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Year 3 - Status Report (Confidential)

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Abstract:

This deliverable will capture all achievements and progress status of the entire project from technical, financial and legal point of view during the final phase. This will be thus under twofold responsibility of Project (SC) and Technical Managers (NEC).. it will describe and synthesize the whole technical achievements provided by the project throughout its whole duration (including thus last phase). Besides, detailed analysis of the financial, legal, and IPR synthesis will be provided in order to compare with the initial planned targets

Executive Summary

This document serves as a stand-alone reference point whilst synthesizing the overall BeFEMTO project activities and achievements during the second Reporting Period (M13-M31).

The primary objective of the document is to demonstrate that contractual objectives have been reached with good quality and on a timely manner.

Besides, a synthetic but clear progress status is thus given in terms of Technical activities, and achievements, together with addressing Project Management related topics, in terms of Financial, Legal or Organization aspects.

The current document is thus composed of five (5) major sections addressing the above mentioned topics.

The second section extracts the list of contractual deliverables due during this period, based on Annex-I of the Grant Agreement.

The third section gives, on a Workpackage (WP) basis, a synthetic progress status, including major achievements and promising innovative concepts.

The fourth section is dedicated to Project Management activities, and covers Financial, Legal, and Organizational aspects.

Then, the fifth section gives the actual status of **produced Deliverables**, both **contractual (7) and non-contractual (7 Internal/Interim Reports)**, compared with the Grant Agreement. Furthermore, the **project Milestones (3)** are also reminded, and their achievement assessed.

Finally, the sixth and last section is dedicated to **Dissemination** aspects of the project, that give other important metrics (**15 standards and industry groups contributions**, **45 conferences publications**, **7 journals articles**, regarding organized events, **5 international workshops**, **2 training school** and **5 panel sessions** have been arranged) to evaluate not only technical achievements of the project over this period, but also its visibility, its real influence and impact towards the ecosystem.

List of Acronyms and Abbreviations

BSCW	Basic Service for Collaborative Working
3G	3rd Generation
3GPP	3rd Generation Partnership Project
AKA	Authentication and Key Agreement
ARPU	Average Revenue Per User
BeFEMTO	Broadband evolved FEMTO networks
BS	Base Station
CO	Confidential
CSG	Closed Subscriber Group
DL	Downlink
DoW	Description of Work
EAP	Extensible Authorization Protocol
ECO	European Communications Office
EFGW	Enterprise Femto Gateway
EFN	Enterprise Femtocell Network
ERO	European Radio Office
ETSI	European Telecommunication Standard Institute
FAP	Femto Access Point
FDD	Frequency Division Duplex
FFR	Fractional Frequency Reuse
FR1	Fractional Reuse 1
FR3	Fractional Reuse 3
FUE	Femtocell User Equipment
GA	Grant Agreement or General assembly
GPS	Global Positioning System
GNSS	Global Navigation Satellite System
GW	Gateway
H(e)NB	Home (evolved) NodeB
HII	High Interference Indicator
HO	Handover
ICIC	Inter Cell Interference Coordination
IEEE	Institute of Electrical and Electronics Engineers
IFR	Inverse Frequency Reuse
IOT	Interoperability Testing
IP	Internet Protocol
IR	Internal/Interim Report
KBB	Key Building Block
LFGW	Local Femtocell GateWay
LIPA	Local IP Access
LTE(-A)	Long Term Evolution (Advanced)
MAC	Medium Access Control
MBSFN	Multimedia Broadcast Single Frequency Network
MIMO	Multiple Input Multiple Output
MME	Mobility Management Entity
MNO	Mobile Network Operator
MRO	Mobility Robustness Optimization

MS	Mobile Station
MUE	Macrocell User Equipment
NGMN	Next Generation Mobile Networks
NoF	Network of Femtocells
PCFICH	Physical Control Format Indicator Channel
PDCCH	Physical Downlink Control Channel
PDCP	Packet Data Convergence Protocol
PHICH	Physical Hybrid Automatic Repeat Request Indicator Channel
PHY	Physical Layer
PM	Project Management
PMT	Project Management Team
PU	Public
QMR	Quarterly Management Report
QoS	Quality of Service
R	Report
RACH	Random Access Channel
RB	Resource Block
RF	Radio Frequency
RLC	Radio Link Control
RRC	Radio Resource Control
RRM	Radio Resource Management
SDO	Standard Development Organization
SFR	Soft Frequency Reuse
SIC	Successive Interference Cancellation
SIPTO	Selected IP Traffic Offload
SON	Self Organizing Network
TDD	Time Division Duplex
UE	User Equipment
UICC	Universal Integrated Circuit Card
UL	Uplink
WP	Workpackage
WPL	WP Leader

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1. Introduction

This deliverable captures all achievements and progress status of the entire project from technical, financial and legal point of view during the second phase (M13-M31). This is thus under twofold responsibility of Project (SC) and Technical Managers (NEC).

This document should be used as a stand-alone reference point whilst synthesizing the overall BeFEMTO project activities and achievements during the second Reporting Period (M13-M31).

Indeed, the primary objective of the document is to demonstrate that contractual objectives have been reached with good quality and on a timely manner.

As a consequence, a synthetic but clear progress status is thus given in terms of Technical activities, and achievements, together with addressing Project Management related topics, in terms of Financial, Legal or Organization aspects.

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The second section extracts the list of contractual deliverables due during this period, based on Annex-I of the Grant Agreement.

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Then, the fifth section gives the actual status of produced Deliverables, both **contractual (14)** and **non-contractual (7 Internal/Interim Reports)**, compared with the Grant Agreement. Furthermore, the **project Milestones (3)** are also reminded, and their achievement assessed.

The sixth and last section is dedicated to **Dissemination** aspects of the project, that give other important metrics (**15 standards and industry groups contributions**, **45 conferences publications**, **7 journals articles, 2 Journal special issues, 5 organized international workshops, 2 training school organized, and 5 international panel session**) to evaluate not only technical achievements of the project over this period, but also its visibility, its real influence and impact towards the ecosystem.

2. Project Objectives for the Reporting Period 2

This section serves as the reference in terms of contractual objectives from the Description of Work (DoW), as Annex-I from the Grant Agreement (GA).

The full list of the **fourteen (14) contractual Deliverables** due during the Reporting Period 2 (M13-M31) is thus given in the Table 22-1 below:

Del. No	Deliverable Name	WP No.	Lead Bene-ficiary	Estimated Indicative Person Months	Nature	Dissem -ination level	Delivery date (Annex I)	Actual Deliv-ery date
D4.2	SON enabling techniques (final)	4	DOCO MO	60	R	PU	M21	M21
D1.3	Evaluation of progress status of the project, issue 2	1	SC	8	R	CO	M24	M24
D2.2	The BeFEMTO system architecture	2	NEC	25	R	PU	M24	M24
D3.1	RF front-end solutions	3	TTI	20	R	PU	M24	M24
D4.3	Multi-cell RRM for networked femtocells (final)	4	UOUL U	100	R	PU	M24	M24
D5.2	Femtocell access control, networking, mobility and management mechanisms (final)	5	CTTC	50	R	PU	M24	M24
D6.2	Integration of selected algorithms into platforms & interfaces finalization	6	SC	80	R	PU	M24	M24
D1.4	Final project report	1	SC	5	R	PU	M30	M30
D2.3	The BeFEMTO system concept and its performance	2	DOCO MO	11,5	R	PU	M30	M30
D3.2	Interference and RRM solutions for indoor standalone femtocells	3	UNIS	88	R	PU	M30	M30
D4.4	Integrated SON techniques for femtocells radio access	4	CEA	49	R	PU	M30	M30
D5.3	Evaluation report of femtocells networking, mobility and management solutions	5	UNIS	18,62	R	PU	M30	M30
D6.3	Final proof of concepts validation, results and analysis	6	SCET	105	R	PU	M30	M30
D7.2	Final report on the standardisation and dissemination activities of the project	7	TID	29,82	R	PU	M30	M30

Table 2-1: Deliverables List (Annex-I Grant Agreement), Reporting Period 2 (Year 2 and Year 3)

3. Work Progress and Achievements

3.1 WP2

This WP consists of four tasks. Tasks 2.1 and 2.2 have already been completed successfully within the first reporting period, resulting in three deliverables: IR2.1, IR2.2 and D2.1. Task 2.3 was successfully completed at the end of 2011 resulting in the submission of deliverable D2.2. The last task pertains to both reporting periods and is meant to result in an assessment methodology for the contributions from the different partners, a simulation calibration campaign between the different partners, establishment of assessment criteria (work on this was already well established in IR2.4) and a description of the system concept. All of these points are addressed in the final deliverable, D2.3 which has already been released for review to the board.

3.1.1 Task 2.4

This task is supposed to result in two deliverables. The major developments in this task have been:

- IR2.4 has been successfully delivered in month 18.
- The final set of innovations from WPs3-5 has been identified and they are synthesised in chapters 4-6 of D2.3 to observe how they impact the overall foreseen system concept proposal.
- An exhaustive collection of a system-level simulator calibration campaigns by the various partners to ensure that their systems perform similarly in order to harmonize the results obtained and reported by our colleagues in the documents D2.1 and IR3.3.
- D2.3 also contains a detailed summary of the BeFEMTO system architecture.
- Finally, D2.3 contains a chapter dedicated to detailing the link of every major contribution to the overall BeFEMTO system concept as well as an indication of how each contribution adheres to the performance goals defined in BeFEMTO.

3.1.2 WP2 outcomes

In summary, in the third reporting period:

- The final deliverable (D2.3) has been submitted for board review.

3.2 WP3

In last six months, the efforts in WP3 have been focused on Tasks 3.2 and 3.3 (Task 3.1 finalised at the end of second year, with the edition of D3.1). In this period, the main outcome of these tasks was the timely delivery of D3.2, which collects the technical activities developed on them along the two years and a half of the BeFEMTO project. The high level objectives of WP3 in BeFEMTO can be summarised in the following points:

- **O3.1:** Research on new RF hardware solutions which meet the very challenging LTE-A specifications.
- **O3.2:** Identification of main interference and co-existence (between indoor standalone femto and macrocells) issue and develop guidelines on how best to deal with them in BeFEMTO.
- **O3.3:** Development of innovative interference mitigation and co-existence mechanisms for indoor standalone femtocells which facilitate system capacity improvements whilst minimising the detrimental impact of placing unplanned BeFEMTO cells into planned cellular networks.
- **O3.4:** Development of next-generation RRM mechanisms tailored to scenarios and problems incorporating indoor standalone femtocells, heavily relying on cross-layer design paradigms.
- **O3.5:** Development of an integral BeFEMTO Radio Access protocol suite composed of the most promising architectural and algorithmic solutions.

3.2.1 Task 3.2

Task 3.2, Interference management for indoor standalone femtocells, main technical achievements can be summarised during the last six months of the project in the following points.

- Continuation of the work started on the statistical modelling of spatial interference management, studying the effect of distributed antenna systems on overall performance
- Development of self-organizing interference management algorithms
- Continuation of the investigations of the effect of indoor band sharing of femtocells on Macrocell performance for different scenarios based on the level of sharing as well as activity ratio
- Work on statistically modelling distributed antenna systems as well as maximizing resource reuse in the network as an extension to previous works
- Updating of Soft and Fractional Frequency reuse scheme studies

3.2.2 Task 3.3

In Task 3.3, named RRM (Radio Resource Management) for indoor standalone femtocells. main achievements have been the following in the last six months:

- Continuation of previous studies regarding RRM and High Order Modulation schemes
- Continuation of the work on hand over in standalone femtocells

3.2.3 WP3 Outcomes

Most important outcomes of this work package on first semester of 2012 have been the following:

- Delivery of **D3.2**, which comprises the activities and the results of the research carried out in T3.2 and T3.3 during the whole duration of the BeFEMTO project.
- Dissemination of technical achievements developed in the Work Package through several conferences and papers.

3.3 WP4

The goal of WP4 are the development of self-organizing femtocells radio access, with a particular focus on entirely novel and unprecedented concepts of networked femtocells, fixed relay and mobile femtocells.

