof.Raymond Knopp
Host institution: CNRS - Eurecom

Research topic: First Steps Towards 5G Modem Prototyping

Starting date: 13/04/2015
Ending date: 12/06/2015

1. Scope of Work

This activity concerns experimental validation of a promising candidate multicarrier waveform known as Universal Filtered Multi-Carrier (UFMC). Eurecom and UniPi focus on the study and development of reduced-complexity UFMC waveform and relative aspects about RF spectrum features at varying of number of employed subcarriers. UFMC waveform has been implemented jointly by Eurecom and UniPi on uplink of 4G system based on Eurecom's OpenAirInterface for the eNB and UE and using Ettus USRP B210 as hardware.

2. Motivations

UFMC targets joint transmission/reception of broadband multimedia traffic and bursty machine-type communications (e.g. car-to-car or health monitoring applications). This is one of the key physical layer issues in 5G and the primary reason for considering a new waveform as opposed to conventional OFDM.

3. Objectives

The main objective of the mobility action is to start a long-term collaboration among the partners in the field of Software-Defined Radio applied to 5G technologies which also allows collaboration to continue beyond NEWCOM#. This visit has been focused on joint investigation about synchronization and similar receiver issues and to develop UFMC multi-carrier waveform from adding to OpenAirInterface.org library in order to enlarge its potentiality.

4. Meetings

- **05/03/2015:** Research activity was planned in details thanks by Skype meeting. Starting from literature, we established basic architecture scheme of UFMC waveform and we discussed what aspects can be improved. We decided to investigate on reduction of transmitter computational complexity focusing on filtering and FFT operation. We planned to simulate UFMC waveform by Matlab and porting the code on real system using by OpenAirInterface after architecture optimization. Attendees: Prof.Raymond Knopp and Carmine Vitiello

- **Eurecom (Sophia-Antipolis) - 13/04/2015:** In the initial meeting we discussed some former results obtained by Matlab simulations and their impacts on development of UFMC waveform. Furthermore we planned to test some solutions employing several FIR filters. Attendees: Prof.Raymond Knopp and Carmine Vitiello
- **Eurecom (Sophia-Antipolis) - 13/04/2015–12/06/2015:** Several meeting have been done thanks by Prof.Knopp availability when a problem occured. Side-by-side work guaranteed constant development of the UFMC waverform, Matalb simulations and C code on OpenAirInterface. Attendees: Prof.Raymond Knopp and Carmine Vitiello
- **Eurecom (Sophia-Antipolis) - 12/06/2015:** Final meeting has been done at the end of Mr.Vitiello visit. Achieved results have been discussed particularly emphasizing the potentially uses of the waveform, for testing and development of future applications. We also delineated future plans in order to exploit UFMC and the joint collaboration between Eurecom and UniPi. Attendees: Prof.Raymond Knopp and Carmine Vitiello

5. Activities

Joint UNIPI and EURECOM activity focus on testing UFMC waveform on real scenario in order to evaluate its features, thus we decided to employ UFMC on a real-system, such as LTE. OpenAirInterface represents the best tool for developing and testing UFMC waveform because it is based on SDR hardware and implements LTE eNB with release 10 and LTE UE with release 8. Starting from this point, we decide to work on LTE uplink level, modifying transmitter modulator, based on OFDMA or SC-FDMA, and adapting standard receiver. In according with literature and supposing we work on 10MHz band, we built an UFMC transmitter as described in Figure 1, using a 1024-IDFT and a Dolph-Chebyshev filter per each branch, both shifted to the center of the respective subband. Filter length L has been fixed to the same length of OFDM cyclic prefix plus one (73 or 81), in order to maintain the same output length at the end of the convolution operation. DFT operation is optionally and it can be used in case of SC-UFMC with comparing to SC-FDMA. Its dimension is fixed to 12B, where B is PRB number and 12 is the number of resource element per PRB (in number of subcarriers).

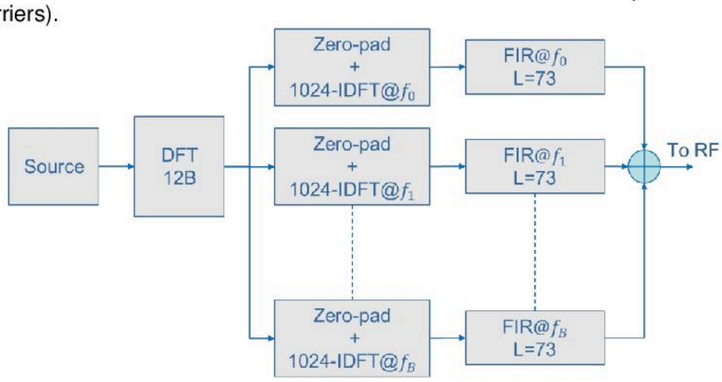

Figure 1 - Classical UFMC transmitter scheme

At the beginning our studies focused on reduction of computational complexity of the transmitter in order to allow real-time execution of the code on common laptop equipped by USRP platform. Especially in case of few PRB transmission, classical scheme doesn't show good computational performance because a 1024-IDFT operation is performed over 12, 24 o 36 complex samples and producing 1024 complex samples that will be filtered entirely. Furthermore using a shifted version of the filter, convolution operation is performed using complex filter taps, redoubling the amount of operations. For simplifying transmitter scheme, we think to decrease IDFT dimension using a correct upsampling and move frequency shift operation to the end of transmission chain per subband as depicted in Figure 2.

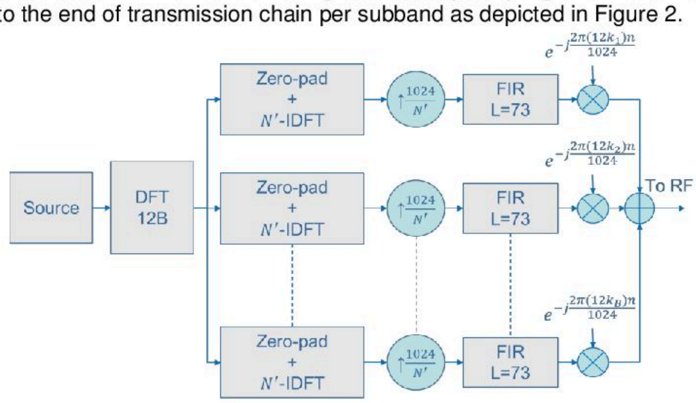

Figure 2 - Modified UFMC transmitter scheme

IDFT dimension, which is indicated with N', represents the heart of our computational complexity reduction process because a value too small leads to have an high upsampling factor thus overlapping of replicated signals in frequency domain while a value too high leads to have a small upsampling rate wasting useful computational resources. Starting from an IDFT dimension of $N' = 16$, found as $2^{\lceil \log_2 12B \rceil}$ using only one PRB, with upsampling factor of $\frac{1024}{N'}$, we tested several sizing of our scheme evaluating UFMC spectrum(blue) shape in terms of OOB emission and in-band signal, comparing with OFDM spectrum(red) and showing in Figure 3 the behaviour in a single subband. Using 16-IDFT dimension and upsampling factor of 64, we can find spurious repetitions within filter bandwidth that create heavy OOB emissions and therefore the quality of our signal is not good. Employing 32-IDFT and upsampling factor of 32, we can find contributes of spurious repetition at the edges of filter bandwidth and it damages the spectrum in terms of OOB emission because they are not attenuated enough (around -30dB). Using 64-IDFT and upsampling factor of 16, finally we have not in-band spurious repetition and only one contribute at -60db out of band, much lower than OFDM OOB emission. Comparing 64IDFT with 1024IDFT, we can note that the spectrums have more or less the same shape and features but saving a lot of computational resources on IDFT operation and filtering. For this reason we define N'= min($64, 2^{\lceil \log_2 12B \rceil}$) improving computational performance of our scheme without losing spectrum features.

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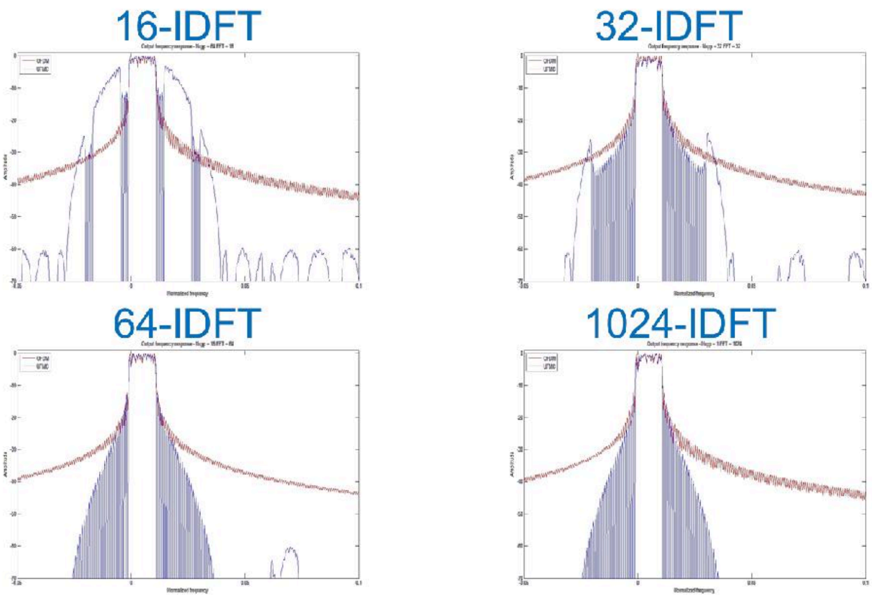

Figure 3 - UFMC spectrum (blue) at varying of IDFT dimension comparing with OFDM spectrum (red)

About receiver, we exploits the same scheme of regular LTE pusch receiver but only adding a functional block to retrieve time synchronization from external function, as depicted in Figure 4. Time synchronization is achieved exploiting DRS signals contained into each third multicarrier symbol of LTE slot. Therefore taking a single subframe, we can exploit two DRS signals for retrieving time synchronism. Here we take a time window of two times employed DFT dimension, in our case 2048. We perform 2048DFT and multiply it with 2048DFT complex conjugate of DRS signal transmitted, performed square complex magnitude and retrieving the delay as peak of this last function.

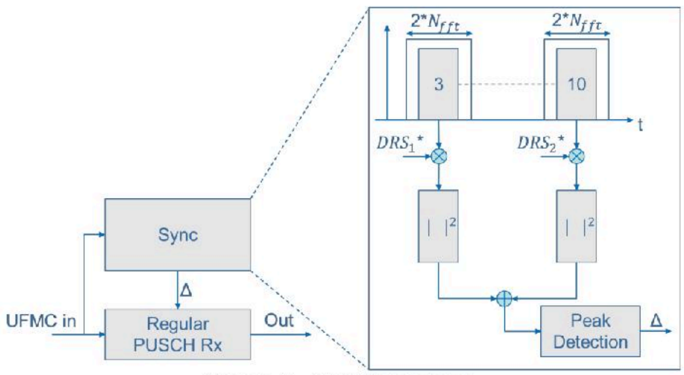

Figure 4 - UFMC receiver

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6. Results

a. Scientific results

Mainly this activity is addressed to implement a new branch on OpenAirInterface tool in order to give new possibilities of experimentation, evaluating impacts of UFMC on real system and in real scenarios. Our work aims to decrease the complexity of the waveform in order to allow real-time execution of the waveform without weaken RF characteristics. In these terms we simplified digital signal processing at the transmitter by performing lower dimension IFFT and using upsampling and baseband filtering. In this way the operations number decreases substantially. UFMC showed a notable decreasing of OOB emission therefore it can facilitate dynamic spectrum access. Furthermore it decreases interference between adjacent signals that access to contiguous resources.

b. Collaboration results

The visit of Carmine Vitiello laid the foundations for a new long-term collaboration between involved institutions, Eurecom and University of Pisa. Furthermore it represents an inter-track activity between Track 1 and Track 2: in particular it assumes relevance on work packages WP1.3 Energy and Bandwidth - Efficient Communications and Networking, Task 1.3.2 Low-interference, low-emission, radio interfaces and WP2.1 Radio Interfaces for next-generation wireless systems, Task 2.1.2 Low-energy-consumption and low-emission radio interfaces.

c. Dissemination

Initial results obtained during the visit of Carmine Vitiello thanks by Newcom# mobility grant will be presented in the next Newcom# workshop on October in Barcelona. All of the results, both numerical and drawn theoretical conclusions, will be presented as papers and conference talks.

7. Plans for Follow-up

Frequency and timing misalignments are still under study as well as the coexistence between OFDMA or SC-FMDA and new proposal waveform UFMC, highlighting new benefits of the latter architecture to its employment on 5G. Furthermore we are planning to perform several tests in order to evaluate UFMC behaviour with IoT-based traffic.

8. Attachments

Presentation: UFMC implementation on OpenAirInterface (OAI)

Signature

Carmine Vitiello

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17. Annex L: Report of Paolo del Fiorentino (Y2)

MOBILITY GRANT
Report

Guest name: Paolo Del Fiorentino
Guest institution: CNIT – University of Pisa (CNIT-PI), Italy

Host name: Miquel Payaró and Nikolaos Bartzoudis
Host institution: CTTC, Centre Tecnològic Telecomunicacions Catalunya

Research topic: Development on software defined radio platform of a packet-oriented bit-interleaved coded (BIC) OFDM communication system and implementation of a resource allocation (RA) algorithm

Starting date: 01/05/2015
Ending date: 31/05/2015

1. Scope of Work

The research activity between CNIT-PI and CTTC aimed at developing a software-defined-architecture for evaluating the over-the-air performance of a resource allocation (RA) algorithm for OFDM systems employing bit interleaved coded (BIC) modulation.
The considered RA method, presented for the first time in [1], selects the best modulation, code rate and transmission energy for each OFDM subcarrier at the transmitter with the goal of maximizing the "goodput" (GP) metric for the "transmitter-receiver" link. The GP metric allows characterizing in a more suitable way the actual performance of a packet-oriented communication system and it is defined as the number of information bits delivered in error-free packets per unit of time. Figure 1 shows the block diagram of the packed-oriented BIC-OFDM communication system considered for this activity. The transmitter consists of: CRC insertion, error-correcting encoder, interleaver and OFDM block (S/P converter, M-QAM modulator, IFFT, P/S converter, cyclic prefix insertion). The receiver is composed of: frequency synchronizer, OFDM block (cyclic prefix removal, FFT), channel estimator, soft demodulator, P/S converter, de-interleaver, Viterbi decoder and CRC check. The receiver returns an ACK, if the received data packet has been correctly decoded, otherwise a NACK is sent. In parallel to the demodulation/decoding process, the receiver evaluates a channel quality indicator using an appropriate link performance predictor (LPP) algorithm called *k*ESM that takes as the input the vector of estimated SNRs on each subcarrier and returns an equivalent signal-to-noise (SNR) figure, called *effective* SNR [1]. This channel quality indicator is sent back to the transmitter that uses it to elaborate an estimate of the GP performance of the radio link, called *expected* GP (EGP) that is taken as the objective function of the RA problem. This procedure assumes a perfect knowledge of the channel state information (CSI) at the transmitter. Moreover, CSI is the vector of the estimated SNRs, one for each subcarrier, and therefore the transmitter can perfectly evaluate the EGP.

The scope of the work is to measure the GP performance for the BIC-OFDM system of Figure 1 in a real-time over-the-air transmission, exploiting the RA technique mentioned above. The GP performance of the transmission featuring RA algorithm is compared with that achieved by the same transmission system without RA, i.e., with fixed modulation and code rate and uniform energy allocation over the OFDM subcarriers. A test BIC-OFDM link was implemented by using two software-defined radios (SDRs) USRP N210 programmed with the GNU Radio Companion software interface [2].

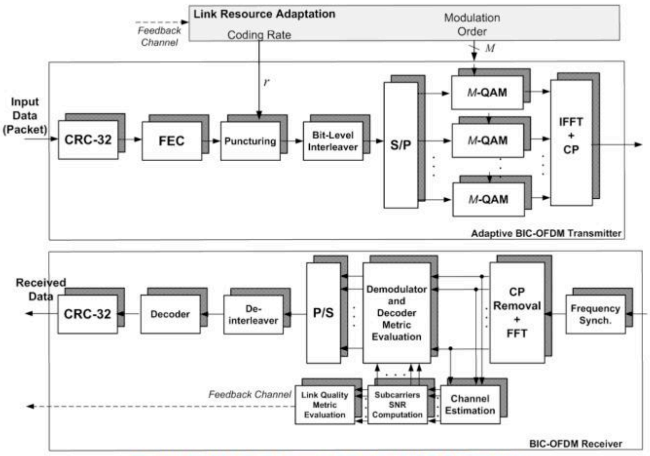

Figure 1: Block diagram of the test BIC-OFDM link

2. Motivation

Physical algorithms are usually tested through high-level software simulations (e.g., Matlab or C/C++), where some assumptions and simplifications are made, such as perfect knowledge and estimation of the channel. This is, however, only the first step of validation of a transmission system and/or algorithm (Step 1).

The joint activity carried out at the CTTC aims at providing an additional level of validation by testing the transmission system on a physical SDR platform in a real-time over-the-air transmission (Step 2). Indeed, so far the considered RA technique was only evaluated in Step 1, for different scenarios, such as cognitive radio communication composed of a secondary source-destination pair and several primary users, or dual-hop transmission with the presence of decode-and-forward relay nodes.

This mobility grant enabled a new collaboration between CNIT-Pisa that developed the RA algorithm and CTTC that made available its laboratory equipment, indispensable in Step 2.

3. Objectives

The mobility grant is a first and effective approach to get in touch and to start a research activity aimed at testing Track 1's analytical findings by using Track 2's hardware platforms.

The first goal is to identify the main problems related to the practical implementation on the SDR USRP N210 platform of the communication system in Figure 1.
Moreover, the second goal is to evaluate the efficiency in terms of GP, computational complexity and energy efficiency of the RA algorithm.

In detail, we want to implement the BIC-OFDM system with the RA algorithm over the USRP N210 platforms that are programmed using the GNU Radio Companion interface. The aim is to carry out performance tests in a real-time over-the-air transmission. During the measurements, a programmable hardware channel emulator is exploited for implementing ITU standard channel.

The following performance metrics are considered: signalling traffic, convergence times, packet error rate and GP. The performance of the RA-based transmission is compared with the transmission without RA.

4. Meetings

- Discussion about the second NEWCOM# Mobility Grant Application,
  Monday 6 October, 2014, Pisa, Italy,
  Paolo Del Fiorentino (CNIT-Pisa), Prof. Filippo Giannetti (CNIT-Pisa),
  Miquel Payaró (CTTC)

- Discussion on the second mobility grant call 2014 involving Track 1/CNIT-Pisa and Track 2/CTTC: definition of visiting period and supervising person(s) at CTTC, preliminary work to be carried out at CNIT-Pisa, work-plan to be carried out at CTTC
  Paolo Del Fiorentino (CNIT-Pisa), Prof. Filippo Giannetti (CNIT-Pisa),
  Miquel Payaró (CTTC)

- Discussion on the work to be carried out during the visit,
  Thursday 4 May, Castelldefels, Spain,
  Paolo Del Fiorentino (CNIT-Pisa), Miquel Payaró (CTTC),
  Nikos Bartzoudis (CTTC)

- Discussion on the state of the work,
  Friday 15 May, Castelldefels, Spain,
  Paolo Del Fiorentino (CNIT-Pisa), Miquel Payaró (CTTC),
  Nikos Bartzoudis (CTTC)

- Discussion on the state of the work after the first part of the visit,
  Friday 29 May, Castelldefels, Spain,
  Paolo Del Fiorentino (CNIT-Pisa), Miquel Payaró (CTTC),
  Nikos Bartzoudis (CTTC)

5. Activities

The work was started with a preliminary meeting at the beginning of the visit between Paolo Del Fiorentino, Miquel Payaró and Nikolaos Bartzoudis. We outlined the joint research activity to be carried out at the CTTC during the mobility grant period; we focused on the development of a GNU Radio Companion simulator of a BIC-OFDM system with the RA algorithm, exploiting two USRP N210 and a channel emulator for a real-time over-the-air transmission; we defined system parameters and performance metrics; we identified the goals of the activity; we specified mathematical and software tools to be used; we identified open issues in the proposed topic and possible solutions.

6. Results

a. Scientific results

Paolo Del Fiorentino has spent this month, firstly to study the GNU Radio Companion platform, and secondly to prepare a programme, which simulates an OFDM system in a real-time radio-frequency transmission, exploiting only one USRP N210 to simultaneously transmit and receive. During the visiting period, the main issues related to a practical implementation of a BIC-OFDM wireless transmission, such as the transmit energy, synchronization, channel estimation and equalization have been addressed.
This BIC-OFDM system represents a good starting point for the next visit in July, when a convolutional code, an interleaver and the RA algorithm will be implemented and tested.

b. Collaboration results

Thanks to the mobility grant, we had the opportunity to create a tight interaction between theoretically-oriented activities Track 1 (WP1.3 CNIT-Pisa) and experimentally-oriented Track 2 EuWin (WP2.1 CTTC). Indeed, the activity has been really helpful to Paolo Del Fiorentino, because he could approach a practical implementation of a transmission system. This has thus led to schedule another visit at the CTTC in July, in order to complete the implementation and test of the studied system and possibly preparing a joint paper to be submitted to a conference by the end of this year.

c. Dissemination

The results obtained in this visit at the CTTC are preliminary, but thanks to the opportunity of mobility grant, this activity research is going on to achieve the goals fixed in the first meeting and to submit an article by the end of the NEWCOM# project.

7. Plans for Follow-up

Another visit is scheduled in July 2015 to complete the implementation of the transmission system described in Sec. 1.

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Furthermore, a system model will be developed with GNU Radio Companion program to simulate a dual-hop BIC-OFDM system with decode-and-forward relays and multiple Primary Users (PUs) in a real-time over-the-air transmission exploiting the same RA algorithm as described above.

8. Attachments

- Minutes of the Meeting held on Monday 6 October, 2014, Pisa, Italy
- Minutes of the Meeting held on Tuesday 18 March, 2015, Pisa, Italy
- Minutes of the Meeting held on Thursday 4 May, Castelldefels, Spain
- Minutes of the Meeting held on Friday 15 May, Castelldefels, Spain
- Minutes of the Meeting held on Friday 29 May, Castelldefels, Spain

9. Bibliography

[1] Stupia, I; Lottici, V.; Giannetti, F.; Vandendorpe, L., ”Link Resource Adaptation for Multiantenna Bit-Interleaved Coded Multicarrier Systems”, *Signal Processing, IEEE Transactions on*, vol.60, no.7, pp.3644, 3656, July 2012

[2] GNU Radio Companion ”https://gnuradio.org/redmine/projects/gnuradio/wiki/GNURadioCompanion“

[3] Van Hecke, Jeroen; Del Fiorentino, Paolo; Andreotti, Riccardo; Lottici, Vincenzo; Giannetti, Filippo; Moeneclaey, Marc, "Goodput-Based Resource Allocation in CognitiveRadio BIC-OFDM systems with DF Relay," *accepted to the IEEE international Conference on Communications (ICC);* 8-12 June 2015.

Signature

Paolo Del Fiorentino

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18. Annex M: Report of Winjie Li (Y2)

MOBILITY GRANT
Report

Guest name: Wenjie Li
Guest institution: CNRS/UPsud

Host name: Prof. Davide Dardari
Host institution: CNIT/Bologna

Research topic: Distributed outlier detection in a wireless sensor network

Starting date: June 10th, 2014
Ending date: October 24th, 2014

1. Scope of Work

This work is related to two tasks one belonging to Track 1, the second to Track 2, and hence it can be considered as an inter-track joint research activity.

Task 1.2.3: Energy-efficient data collection in sensor networks.

Task 2.2.2: Distributed and cooperative (multi-terminal) localization and tracking.

2. Motivations

During the last decade, wireless sensor networks (WSN) have attracted a wide interest from different scientific communities [1]. A sensor network consists of spatially spread, autonomous devices, locally measuring some physical quantity (e.g., pressure, temperature, sound). Appropriate processing of the acquired signals allows performing some task (e.g., surveillance, localization, environmental monitoring).

Outliers are defined as abnormal measurements which cannot be justified by the mere effects of sensing noise. They may be informative because associated to the insurgence of some critical event (e.g., a forest fire), or caused by some sensor impairment. Outliers exhibit spatial and/or temporal correlation when indicating some event of interest (when the forest fire occurs, an entire region should have significantly higher temperature), while can be assumed as independent if originated by defective sensors. Since the presence of uninformative outliers in the set of measurements may seriously disrupt the functionality of the system, the detection of the defective sensors is very important.

Many distributed fault detection (DFD) algorithms have already been proposed in the literature. The basic assumption is that all the nodes take noisy measurements of the same physical quantity. The algorithm devised in [2] allows each node to estimate its own functioning status by comparing the local measurement with the ones at neighboring nodes.

In a first phase only a tendency status (good, faulty, likely good, or likely faulty) is determined. In the second phase the tendency status of neighbors are collected and associated to their measurements to obtain a more reliable assessment. In [3] the local test is based on the comparison between the local measurement and the median of the measurements of the neighbors. Iterative algorithms are proposed in [4], [5], where the weighted-median and the weighted average criterion are considered, respectively. In both cases the local test weights the measurements of the neighbors by the confidence level obtained from the previous detection round, under the assumption of permanent node failure. Intermittent faults in sensing and in communication are considered in [6], which proposes an adaptive DFD algorithm with a decision threshold adjusted at each round.
In the theoretical part of this work, we aim to propose a low complexity DFD algorithm for large WSNs [7]. Our approach differs with respect to classical solutions in the fact that the comparison of the local and neighboring measurements in the first phase of the algorithm only determines whether an outlier is present in the measurement set. This is usually an easier task than attempting to identify it.
In the experimental part, we aim to verify the behavior of the proposed algorithm in a real context. Since it is not enough to propose an algorithm and simulate it in an ideal case for the lower layers of the network.

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[2] J. Chen, S. Kher, and A. Somani, "Distributed fault detection of wireless sensor networks," in Proc Workshop DIWANS, New York, NY, USA, pp. 65-72, 2006.
[3] M. Ding, D. Chen, K. Xing, and X. Cheng, "Localized fault-tolerant event boundary detection in sensor networks," in Proc IEEE INFOCOM, Miami, FL, USA, 2005, pp. 902 – 913.
[4] J.-L. Gao, Y.-J. Xu, and X.-W. Li, "Weighted-median based distributed fault detection for wireless sensor networks," Journal of Software, vol. 18, no. 5, pp. 1208 – 1217, 2007.
[5] S. Ji, S.-F. Yuan, T.-H. Ma, and C. Tan, "Distributed fault detection for wireless sensor based on weighted average," in Proc NSWCTC, Wuhan, China, 2010, pp. 57 – 60.
[6] M.-H. Lee and Y.-H. Choi, "Fault detection of wireless sensor networks," Computer Communications, vol. 31, no. 14, pp. 3469–3475, 2008.
[7] W. Li, F. Bassi, D. Dardari, M. Kieffer, G. Pasolini, "Efficient Distributed Fault Detection for Wireless Sensor Networks", Accepted by IEEE ICC, 2015.

3. Objectives

The first objective is to accurately model the behavior of the outlier detection technique as a function of the number of valid measurements, outliers, noise, and propagation characteristics. With this model and spatial models of node distribution, our aim is to perform a theoretical analysis of the detection probability and the false alarm probability using stochastic geometry tools.
The second objective is to deploy the outlier detection technique on the EuWIn@CNIT/Bologna platform DATASENS. This platform is particularly well suited to perform experiments related to distributed estimation, and more specificall to robust estimation in presence of outliers. The algorithms proposed in [7] have the advantage of allowing a

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relatively simple implementation. This will allow an experimental verification of the theoretical results we aim to develop.

4. Meetings (meeting purpose, dates, location, attendance)

Virtual meeting (Skype) on 11th June, 2014
Attendances: Wenjie Li (WL), Vincenzo Zambianchi (VZ), Gianni Pasolini (GP), Michel Kieffer (MK), Francesca Bassi (FB)
Purpose: Settling of WL in Cesena's faculty.

Virtual meeting (Skype) on 18th June, 2014
Attendances: Davide Dardari (DD), WL, VZ, MK, FB
Purpose: Discussion on the approximation detail of the probability of false alarm and the approaches to learn the dynamic property of the adaptive algorithm.

Physical meeting (in EuCNC, Bologna) on 25th June, 2014
Attendances: WL, DD, MK
Purpose: Discussion on the dynamic evolutions of the detection probability and the false alarm probability by considering a finite state machine in the adaptive algorithm.

Virtual meeting (Skype) on 3rd July, 2014
Attendances: WL, VZ, DD, MK
Purpose: Discussion on the initial ideas of the proof of the existence and uniqueness of the equilibrium point of the considered dynamic system.

Virtual meeting (Skype) on 9th July, 2014
Attendances: WL, DD, GP, MK
Purpose: Discussion on possible improvements of our paper in preparation, such as the introduction and the state of the art.

Virtual meeting (Skype) on 17th July, 2014
Attendances: WL, VZ, DD, MK
Purpose: Discussion on the modification of the current version of the paper.

Physical meeting (in Cesena) on 23rd July, 2014
Attendances: WL, DD
Purpose: Discussion on the different fault models to be investigated.

Virtual meeting (Skype) on 9th September, 2014
Attendances: WL, VZ, DD, MK, FB
Purpose: Discussion on the modification of the current version of the paper.

Virtual meeting (Skype) on 19th September, 2014
Attendances: WL, VZ, DD, GP, MK, FB
Purpose: Decision on the submission of a conference paper to ICC 2015.

Physical meeting (in Cesena) on 23rd September, 2014
Attendances: WL, DD
Purpose: Discussion on the proof of locally stability of the equilibrium point of the adaptive algorithm.

Virtual meeting (Skype) on 21st October, 2014
Attendances: WL, VZ, DD, GP, MK
Purpose: Report of the progresses of experimental activity.

Physical meeting (in Cesena) on 24th October, 2014
Attendances: WL, VZ, DD
Purpose: Presentation of the functioning of the implemented algorithm by using five sensor nodes.

5. Activities

The first period of my stay in CNIT/Bologna focused the theoretical performance of the proposed distributed outlier identification algorithm. The analysis included: 1) approximation of detection probability and false alarm probability, 2) dynamic evolution of the adaptive algorithm, 3) existence and uniqueness of the equilibrium point of the adaptive algorithm, 4) locally stability of the equilibrium point. We have submitted a paper to ICC 2015 and now it has been accepted.
I had the experimental activity in collaboration with Vincenzo Zambianchi. We used the EuWln@CNIT/BO Datasens platform to implement the proposed algorithm. Sensor nodes (TI CC2530) measure the real temperature. A small part of nodes are manually added by a random bias so that they are considered as the "outliers". Different from the theoretical analysis, we have to consider some impact of the real situations. For example we made each sensor wait a random time at each system round to avoid collisions, since sensors need to broadcast their packets in our algorithm. The implementation is simple, thanks to the low-complexity of the proposed algorithm.