Technically, this can be summarized as:

- enabling SON techniques as a basis for subsequent system design.
- femto RRM techniques for maximum capacity at minimum interference.
- complete SON framework for networked, relay and mobile femtos.

with the following specific objectives:

- O4.1: Real-time location and autonomous coverage estimation.
- O4.2: (De-)centralized learning, synchronization, self-organization.
- O4.3: RRM for interference, resource allocation, scheduling, handover, etc.
- O4.4: Self-optimization considering control plane & energy requirements.
- O4.5: Adaptation to the needs of fixed relay and mobile femtocells.

To this end, the work package is split into four complementary tasks that are described hereafter together with their respective main achievements.

3.3.1 Task 4.1

Task 4.1, “Enabling Self-Organising Networking Techniques”, deals with:

- Automatic Location Determination of Femto BS & MS
- Automatic & Autonomous Coverage Estimation
- Radio Context Aware Learning Mechanisms
- Biologically inspired Network synchronization

- Dynamics and Time-Scale Classification for System Stability

This task has finished in 2011 and the following has been achieved, completely meeting the requirements set out in the DoW to date:

- Automatic Location Determination. It enables accurate real-time geographic location determination of femto base stations, as well as their associated mobile terminals. In areas where signal reception from satellite navigation (e.g. GPS) is limited, such as in indoor environments, an approach is pursued where the relative position of all nodes towards a few reference nodes is determined. Given that these reference nodes have accurate location information, the absolute position of all nodes in the network can be established.
- Automatic Coverage Estimation & Control. Current radio network planning is based on average statistics, whereas the radio environment is fully dynamic in terms of propagation and traffic variations. The measurement capabilities implemented by LTE equipments are utilized to estimate and control the coverage area of femtocells.
- Biologically Inspired Network Synchronization. Accurate network synchronization of femto networks is an enabler for advanced self-organized radio resource management and interference avoidance schemes. A biologically inspired solution is presented that extends previous work on slot synchronization to a fully autonomous and distributed synchronization to a common carrier frequency and sampling clock frequency.
- Radio Context Aware Learning. It focuses on the design of machine learning-inspired interference mitigation strategies, when information exchange among femtocells is possible, either through an X2 interface or over-the-air (OTA) signalling. Simulation results demonstrate that approaches based on evolutionary game theory outperform classical Q-learning in terms of convergence time and achieved sum-rate; however, these performance benefits are traded with a significant increase in signalling overhead.
- Dynamics and Time-Scale Classification for System Stability. System stability is an important issue in self-organising systems. An approach to classify a variety of self-organizing algorithms into three categories is proposed: Time scale based classification; objective based classification where different SO algorithms share the same, different or multiple objectives; as well as life cycle phase based classification, which distinguishes between deployment, operation and maintenance phases.

3.3.2 Task 4.2

Task 4.2, “Multi-Cell RRM for Networked Femtocells”, deals with:

- Interference Management
- Resource Allocation for Networked Femtocells
- Integrated Admission Control and Scheduling
- Flow Control in Networked Femtocells

The following has been achieved over the entire project duration:

- Interference Minimization: The impacts of dominant interference conditions in the downlink when macro UEs are in close proximity of femtocells are assessed. Next, the performance of a macro/femto network equipped with MIMO spatial multiplexing mode is presented. By combining spatial multiplexing characterized by 4x4 antenna configuration and interference mitigation, the BeFEMTO average femtocell spectral efficiency target of 8bps/Hz is achieved. In addition, SON-enablers for interference minimization are examined as a means of minimizing the overall interference per resource block (RB) generated outside the femtocell coverage range while reducing the transmission power in each resource block. Finally, spectral efficiency enhancement on the access link of outdoor fixed relay femtocells through self-organization of eNB antennas tilt has been investigated. A subsequent task has been to evaluate this interference level, both in a realistic large scale deployment, using environment data from an existing macro network, and in some worst case scenarios, using 3GPP LTE-A simulation parameters for femtocells deployment. One result is that cross-tier interference does not seem to be very harmful when access to femtocells is not restricted, i.e, when working in open access
- Radio Resource Management: A set of innovative SON-enabled radio resource management methods have been developed. It was focused on Multi-Cell RRM for Networked Femtocells,

where several methods have been proposed in order to mitigate interference, both to and from the macrocell network (*cross-tier interference*), and between the femtocell networks (*co-tier interference*).. Several centralized or distributed methods are proposed, with various level of information exchange between femto cells, or between macro and femto cells. Most of these methods are based on power management and/or resource partitioning schemes. By ensuring QoS for femto users under a constraint related to co-tier and cross-tier interference, several game theory-based algorithms have also been proposed, with or without a learning phase, and with different level of information exchange between involved base stations. In the same context, another appropriate distributed and iterative approach is the Q-learning algorithm. Another family of methods assumes that each femto/macro base station has an antenna array and a certain level of cooperation between these base stations (Coordinated Multiple Point –CoMP approaches). A distributed scheme is presented, where both transmitted power and beam vectors are optimized in order to maximize the received SINR for all users, while keeping information exchange at a minimum. Another CoMP method assumes the existence of a codebook, and introduces an additional UE feedback signal, indicating the worst interfering precoding matrix for a neighbour femto cells. Avoiding this worst case leads to significant improvements. Finally, a centralized graph theory based dynamic frequency reuse scheme is presented, whose goal is to improve the throughput of cell edge UEs, while minimizing the decrease in the overall throughput.

3.3.3 Task 4.3

Task 4.3, "Integration and Optimization of SON Enabling Techniques", deals with:

- Self-Optimization of Radio Access Parameters
- Energy Requirements of Self-Organizing Schemes
- Self-Organizing Control Plane

The following has been achieved to date:

- Architectural requirements of SON 3GPP & BeFEMTO HeNB: SON use case functionalities have been discussed with a preliminary analysis of their relevance for the case of HeNB-HeNB as well as for the case of eNB-HeNB. In addition, a look into recent Release 10 additions to SON functions and the extension to interference management case is provided. Finally, an overview of ongoing work for Release 11, where a new Work Item on SON has been opened, and recent trends has been included in WP4 studies and documentations.
- SON for Energy Efficiency: Focus here has been on energy efficiency within the context of SON where an admission control and resource allocation scheme are proposed, which aims at balancing the energy usage by femto cell users between the signalling and the data transmission. Also, RF front-end functionalities for SON have been dealt with over the period of the 2nd year in WP4, including an implementation of power control for downlink that combines both open-loop and closed-loop.
- Alignment with 3GPP/NGMN SON Classification: Following NGMN/3GPP terminology, the SON algorithms in WP4 have been classified according to "local algorithms", "distributed algorithms between eNBs and HeNBs", "distributed algorithms between HeNBs", and "centralized algorithms". The "local" category does not require an air interface coordination; the two "distributed" categories make use of an interface for exchanging information between BSs, extending the role of the X2 interface, as defined in 3GPP LTE Release 10; and the "centralized" category makes use of another BeFEMTO architecture innovation: the Local Femto Gateway, which enables powerful interference management schemes for networked femto-cells.
- Local SON Algorithms: A local algorithm, inspired from reinforcement learning (RL), had been proposed to investigate the problem of cross-tier ICIC in femtocell networks.
- Global Distributed SON Algorithms: Introduced were BeFEMTO distributed algorithms, with coordination between HeNBs and eNBs, via an extended X2 interface. It addresses mainly cross tier interference, and also the specific issue of relays, fixed or mobile femtos viewed as small cells. Notably, we dealt with a coordinated beam selection scheme: a victim MUE sends its serving cell a request to be forwarded over X2 to an interfering HeNB, asking it not to use a certain precoding matrix. The same scheme can actually be also used in a cross tier scenario. Furthermore, cell edge MUEs leverage on the neighbouring small cells, establishing a device-to-device connection whereby MUEs forward their traffic to the FUEs. In return for its cooperation,

each macrocell user grants the FUE a fraction of its super-frame as a reward mechanism. The, we present a cross-tier ICIC based on a learning approach. Femtocells first independently learn a policy which allows them to control their interference at potentially close MUEs. Since the learning task takes time, as a second step femtocells can take advantage of the policies already learnt by other more expert nodes (docitive approach).

- Local Distributed SON Algorithms: Referred to are BeFEMTO distributed algorithms, with coordination between HeNBs via an X2 interface. Notably, it had been shown that femtocells can converge much faster to the optimal network operating point, at the cost of exchanging information with neighbouring femtocells. This is done through the X2 interface. In both replication by dynamics and fictitious play procedures, there is a need for an X2 interface within the femtocell tier, in addition to an X2 interface to gauge the interference caused on the macrocell tier. Furthermore, dealing with TDD mode, a downlink beamformer design is proposed for minimizing the total transmitted power of HeNBs subject to fixed cross-tier interference constraints and femto-UE specific SINR constraints. A limited backhaul information exchange is needed between HeNBs which can take place over X2 interface. Then, co tier interference is managed by a novel dynamic and autonomous subband assignment method based on a modified graph colouring algorithm. HeNBs send measurements from their users to the interfering neighbours by an indicator on an X2 interface. We also have focused on a new collaborative power usage among the femtocell users that aims at enhancing the energy efficiency of the SON operation in a distributed manner. Unlike conventional schemes addressing only the power usage for the data, power usage for the channel information feedbacks has been also taken into account. For this achievable benefit, the X2 interface between femtocells is used. We also consider a two–tier co–channel femtocells network, where each femtocell shares the radio spectrum with the overlaid macrocell. Given an orthogonal channel deployment between femtocells, achievable by low signalling over the X2 interface, a new distributed method for admission control and radio resource scheduling (RSS) that aims at enhancing the ergodic sum capacity on the uplink of the femtocells has been proposed. The key of the method is that it takes into account the energy usage for both the signalling and the data transmission. Finally, the solution for the aggregated interference problem from femtocells to macrocells has been based on a learning approach; completely autonomous solution based on Partially Observable Markov Decision Process (POMDP) has been proposed, where femtocells estimate their impact in the macro user through interpolation techniques.

- Centralised SON Algorithms: A centralized co tier interference mitigation algorithm has been dealt with. Similar to the case above, HeNBs define its interfering neighbours with the help of the measurement reports from the users. Here, a central controller, (LFGW) collects the measurements. Then, the controller assigns subbands by using a modified graph colouring algorithm. In order to protect primary subbands, HeNBs send the assignment information to the interfering neighbours via an X2 interfaceWe then also proposed a novel graph-based multi-cell scheduling framework to efficiently mitigate downlink inter-cell interference in small cell OFDMA networks. This framework incorporates adaptive graph-partitioning and utility optimization concepts to address inter-cell interference in two phases: both phases rely on sharing the channel state information in centralized manner via a Local femto Gateway (LFGW). Furthermore, we present a comparison between two interference mitigation algorithms, based on the concept of "Ghost" femtocells. "Ghost" is a resource allocation paradigm that takes advantage of the large amount of available spectrum vs. the low number of users in a femto cell. It is both a co-tier interference and a cross-tier interference scheme. For standalone femtos, HeNBs selfishly attempt to maximize the spectrum reuse. In networked femtos, first a distributed method for estimating how neighbouring HeNBs affect each other transmission reliability is introduced. Then, the LFGW uses this information to locally coordinate the access of neighbouring femtocells and manage the frequency reuse amongst nearby HeNBs. A distributed version of $Ghost_{NF}$, where signalling and computation costs are shared amongst neighbouring HeNBs over the X2 interface is made feasible. However, this solution results in higher overhead and latency. Finally, a HetNet-based centralized power setting algorithm for femtocell clusters has been introduced, which makes use of a linear programming framework. The method exploits the LFGW, which coordinates co-located femtocell measurements/actions and perform the linear programming resolution. An iterative distributed implementation is also possible. This algorithm encompasses the possibility to automatically switch-off the most disturbing femtocells under SON operation.