6. Results

a. Scientific results

We proposed two variants of a two-staged DFD algorithm, which allows each node to decide whether its sensor is producing outliers. An analytical framework for the analysis of the adaptive variant has been sketched. The performance of both variants have been characterized by simulations, which allowed to draw insights on the impact of the algorithm parameters (number of rounds, local test threshold) and of the network topology (density of faulty sensors, size of the neighborhood) on the trade-off between the detection probability and the false alarm property.
We have implemented the proposed algorithm by considering the real protocol and the real propagation conditions. We have used a simple example to show that both non-adaptive and adaptive algorithms work normally in the real situations.

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b. Collaboration results

Both the theoretical part and the experimental verification are performed in collaboration between CNIT/Bologna and CNRS/UPsud. I have benefitted from the experience of CNIT/Bologna in wireless sensor networks, distributed signal processing, and theoretical aspects related to spatial fields in general. The collaboration will continue in the future.

c. Dissemination

This work has presented in

Special technical session on "Advanced techniques for energy- and bandwidth-efficient communications" @ EuCNC Bologna, 2014

and

NEWCOM# Track1-Track2 meeting, Athens, 2015.

It will also be presented in IEEE ICC, London, 2015

7. Plans for Follow-up

The experimental part is still on going. We are using more sensor nodes to perform the tests. A large number of experimentations are needed to evaluate the detection probabilities and the false alarm probabilities of the proposed algorithm. The results will be compared with the simulation results that we have obtained.

We are also working on the journal paper to be submitted to IEEE Transactions on Signal Processing very soon.

8. Attachments

(draft of papers/papers, slides of presentations etc…..)

Signature

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19. Annex N: Report of Alejandro de la Fuente (Y2)

MOBILITY GRANT
Report

Guest name: Alejandro de la Fuente
Guest institution: Universidad Carlos III de Madrid (Spain)

Host name: Raymond Knopp
Host institution: Eurecom (France)

Research topic: Resource allocation for multicast service in 4G/5G mobile networks

Starting date: 1st of April 2015
Ending date: 30th of May 2015

1. Scope of Work

This work is part of the Mobility Action Plan in NEWCOM# project, which has the objective of doing experimental validation of the resource allocation algorithms developed and integrate them into the network topologies deployed in the lab.

The NEWCOM# WP1.3 is focused in addressing solutions for energy and bandwidth efficient links and networks. The utilization of techniques for power-efficient communications, the use of low interference and low-emission radio interfaces and the improvement of resource allocation for optimized radio access are the tasks included in this Work Package. Our contributions present theoretical improvements in this area, focused on the multicast service delivered in an heterogeneous multi-user scenario.

The NEWCOM# WP2.3 is focused in flexible communication terminals and networks. Our contributions can be useful in the lab planning and, furthermore, we can do experiments in collaborative communications in multi-hop network topologies. Specially interesting could be the integration of the resource allocation techniques developed for improving the energy and bandwidth efficiency in the network topologies deployed in the lab.

2. Motivations

Mobile video service is one of the most increasing uses expected in future generation cellular networks, including multicast video services. Based upon Evolved Multimedia Broadcast and Multicast Service (eMBMS) available with 3rd Generation Partnership Project (3GPP) release 9, Long Term Evolution (LTE) can provide broadcast/multicast content delivery with a single-frequency network mode. This means sending the same multimedia content to a mass audience within a specific area.

The increasing number of applications and services the users can be provided using the mobile networks yields an heterogeneous scenario, with a diversity of unicast and multicast services provided. The resource allocation for unicast transmissions in mobile networks is widely studied. Nevertheless, the resource allocation among the different multicast groups and the joint allocation between unicast and multicast transmissions need to be studied more deeply to improve the efficiency of mobile networks, specially in the scenarios with heterogeneous services provided.

On the one hand, using multicast transmissions improves the efficient utilization of network resources, however it requires setting equal transmission parameters to all the users in the multicast area. Consequently, in multicast transmissions, the Modulation and Coding Scheme (MCS) is unique and set by upper layers. Therefore, the multicast transmission throughput in the multicast area is jointly established by the MCS and the transmission bandwidth.

Differently, unicast transmissions can use link adaptation and channel dependent scheduling, based on the Channel Quality Indicator (CQI) the user sends periodically to the Evolved Node B (eNodeB). Therefore, Evolved Universal Terrestrial Radio Access (E-UTRA) can dynamically allocate resources, both Resource Block (RB) and MCS, to the User Equipment (UE)s at each Transmission Time Interval (TTI).

On the other hand, in multicast services over a cellular network, due to the nature of the multicast communication, from a source to multiple recipients, and due to the characteristics of the radio channel, different for each receiver, transmission errors cannot be avoided for all the users. For that reason, 3GPP proposed these errors are addressed at the application level by using Forward Error Correction (FEC) techniques. Furthermore, in order to protect the communication over the radio channel, FEC techniques are also applied at the physical layer using Turbo codes.

It is worth noting that cross-layer optimization techniques must be used in the resource allocation mechanisms when unicast and multicast transmissions have to be provided. This techniques must guarantee not only the fulfilment of the Quality of Service (QoS) requirements, but also the improvement in the efficient use of the limited resources, leading to a bandwidth and energy optimization.

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3. Objectives

The main objectives of this work are the following:

• Create new collaborations with other researchers working in multicast resource allocation
• Develop new resource allocation algorithms to improve energy and bandwidth efficiency
• Do experiments in the lab using new resource allocation algorithms
• Integrate the software simulated algorithms into collaborative communications network topologies

Despite the fact that these are the main a priori objectives of this work based on the NEWCOM# mobility plan, opening new lines of researching, collaborating and sharing the knowledge with other colleagues in complementary study areas is not only an objective but also a great opportunity of this work.

4. Meetings

There are not meetings scheduled.

5. Activities

We have started this work with the study of the Information Elements, defined in 3GPP LTE standards, which have influence in eMBMS configuration. After this study, we have checked the eMBMS configuration in OpenAir Interface. Following, we have compiled OpenAir Interface code using 3GPP LTE Rel 10 messages specified in 3GPP TS 36.331 V10.2.0, and we have launched some simulations to trace and analyse them. As a part of this work, some issues to be fixed have been studied and documented in this paper. Finally, we have presented the degrees of freedom to allocate multiple multicast services in LTE networks.

A. MBMS Information Elements

This section shows the Information Elements that take part in the multicast scheduling configuration in LTE standards.

Firstly, the LTE System Information Block (SIB) 13 delivers the following Multimedia Broadcast and Multicast Service (MBMS) information elements:

• **MBSFN-AreaInfoList** that contains the information required to acquire the MBMS control information associated with one or more Multicast/Broadcast over Single Frequency Network (MBSFN) areas. This information element contains the following fields:

– **mbsfn-AreaId**
– **mcch-ModificationPeriod**
– **mcch-Offset**
– **mcch-RepetitionPeriod**
– **non-MBSFNregionLength**
– **notificationIndicator**
– **sf-AllocInfo**
– **signallingMCS**

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• **MBMS-NotificationConfig** that specifies the MBMS notification related configuration parameters, that are applicable for all MBSFN areas. This information element contains the following fields:

- **notificationOffset**
- **notificationRepetitionCoeff**
- **notificationSF-Index**

With this information in SIB 13 users can acquire the Multicast Control Channel (MCCH) message. The different time periods defined in these elements establish how dynamically can change the resource allocation for multicast services.

Secondly, SIB 2 delivers the following MBMS information element:

• **MBSFN-SubframeConfig** which defines subframes that are reserved for MBSFN in the downlink. This information element contains the following fields:

- **fourFrames**
- **oneFrame**
- **radioFrameAllocationPeriod**
- **radioFrameAllocationOffset**
- **subframeAllocation**

Here we have a first level in the resource allocation for multicast services. The amount of subframes allocated to MBSFN and their position are defined. This level is in charge of allocating LTE resources among unicast and multicast transmissions inside the MBSFN area.

Thirdly, through MCCH the terminal receives the following MBMS information element:

• **PMCH-InfoList** which specifies configuration of all Physical Multicast Channel (PMCH)s of an MBSFN area. The information provided for an individual PMCH includes the configuration parameters of the sessions that are carried by the concerned PMCH. This information element contains the following fields:

- **dataMCS**
- **mch-SchedulingPeriod**
- **plmn-Index**
- **sessionId**
- **serviceId**
- **sf-AllocEnd**

This information element is in charge of resource allocation between different Multicast Channel (MCH) or sessions. Each one can have allocated different number of subframes, use different MCS, and/or different scheduling period.

The parameter **commonSF AllocPerio**d defines the Common Subframe Allocation (CSA) period that is the time period in which all MCHs share resources.

MCH transmission may occur in subframes configured by upper layer for MCCH or Multicast Traffic Channel (MTCH) transmission. For each such subframe, upper layer indicates if

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signallingMCS or *dataMCS* applies. The transmission of an MCH occurs in a set of subframes defined by **PMCH Config**.

Finally, an MCH Scheduling Information (MSI) MAC control element is included in the first subframe allocated to each MCH every MCH Scheduling Period (MSP). This MSI indicates the position of each MTCH and unused subframes on the MCH. The UE shall assume that the first scheduled MTCH starts immediately after the MCCH or the MSI MAC control element if the MCCH is not present, and the other scheduled MTCH(s) start immediately after the previous MTCH, at the earliest subframe where the previous MTCH stops.

The MSI MAC Control Element is identified by a MAC PDU subheader with Logical Channel ID (LCID). This control element has a variable size. For each MTCH the fields below are included:
• **lcid**: this field indicates the Logical Channel ID of the MTCH. The length of the field is 5 bits.
• **stop-MTCH**: this field indicates the ordinal number of the subframe within the MSP, counting only the subframes allocated to the MCH, where the corresponding MTCH stops. Value 0 corresponds to the first subframe. The length of the field is 11 bits. The special Stop MTCH value 2047 indicates that the corresponding MTCH is not scheduled. The value range 2043 to 2046 is reserved.

This is the last level in the resource allocation for multicast services, where different channels (MTCH) are time multiplexed in a session (MCH), and they are sharing the common configuration of MCH parameters. However, each channel (MTCH) can have different quantity of subframes allocated within the MSP.

B. eMBMS configuration in OpenAir Interface

This section shows the configuration of the Information Elements involved in eMBMS scheduling.

In the file *openair4G/openair2/RRC/LITE/MESSAGES/asn1 msg.c*, we have checked the values of the following information elements: **MBSFN-AreaInfoLis**t, and **MBMS-NotificationConfig**, both of them included in SIB 13, the **MBSFN-SubframeConfig** included into SIB 2, and the **PMCH-InfoList** included in MCCH information.

• **MBSFN-AreaInfoList** is setup as follows:

– MBSFN Area 1:
MBSFN_Area1- > mbsfn AreaId r9 = 1
MBSFN_Area1- > mcch Config r9.mcch ModificationPeriod r9 = rf512
MBSFN_Area1- > mcch Config r9.mcch Offset r9 = 1
MBSFN_Area1- > mcch Config r9.mcch RepetitionPeriod r9 = rf32
MBSFN_Area1- > non MBSFNregionLength = s2
MBSFN_Area1- > notificationIndicator r9 = 0
MBSFN_Area1- > mcch Config r9.sf AllocInfo r9.buf= MALLOC(1)
MBSFN_Area1- > mcch Config r9.sf AllocInfo r9.size = 1
MBSFN_Area1- > mcch Config r9.sf AllocInfo r9.bits unused = 2
MBSFN_Area1- > mcch Config r9.sf AllocInfo r9.buf[0] = 0x20 << 2 (100000 for FDD)
MBSFN_Area1- > mcch Config r9.sf AllocInfo r9.buf[0] = 0x08 << 2 (001000 for TDD)

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MBSFN_Area1- > mcch Config r9.signallingMCS r9 = n7

– MBSFN Area 2 (currently only activated for eMBMS relaying):
MBSFN_Area2- > mbsfn AreaId r9 = 2
MBSFN_Area2- > mcch Config r9.mcch ModificationPeriod r9 = rf512
MBSFN_Area2- > mcch Config r9.mcch Offset r9 = 1
MBSFN_Area2- > mcch Config r9.mcch RepetitionPeriod r9 = rf32
MBSFN_Area2- > non MBSFNregionLength = s2
MBSFN_Area2- > notificationIndicator r9 = 1
MBSFN_Area2- > mcch Config r9.sf AllocInfo r9.buf= MALLOC(1)
MBSFN_Area2- > mcch Config r9.sf AllocInfo r9.size = 1
MBSFN_Area2- > mcch Config r9.sf AllocInfo r9.bits unused = 2
MBSFN_Area2- > mcch Config r9.sf AllocInfo r9.buf[0] = 0x04 << 2 (000100 for FDD)
MBSFN_Area2- > mcch Config r9.sf AllocInfo r9.buf[0] = 0x08 << 2 (001000 for TDD)
MBSFN_Area2- > mcch Config r9.sf AllocInfo r9.bits unused = 2
MBSFN_Area2- > mcch Config r9.signallingMCS r9 = n7

• **MBMS-NotificationConfig** is configured as follows:
(*sib13)- > notificationConfig r9.notificationOffset r9 = 0
(*sib13)- > notificationConfig r9.notificationRepetitionCoeff r9 = n2
(*sib13)- > notificationConfig r9.notificationSF Index r9 = 1

• The configuration of **MBSFN-SubframeConfig** is:

– MBSFN Area 1:
sib2_mbsfn_SubframeConfig1- > radioFrameAllocationPeriod = n4
sib2_mbsfn_SubframeConfig1- > radioFrameAllocationOffset = 1
sib2_mbsfn_SubframeConfig1- > subframeAllocation.present = oneFrame
sib2_mbsfn_SubframeConfig1- > subframeAllocation.choice.oneFrame.buf = MALLOC(1)
sib2_mbsfn_SubframeConfig1- > subframeAllocation.choice.oneFrame.size = 1
sib2_mbsfn_SubframeConfig1- > subframeAllocation.choice.oneFrame.bits unused = 2
sib2_mbsfn_SubframeConfig1- > subframeAllocation.choice.oneFrame.buf[0] = 0x38 << 2 (111000 for FDD)
sib2_mbsfn_SubframeConfig1- > subframeAllocation.choice.oneFrame.buf[0] = 0x08 << 2 (001000 for TDD)

– MBSFN Area 2 (currently only activated for eMBMS relaying):
sib2_mbsfn_SubframeConfig2- > radioFrameAllocationPeriod = n4
sib2_mbsfn_SubframeConfig2- > radioFrameAllocationOffset = 1
sib2_mbsfn_SubframeConfig2- > subframeAllocation.present = oneFrame
sib2_mbsfn_SubframeConfig2- > subframeAllocation.choice.oneFrame.buf = MALLOC(1)
sib2_mbsfn_SubframeConfig2- > subframeAllocation.choice.oneFrame.size = 1
sib2_mbsfn_SubframeConfig2- > subframeAllocation.choice.oneFrame.bits unused = 2
sib2_mbsfn_SubframeConfig2- > subframeAllocation.choice.oneFrame.buf[0] = 0x07 << 2 (000111 for FDD)

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sib2_mbsfn_SubframeConfig2- > subframeAllocation.choice.oneFrame.buf[0] = 0x08 << 2 (001000 for TDD)

• The Information Element **commonSF-AllocPeriod** is setup as follows:
(mbsfnAreaConfiguration)- > commonSF AllocPeriod r9 = rf16

• The MCCH information **PMCH-InfoList**, presents the following values:

– PMCH 1 Config (only one MCH is configured with 1 session):
pmch_Info 1- > pmch Config r9.sf AllocEnd = 3
pmch_Info 1- > pmch Config r9.dataMCS r9 = 7
pmch_Info 1- > pmch Config r9.mch SchedulingPeriod r9 = rf16
mbms_Session 1- > tmgi r9.choice.plmn Index r9 = 1
mbms_ Session 1- > sessionId r9 = MTCH

In addition, in the file openair4G/openair2/LAYER2/MAC/eNB scheduler mch.c, we have checked the configuration of the MAC control element called **MCH Scheduling Information**, the **stop-MTCH** has the following values:

((MSI_ELEMENT *) msi_ptr)- > stop_sf_MSB = 0
((MSI_ELEMENT *) msi_ptr)- > stop_sf_LSB = 0 stop value is 0 if MCCH
((MSI_ELEMENT *) msi_ptr)- > stop_sf_MSB = 0x7
((MSI_ELEMENT *) msi_ptr)- > stop_sf_LSB = 0xFF stop value is 2047 if MSI
((MSI_ELEMENT *) msi_ptr)- > stop_sf_MSB = 0
((MSI_ELEMENT *) msi_ptr)- > stop_sf_LSB = 0xB stop value is 11 if MTCH (only one MTCH in the MCH)

Fig. 1 illustrates how the subframes into LTE frames are configured for eMBMS resource allocation in OpenAir Interface.

Note that *commonSF-AllocPeriod* and *mch-SchedulingPeriod* have the same value of 16 radio frames. For that reason, the configuration of *sf-AllocEnd* = 3 and *stop-MTCH* = 11 means that MTCH is longer than MCH in which is allocated, and it has no sense. We have checked this issue using traces, in section.

6. Results

A. Compiling and simulating using 3GPP Release 10

After checking the OpenAir Interface configuration for MBMS, we have compiled it using 3GPP Release 10 messages. In such a way, in the folder /openair4G/openair2/RRC/LITE/MESSAGES/asn1c/ASN1 files these three files are generated:

- *EUTRA-RRC-Definitions.asn*
- *EUTRA-UE-Variables.asn*
- *EUTRA-InterNodeDefinitions.asn*

Only 1 MCH and 1 MTCH are configured:

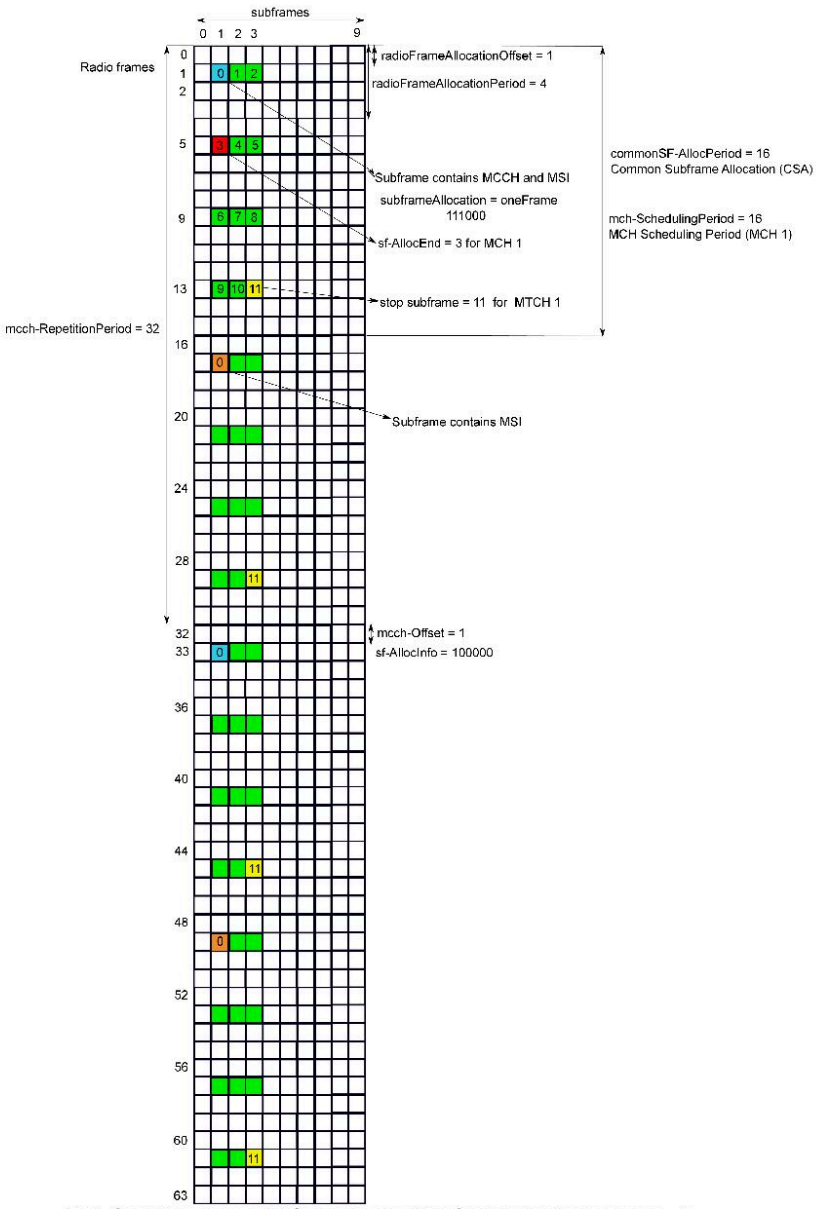

Fig 1. OpenAir Interface eMBMS resource allocation: Configuration 1 for sync area = 0

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Now, we can compile OpenAir Interface code using messages specified in 3GPP TS 36.331 V10.2.0 (Release 10). In the folder, */openair4G/targets/SIMU/USER/* execute:

make cleanall
make Rel10=1 -j4 DEBUG=1

The OpenAir Interface code is compiled and linked to use eMBMS supported in 3GPP Release 10. Several simulations have been launched to analyze the multicast scheduling in 3GPP standards.

Firstly, in the folder /openair4G/targets/SIMU/USER/, we have executed the following simulation:

./oaisim -a -Q3 -n200 -F -l9 > logsimulation1.txt

Note that *-a* activates PHY abstraction mode, *-Q* activates and set the MBMS service (value 3 corresponds to eMBMS enabled and unicast disabled, this value corresponds to *MBMS_flag* checked in the *asn1 msg.c*, -n set the number of frames for the simulation, *-F* activates Frequency Division Duplexing (FDD) transmission mode, and *-l* set the global log level.

By means of this simulation we can check the following items:

• **MBSFN SubframeConfig** is configured in SIB 2 by eNodeB:

< sib2 >
< radioResourceConfigCommon >
..
< mbsfn-SubframeConfigList >
< MBSFN-SubframeConfig >
< radioframeAllocationPeriod >< n4/ >< /radioframeAllocationPeriod >
< radioframeAllocationOffset > 1 < /radioframeAllocationOffset >
< subframeAllocation >
< oneFrame >
111000
< /oneFrame >
< /subframeAllocation >
< /MBSFN-SubframeConfig >
..
< /mbsfn-SubframeConfigList >

• **MBMS-NotificationConfig** and **MBSFN-AreaInfoList** are configured in SIB 13 by eNodeB:

< sib13-v920 >
< mbsfn-AreaInfoList-r9 >
< MBSFN-AreaInfo-r9 >
< mbsfn-AreaId-r9 > 1 < /mbsfn-AreaId-r9 >
< non-MBSFNregionLength >< s2/ >< /non-MBSFNregionLength >
< notificationIndicator-r9 > 0 < /notificationIndicator-r9 >
< mcch-Config-r9 >
< mcch-RepetitionPeriod-r9 >< rf32/ >< /mcch-RepetitionPeriod-r9 >

< mcch-Offset-r9 > 1 < /mcch-Offset-r9 >
< mcch-ModificationPeriod-r9 >< rf512/ >< /mcch-ModificationPeriod-r9 >
< sf-AllocInfo-r9 >
100000
< /sf-AllocInfo-r9 >
< signallingMCS-r9 >< n7/ >< /signallingMCS-r9 >
< /mcch-Config-r9 >
< /MBSFN-AreaInfo-r9 >
< /mbsfn-AreaInfoList-r9 >
< notificationConfig-r9 >
< notificationRepetitionCoeff-r9 >< n2/ >< /notificationRepetitionCoeff-r9 >
< notificationOffset-r9 > 0 < /notificationOffset-r9 >
< notificationSF-Index-r9 > 1 < /notificationSF-Index-r9 >
< /notificationConfig-r9 >
< /sib13-v920 >

• eNodeB sends MCCH with the **PMCH-InfoList** with the following information:

< MCCH-Message >
< message >
< c1 >
< mbsfnAreaConfiguration-r9 >
< commonSF-Alloc-r9 >
< MBSFN-SubframeConfig >
< radioframeAllocationPeriod >< n4/ >< /radioframeAllocationPeriod >
< radioframeAllocationOffset > 1 < /radioframeAllocationOffset >
< subframeAllocation >
< oneFrame >
111000
< /oneFrame >
< /subframeAllocation >
< /MBSFN-SubframeConfig >
< /commonSF-Alloc-r9 >
< commonSF-AllocPeriod-r9 >< rf16/ >< /commonSF-AllocPeriod-r9 >
< pmch-InfoList-r9 >
< PMCH-Info-r9 >
< pmch-Config-r9 >
< sf-AllocEnd-r9 > 3 < /sf-AllocEnd-r9 >
< dataMCS-r9 > 7 < /dataMCS-r9 >
< mch-SchedulingPeriod-r9 >< rf16/ >< /mch-SchedulingPeriod-r9 >
< /pmch-Config-r9 >
< mbms-SessionInfoList-r9 >
< MBMS-SessionInfo-r9 >
< tmgi-r9 >
< plmn-Id-r9 >
< plmn-Index-r9 > 1 < /plmn-Index-r9 >
< /plmn-Id-r9 >
< serviceId-r9 > 02 01 00 < /serviceId-r9 >
< /tmgi-r9 >
< sessionId-r9 > 01 < /sessionId-r9 >
< logicalChannelIdentity-r9 > 1 < /logicalChannelIdentity-r9 >

< /MBMS-SessionInfo-r9 >
< /mbms-SessionInfoList-r9 >
< /PMCH-Info-r9 >
< /pmch-InfoList-r9 >
< /mbsfnAreaConfiguration-r9 >
< /c1 >
< /message >
< /MCCH-Message >

• eNodeB schedules MCCH message each 32 frames (*mcch-RepetitionPeriod*), from the frame 1 ((*mcch-Offset*) and in subframe 1 (*sf-AllocInfo*):

[MAC][D][eNB 0] Frame 1 Subframe 1: Schedule MCCH MESSAGE (area 0, sfAlloc 0)
[MAC][D][eNB 0] Frame 33 Subframe 1: Schedule MCCH MESSAGE (area 0, sfAlloc 0)
[MAC][D][eNB 0] Frame 65 Subframe 1: Schedule MCCH MESSAGE (area 0, sfAlloc 0)
[MAC][D][eNB 0] Frame 97 Subframe 1: Schedule MCCH MESSAGE (area 0, sfAlloc 0)

• UE receives SIB 13 from eNodeB 0, which includes **MBSFN-AreaInfoList** and **MBMS-NotificationConfig** with the following configuration:

[RRC][I][RRC][UE 0] Found SIB13 from eNB 0
[RRC][D][RRC][UE] NotificationRepetitionCoeff-r9 : 0
[RRC][D][RRC][UE] NotificationOffset-r9 : 0
[RRC][D][RRC][UE] NotificationSF-Index-r9 : 1
[RRC][D][FRAME 00009][RRC UE][MOD 00][][— MAC CONFIG REQ (SIB13 params eNB 0) -->][MAC UE][MOD 00][]
[MAC][I][CONFIG][UE 0] Configuring MAC/PHY from eNB 0
[MAC][I][UE 0][CONFIG] Received 1 MBSFN Area Info
[MAC][I][UE 0] MBSFN AreaInfo[0]: MCCH Repetition Period = 0
[PHY][I][UE0] Frame 9: Applying MBSFN Area id 1 for index 0

• UE receives **MBSFNAreaConfiguration** from eNodeB. This will configure *MAC/RLC/PDCP as follows:*

[RRC][I][UE 0] Frame 33 : Found MBSFNAreaConfiguration from eNB 0
[RRC][D][UE 0] Frame 33 : Number of MCH(s) in the MBSFN Sync Area 0 is 1
[MAC][I][CONFIG][UE 0] Configuring MAC/PHY from eNB 0
[MAC][I][UE 0] Configuring PMCH config from MCCH MESSAGE
[MAC][I][UE 0] PMCH[0]: MCH Scheduling Period = 1
[PDCP][D] CONFIG ACTION MBMS ADD service id/mch index 0, session id/lcid 1, rbid 1 configured
[RLC][D][FRAME 00033][UE][MOD 00][RNTI c6b8] CONFIG REQ ASN1
[RLC][I][FRAME 00033][UE][MOD 00][RNTI c6b8] RLC service id 0 session id 1 rrc rlc add rlc
[RLC][D][FRAME 00033][UE][MOD 00][RNTI c6b8] CONFIG REQ MBMS ASN1 LC ID 1 RB ID 1 SESSION ID 1 SERVICE ID 0
[RLC][D][FRAME 00033][UE][MOD 00][RNTI c6b8][SRB UM 00] config req rlc um asn1() CONFIG REQ timer reordering=0ms sn field length= RB 1
[RLC][D][FRAME 00033][UE][MOD 00][RNTI c6b8][SRB UM 00] rlc um init() [INIT] STATE VARIABLES, BUFFERS, LISTS
[RLC][D][FRAME 00033][UE][MOD 00][RNTI c6b8][SRB UM 00] rlc um fsm notify event() FSM RLC NULL STATE - > RLC DATA TRANSFER READY STATE

[RLC][D][FRAME 00033][UE][MOD 00][RNTI c6b8][SRB UM 00] rlc um set debug infos()
[SET DEBUG INFOS] rb id 1 srb flag 0
[RLC][D][FRAME 00033][UE][MOD 00][RNTI c6b8] CONFIG REQ ASN1 END

• UE receives MCCH every 32 frames in subframe 1 (*mcch-RepetitionPeriod, sf-AllocInfo*):
[PHY][D][UE 0] Frame 33, subframe 1: Querying for PMCH demodulation(3)
[MAC][D][UE 0] Frame 33 subframe 1: Checking MBSFN Sync Area 0/1 with SF allocation 0/1 for MCCH and MTCH (mbsfn period 4, mcch period 32,mac sched period (-1,1))
[MAC][D][UE 0] Frame 33 Subframe 1: sync area 0 SF alloc 0: msi flag 0, mcch flag 1, mtch flag 1
[PHY][D][UE 0] Frame 33, subframe 1: Programming PMCH demodulation for mcs 7
..
[PHY][D][UE 0] Frame 65, subframe 1: Querying for PMCH demodulation(3)
[MAC][D][UE 0] Frame 65 subframe 1: Checking MBSFN Sync Area 0/1 with SF allocation 0/1 for MCCH and MTCH (mbsfn period 4, mcch period 32,mac sched period (16,1))
[MAC][D][UE 0] Frame 65 Subframe 1: sync area 0 SF alloc 0: msi flag 1, mcch flag 1, mtch flag 1
[PHY][D][UE 0] Frame 65, subframe 1: Programming PMCH demodulation for mcs 7

• UE receives MSI every 16 frames in subframe 1 *(mch-SchedulingPeriod):*
[PHY][D][UE 0] Frame 49, subframe 1: Querying for PMCH demodulation(3)
[MAC][D][UE 0] Frame 49 subframe 1: Checking MBSFN Sync Area 0/1 with SF allocation 0/1 for MCCH and MTCH (mbsfn period 4, mcch period 32,mac sched period (16,1))
[MAC][D][UE 0] Frame 49 Subframe 1: sync area 0 SF alloc 0: msi flag 1, mcch flag 0, mtch flag 1
[PHY][D][UE 0] Frame 49, subframe 1: Programming PMCH demodulation for mcs 7
..
[PHY][D][UE 0] Frame 65, subframe 1: Querying for PMCH demodulation(3)
[MAC][D][UE 0] Frame 65 subframe 1: Checking MBSFN Sync Area 0/1 with SF allocation 0/1 for MCCH and MTCH (mbsfn period 4, mcch period 32,mac sched period (16,1))
[MAC][D][UE 0] Frame 65 Subframe 1: sync area 0 SF alloc 0: msi flag 1, mcch flag 1, mtch flag 1
[PHY][D][UE 0] Frame 65, subframe 1: Programming PMCH demodulation for mcs 7
..