3.3.4 Task 4.4

Task 4.4, "Self-Organisation for Mobile and Fixed-Relay Femtocells", deals with:

- Resource Allocation for Mobile and Fixed Relay Femtocells
- Adaptation of SON Techniques to Mobile and Fixed Relay Femtocells
- Mobile Femto Handover and Admission Control
- Backhaul Discovery based on Context Awareness
- Integration of Above Techniques and Evaluation

The following has been achieved to date:

- Fixed and mobile femtocell relays: Focus has first been on the fixed femtocell relay where a femto BS is used as a relay in an indoor environment for coverage extension. Furthermore, moving relays are investigated with a main emphasis on in-band backhauling.
- SON-Enabled Global Distributed Algorithms: Femtocells rely on some information from the macrocell system; assumed to be conveyed over X2: In a scenario where an Outdoor Fixed Relay (OFR) is interfered by neighbouring macro cells, it has been shown that a SO optimization of eNB antennas tilt leads to a Spectral Efficiency enhancement of the OFR access link. We have dealt with the issue of heterogeneous (wired/wireless) backhaul capacity, in which backhaul-aware cell selection is of utmost importance, through which UEs autonomously associate to the best cell taking account both access and backhaul links. LTE Rel-10 is focusing on fixed relays, while advanced relay scenarios like high speed train can become quite popular. Thus, a mobile relay architecture has been first defined, enhancing that of LTE Rel 10; and a contribution on cooperative moving relays, coping with a limited capacity backhaul, has also been dealt with.

3.3.5 WP4 Outcomes

Summarizing, the major achievement over reporting period:

- Timely submission of all deliverables with all partners contributing
- A fair share f joint publications and work
- Finalization of SON-enabling techniques, covering the important spectrum of algorithmic approaches
- Finalized RRM framework, with a clear understanding of interference from macros as well as between femtos
- Innovative SON approaches, ranging from game theoretical to machine learning approaches, with direct impact on performance, robustness, energy efficiency
- Successful application of prior art to mobile and relay femtos
- Good knowledge on standards developments, with regular updates on 3GPP developments by BeFEMTO members taking part in standardisation
- Contribution to 3GPP standard in the area of mobile femtos
- Input to WP6 testbed to prove viability of algorithmic work

3.4 WP5

WP5 covered the traffic management, mobility management, network management, and security aspects of standalone, networked and mobile femtocells.

WP5 has reached all of its technical objectives, which were:

- O5.1: access control mechanisms to the local network and services
- O5.2: loosely-coupled femtocell subscriber authentication
- O5.3: resource-efficient traffic forwarding
- O5.4: routing metrics and adaptive routing strategies

- O5.5: local mobility management reducing signalling and user traffic over the backhaul
- O5.6: remote and self-management
- ~~O5.7 zero-configuration~~ (This objective had been re-prioritized towards O5.6 during project initialization.)

3.4.1 Task 5.1

Task 5.1 addressed security aspects of standalone and networked femtocells with a focus on subscriber authentication and access control. As a side activity, security implications of standalone and networked femtocells have been analysed. The achievements of this task are:

- Design of a **local access control solution for multi-operator networked femtocell scenarios**. This solution enables the Local Network Operator to jointly control with the Mobile Network Operator which subscribers can access which local network resources and services via the network's femtocells. In an enterprise femtocell scenario this would, for example, make it easy for the enterprise's IT department to allow or block femtocell access to the Internet or to a meeting room's conferencing system for selected visitors.
- Design, implementation and test of an access network architecture for **loosely-coupled femtocell subscriber authentication**. The solution allows subscribers to be authenticated towards the fixed broadband access via a UICC card and using EAP-AKA procedures instead of via port-based identification. An initial design for standalone femtocells with single broadband backhaul link has subsequently been generalized for the case of networked femtocell with multiple broadband backhaul link, supporting both centralized and distributed management.
- Security in femtocell networks has been studied and the bases for security considerations and initial **security analysis of a femtocell network** outlined.

3.4.2 Task 5.2

Task 5.2 addressed traffic management for standalone and networked femtocells. Important achievements of this task are:

- Study of the (CS and PS) **voice call capacity of using long range WiFi for femtocell backhauling** as a low-cost alternative to microwave backhauls. Further, design, implementation and evaluation of a rate adaptation mechanism and algorithm for AMR voice codecs on the UEs that adapt not only to changes in the radio access link quality, but also in the wireless backhaul link's quality.
- Design, implementation and evaluation of a new **QoS based call admission control and resource allocation mechanism and algorithm** for LTE femtocell deployments. This solution addresses the problem of poor call quality despite excellent radio access link quality that can occur when a large number of femtocells utilise DSL as a backhaul link. It maintains protects on-going femtocell voice calls by rejecting new calls when they would start to degrade the on-going calls' QoS and by adjusting the available bandwidth of the backhaul links as needed.
- Modelling and analysis of the **impact of traffic offloading on the mobile core network.** The study investigated the offload effect on a theoretical level by modelling the process of offloading opportunities as well as the process of user activity and correlating both. It has shown that offloading may in some circumstances actually increase the burstiness of the non-offloaded traffic at the core network, requiring an increase in core network resources.
- Design and evaluation of a **Local Femtocell Gateway-based local breakout solution** (for LIPA and SIPTO) that supports full mobility and service continuity for inter-femtocell handovers, hand-ins and hand-outs from/to the macro network and connection (re-)establishment while camped on a macro base station. It has been shown that the mean queuing delay on the bottleneck link as well as the signalling loads on the backhaul and core networks can be significantly reduced using this solution.
- Design and evaluation of a **centralized traffic management solution** that allows effective sharing of the local network's resources between multi-class traffic from multiple stakeholders (e.g. mobile operator and Enterprise IT) and improves the utilization of the local network's resources through load balancing over the whole topology.
- Design, implementation and evaluation of a **scalable, stateless, and distributed routing solution for large-scale all-wireless networks of femtocells** based on a combination of

geographic and backpressure routing. The solution distributes resource consumption throughout all the nodes of the network, hence maximizing global performance. Several extensions have been introduced and evaluated, like the capability to trade-off stability and end-to-end latency / the “directedness” of the routing towards the sink, the automatic adaptation of the trade-off parameter, support for multi-gateway scenarios, and tolerance for topologies with “dead ends”.

3.4.3 Task 5.3

Task 5.3 covered mobility aspects of standalone, networked and mobile femtocells. Its achievements during the project are:

- Design and evaluation of a Local Femtocell Gateway-based **local mobility management solution** enabling inter-femtocell handovers within a femtocell network and direct routing of user plane traffic between local users without round-trip over the backhaul and core network.
- Design and evaluation of a **distributed location management scheme** that exploits geographic information and acts transparently to 3GPP procedures, hence allowing it to scale to large all-wireless networks of femtocells.
- Design and evaluation of a **self-organized Tracking Area List (TAL) mechanism** that adapts the size of UE-specific TALs to the mobility state and the paging arrival rate of each terminal. The scheme is particularly suitable for large-scale networks of femtocells, where handovers and cell reselections happen more frequently than in macrocell deployments.
- Design and evaluation of a **distributed paging mechanism over the X2 interface**. This scheme improves the paging performance in large-scale, all-wireless networks of femtocells by sending a single unicast S1AP paging message to the closest femtocell in the destination tracking area and letting that femtocell propagate the paging message to the neighbouring femtocells in the TA through the X2 interface.
- Design and evaluation of a **mobility management approach for networked femtocells based on X2 traffic forwarding**. It avoids heavy signalling over femtocell backhaul links as a result of frequent handovers between femtocells by continuing to forward traffic over the X2 interface between the old to the new serving femtocell also after the handover. This work has been submitted to Transactions on Vehicular Technologies journal.
- Development and evaluation of a **fast handover failure recovery scheme** to overcome the effect of large handover preparation delay due to the Internet backhaul and the rapid signal degradation due to the wall loss. A UE-based forward handover with predictive context transfer is proposed to minimize the service interruption time when a handover failure happens.
- Development and evaluation of a **reactive data bicasting scheme** that makes macro-femto handovers more seamless by duplicating the downlink data packets at the S-GW and bicasting them to both the handover source and the handover target until the handover is complete.
- 3GPP’s **fixed relay architecture alternatives have been re-examined in-depth for their suitability for supporting mobile relays**. The conclusion is that architecture Alternative 1 (a full L3 relay) has more benefits than other architecture architectures, due to the stable IP anchor point, which avoids time-consuming relay re-attach procedures during handovers, handles interworking between mobile relay node and OAM without connectivity interruption and does not require the downlink data path switches related to different S-GWs/MMEs serving UEs (→ group mobility).
- A design and overhead analysis of a **mobile femtocell approach based on multi-homing** has been performed. The approach suggests replacing GTP-U/UDP as user plane protocol by SCTP, which is already used on the control plane as well. This approach does not only provide multi-homing with load-balancing or fail-over support, but an overhead analysis shows that the additional overhead can be fully amortized through chunk bundling.
- Finally, the **deployment, handover and performance of networked femtocells in an enterprise LAN have been studied experimentally**. Specifically, the experiments studied necessary LAN configuration changes, the logical connectivity of femtocells to the femtocell subsystem, group radio planning and radio coverage, self-configuration and mobility aspects.

3.4.4 Task 5.4

Task 5.4 covered network management aspects of standalone and networked femtocells. Its achievements during the project are:

- Design of a **distributed fault diagnosis framework** (architecture, mechanisms and initial algorithms). The framework allows detection and diagnosis of faults across multiple network domains (e.g. local femtocell network, access network and mobile core network) while reducing the load of alarms and other messages exchanged between domains.
- Design and evaluation of an **enhanced power management solution for femtocell networks** that switches on only those femtocells within a building that are likely to be used by mobile network users in the near future. The scheme uses entry-triggers from defined edge femtocells to detect and identify users and then wake up femtocells on the respective user's path based on that user's movement history.
- Analysis of the **energy saving and performance in HetNets**. This study analysed the aggregated throughput and the energy efficiency in a traditional deployment based on outdoor macro base stations for the provision of outdoor and indoor coverage and used this as benchmark for the subsequent analysis of these KPIs in a deployment where some of the indoor traffic was supported by femtocells.

3.4.5 WP5 Outcomes

In summary, the major achievements over the reporting period have been:

- All deliverables have been submitted in a timely manner.
- A large number of publications in journals and conference proceedings, including joint publications with multiple partners and a publication that received a "best paper" award.
- Several presentations of BeFEMTO innovations at Small Cell Forum and contributions to 3GPP SA2 discussion papers, leading, among other things, to the inclusion of a BeFEMTO result into one of 3GPP's technical reports.
- Finalization of techniques for authentication and access control for standalone and networked femtocells.
- Finalization of several techniques for improving the QoS with resource-limited femtocell backhauls, for traffic offloading and for routing, load-balancing and resource sharing within wired or all-wireless networked femtocells.
- Finalization of a large number of techniques for improving the performance of macro-femto handovers, inter-femto handovers and idle mode procedures for standalone and networked femtocells. Further, finalization of studies comparing different mobile relay and mobile femtocell architecture options.
- Finalization of a network management approach for networked femtocells that reduces related signalling traffic between the femtocell network and the mobile core through self-management. The approach has been instantiated for energy management and fault management.

3.5 WP6

WP6 is in charge of the proof of concept activity within the BeFEMTO project. Based on the use cases developed by WP2, five testbeds have been settled to demonstrate a down-selection of the most promising concepts and algorithms coming from WP3, WP4 and WP5. The high level objectives of WP6 are the following:

- O6.1: Synthesis of results for each theme & Recommendations (jointly with other WPs)
- O6.2: Down-selection of use cases and solutions targeting final Proof of concept platforms
- O6.3: Hardware / Software Key Building blocks development, testing and validation (LTE-A PHY/MAC, Protocol stack, RF Front End, Routing protocols, RRM)
- O6.4: Integration into platforms

- O6.5: Implementation of key BeFEMTO concepts supporting one or several key BeFEMTO use case
- O6.6: Assessment against identified objectives and targets

To reach those objectives WP6 was divided in 4 tasks which all apply to each testbed developed within BeFEMTO.

- Task 6.1: integrated solutions
- Task 6.2: key building blocks
- Task 6.3: integration into platforms
- Task 6.4: validation

Last year report D1.3 [1] concluded that Task 6.1 was done for all testbeds (completing O6.1 and O6.2), while Tasks 6.2 and Task 6.3 were almost completely finished (addressing O6.3, O6.4 and O6.4). In addition to the remaining work performed to end those tasks for the testbeds concerned, the last six month covered by this report essentially addressed Task 6.4 (related to O6.6).

While three testbeds were on their way toward the end of the project, two new testbeds have been added during these last six months for which obviously the original task/objective completion schedule was not applicable: one testbed comes from the split of the Protocol Stack from Testbed 1 with the addition of a new feature, namely the SON server, while the other testbed assesses the benefit of an X2 interface in a macro/femto deployment for interference mitigation through frequency partitioning.