• UE queries for the active eMBMS subframes, every 4 frames in subframes 1, 2, and 3 (*radioFrameAllocationPeriod*, *subframeAllocation*):
[PHY][D][UE 0] Frame 69, subframe 1: Querying for PMCH demodulation(3)
[MAC][D][UE 0] Frame 69 subframe 1: Checking MBSFN Sync Area 0/1 with SF allocation 0/1 for MCCH and MTCH (mbsfn period 4, mcch period 32,mac sched period (16,1))
[MAC][D][UE 0] Frame 69 Subframe 1: sync area 0 SF alloc 0: msi flag 0, mcch flag 0, mtch flag 1
[PHY][D][UE 0] Frame 69, subframe 1: Programming PMCH demodulation for mcs 7
[PHY][D][UE] dlsch decoding emul : subframe 1, eNB id 0, dlsch id 5
[PHY][D]decoding pmch emul (size is 389, enb 0 0)

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*[MAC][D][UE 0] Frame 69 : process the mch PDU for sync area 0
[MAC][D][UE 0] sdu: 3e.4
[MAC][D][UE 0] parse mch header, demultiplex
[MAC][D][UE 0] parse mch header, found 2 sdus
[MAC][I][UE 0] Frame 69 : MCH- > MSI for sync area 0 (eNB 0, 4 bytes)
[MAC][I][UE 0] Frame 69 : SDU 1 MCH- > MCCH for sync area 0 (eNB 0, 12 bytes)
[RRC][D][UE 0] Frame 69: MCCH MESSAGE for MBSFN sync area 0 has been already received!
..
[PHY][D][UE 0] Frame 69, subframe 2: Querying for PMCH demodulation(5)
[MAC][D][UE 0] Frame 69 subframe 2: Checking MBSFN Sync Area 0/1 with SF allocation 0/1 for MCCH and MTCH (mbsfn period 4, mcch period 32,mac sched period (16,1))
[MAC][D][UE 0] Frame 69 Subframe 2: sync area 0 SF alloc 0: msi flag 0, mcch flag 0, mtch flag 1
[PHY][D][UE 0] Frame 69, subframe 2: Programming PMCH demodulation for mcs 7
..
[PHY][D][UE 0] Frame 69, subframe 3: Querying for PMCH demodulation(7)
[MAC][D][UE 0] Frame 69 subframe 3: Checking MBSFN Sync Area 0/1 with SF allocation 0/1 for MCCH and MTCH (mbsfn period 4, mcch period 32,mac sched period (16,1))
[MAC][D][UE 0] Frame 69 Subframe 3: sync area 0 SF alloc 0: msi flag 0, mcch flag 0, mtch flag 1
[PHY][D][UE 0] Frame 69, subframe 3: Programming PMCH demodulation for mcs 7
..
[PHY][D][UE 0] Frame 73, subframe 1: Querying for PMCH demodulation(3)
[MAC][D][UE 0] Frame 73 subframe 1: Checking MBSFN Sync Area 0/1 with SF allocation 0/1 for MCCH and MTCH (mbsfn period 4, mcch period 32,mac sched period (16,1))
[MAC][D][UE 0] Frame 73 Subframe 1: sync area 0 SF alloc 0: msi flag 0, mcch flag 0, mtch flag 1
[PHY][D][UE 0] Frame 73, subframe 1: Programming PMCH demodulation for mcs 7
[PHY][D]decoding pmch emul (size is 389, enb 0 0)
[MAC][D][UE 0] Frame 73 : process the mch PDU for sync area 0
..
[MAC][D][UE 0] Frame 73 subframe 2: Checking MBSFN Sync Area 0/1 with SF allocation 0/1 for MCCH and MTCH (mbsfn period 4, mcch period 32,mac sched period (16,1))
[MAC][D][UE 0] Frame 73 Subframe 2: sync area 0 SF alloc 0: msi flag 0, mcch flag 0, mtch flag 1
[PHY][D][UE 0] Frame 73, subframe 2: Programming PMCH demodulation for mcs 7
..
[PHY][D][UE 0] Frame 73, subframe 3: Querying for PMCH demodulation(7)
[MAC][D][UE 0] Frame 73 subframe 3: Checking MBSFN Sync Area 0/1 with SF allocation 0/1 for MCCH and MTCH (mbsfn period 4, mcch period 32,mac sched period (16,1))
[MAC][D][UE 0] Frame 73 Subframe 3: sync area 0 SF alloc 0: msi flag 0, mcch flag 0, mtch flag 1
[PHY][D][UE 0] Frame 73, subframe 3: Programming PMCH demodulation for mcs 7
..*

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Secondly, in the folder */openair4G/targets/SIMU/USER/* we execute the following simulation:
./oaisim -a -Q3 -n200 -F -l7 -T mscbr > log2.txt

Note that *-T* activates the traffic generator: cbr, scbr, mcbr, bcbr, mscbr.

We execute the following to see that the traffic is configured:
cat log2.txt | grep -i otg

By means of this simulation we can check the following:

• By default Openair Traffic Generator (OTG) will generate traffic for the following services and sessions, however, Radio Resource Control (RRC) will only configure certain services and sessions to transmit the eMBMS traffic:
[OTG][D]configure MSCBR for eMBMS (service 0, session 1, app 0)
[OTG][D]configure MSCBR for eMBMS (service 0, session 2, app 0)
[OTG][D]configure MSCBR for eMBMS (service 1, session 1, app 0)
[OTG][D]configure MSCBR for eMBMS (service 1, session 2, app 0)

• OTG generates the traffic and hands it to the Packet Data Convergence Protocol (PDCP):
[I]multicast gen: entering generating
[D]ptime 320, ctime 360 idt 40 (min 40, max 40) size 256 (min 256, max 256)
[D]otg multicast info- > tx num bytes[0][1][0] = 3130
[I][src 0][dst 1]TX INFO pkt at time 360 Size= [payload 256] [Total 313] with seq num9:272261061594909177711597767363Lp8]FSyrQxyPZOl9CqGjrYlHdDbQpO`rsT:Cfx [A{m>V}M[ODlrMrgm8VNHvXz[uYSPrwzfm6mfHdstb}iMZ]xf<Ol¿2SN}6PQ=a:XYUu6Uk6 D'iOl3['PK}5?}7Aux}>CSp1@orRgE0;2q6H>M3<vct4PGh7C=p3sGw1pVdYJMLl]z[BVeP dR{'JKDBfD'S?Ui; >IALJM6;cB@y:f2;\RywV?l?S3Py0;TODF3L1KwuEskL:;
[OTG][D]
[OTG][I]traffic type 0
[EMU][I][eNB 0] ADD packet (0x35c9a890) multicast to OTG buffer for dst 1 on rb id 1
[PHY][D][eNB 0] Frame 36 subframe 1 : Doing phy procedures eNB TX
[MAC][D][eNB 0] Frame 36, Subframe 1, entering MAC scheduler (UE list- > head 0)
[MAC][D]UE 0: rnti 6041 (0xb5e246d4)
[OTG][I]Mod id 0 Frame 36 Got a packet (0x35c9a890), HEAD of otg pdcp buffer[0] is (nil) and Nb elements is 0
[OTG][D][eNB 0] Frame 36 sending packet 9 from module 0 on rab id 1 (src 0, dst 1) pkt size 313 for pdcp mode 3
[PDCP][D] [TM] Asking for a new mem block of size 313

• Packet is added to the Radio Link Control (RLC):
[RLC][D][FRAME 00036][eNB][MOD 00][RNTI 0]rlc data req: rb id 1 (MAX 11), muip 0, confirmP 0, sud sizeP 313, sdu pP 0x330d3590
[RLC][I]received a packet with size 313 for MBMS

• MAC schedules the MTCH and passes the transport block to the PHY:
[PHY][D][eNB 0] Frame 37 subframe 1 : Doing phy procedures eNB TX
[MAC][D][eNB 0] Frame 37 subframeP 1 : Checking MBSFN Sync Area 0/1 with SF allocation 0/1 for MCCH and MTCH (mbsfn period 4, mcch period 32)
[MAC][D][eNB 0] Frame 37 Subframe 1: sync area 0 SF alloc 0: msi flag 0, mcch flag 0, mtch flag 1

[MAC][D][eNB 0] Frame 37 subframeP 1: Schedule MTCH (area 0, sfAlloc 0)
[MAC][D][eNB 0], Frame 37, MTCH- > MCH, Checking RLC status (rab 1, tbs 389, len 386)
[MAC][D]e-MBMS log channel 1 frameP 37, subframeP 1, rlc status.bytes in buffer is 314
[MAC][I][eNB 0][MBMS USER-PLANE], Frame 37, MTCH- > MCH, Requesting 386 bytes from RLC(header len mtch 3)
[RLC][D][FRAME 00037][eNB][MOD 00][RNTI 0] MAC RLC DATA REQ channel 1 (528) MAX RB 14, Num tb 105
[RLC][D][FRAME 00037][eNB][MOD 00][RNTI 0][DRB UM 01] rlc um mac data request() MAC DATA REQUEST TB SIZE 314
[MAC][I][eNB 0][MBMS USER-PLANE] Got 314 bytes for MTCH 1
[MAC][D] MCS for this sf is 7 (mcch active 0, mtch active 1)
[MAC][I][eNB 0][MBMS USER-PLANE] Generate header : sdu length total 314, num sdus 1, sdu lengths[0] 314, sdu lcids[0] 1 = > payload offset 4,padding 0,post padding 72 (mcs 7, TBS 389), header MTCH 3, header MCCH 0, header MSI 0

• UE receives the traffic generated in subframe 1:
[PHY][D][UE 0] Frame 53, subframe 1: Querying for PMCH demodulation(3)
[MAC][D][UE 0] Frame 53 subframe 1: Checking MBSFN Sync Area 0/1 with SF allocation 0/1 for MCCH and MTCH (mbsfn period 4, mcch period 32,mac sched period (16,1))
[MAC][D][UE 0] Frame 53 Subframe 1: sync area 0 SF alloc 0: msi flag 0, mcch flag 0, mtch flag 1
[PHY][D][UE 0] Frame 53, subframe 1: Programming PMCH demodulation for mcs 7
[PHY][D][UE] dlsch decoding emul : subframe 1, eNB id 0, dlsch id 5
[PHY][D]decoding pmc
[MAC][D][UE 0] Frame 53 : process the mch PDU for sync area 0
[MAC][D][UE 0] sdu: 21.81
[MAC][D][UE 0] parse mch header, demultiplex
[MAC][D][UE 0] parse mch header, found 1 sdus
[MAC][I][UE 0] Frame 53 : MCH- > MTCH for sync area 0 (eNB 0, 314 bytes)
[RLC][D][FRAME 00053][UE][MOD 00][RNTI b6c7] MAC RLC DATA IND on channel 1 (528), rb max 14, Num tb 1
[RLC][D][FRAME 00053][UE][MOD 00][RNTI b6c7][DRB UM 01] rlc um rx() MAC DATA IND 1 TBs
[RLC][D][FRAME 00053][UE][MOD 00][RNTI b6c7][DRB UM 01] rlc um reassembly() [REASSEMBLY] reassembly() 313 bytes 0 bytes already reassemblied
[RLC][D][FRAME 00053][UE][MOD 00][RNTI b6c7][DRB UM 01] rlc um send sdu() SEND SDU to upper layers 313 bytes sdu 0x13c86140
[PDCP][D]e-MBMS Data indication notification for PDCP entity from eNB 0 to UE b6c7 and radio bearer ID 1 rlc sdu size 313 ctxt pP- > enb flag 0
[OTG][D]otg rx pkt functions: destination 1, size 313, otg hdr info rx- > flag 1000, otg hdr info rx-> size 313
[OTG][I]MAX RX INFO 1 1
[OTG][I][SRC 0][DST 1] [FLOW idx 0][APP TYPE 0] RX INFO pkt at time 532: flag 0x 1000, seq number 0, tx time 500, size (hdr 313, pdcp 313)
[OTG][I]received a multicast packet with size 313 sn 0 ran owd 32 loss rate 0
[OTG][D][0][1] AGGREGATION LEVEL (RX) 1
[OTG][D]check packet :: (src=0,dst=1, flag=0x1000) packet seq num TX=0, seq num RX=0

[OTG][D][src 0][dst 1] ctime 532 tx time 500: OWD 32.000000 E2E OWD 75.750000
[OTG][D]The packet jitter for the pair (src 0, dst 1)) at 532 is 0.000000 (current 32.000000, previous 0.000000)
[OTG][D]The packet jitter for the pair (src 0, dst 1)) at 532 is 0.000000 (current 75.750000, previous 0.000000)
[OTG][I][SRC0 - > DST 1] Received a multicast packet at time 532 with size 313, seq num 0, ran owd 32 number loss packet 0

Finally, in the folder /openair4G/targets/SIMU/USER/ we can execute the following simulation:
./oaisim -a -Q3 -F -c 34 > log3.txt

Note that *-c* activates the Openair Config Generator (OCG) to process the scenario descriptor, or give the scenario manually: *-c template 34.xml*. Option *-l* and *-n* cannot be configured with the xml config file.

The configuration files are located in the folder */openair4G/targets/SIMU/EXAMPLES/OSD/WEBXML/*. See template 34.xml as an example.

B. *Simulations to fix an issue in UE decoding of multicast traffic*

By means of tracing some simulations we have analysed some issues regarding with multicast scheduling that is needed to be fixed in the OpenAir Interface code. The following subsections detailed these issues.

We have carried out different simulation using two different types of multicast traffic, and with three different values for MCS to transmit the generated traffic. Table I illustrates the payload of the traffic generated and the MCS used.

Payload	*MCS*
256 KB	2
256 KB	7
256 KB	18
768 KB	2
768 KB	7
768 KB	18

Table I. Values of payload and MCS in the simulations

The goal of these simulations is, firstly, to check the traffic generation using OTG. Then, how the MAC layer at the eNodeB checks the rlc status, schedules the MTCH and passes the the Transport Block (TB) to the PHY layer. And, finally, how the UE receives and decodes this information.

The first step, consisting of the OTG payload generation, is illustrated in the following lines of the traces:

• OTG is generating payload of 256 KB every 40 ms.
[OTG][I]multicast gen: entering generating:
[OTG][D]ptime 0, ctime 500 idt 40 (min 40, max 40) size 256 (min 256, max 256)
[OTG][D]otg multicast info- > tx num bytes[0][1][0] = 313
[OTG][I][src 0][dst 1]TX INFO pkt at time 500 Size = [payload 256] [Total 313] with seq num 0:

• OTG is generating payload of 768 KB every 40 ms.
[OTG][I]multicast gen: entering generating:
[OTG][D]ptime 0, ctime 500 idt 34 (min 30, max 40) size 768 (min 768, max 768)
[OTG][D]otg multicast info- > tx num bytes[0][1][0] = 825
[OTG][I][src 0][dst 1]TX INFO pkt at time 500 Size= [payload 768] [Total 825] with seq num 0:

Traffic is correctly generated by OTG with the corresponding payload size.

The following step, consisting of the scheduling at eNodeB MAC layer of the traffic generated, is shown in the following lines of the traces:

• Traffic for a payload of 256 KB is in rlc buffer, and MCS=2 is used, so the Transport Block Size (TBS) = 137 KB:
[MAC][D][eNB 0] Frame 53 subframeP 1: Schedule MTCH (area 0, sfAlloc 0)
[MAC][D][eNB 0], Frame 53, MTCH- > MCH, Checking RLC status (rab 1, tbs 137, len 134)
[MAC][D]e-MBMS log channel 1 frameP 53, subframeP 1, rlc status.bytes in buffer is 314
[MAC][I][eNB 0][MBMS USER-PLANE], Frame 53, MTCH- > MCH, Requesting 134 bytes from RLC (header len mtch 3)
[MAC][D][eNB 0] Frame 53 subframeP 2: Schedule MTCH (area 0, sfAlloc 0)
[MAC][D][eNB 0], Frame 53, MTCH- > MCH, Checking RLC status (rab 1, tbs 137, len 134)
[MAC][D]e-MBMS log channel 1 frameP 53, subframeP 2, rlc status.bytes in buffer is 181
[MAC][I][eNB 0][MBMS USER-PLANE], Frame 53, MTCH- > MCH, Requesting 134 bytes from RLC (header len mtch 3)
[MAC][D][eNB 0] Frame 53 subframeP 3: Schedule MTCH (area 0, sfAlloc 0)
[MAC][D][eNB 0], Frame 53, MTCH- > MCH, Checking RLC status (rab 1, tbs 137, len 134)
[MAC][D]e-MBMS log channel 1 frameP 53, subframeP 3, rlc status.bytes in buffer is 48
[MAC][I][eNB 0][MBMS USER-PLANE], Frame 53, MTCH- > MCH, Requesting 134 bytes from RLC (header len mtch 3)

• Traffic for a payload of 768 KB is in rlc buffer, and MCS=18 is used, so the TBS = 999 KB:
[MAC][D][eNB 0] Frame 53 subframeP 1: Schedule MTCH (area 0, sfAlloc 0)
[MAC][D][eNB 0], Frame 53, MTCH- > MCH, Checking RLC status (rab 1, tbs 999, len 996)
[MAC][D]e-MBMS log channel 1 frameP 53, subframeP 1, rlc status.bytes in buffer is 826
[MAC][I][eNB 0][MBMS USER-PLANE], Frame 53, MTCH- > MCH, Requesting 996 bytes from RLC (header len mtch 3)
[MAC][D][eNB 0] Frame 53 subframeP 2: Schedule MTCH (area 0, sfAlloc 0)
[MAC][D][eNB 0], Frame 53, MTCH- > MCH, Checking RLC status (rab 1, tbs 999, len 996)

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[MAC][D]e-MBMS log channel 1 frameP 53, subframeP 2, rlc status.bytes in buffer is 0
[MAC][D][eNB 0] Frame 53 subframeP 3: Schedule MTCH (area 0, sfAlloc 0)
[MAC][D][eNB 0], Frame 53, MTCH- > MCH, Checking RLC status (rab 1, tbs 999, len 996)
[MAC][D]e-MBMS log channel 1 frameP 53, subframeP 3, rlc status.bytes in buffer is 0

The eNodeB MAC layer is correctly scheduling the traffic available in *rlc_buffer*. Segmentation is correctly done when the load available in *rlc_buffer* is greater than the TBS with the MCS used. On the other hand, when the load available is smaller than the TBS, all the payload is included in the first subframe and the following subframes are empty until new payload is available in *rlc_buffer*.

Finally, we have checked how the UE receives and decodes the multicast payload and it is shown in the following lines of the traces:

• Traffic for a payload of 256 KB is in *rlc_buffer,* and MCS = 2 is used, so the TBS = 137 KB:
[PHY][D][UE 0] Frame 53, subframe 1: Querying for PMCH demodulation(3)
[MAC][D][UE 0] Frame 53 subframe 1: Checking MBSFN Sync Area 0/1 with SF allocation 0/1 for MCCH and MTCH (mbsfn period 4, mcch period 32,mac sched period (16,1))
[MAC][D][UE 0] Frame 53 Subframe 1: sync area 0 SF alloc 0: msi flag 0, mcch flag 0, mtch flag 1
[PHY][D][UE 0] Frame 53, subframe 1: Programming PMCH demodulation for mcs 2
Payload : 75 39 66 66 73 4e 79 43 4a 64 53 42 77 76 43 4a 32 78 55 74 42 55 76 64 3b 37 3b 5a 36 3a 30 37 3d 48 68 35 48 48 64 7a 4f 6c 71 4b 6c 51 3f
[PHY][D][UE 0] Frame 53, subframe 2: Querying for PMCH demodulation(5)
[MAC][D][UE 0] Frame 53 subframe 2: Checking MBSFN Sync Area 0/1 with SF allocation 0/1 for MCCH and MTCH (mbsfn period 4, mcch period 32,mac sched period (16,1))
[MAC][D][UE 0] Frame 53 Subframe 2: sync area 0 SF alloc 0: msi flag 0, mcch flag 0, mtch flag 1
[PHY][D][UE 0] Frame 53, subframe 2: Programming PMCH demodulation for mcs 2
Payload : 75 39 66 66 73 4e 79 43 4a 64 53 42 77 76 43 4a 32 78 55 74 42 55 76 64 3b 37 3b 5a 36 3a 30 37 3d 48 68 35 48 48 64 7a 4f 6c 71 4b 6c 51 3f
[PHY][D][UE 0] Frame 53, subframe 3: Querying for PMCH demodulation(7)
[MAC][D][UE 0] Frame 53 subframe 3: Checking MBSFN Sync Area 0/1 with SF allocation 0/1 for MCCH and MTCH (mbsfn period 4, mcch period 32,mac sched period (16,1))
[MAC][D][UE 0] Frame 53 Subframe 3: sync area 0 SF alloc 0: msi flag 0, mcch flag 0, mtch flag 1
[PHY][D][UE 0] Frame 53, subframe 3: Programming PMCH demodulation for mcs 2
Payload : 75 39 66 66 73 4e 79 43 4a 64 53 42 77 76 43 4a 32 78 55 74 42 55 76 64 3b 37 3b 5a 36 3a 30 37 3d 48 68 35 48 48 64 7a 4f 6c 71 4b 6c 51 3f

The payload received by the UE in the three subframes is the same and corresponds to the payload loaded by the eNodeB in the last subframe. In this case, the eNodeB makes a segmentation of the payload in the three subframes that it uses to transmit multicast traffic, but the UE is only decoding the last one. The following trace lines shows the payload included in the third subframe by the eNodeB:

[MAC][D][eNB 0] Frame 53 subframeP 3: Schedule MTCH (area 0, sfAlloc 0)
[MAC][D][eNB 0], Frame 53, MTCH- > MCH, Checking RLC status (rab 1, tbs 137, len 134)
[MAC][D]e-MBMS log channel 1 frameP 53, subframeP 3, rlc status.bytes in buffer is 48
[MAC][I][eNB 0][MBMS USER-PLANE], Frame 53, MTCH- > MCH, Requesting 134 bytes from RLC (header len mtch 3)
Payload : 39 66 66 73 4e 79 43 4a 64 53 42 77 76 43 4a 32 78 55 74 42 55 76 64 3b 37 3b 5a 36 3a 30 37 3d 48 68 35 48 48 64 7a 4f 6c 71 4b 6c 51 3f
[MAC][I][eNB 0][MBMS USER-PLANE] Got 48 bytes for MTCH 1

• Traffic for a payload of 768 KB is in *rlc_buffer*, and MCS = 18 is used, so the TBS = 999 KB:

[PHY][D][UE 0] Frame 53, subframe 1: Querying for PMCH demodulation(3)
[MAC][D][UE 0] Frame 53 subframe 1: Checking MBSFN Sync Area 0/1 with SF allocation 0/1 for MCCH and MTCH (mbsfn period 4, mcch period 32,mac sched period (16,1))
[MAC][D][UE 0] Frame 53 Subframe 1: sync area 0 SF alloc 0: msi flag 0, mcch flag 0, mtch flag 1
[PHY][D][UE 0] Frame 53, subframe 1: Programming PMCH demodulation for mcs 18
Payload : 00 10 00 00 39 03 00 00 00 f4 01 00 00 00 00 00 00 1c 00 00 01 00 00 01 00 00 00 00 00 30 34 39 38 32 30 33 39 38 34 33 30 39 38 34 30 39 33 34 37 37 34 33 37 38 37 39 33 38 34 79 7361 4c 52 6f ...
[PHY][D][UE 0] Frame 53, subframe 2: Querying for PMCH demodulation(5)
[MAC][D][UE 0] Frame 53 subframe 2: Checking MBSFN Sync Area 0/1 with SF allocation 0/1 for MCCH and MTCH (mbsfn period 4, mcch period 32,mac sched period (16,1))
[MAC][D][UE 0] Frame 53 Subframe 2: sync area 0 SF alloc 0: msi flag 0, mcch flag 0, mtch flag 1
[PHY][D][UE 0] Frame 53, subframe 2: Programming PMCH demodulation for mcs 18
Payload : 00 10 00 00 39 03 00 00 00 f4 01 00 00 00 00 00 00 1c 00 00 01 00 00 01 00 00 00 00 00 30 34 39 38 32 30 33 39 38 34 33 30 39 38 34 30 39 33 34 37 37 34 33 37 38 37 39 33 38 34 79 73 61 4c 52 6f ...
[PHY][D][UE 0] Frame 53, subframe 3: Querying for PMCH demodulation(7)
[MAC][D][UE 0] Frame 53 subframe 3: Checking MBSFN Sync Area 0/1 with SF allocation 0/1 for MCCH and MTCH (mbsfn period 4, mcch period 32,mac sched period (16,1))
[MAC][D][UE 0] Frame 53 Subframe 3: sync area 0 SF alloc 0: msi flag 0, mcch flag 0, mtch flag 1
[PHY][D][UE 0] Frame 53, subframe 3: Programming PMCH demodulation for mcs 18
Payload : 00 10 00 00 39 03 00 00 00 f4 01 00 00 00 00 00 00 1c 00 00 01 00 00 01 00 00 00 00 00 30 34 39 38 32 30 33 39 38 34 33 30 39 38 34 30 39 33 34 37 37 34 33 37 38 37 39 33 38 34 79 73 61 4c 52 6f ...

The payload received by the UE in the three subframes is the same and corresponds to the payload loaded by the eNodeB in the first subframe that is the only subframe loaded with traffic. In this case, the eNodeB does not need to make a segmentation of the payload, and the UE decodes the last traffic loaded by eNodeB in the three subframes where it waits for multicast traffic. The following trace lines shows the payload included in the first subframe by the eNodeB:

[MAC][D][eNB 0] Frame 53 subframeP 1: Schedule MTCH (area 0, sfAlloc 0)
[MAC][D][eNB 0], Frame 53, MTCH- > MCH, Checking RLC status (rab 1, tbs 999, len 996)
[MAC][D]e-MBMS log channel 1 frameP 53, subframeP 1, rlc status.bytes in buffer is 826
[MAC][I][eNB 0][MBMS USER-PLANE], Frame 53, MTCH- > MCH, Requesting 996 bytes from RLC (header len mtch 3)
Payload : 10 00 00 39 03 00 00 00 f4 01 00 00 00 00 00 00 1c 00 00 01 00 00 01 00 00 00 00 00 30 34 39 38 32 30 33 39 38 34 33 30 39 38 34 30 39 33 34 37 37 34 33 37 38 37 39 33 38 34 79 73 61 4c 52 6f ...

C. Simulations to fix an issue in checking *sf-AllocEnd* of each MCH

We have checked using traces three different configuration for *sf-AllocEnd* in order to check how the multicast subframes are allocated to MCH 1. Note that *commonSF-AllocPeriod* = 16, and three subframes are allocated for multicast every four frames. Consequently, the total amount of multicast subframes during the *commonSF-AllocPeriod* is twelve. We have used the values 1, 5, and 11 for the last subframe of MCH 1 to analize the different way of working.

Nevertheless, the three traces made can demonstrate that *sf-AllocEnd* is not taking into account when the multicast traffic is allocated into the multicast subframes. All the twelve subframes allocated for multicast services are allocated to MCH 1. The following lines of traces are extracted when *sf-AllocEnd* is set to 1. However, when *sf-AllocEnd* is set to 5, or 11 the traces have shown the same results.

[MAC][D][eNB 0], Frame 53, MTCH- > MCH, Checking RLC status (rab 1, tbs 137, len 134)
[MAC][D]e-MBMS log channel 1 frameP 53, subframeP 1, rlc status.bytes in buffer is 314
[MAC][I][eNB 0][MBMS USER-PLANE], Frame 53, MTCH- > MCH, Requesting 134 bytes from RLC (header len mtch 3)
[MAC][D][eNB 0] Frame 53 subframeP 2: Schedule MTCH (area 0, sfAlloc 0)
[MAC][D][eNB 0], Frame 53, MTCH- > MCH, Checking RLC status (rab 1, tbs 137, len 134)
[MAC][D]e-MBMS log channel 1 frameP 53, subframeP 2, rlc status.bytes in buffer is 181
[MAC][D][eNB 0] Frame 53 subframeP 3: Schedule MTCH (area 0, sfAlloc 0)
[MAC][D][eNB 0], Frame 53, MTCH- > MCH, Checking RLC status (rab 1, tbs 137, len 134)
[MAC][D]e-MBMS log channel 1 frameP 53, subframeP 3, rlc status.bytes in buffer is 48
..
[MAC][D][eNB 0] Frame 57 subframeP 3: Schedule MTCH (area 0, sfAlloc 0)
[MAC][D][eNB 0], Frame 57, MTCH- > MCH, Checking RLC status (rab 1, tbs 137, len 134)
[MAC][D]e-MBMS log channel 1 frameP 57, subframeP 3, rlc status.bytes in buffer is 48
..
[MAC][D][eNB 0] Frame 61 subframeP 2: Schedule MTCH (area 0, sfAlloc 0)

[MAC][D][eNB 0], Frame 61, MTCH- > MCH, Checking RLC status (rab 1, tbs 137, len 134)
[MAC][D]e-MBMS log channel 1 frameP 61, subframeP 2, rlc status.bytes in buffer is 181
..
[MAC][D][eNB 0] Frame 65 subframeP 3: Schedule MTCH (area 0, sfAlloc 0)
[MAC][D][eNB 0], Frame 65, MTCH- > MCH, Checking RLC status (rab 1, tbs 137, len 134)
[MAC][D]e-MBMS log channel 1 frameP 65, subframeP 3, rlc status.bytes in buffer is 68

This analysis shows that *sf-AllocEnd* is not taken into account in the eNodeB multicast allocation. This parameter is needed to implement more MCHs time multiplexed in the *commonSF-AllocPeriod*.