Therefore, the objective completion is recalled on a testbed basis. Each testbed is briefly described before mentioning the major outcomes of WP6: the validation of all the concepts demonstrated by the testbeds is the main achievement of WP6.

3.5.1 Testbed 1 – Standalone LTE radio

3.5.1.1 Final Status

Testbed 1 addresses the interference management topic for co-channel LTE femtocells deployment. It mainly relates to the WP2 use case “Family 2.0”, but could also be extended to “Femto for enterprise” use case (D2.1 [2]). The down-selected algorithm coming from WP4 (D4.3 [3]), “extension of graph colouring with dynamic frequency reuse”, has been adapted to Testbed 1 capabilities.

Testbed 1 consists of two femtocells (HeNBs) and one user equipment (UE) (all supervised by a PC). Each main component is made of an LTE-compliant RF front-end and an LTE-like physical (PHY) baseband. Figure 33-1 gives the setup of Testbed1, while Figure 33-2 shows the real hardware setup.

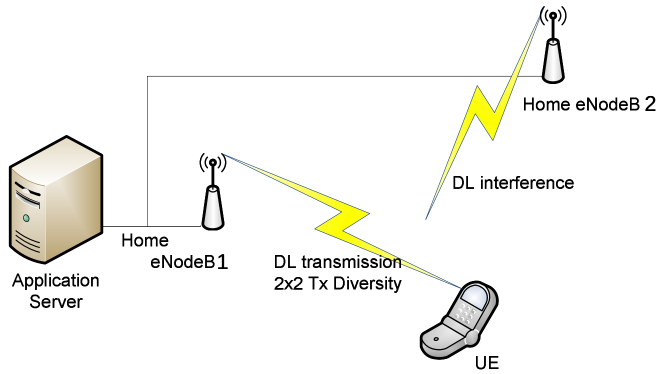


Figure 3-1: Testbed1 setup

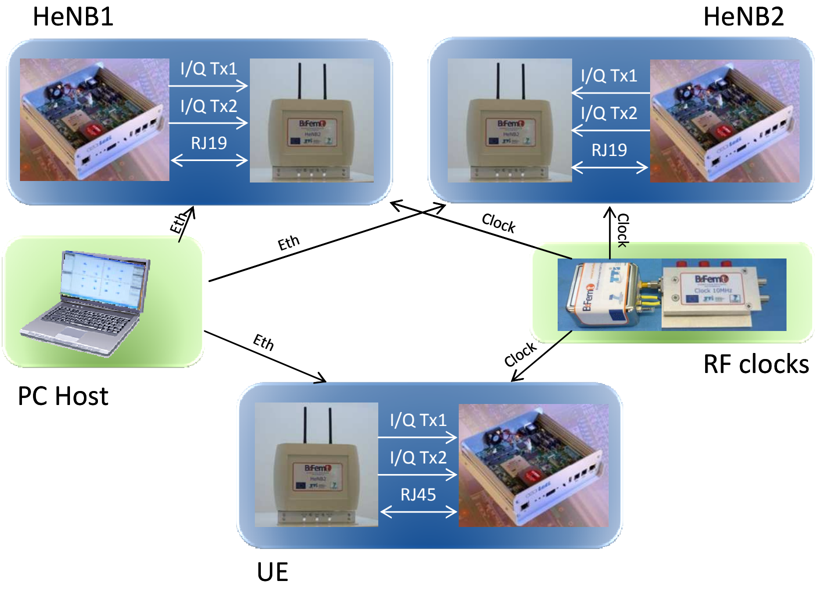


Figure 3-2: Testbed 1 hardware

Note that the LTE-compliant Protocol Stack originally planned to run on top of the RF+PHY is demonstrated separately as part of Testbed 5. Indeed, investigations on the efforts needed to perform the stack-PHY integration (mentioned in BeFEMTO D1.3 [1]) lead to a separate demonstration of the Protocol stack with no effect at all on the algorithm down-selection process or on the scenario envisaged in Testbed 1.

3.5.1.2 Validation Against Objective

The demonstration scenario given in Figure 33-3 has been established to assess the interference management over the air.

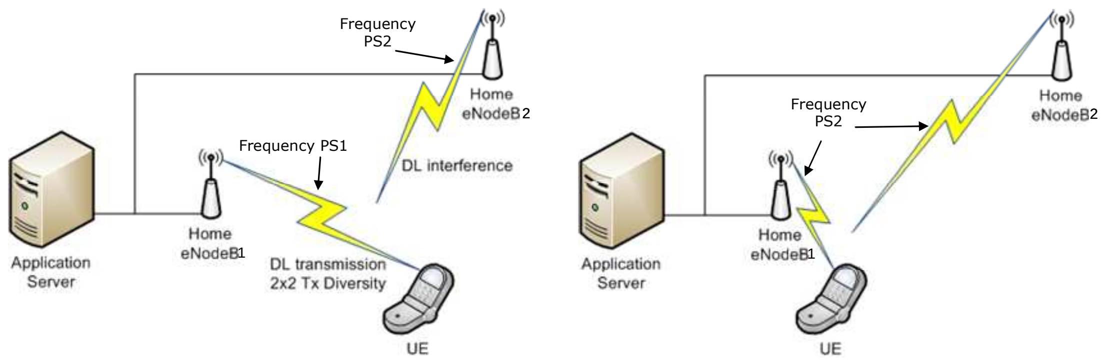


Figure 3-3: Testbed 1 setup: FUE served by HeNB1 moves from cell edge (left), to cell centre (right)

BeFEMTO D1.3 [1] reported that some objectives were not fully completed by the end of the second year for Testbed 1, in particular O6.3 on the Key Building Block (KBB) development and O6.4 on the integration process.

During these six months, the PHY baseband and the RF front-end were finalised completing O6.3. Integration was performed of both RF and PHY KBB to complete O6.4. A simplified transmission scheme was setup between one transmitter and one receiver for an Over-The-Air (OTA) straight communication (see red arrow in Figure 33-4).

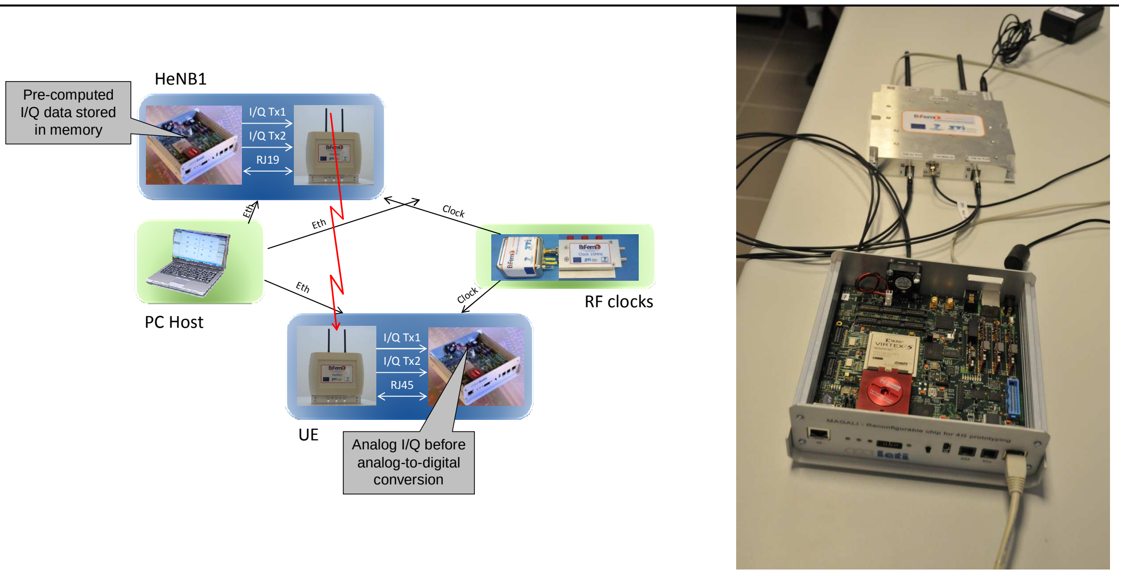


Figure 3-4: Testbed 1simplified transmitter/receive chain with RF and PHY integrated

Regarding the validation objective O6.6 which was meant to be assessed during these final six months, the move from the UE away from its serving HeNB (which is part of the scenario) was assessed using hardware simulator (which is bit-accurate with the real hardware) leading to a correct behaviour as depicted in Figure 33-5.

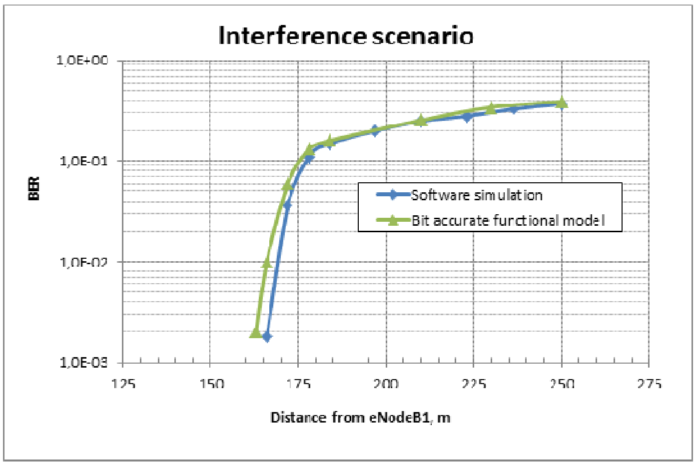


Figure 3-5: Testbed 1 BER as a function of the position of the UE

The next and final step is to go through OTA complete scenario demonstration which should occur in M31, thus, completely finalizing O6.6.

3.5.2 Testbed 2 – Networked Femtocells

3.5.2.1 Final Status

Testbed 2 addresses the network femtocells topic with an emphasis on the traffic management and load balancing between the femtocells. It mainly relates to the WP2 use cases “Femto for enterprise” and “Stuck at the airport” (D2.1 [2]) which for reference assumes (common) Closed Subscriber Group (CSG) and open access policy, respectively.

The objective of Testbed 2 is to demonstrate BeFEMTO concepts developed in WP5 (D5.1 [4] to D5.3 [6]) for a network of femtocells. More particularly, traffic management and load balancing are investigated in two complementary configurations:

- In CTTC premises (Barcelona, Spain), distributed traffic management and load balancing within an all-wireless femtocell network of femtocells are investigated through the evaluation of geographic + dynamic backpressure routing algorithm.

- In NEC premises (Heidelberg, Germany), centralised traffic management within an all-wired femtocell network investigated through the Iuh-Tap capability (namely, the dissection of messages from/to the core network on the fly) of the central BeFEMTO Local Femto Gateway (LFGW). It is worth mentioning that the femtocell gateway and core emulator handling the femtocell is located in CTTC premises (IPsec tunnel mounted).

The all-wireless part of Testbed 2 is mainly made of twelve Sagemcom 3G femtocells, each connected to a Wi-Fi Wireless Mesh Router (WMR, which can also plays the role of a LFGW), see Figure 33-6 to Figure 33-8 for the architecture and the real hardware pictures (with commercial 3G UEs).

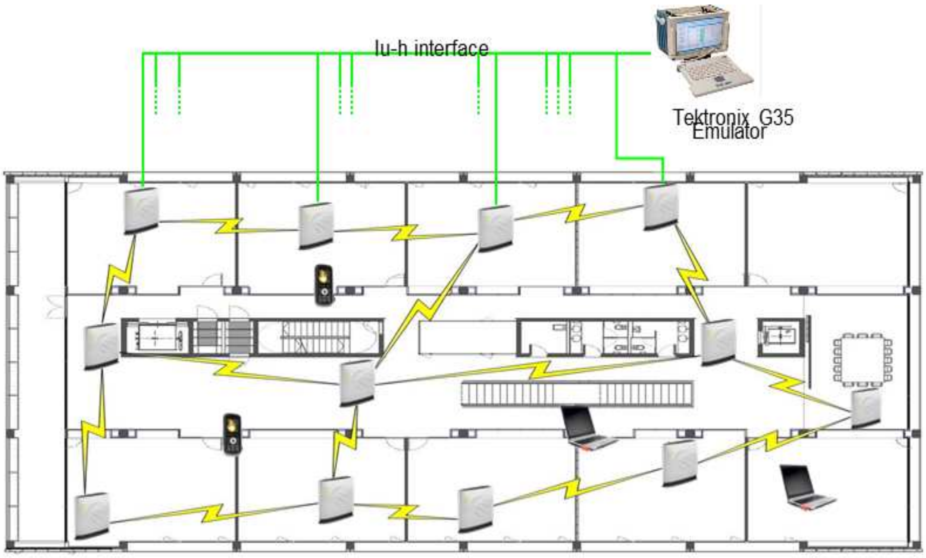


Figure 3-6: Testbed 2 (distributed routing) setup

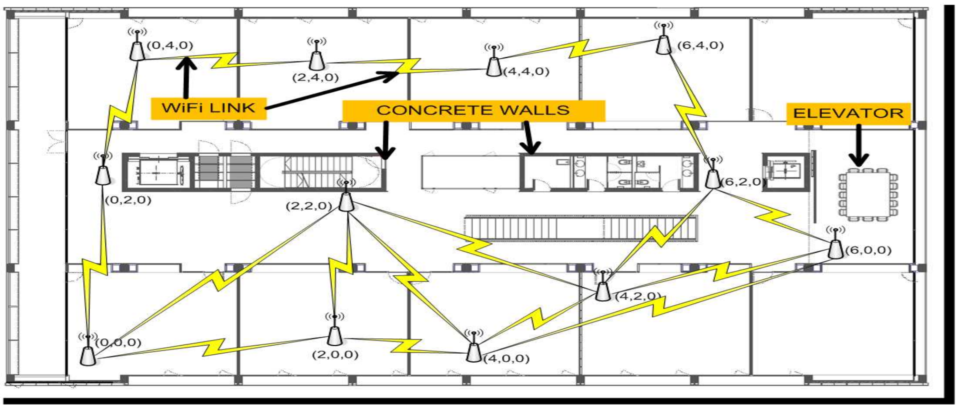


Figure 3-7: Testbed 2 (distributed routing) single radio single channel wireless backhaul

a) b)

Figure 3-8: Testbed 2 (distributed routing) a) Wireless HNB Sagemcom 3G femtocell connected to a Wireless Mesh Router b) UE with 3G PCMCIA card

The wired part of Testbed2 is mainly made of three Sagemcom 3G femtocells, an openFlow switch (allowing virtual switches to be created) and a PC acting like a LFGW, see Figure 33-9 to Figure 33-11 for the architecture and the real hardware pictures (with commercial 3G UEs).

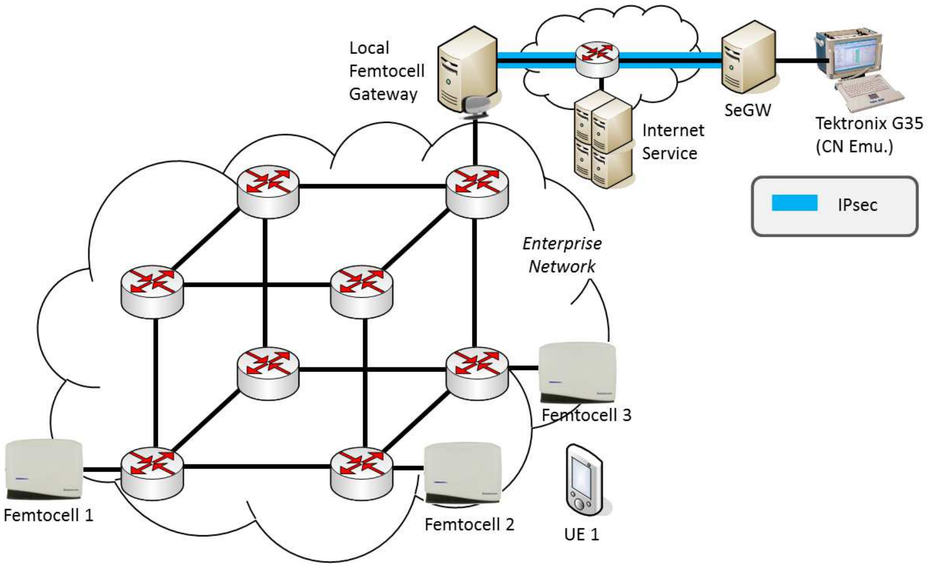


Figure 3-9: Testbed 2 (Iuh-Tap) setup

Figure 3-10: Testbed 2 (Iuh-Tap) LFGW, NEC PF5820 openFlow switch and Sagemcom 3G femtocell

Figure 3-11: Testbed 2 (Iuh-Tap) different UEs (left: 3G dongles Huawei E353, right: android smartphones)

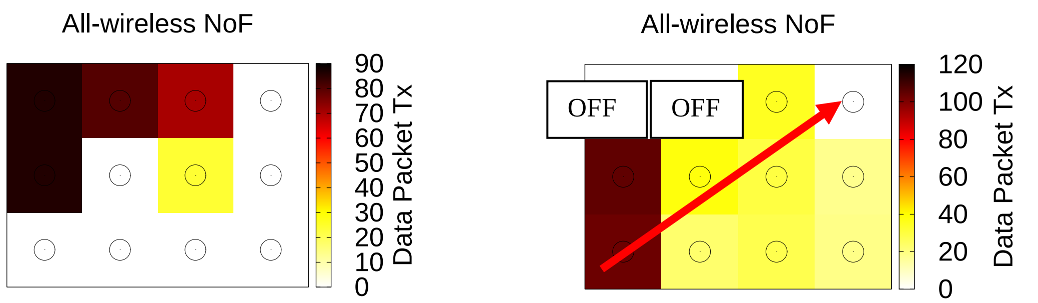
Both parts make use of the same core network emulator (namely the Tektronix G35, see Figure 33-12) to connect the Sagemcom 3G femtocell relying on a fully compliant (and validated) Iuh interface.

Figure 3-12: Testbed 2 3G core network emulator

3.5.2.2 Validation Against Objective

3.5.2.2.1 Distributed Routing Algorithm

BeFEMTO D1.3 [1] reported that the only objective left for the distributed traffic management part in the all-wireless network was the validation (O6.6). Several scenarios have been tested in real-time over-the-air to assess the distributed routing algorithm. For instance, one flow produced by a 3G UE was injected from one femtocell (upper left node of Figure 33-13) through the network of femtocells toward the LFGW (upper right node of Figure 33-13) under various configurations to stress the algorithm: when all nodes are on (see Figure 33-13a), or some are off (see Figure 33-13b), or some periodically goes off, then on (see Figure 33-14). All those experiments lead to a completion of O6.6 for this part of Testbed 2.



a) All the nodes turned ON b) Some nodes of the shortest path turned OFF

Figure 3-13: Testbed 2 (distributed routing) heatmap illustration of data packet distribution with the variable-V distributed routing

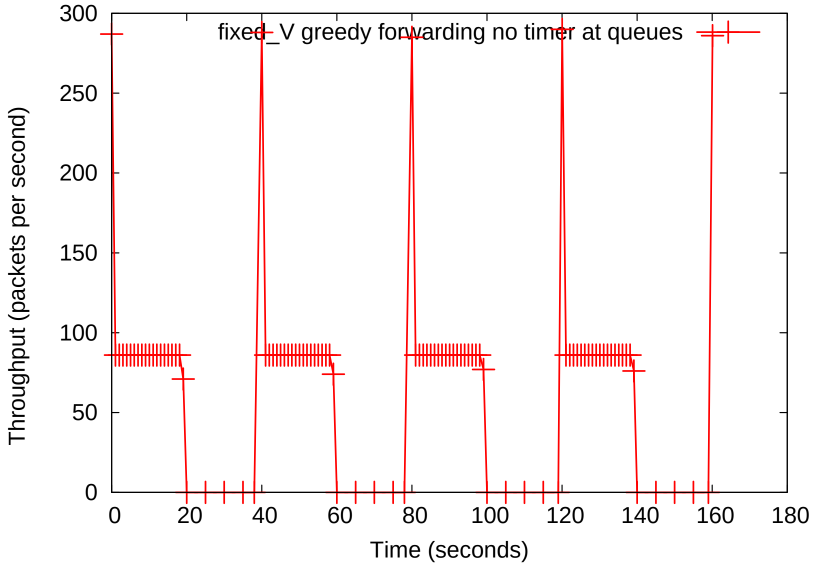


Figure 3-14: Testbed 2 (distributed routing) projection over time of the attained LFGW throughput with distributed backpressure routing with a fixed-*V* algorithm based on giving all the importance to the geographic component without a timer implemented in the queue for dropping data packets

3.5.2.2.2 Iuh-Tap

BeFEMTO D1.3 [1] reported that for the centralised traffic management part in the all-wired network (Iuh-Tap) experienced some delays in the realisation of O6.3, O6.4 and O6.5 due to issues with the licence of the core network emulator. Fortunately, the issue was solved at the beginning of year 3 (M25) allowing the completion of all these objectives with no impact on the planning. Three scenarios, namely traffic breakout (see Figure 33-15), routing (see Figure 33-16) and control (see Figure 33-17), have been setup in real-time highlighting the benefit of having a LFGW capable of message dissection to reduce for instance the latency. All those experiments lead to a completion of O6.6 for this part of Testbed 2.

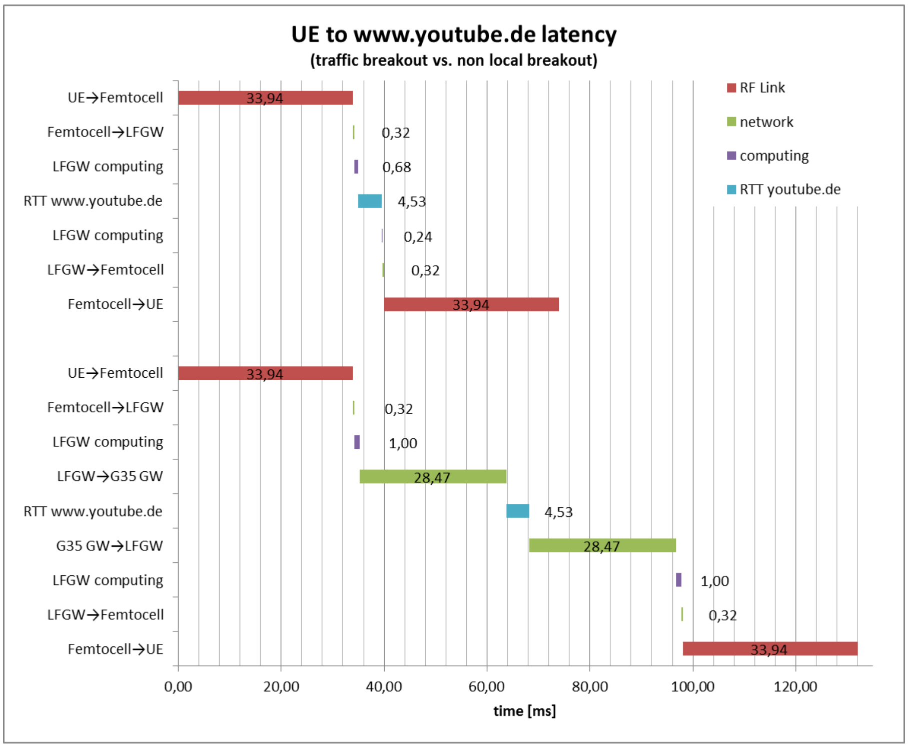


Figure 3-15: Testbed 2 (Iuh-Tap) packet latency for the traffic breakout scenario