D. Simulations to fix an issue in checking *stop-MTCH* of each MTCH

We have checked the use of MTCH into an MCH. For this analysis, we have setup the *sf-AllocEnd* = 11 (all the twelve subframes in the *commonSF-AllocPeriod*), and the value of *stop-MTCH* is set to 1, 55, and 11 for the MTCH 1. This analysis have shown the same results than the issue before so that demonstrate that *stop-MTCH* is not taking into account, too. The following lines are extracted from the trace with *stop-MTCH* = 1.

[MAC][D][eNB 0], Frame 53, MTCH- > MCH, Checking RLC status (rab 1, tbs 137, len 134)
[MAC][D]e-MBMS log channel 1 frameP 53, subframeP 1, rlc status.bytes in buffer is 314
[MAC][I][eNB 0][MBMS USER-PLANE], Frame 53, MTCH- > MCH, Requesting 134 bytes from RLC (header len mtch 3)
[MAC][D][eNB 0] Frame 53 subframeP 2: Schedule MTCH (area 0, sfAlloc 0)
[MAC][D][eNB 0], Frame 53, MTCH- > MCH, Checking RLC status (rab 1, tbs 137, len 134)
[MAC][D]e-MBMS log channel 1 frameP 53, subframeP 2, rlc status.bytes in buffer is 181
[MAC][D][eNB 0] Frame 53 subframeP 3: Schedule MTCH (area 0, sfAlloc 0)
[MAC][D][eNB 0], Frame 53, MTCH- > MCH, Checking RLC status (rab 1, tbs 137, len 134)
[MAC][D]e-MBMS log channel 1 frameP 53, subframeP 3, rlc status.bytes in buffer is 48
..
[MAC][D][eNB 0] Frame 57 subframeP 3: Schedule MTCH (area 0, sfAlloc 0)
[MAC][D][eNB 0], Frame 57, MTCH- > MCH, Checking RLC status (rab 1, tbs 137, len 134)
[MAC][D]e-MBMS log channel 1 frameP 57, subframeP 3, rlc status.bytes in buffer is 48
..
[MAC][D][eNB 0] Frame 61 subframeP 2: Schedule MTCH (area 0, sfAlloc 0)
[MAC][D][eNB 0], Frame 61, MTCH- > MCH, Checking RLC status (rab 1, tbs 137, len 134)
[MAC][D]e-MBMS log channel 1 frameP 61, subframeP 2, rlc status.bytes in buffer is 181
..

[MAC][D][eNB 0] Frame 65 subframeP 3: Schedule MTCH (area 0, sfAlloc 0)
[MAC][D][eNB 0], Frame 65, MTCH- > MCH, Checking RLC status (rab 1, tbs 137, len 134)
[MAC][D]e-MBMS log channel 1 frameP 65, subframeP 3, rlc status.bytes in buffer is 68

This analysis shows that *stop-MTCH* is not taken into account in the eNodeB multicast allocation. This parameter is needed to implement more MTCHs time multiplexed in the *mch-SchedulingPeriod* of each MCH.

E. Degrees of Freedom to allocate multicast services in LTE Networks

In order to study the degrees of freedom to allocate multicast services in LTE networks, we can allocate the multicast resources among different MCHs. The first example consists of allocating only the third part of each CSA resources for MCH 1. In this way, if more MCHs are created to be delivered in the MBSFN area the following configuration can be used (i.e. for 3 MCHs) . We can change the following parameter:

- sf-AllocEnd = 3 (for MCH 1)
- sf-AllocEnd = 7 (for MCH 2)
- sf-AllocEnd = 11 (for MCH 3)

Such a way, 3 MCHs are going to be served in the MBSFN, using a time multiplexing scheme to share the multicast resources among them. Each MCH is allocated 4 subframes each CSA to deliver the service.

Fig. 2 illustrates the multicast resource allocation among the 3 MCHs, in a CSA of 16 radio frames, in an MBSFN area.

When the amount of services to be delivered is increased, it can be needed to increase the resources allocated to multicast. We can change *subframeAllocation* pattern to *fourFrames* and using the six available subframes for multicast purpose. If the *radioFrameAllocationPeriod* is maintained to four, we have 96 subframes to be allocated, during a CSA period of 16 frames, to multiple MCHs in a time multiplexing way. For instance, we can configure the delivery of 5 multicast services using each one the following resources:

- MCH 1 uses 41.67% of resources (40 subframes each 16 LTE frames)
- MCH 2 uses 20.83% of resources (20 subframes each 16 LTE frames)
- MCH 3 uses 20.83% of resources (20 subframes each 16 LTE frames)
- MCH 4 uses 8.33% of resources (8 subframes each 16 LTE frames)
- MCH 5 uses 8.33% of resources (8 subframes each 16 LTE frames)

- The configuration of **MBSFN-SubframeConfig** can be changed to:
  – radioFrameAllocationPeriod = n4
  – radioFrameAllocationOffset = 1
  – subframeAllocation = fourFrames pattern with 111111 for FDD sync area = 0

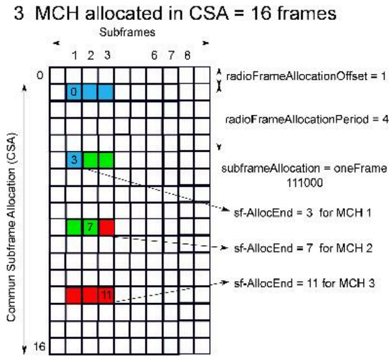

Fig 2. Multicast resource allocation among 3 MCHs in an MBSFN area

- We can change this parameter in the MCCH information **PMCH-InfoList**:
  - sf-AllocEnd = 39 (for MCH 1)
  - sf-AllocEnd = 59 (for MCH 2)
  - sf-AllocEnd = 79 (for MCH 3)
  - sf-AllocEnd = 87 (for MCH 4)
  - sf-AllocEnd = 95 (for MCH 5)

Fig. 3 illustrates the multicast resource allocation among the 5 MCHs in a CSA of 16 frames, using *fourFrames* pattern, and the 6 subframes enabled for multicast in an MBSFN area.

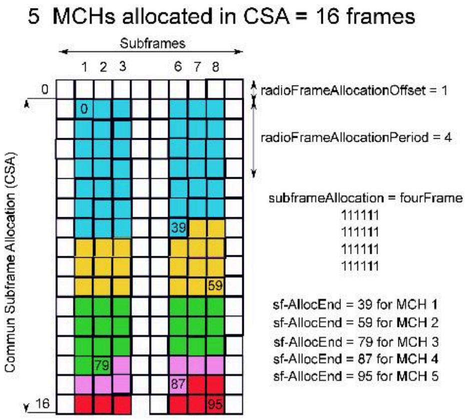

Fig 3. Multicast resource allocation among 5 MCHs in an MBSFN area

Finally, it is worth noting that each MCH can include more than one MTCH. Each MCH can be configured to use different MCS and different number of subframes in a CSA. Nonetheless, all the MTCHs in the same MCH must use the same MCS to be delivered. However, each MTCH can be allocated with a different number of subframes during a MSP.

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Considering the MCH 1 of the previous configuration with an *mch-SchedulingPeriod* = 16, we can deliver 3 different multicast content using 3 MTCHs with the same MCS. Each MTCH can allocate different number of subframes in the MCH 1 MSP. Note that in 16 frames, 40 subframes are allocated to MCH 1 which are going to split into the 3 MTCHs as follows:

- MTCH 1 uses 50% of MCH 1 resources (20 subframes each MCH 1 MSP)
- MTCH 2 uses 30% of MCH 1 resources (12 subframes each MCH 1 MSP)
- MTCH 3 uses 20% of MCH 1 resources (8 subframes each MCH 1 MSP)

Consequently:

- sf-AllocEnd = 19 (for MTCH 1 in MCH 1)
- sf-AllocEnd = 31 (for MTCH 2 in MCH 1)
- sf-AllocEnd = 39 (for MTCH 3 in MCH 1)

Fig. 4 illustrates the multicast resource allocation among the 3 MTCHs in one MCH of 16 frames in an MBSFN area.

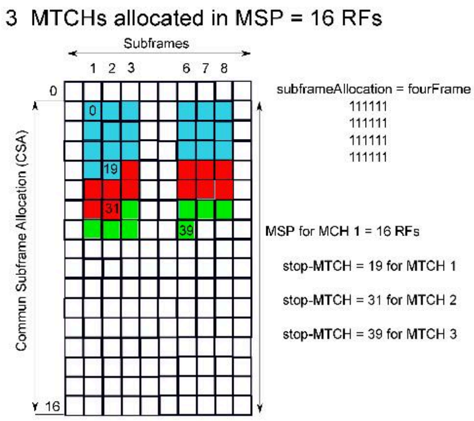

Fig 4. Multicast resource allocation among 3 MTCHs in a MCH

E1. Scheduling multiple multicast services in LTE

Throughout this work we have illustrated different levels used in the the resource allocation strategy for multicast services in LTE.

Therefore, the first step to be considered in the resource allocation strategy is the number of resources allocated to multicast services in an MBSFN area. Taking into account that no more than 60% of the total amount of resources can be used in multicast, a high flexibility to this allocation can be applied by means of **MBSFN-SubframeConfig** information element.

Once the network operator establishes the total resources for multicast, the number of MCHs to be delivered must be chosen. Each MCH can be considered as a group of resources allocated to deliver multicast services using the same MCS. This means that the services provided by one MCH will be correctly decoded by the UEs experiencing radio channel conditions such that their Signal to Interference plus Noise Ratio (SINR) is higher than certain threshold. We can consider an MCH as the group of multicast services delivered to a group of UEs with similar channel conditions. The number of resources (subframes) allocated to an MCH inside a CSA period must be chosen taking into account the number of services delivered in this MCH, the MCS used, and the bit rate needed for each service.

The third level of resource allocation consists on allocating resources to each MTCH in the MCH. Depending on the bit rate guaranteed for each service, different number of subframes in an MSP can be allocated. These time resources allocated join with the MCS used give the bit rate of each MTCH.

In the following subsection we have illustrated one example for delivering multicast services.

E1. An example of two multicast service delivery using different rates according to channel conditions

In this example, two multicast services are delivered in an MBSFN area. Based on some statistics, the network operator have decided to use two different MCSs to deliver de services, i.e. MCS 7 and MCS 14. The QoS requirements for each service depends on the channel conditions of the UEs. On the one hand, users capable of decoding MCS 14 must receive the services with the following rates: r 1 = 1.5 Mbps and r 2 = 700 kbps. On the other hand, users capable of decoding MCS 7, but not MCS 14, must receive the services with the following rates:

r_1 = 500 kbps and r_2 = 250 kbps.

First of all, we should know the number of resources needed to deliver the two services, using both MCSs, which allow the system to achieve the required bit rates. The CSA period used by the network operator consists on 16 radio frames.

The TBS for MCS 7 is 6,200 bits (10 MHz bandwidth, i.e. 50 RBs). Using 1 TB every CSA, a bit rate of 38.75 kbps can be achieved with MCS 7. Consequently, at least 13 and 7 TBs are needed to achieve the required rates. In such a way, the MCH 1 uses MCS 7, and is allocated 20 subframes every CSA period.

The TBS for MCS 14 is 12,960 bits (10 MHz bandwidth, i.e. 50 RBs). Using 1 TB every CSA, a bit rate of 81 kbps can be achieved with MCS 14. Consequently, at least 19 and 9 TBs are needed to achieve the required rates.

In such a way, the MCH 2 uses MCS 14, and is allocated 28 subframes every CSA period.

As a consequence of these results, the total amount of resources needed to be allocated to multicast every CSA period is 48 subframes. Using oneFrame allocation pattern, 3 subframes must be allocated to multicast every *radioFrameAllocationPeriod*, i.e. *subframeAllocation* = 111000, and *radioFrameAllocationPeriod* = 1.

Fig. 5 illustrates the multicast resource allocation of this example among the 2 MCHs with 2 MTCHs each one.

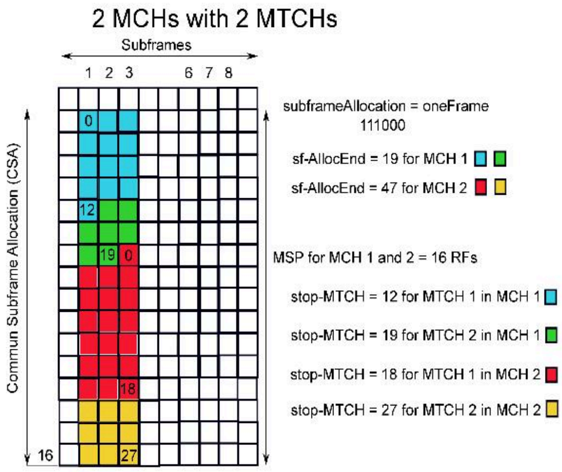

Fig 5. Multicast resource allocation among two MCHs with two MTCHs each one

7. Plans for Follow-up

After the analysis carried out in this work, the next step consists of fixing the issues reported:
- Issue in UE decoding of multicast traffic
- Issue in checking *sf-AllocEnd* of each MCH
- Issue in checking *stop-MTCH* of each MTCH

Once these issues are fixed in the OpenAir Interface code, more than one MCH, and more than one MTCH per MCH can be transmitted and decoded in the MBSFN area.

The second step consists of the implementation of an LTE multicast scheduler user interface, that allows users to configure the parameters described in this paper, without modifying the OpenAir Interface code. Jointly to this paper, an extension of the MAC scheduler interface specifications is done.

Finally, OpenAir Interface will become a strategic tool to implement, develop, and test multicast scheduling strategies in order to maximize the network capacity, and taking into account the QoS requirements of all multicast users. Different strategies for maximizing the multicast service capacity, or the fairness among multicast users, taking into account QoS requirements can be evaluated using OpenAir Interface. In addition, a complete resource allocation strategy that takes into account not only the multicast services delivered but also the unicast traffic that the network is supporting can be implemented and tested in OpenAir Interface simulation tool.

8. Attachments

- Presentation: **Resource Allocation Management to Broadcast:Multicast Services.pdf**
- FAPI MAC Scheduler Interface extensions: **mac_sched_api_embms_rel_1.0.pdf**
- Draft of paper: **Resource allocation for multicast service in 4G:5G mobile networks.pdf**

Signature

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20. Annex O: Report of Georg Pichler (Y2)

MOBILITY GRANT

Report

Guest name: Georg Pichler
Guest institution: Vienna University of Technology

Host name: Pablo Piantanida
Host institution: CentraleSupélec-CNRS-Université Paris-Sud

Research topic: Multiterminal source coding based on the information-bottleneck principle

Starting date: 2014-11-01
Ending date: 2014-12-02

1. Scope of Work

The work in undertaken in this mobility action deals with a problem in Network Information Theory. Specifically, we consider a specific distributed source coding problem and intend to characterize its achievable region. Applying the Information Bottleneck (IB) method in a distributed setting, gave rise to this novel problem.

The IB method has been applied to several machine learning and communications problems. In contrast to usual lossy source coding we do not specify a distortion but instead quantify fidelity in terms of mutual information with a relevance variable. Although the IB method was originally derived from purely conceptual statistical considerations, it can well be stated within an information theoretic framework. We extend upon that idea and consider an even more general problem in a distributed setting.

In essence we generalize the IB method to a distributed source coding problem where fidelity is quantified in terms of mutual information. In the process we make strong use of Network Information Theory to adequately deal with the dependencies between the involved random quantities. The final goal is to provide good characterizations the achievable region of this resulting problem.