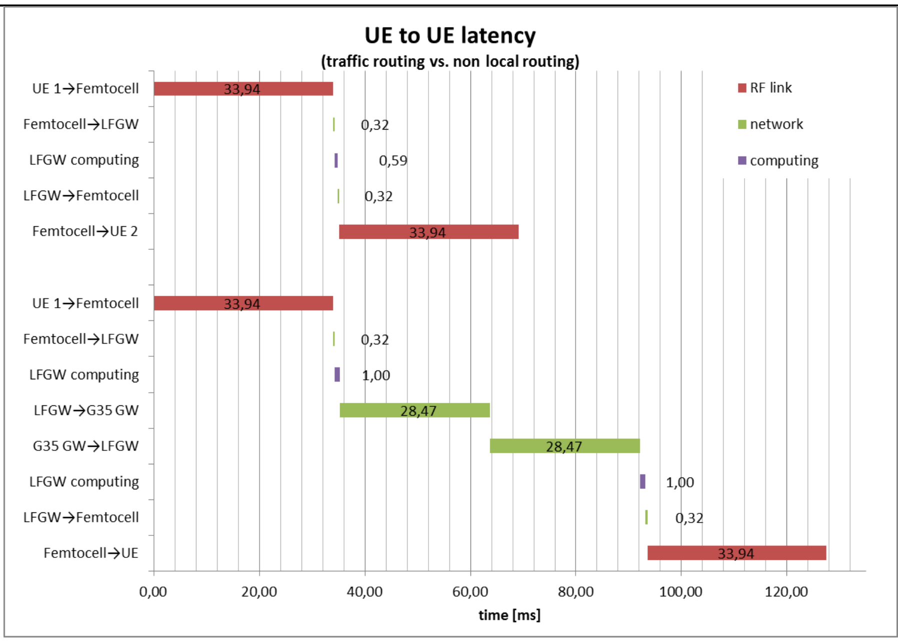


Figure 3-16: Testbed 2 (Iuh-Tap) packet latency for the traffic routing scenario

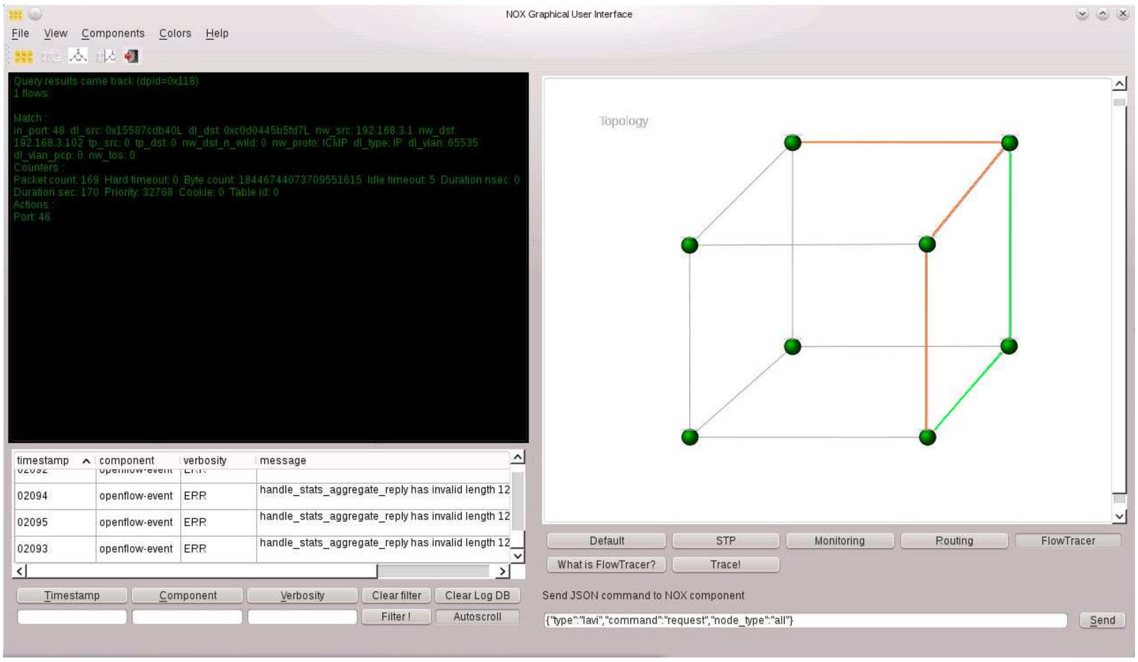


Figure 3-17: Testbed 2 (Iuh-Tap) flow paths inside the openFlow network

3.5.3 Testbed 3 – Multi-Radio FemtoNode Authentication in the Fixed Access Network

3.5.3.1 Final Status

Testbed 3 addresses the authentication of a femtocell subscriber by the way of a removable Universal Integrated Circuit Card (UICC) enabling a geogrphical and infrastructure free service delivering through multiple radio access technology. It mainly relates to the WP2 use case “Family 2.0”, with an emphasis on the scenairio “my home moves with me” (D2.1 [2]). The WP5 algorithm “Secure, Loose-Coupled Authentication of the Femtocell Subscriber” (D5.1 [4]) has been implemented into the Testbed 3 for the authentication process.

Figure 33-18 represents the overall architecture of Testbed 3, while Figure 33-19 and Figure 33-20 represent some of the end-user hardware available for demonstration.

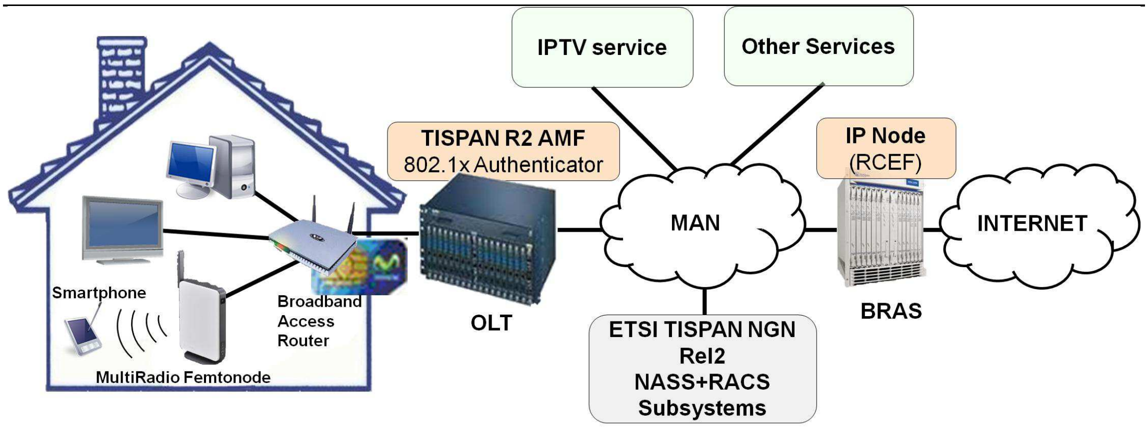


Figure 3-18: Testbed 3 setup

Figure 3-19: Testbed 3 UICC Card

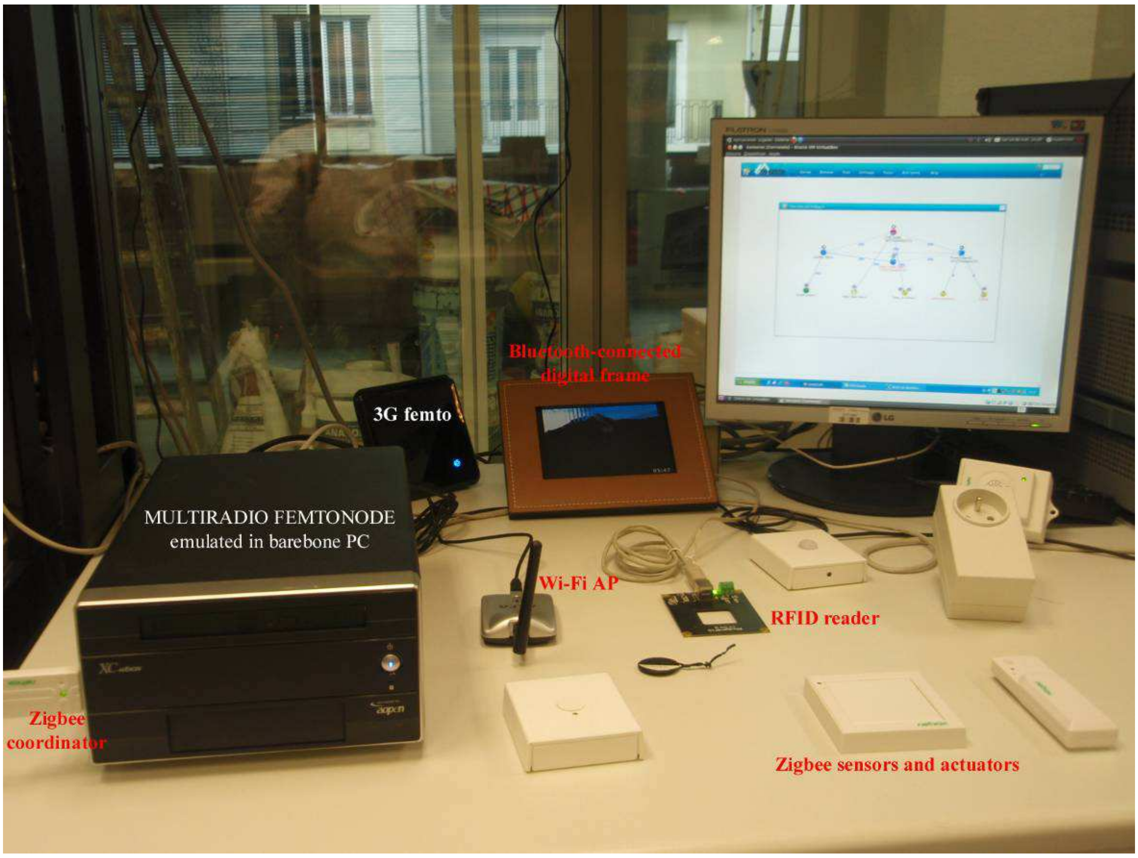


Figure 3-20: Testbed 3 Multi-radio femtonode demo elements

3.5.3.2 Validation Against Objective

BeFEMTO D1.3 [1] reported that the integration objective O6.4 and algorithm implementation objective O6.5 would be completed by the beginning of year 3 (M25) which was the case. Several scenarios were implemented in real-time in which the easy card subscriber authentication success enables new services to be delivered thanks to a multi radio access technology femtocell such as RFID user identification (see Figure 33-21), home automation (see Figure 33-22) or home surveillance (see Figure 33-23, with a robot equipped with a camera can be controlled). All those experiments lead to a completion of O6.6 for Testbed 3.

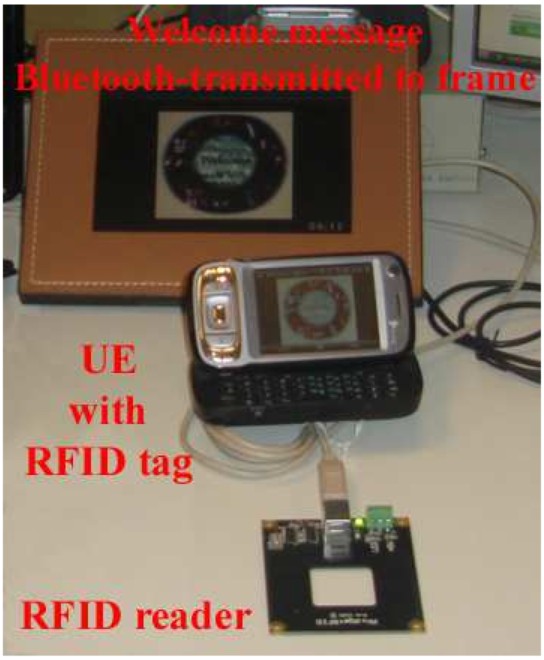


Figure 3-21: Testbed 3 user identification by means of RFID and home services personalization

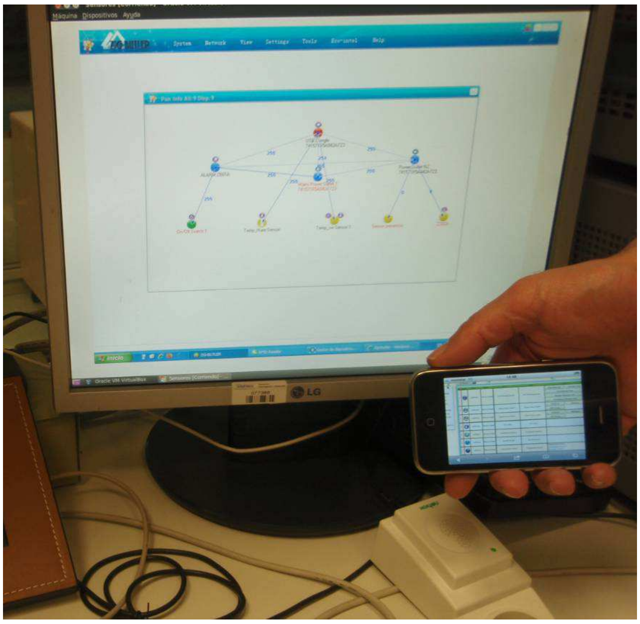


Figure 3-22: Testbed 3 home automation control from the UE

Figure 3-23: Testbed 3 Home surveillance from the UE

3.5.4 Testbed 5 – SON Server in HetNet Deployment

3.5.4.1 Final Status

Testbed 5 is a new testbed activity which started at the beginning of year 3 (M25). One of its main KBB comes from Testbed1, specifically the Protocol Stack, while another important KBB is a server dedicated to Self-Organising Network (SON) operations.

Testbed 5 addresses the interference management topic for co-channel LTE macro/femto heterogeneous deployment. It mainly relates to WP2 use case ‘Family 2.0” but the presence of the SON server makes straightforward adaptation to the “Femto to enterprise” use case (D2.1 [2]). Testbed 5 implemented one of the latest interference mitigation algorithms coming from WP3, namely “Victim User Aware Soft Frequency Reuse in Macro/Femto HetNet” (D3.2 [7]). In its original expression, this algorithm relies on X2 message exchange from the macrocell to the femtocell (requesting it to reduce its power on a set of subbands in the frequency domain). Such direct link is replaced here by the SON server which gathers the requests of the macrocell, does the processing and sends command to the femtocell.

Testbed 5 is made of two (H)eNB boards running the LTE-compliant Protocol Stack (scheduler), two commercial LTE UEs, one SON server hosted by a PC and a core network emulator. Figure 33-24 shows Testbed 5 setup, while Figure 33-25 and Figure 33-26 show the (H)eNB and UE hardware, respectively. Table 33-1 and Table 33-2 present the global set of input/output parameters of the SON server.

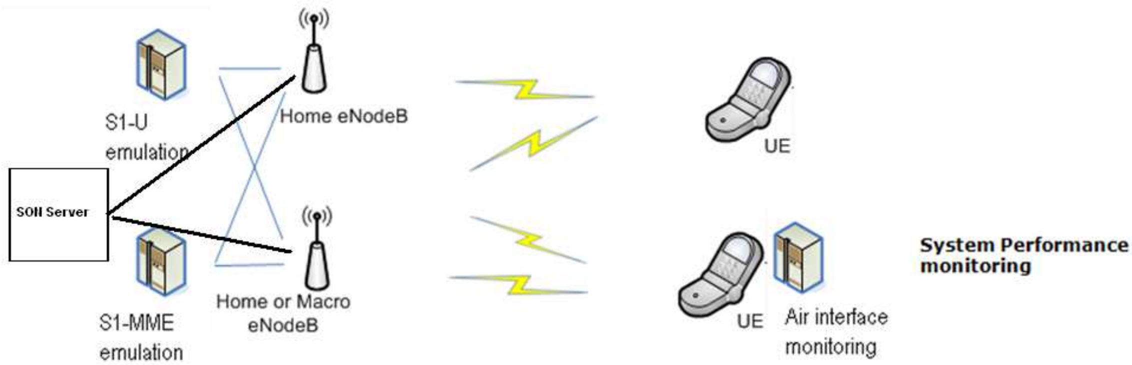


Figure 3-24: Testbed 5 setup

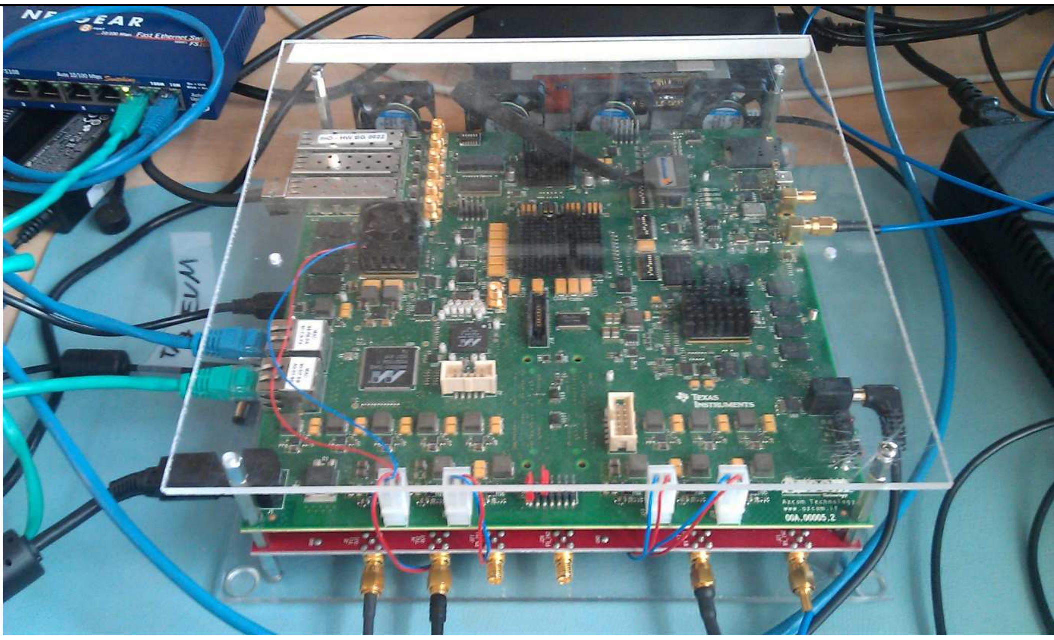


Figure 3-25: Testbed 5 (H)eNBs -The SCBP board as used in the demo

Figure 3-26: Testbed 5 Huawei dongle

Table 3-1: Testbed 5 SON server input parameters

CQI information reported by UEs	- Wideband CQI - Subband CQIs - Subband PMIs - Rank Indicator RI
RSRP/RSRQ measurements reported by UEs	- RSRQ for serving cell - RSRP for serving cell - RSRQ for neighbouring cells - RSRQ for neighbouring cells
Cell performance indicators	- cell scheduled throughput - cell effective throughput - percentage of UEs with satisfied QoS requirements
UE performance indicators	- effective throughput per MIMO steam and total - scheduled throughput per MIMO steam and total - BLER per stream and total - average number of retransmissions per HARQ process - scheduling delay
Cell load indicator	- RB usage statistics

Table 3-2: Testbed 5 SON server output control parameters

Power parameters	- DL Max cell transmit power - DL Power backoff per subband (soft frequency reuse) - Power backoff per UE
Mobility parameters	- Handover threshold (Hysteresis) - Handover cell offsets - Time-to-trigger - Event thresholds
Precoding parameters	- Precoding restrictions per subband at scheduler

3.5.4.2 Validation Against Objective

To assess Testbed 5 capability, the scenario depicted in Figure 33-27 was implemented in real-time. When a macro user experiences high interference coming from a close femtocell, its macrocell feeds back all the necessary information to the SON server for it to trigger femtocell power reduction on specific subbands. Dynamic soft frequency reuse at the femtocell is performed under the SON server control as long as the condition of the macro user does not guarantee a given QoS (throughput).

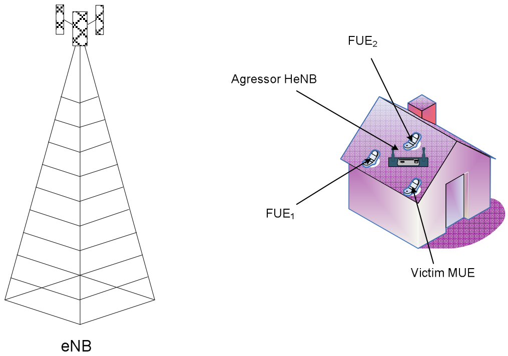


Figure 3-27: Testbed 5 macro users in the vicinity of HeNB prone to be high interference from femto transmitter

Figure 33-28 gives an example of the SON server output when a temporary protection was performed to guarantee a 6Mbps throughput to the victim macro user. Within six months, Testbed 5 fulfilled the same six objectives as the older testbeds, the final one being the validation of the overall algorithm operated via a SON server.

```
mimoon@mimoon-desktop:~/befemto$ ./son_server
The BeFemto SON Server
Server initialized
Connection accepted (ip = 100007f)
Connection accepted (ip = 9b03000a)
Enable protection: macroRsrp = 10, femtoRsp = 10
Protecting 5 of 50 RBs. Protected capacity (based on reported CQI) = 2141 kbit/s
Protection is still needed: macroRsrp = 10, femtoRsp = 10
Protecting 4 of 50 RBs. Protected capacity (based on reported CQI) = 2864 kbit/s
Protection is still needed: macroRsrp = 10, femtoRsp = 10
Protecting 5 of 50 RBs. Protected capacity (based on reported CQI) = 3580 kbit/s
Protection is still needed: macroRsrp = 10, femtoRsp = 10
Protecting 6 of 50 RBs. Protected capacity (based on reported CQI) = 4296 kbit/s
Protection is still needed: macroRsrp = 10, femtoRsp = 10
Protecting 7 of 50 RBs. Protected capacity (based on reported CQI) = 5012 kbit/s
Protection is still needed: macroRsrp = 10, femtoRsp = 10
Protecting 8 of 50 RBs. Protected capacity (based on reported CQI) = 5728 kbit/s
Protection is still needed: macroRsrp = 10, femtoRsp = 10
Protecting 9 of 50 RBs. Protected capacity (based on reported CQI) = 6444 kbit/s
Protection is still needed: macroRsrp = 10, femtoRsp = 10
Protection is still needed: macroRsrp = 10, femtoRsp = 10
Protection is still needed: macroRsrp = 10, femtoRsp = 10
Protection is still needed: macroRsrp = 10, femtoRsp = 7
Protection is still needed: macroRsrp = 10, femtoRsp = 7
Protection is still needed: macroRsrp = 10, femtoRsp = 7
Protection is not needed anymore: macroRsrp = 13, femtoRsp = 7
Connection closed (ip = 100007f)
Connection closed (ip = 9b03000a)
```

Figure 3-28: Console SON Server output

3.5.5 Testbed 6 – Macrocell/Femtocell Coordination for the Interference Management

3.5.5.1 Final Status

Testbed 6 is also a new testbed activity which started at the beginning of year 3 (M25). Testbed 5 addresses the interference management topic for co-channel LTE macro/femto heterogeneous deployment. It mainly relates to WP2 use case 'Family 2.0" but the presence of the SON server makes straightforward adaptation to the "Femto to enterprise" use case (D2.1 [2]). Testbed 6 also implemented the WP3 "Victim User Aware Soft Frequency Reuse in Macro/Femto HetNet" algorithm (D3.2 [7]). Contrary to Testbed 5 and its SON server, a direct link is used to connect the macro to the femtocell (X2 interface). Instead of power reduction, the algorithm dynamically requests a complete muting on a part of the spectrum.

Testbed 6 is mainly made of one eNB, one HeNB, one macro UE and one femto UE in a configuration similar to Testbed 5 but with an X2 interface instead of the SON server. Figure 33-29 shows the implementation of the previous components, while Figure 33-30 represents Testbed 6 real hardware.