2. Motivations

The IB method, although initially introduced as an heuristic approach to solve clustering problems, can be stated in an information theoretic context. But, although 15 years old, it is still lacking rigorous information theoretic treatment. We aim at providing performance bounds for the application of this potentially valuable method in distributed source coding. Finding this bounds might provide insight into the benefits an drawbacks of using mutual information for assessing the performance of a source code. And furthermore, the ideas used in the proofs of these bounds could indicate possible strategies for achieving these limits in practice.

But the IB method also proves to be of purely academic interest, as it is related to interesting and partially unsolved problems in hypothesis testing [1], rate distortion theory [2] and also to a long standing open problem in Network Information Theory, the Körner-Marton binary sum network [3].

3. Objectives

We aim at characterizing the achievable region of the Distributed IB as tight as possible. In the process we want to further develop the intrinsic connections this problem has to other information theoretic problems. Exploiting these connections together with our original work should allow us to compile a complete picture of the distributed IB and the solved and open problems contained within this framework.

4. Meetings

During the period of the mobility action 2014-11-01 until 2014-12-02 daily meetings took place on every weekday. These meetings were attended by P. Piantanida and G. Pichler.

5. Activities

No extra activities were undertaken.

6. Results

(a) Scientific results

We were able to characterize the achievable region of the Distributed IB Problem in the general case in terms of outer and inner bounds. For special cases we obtained exact descriptions of said region. Furthermore, we discovered new connections with existing problems and investigated a generalization of the distributed IB with interesting properties and connections to hypothesis testing against independence under communication constraints [1].

(b) Collaboration results

The collaboration proved very beneficial for both parties.

(c) Dissemination

A paper entitled "The Distributed Information Bottleneck" is currently under review for the IEEE Internation Symposium on Information Theory 2015, Hong Kong, China. A draft of this paper is attached. We presented this work in WP1.1 at the 2015 NEWCOM# meeting in Athens, Greece. The slides of this presentation are attached. Additionally, we are currently working on paper to be submitted to the IEEE Transactions on Information Theory.

7. Plans for Follow-up

P. Piantanida and G. Pichler will keep in contact online. Further mobility actions are already being planned for 2015 to push this collaboration further.

8. Attachments

Draft of the ISIT paper under review; Slides of the NEWCOM# meeting presentation;

Signature

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9. Bibliography

[1] R. Ahlswede and I. Csiszár, "Hypothesis testing with communication constraints", IEEE Trans. Inf. Theory, vol. 32, no. 4, pp. 533-542, 1986

[2] T. A. Courtade and T. Weissman, "Multiterminal source coding under logarithmic loss", IEEE Trans. Inf. Theory, vol. 60, no. 1, pp. 219-221, 1979

[3] J. Körner and K. Marton, "How to encode the modulo-two sum of binary sources", IEEE Trans. Inf. Theory, vol. 25, no. 2, pp. 219-221, 1979

21. Annex P: Yi Chu (Y2)

MOBILITY GRANT
Report

Guest name: YI CHU
Guest institution: University of York

Host name: Florian Kaltenberger
Host institution: Eurecom

Research topic: Software Defined Radio Hardware Investigation on 4G and Beyond-4G Networks

Starting date: 24/04/2015
Ending date: 22/05/2015

1. Scope of Work

1. Set up a working environment for Software Defined Radio (SDR) hardware.
2. Implement Openairinterface (OAI) core network plus eNB on one or two PCs, and connect the eNB to a commercial device (4G dongle or smart phone) with a blank USIM.
3. Summary the procedure of OAI usage, report the errors occurred during testing and try to correct the errors.

2. Motivations

My current post doctoral research is developing cognitive and intelligent MAC and resource allocation techniques for beyond 4G networks. Performance evaluation through both simulation and practical SDR platforms are all involved in my research. Valuable experience on practical SDR investigation could be obtained during the visit at the Eurecom lab and implementing Open Air Interface (OAI).

3. Objectives

1. Set up a working environment for Software Defined Radio (SDR) hardware, install required system kernel, build up dependencies and necessary software packages.

2. Build eNB without S1 support first, find correct setup of its configuration file and make the eNB visible on commercial devices. Then build OAI eNB.
3. Build OAI Mobility Management Entity (MME) + Serving Gateway (SGW) + Packet Data Network Gateway (PGW), which is OAI Evolved Packet Core (EPC), find correct configuration for both local (eNB and EPC on the same PC) and remote (eNB and EPC on different PCs) eNB.
4. Build OAI Home Subscriber Server (HSS), and input USIM authentication information into HSS database.
5. Connect OAI eNB + EPC + HSS, make sure S1U, S1MME and S11 interfaces are correctly connected.
6. Search OAI eNB on commercial device, pass authentication and attach procedures and grant internet access.

4. Meetings (meeting purpose, dates, location, attendance)

24/04/2015: Yi Chu and Florian Kaltenberger, introduction after arrival, hardware setup and initial OAI software setup.
06/05/2015: Yi Chu and Florian Kaltenberger, discussions of errors occurred during making executable files.
12/05/2015: Yi Chu, Florian Kaltenberger and Lionel Gauthier, discussions and debugging of errors occurred on EPC and eNB while connecting a smart phone to OAI eNB.
20/05/2015: Yi Chu and Florian Kaltenberger, discussions of the effect to OAI while using different forms of USIMs.

5. Activities

Week 1: Build OAI eNB, EPC and HSS using both old makefile and new cmake tools. Study how to use the configuration files of EPC and eNB to adapt the OAI system to different network situations.
Week 2: Connect OAI eNB to EPC and HSS. Two scenarios are implemented: 1. eNB, EPC and HSS all run on the same PC, via interfaces using local tunnels. 2: eNB and EPC+HSS run on different PCs, via interfaces using Ethernet cable.
Week 3: Test the OAI system using a commercial UE (a Samsung S5 smart phone) and a Comprion USIM. The UE fails at authentication process (with MAC error), however after hard

coded all authentication information into HSS, the UE can complete the authentication process.

Week 4: Test the OAI system with the same smart phone and a milenage USIM of different brand. The UE passes authentication process but does not response after eNB sends accept attach message.

6. Results

During the visit at Eurecom, I have learnt different ways of using OAI platform. Due to the lack of comprehensive instructions for fresh OAI users, I would like to summaries step-by-step OAI user instructions here, which could potentially help other OAI users at starting stage.

Preparation:

OAI has two different versions, release and trunk. Release is a stable version but it is out of date and has less support. Trunk versions is recommended, its code is frequently updated and currently used by most OAI developers. The recommended operating system is Ubuntu 14.04 LTS, with low latency kernel (version 3.17).

Get OAI trunk version from Eurecom svn server:

$mkdir openair4G

$svn co http://svn.eurecom.fr/openair4G/trunk openair4G

Export OAI environment parameters to the system:

$cd openair4G

$. oaienv

Build and run eNB:

$cd openair4G/cmake_targets

$sudo ./build_oai –c –w USRP –eNB –V –x #Build OAI eNB from scratch, using USRP ,enabling debug and xforms. Run ./build_oai –h can observe all available options, the option –I and –install-system-files are recommended to run on the first time, to install necessary packages and OAI required files.

$cd openair4G/cmake_targets/lte_build_oai/build

$sudo ./lte-softmodem –O ../../../targets/PROJECTS/GENERIC-LTE-EPC/CONF/enb.band7.tm1.usrpb210.conf -S –d #Run OAI eNB with provided configuration file, -d is enable xforms.

Many configuration files are provided in openair4G/targets/PROJECTS/GENERIC-LTE-EPC/CONF/, for eNB with different bands and hardware. To use the correct configuration file, first find the configuration file name with associated frequency band and hardware (USRP/ExpressMIMO), and then edit the configuration file:

tracking_area_code, mobile_country_code and mobile_network_code must match the USIM used for UE.

mme_ip_address (ipv4) should be set to the ip of the PC (Ethernet) running OAI EPC if eNB and EPC are running on different PCs (local eNB), or if eNB and EPC are running on the same PC (remote eNB), it should match the ip of s1_mme interface in EPC configuration file (tun2, 192.188.2.2).

s1_mme interface should be set to the ip of the PC running eNB (eg. eth0, 192.168.x.x) if it is remote eNB, for local eNB it should match the ip of s1_mme interface in EPC configuration file (eg. tun2, 192.188.2.2).

s1u interface should be set to the ip of the PC running eNB (eg. eth0, 192.168.x.x) if it is remote eNB, for local eNB it should match the ip of s1u interface in EPC configuration file (eg. tun3, 192.188.3.3).

Build and run HSS:

$cd openair4G/cmake_targets/tools

$sudo ./build_hss -c --connect-to-mme yc541.eur (fqdn of pc,) -t -T --realm eur (realm of PC)   #Build HSS with given fqdn and realm of the PC, MME acts as s6a server and HSS as a client. Fqdn and realm of the PC can be changed by editing /etc/hosts (using root user) at the line starts with 127.0.1.1 (eg. 127.0.1.1 yc541.eur).

Use the HSS database:

$sudo apt-get install phpmyadmin   #install phpmyadmin for database management

$mysqld_safe --skip-grant-tables&

mysql -u root mysql

mysql> UPDATE user SET password=PASSWORD("linux") WHERE user='root';

mysql> FLUSH PRIVILEGES;   #change mysql root password to linux

Open an Internet browser and put address line http://127.0.0.1/phpmyadmin and login with root and password (linux). Select database oai_db.

In table mmeidentity, enter the information of the mme (idmmeidentity, mmehost and mmerealm).

In table pdn, enter the IMSI to allow the UE to connect to an APN.

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In table users, enter the information of the USIM and UE device, including IMSI, IMEI (optional), KEY, RAND, SQN. KEY and RAND should use UNHEX as the input format, SQN should be converted to integer if it is provided in HEX format.

$sudo ./run_hss –g   #Run OAI HSS.

Build and run OAI EPC

$cd openair4G/cmake_targets/tools

$sudo ./build_epc –c –d –t –T –s6a-server   #Build OAI EPC, EPC acts as an s6a server to connect with HSS.

EPC configuration files are in openair4G/cmake_targets/tools, epc.conf.in is for EPC with remote eNB and epc.local.enb.conf.in is for EPC with local eNB. The configuration file should be edited before build EPC, they are copied to openair4G/targets/bin during build EPC.

To use the EPC configuration files:

Set REALM to realm of the PC (can change in /etc/hosts, eg. eur).

In PLMN, input the MCC. MNC and TAC of the USIM.

s1_mme interface should be set to the ip of the PC running EPC (eg. eth0, 192.168.x.x) if it is remote eNB, for local eNB it should match the ip of s1_mme interface in eNB configuration file (eg. tun2, 192.188.2.2).

s1u (SGW) interface should be set to the ip of the PC running EPC (eg. eth0, 192.168.x.x) if it is remote eNB, for local eNB it should match the ip of s1u interface in eNB configuration file (eg. tun3, 192.188.3.3).

SGI (PGW) interface is the outgoing network (Internet), it could use ip of the wireless network for remote eNB (wlan0), or the Ethernet ip for local eNB (eth0). The ip address of available network interfaces can be observed using $ip –d addr.

$sudo ./run_epc -g -l -K to run EPC for local eNB, $sudo ./run_epc -g -K to run EPC for remote eNB.

Configure the smart phone:

For Samsung S5, following the steps below:

Enter *#0011# in keypad to get into service mode.

Enter these in sequence: press Back, enter Q then press OK, enter 0000 then press OK. Wait for a few seconds the phone will enter service mode main menu.

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At main menu: UE SETTING & INFO – SETTING – PROTOCOL – NAS – NETWORK CONTROL – BAND SELECTION – LTE BAND PREFERENCE, then select the band used by eNB.

Test the OAI system with UE:

First run EPC, HSS, eNB in this sequence, after they are successfully connected, search service providers on smart phone, the OAI eNB should appear as a five-digit number of its MCC+MNC. Wireshark can be used to observe the packets that UE, EPC, HSS and eNB use during the attach process. To use wireshark:

$sudo apt-get install wireshark   #Get wireshark software.

$wireshark $Run wireshark, recommended to use root user here.

After EPC and HSS are connected, we can see interfaces the OAI system uses, and select all interfaces in the interface list of wireshark.

Input “s1ap or lte_rrc or mac-lte or rlc-lte or pdcp-lte” in filter field to only display the packets we are interested in.

A new capture should be started every time after we run a new EPC + HSS.

Common errors and problems during using OAI:

1. During compilation or running of OAI, error “No such file or directory” appears a lot. It is usually caused by not setting the environment parameters correctly. Run “. oaienv” usually solves this.
2. “Permission denied”: try run the commands again with sudo, and make sure the sudo password, the root user password and mysql root user password are set to “linux”.
3. Errors involving mysql: make sure mysql root user password is set to linux, see Build and run HSS section.
4. Other errors during compilation and make: usually caused by legacy files generated by previous compilations, get a fresh openair4G trunk can solve these errors.
5. “Failed to bind socket”: usually happens when eNB cannot connect to EPC, make sure eNB and EPC configuration files are edited correctly.

Important issues occurred when using OAI:

I first tested OAI using a USIM of which IMSI starts with 00101 (USIM’s MCC + MNC), it has a few different authentication parameters as OAI default settings. The default values of OP and AMF are hard coded in OAI HSS, they can be changed in openair4G/openair-

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cn/OPENAIRHSS/auc/kdf.c. However when I changed these parameters and run a new HSS, UE rejected the authentication sent from eNB, with the cause of 20: MAC failure. eNB sends RAND and AUTN to UE in the authentication request message, so I hard coded all authentication parameters in openair4G/openair-cn/OPENAIRHSS/auc/fx.c which is the milenage algorithm, including RAND, CK, AK, MAC_A, MAC_S and RES. The UE has then replied authentication response (authentication successful) but cannot proceed any further, because the EPC message shows that the first two zeros of IMSI is truncated (IMSI is taken as string but later converted to usigned64) and UE is removed with the reason of no such IMSI in HSS database.

The second USIM I tested has IMSI starts with 20893, which can be recognised by HSS during authentication and UE sends back authentication response indicating the authentication process is completed. The authentication parameters of OAI HSS are default settings. After authentication, eNB sends attach accept and UE capability requests to the UE however the UE does not response anything. After a few uplink reception failures, UE is released by eNB by sending UE Release Requests to EPC. Sometimes eNB stops working after sending this message, it could be solved by commenting out line 503 of file openair4G/common/utils/msc/msc.c. The similar problem (UE not responding to attach accept message) has happened to many OAI developers, according to this message (http://www.openairinterface.org/openairfiles/openair4g-devel/msg00964.html) it can be solved (to some UE devices) by modifying openair4G/openair-cn/NAS/EURECOM-NAS/src/emm/sap/emm_send.c and change "emm_msg->epsattachresult = EPS_ATTACH_RESULT_EPS;" to "emm_msg->epsattachresult = EPS_ATTACH_RESULT_EPS_IMSI;", however it is not affecting my problem while using Samsung S5. Further updates of both eNB and EPC are expected to solve this problem.

7. Plans for Follow-up

During one month investigation of OAI at Eurecom, I have obtained significant amount of experience on OAI usage. OAI is a good open source platform for LTE research purposes and I will continue the investigation on OAI remotely in York. OAI PHY simulator could be another useful tool to test our algorithms for LTE systems, and we will proceed to this direction in the future either. If further stable version of OAI is released and we will also test our algorithms using our USRPs, in order to address practical issues during investigation.

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8. Attachments

(draft of papers/papers, slides of presentations etc…..)

Signature

YI CHU

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Comments and suggestions for the improvement of this document are most welcome and should be sent to:

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