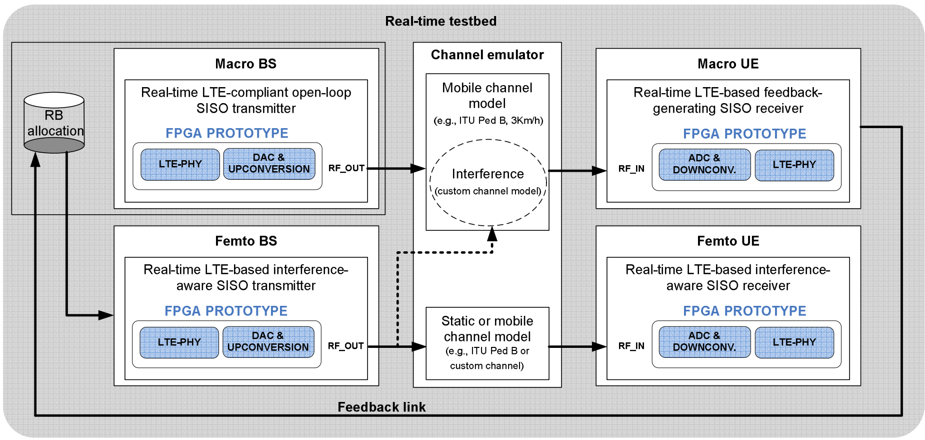


Figure 3-29: Testbed 6 scenario deployed in the GEDOMIS® testbed

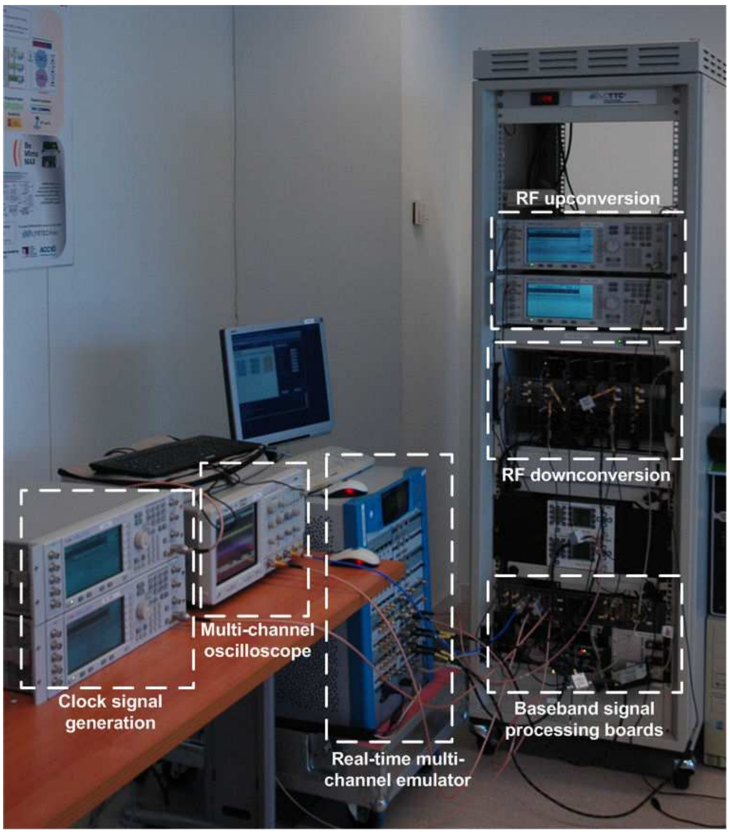


Figure 3-30: Testbed 6 hardware used to recreate the desired scenarios using the real-time multi-channel emulator

3.5.5.2 Validation Against Objective

The scenario depicted in Figure 33-31 was implemented in real-time to demonstrate the interference mitigation mechanism implemented in Testbed 6. When interfered, the macro UE sends to its serving eNB the part of the spectrum which is in bad condition. The eNB triggers an X2 message toward the HeNB for it to mute its power on the subbands leading to an improvement of the channel condition of the macro UE.

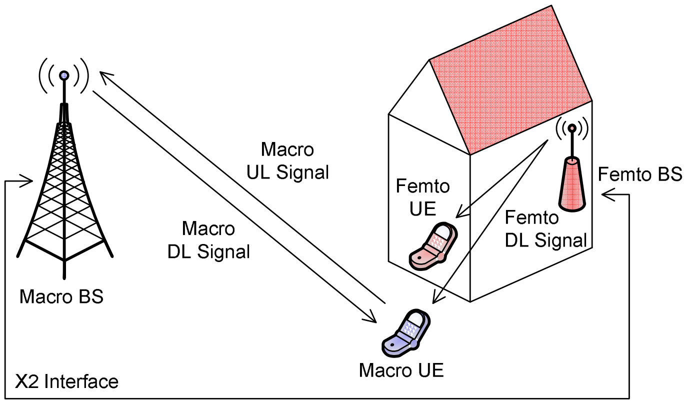
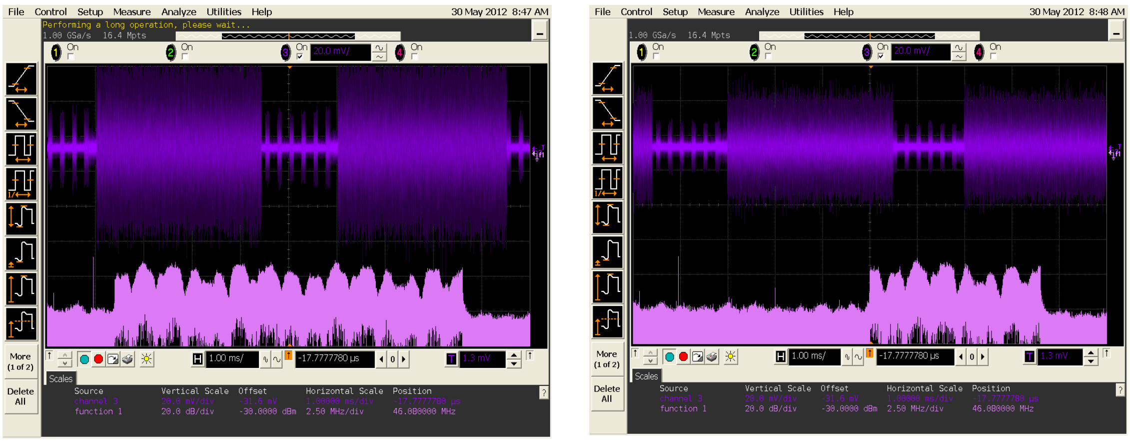


Figure 3-31: Testbed 6 Setup

Figure 33-32 shows that the interference detection module manages to locate which part of the spectrum is interfered, while



a) Femto BS signal occupying the whole 20 MHz bandwidth

b) Femto BS signal featuring a PRB allocation that only uses the last 10 MHz subband

Figure 33-33

assessed that the femtocell does respect the forbidden subbands by not transmitting power on them. Within six months, Testbed 6 fulfilled the same six objectives as the older testbeds, the final one being the validation of the overall algorithm operated through the X2 interface.

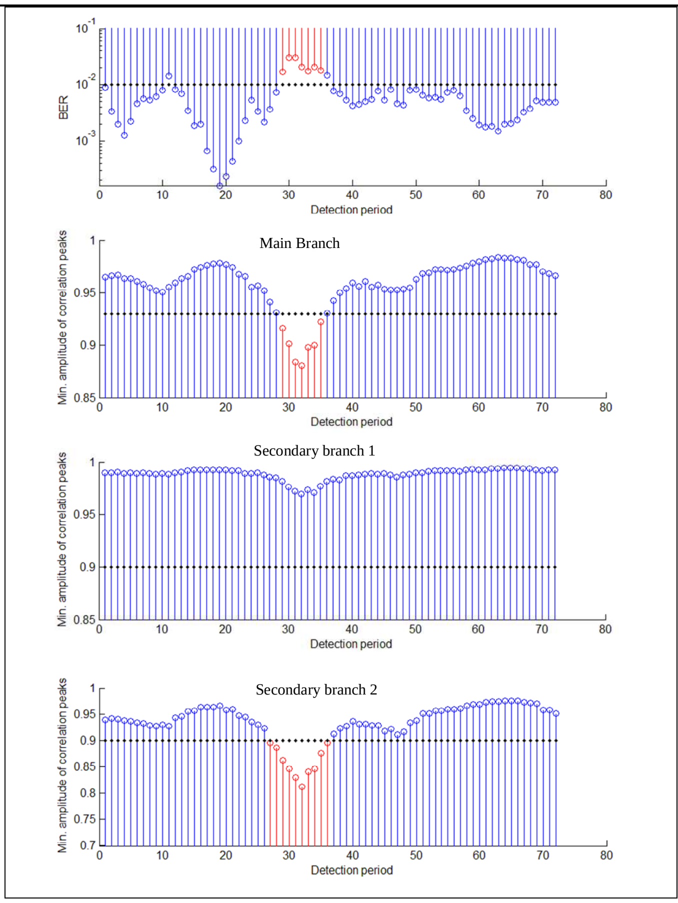
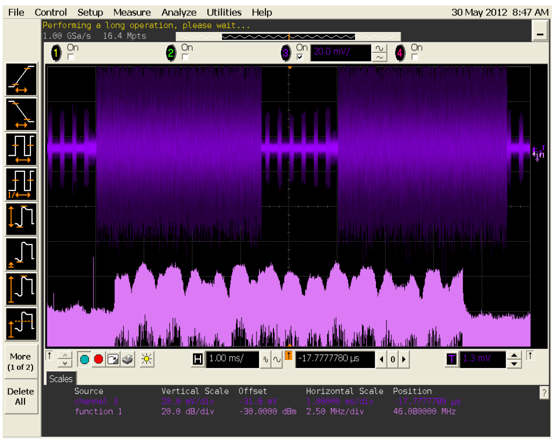
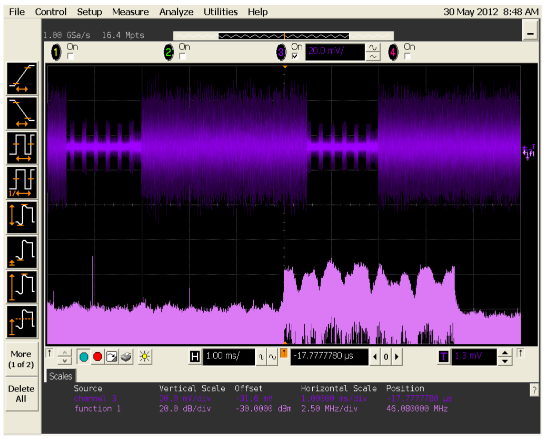


Figure 3-32: Testbed 6 illustration of the interference detection method in GEDOMIS® platform when the interference is present in the half of the bandwidth



a) Femto BS signal occupying the whole 20 MHz bandwidth



b) Femto BS signal featuring a PRB allocation that only uses the last 10 MHz subband

Figure 3-33: Testbed 6 visualization of the adaptive PRB allocation of the Macro BS, as a response to a detected interference, through a multi-channel emulator

3.5.6 WP6 Outcomes

During the last six month of the project, WP6 delivered in time its final report:

- **D6.3** [8] (M30), which presented the evaluation and performance assessment of the down-selected BeFEMTO concepts implemented into the testbeds.

At the end of the project, WP6 ended with five operational testbeds (more than originally planned), each one demonstrating some novel concepts from the BeFEMTO project in coordination with other WPs. These testbeds can be regrouped in three categories, each covering a specific area:

- **Radio Access Network (RAN) Interference Management**: Relying on LTE standard, Testbed 1 demonstrated that femto-femto interference can be controlled with frequency partitioning, while Testbed 5 and Testbed 6 enabled macro-femto co-channel deployment by managing the interference toward a the macro network through a SON server and X2 interface, respectively.
- **Local Backhaul for Networked Femtocells**: Testbed 2 addressed traffic management and load balancing within a wireless and wired network of femtocells in a distributed and centralised way, respectively. Independent from the radio access technology (3G or LTE), the concept of Local Femto Gateway (LFGW) was successfully introduced enabling a centralised finer traffic control (routing/control/breakout) while innovative routing algorithm (geographic+backpressure) was implemented in an adaptive and distributed fashion.
- **Authentication**: Testbed 3 demonstrated a simple process for a user to be authenticated thanks to a card, enabling the new services to be delivered to him through a multi radio femtocell where ever he wants.

The validation of all these testbeds and the concept they support is the main achievement of WP6.

3.6 WP7

WP7 is composed of two tasks:

- Task 7.1 Standardization and Radio Regulation
- Task 7.2 Dissemination.

The objective of Task 7.1 is to promote the participation of BeFEMTO in Standardization Development Organizations (SDOs) and Regulation organizations, through those partners that are actively involved in these organizations, and the objective of Task 7.2 is the dissemination of BeFEMTO knowledge in a wide range of dissemination channel from technical conferences and workshop until internet dissemination.

3.6.1 Task 7.1

The major achievements of Task 7.1 during the third year of the project (M24-M30) have been:

- Standardization results. In 2012 standardization results have been 2 contributions to the Small Cell Forum.
  - LIPA & SIPTO Mobility Support – Status and Plans in 3GPP
  - Wi-Fi / Smallcell Mobility for Local/Enterprise Networks
- Monitoring of the correct use of the **standardization infrastructure** by all the partners, defined in the first year of WP7 activities, composed of standardization plan, standardization register and standardization repository [10].
- **Promotion of standardization** contributions, especially during the BeFEMTO General Assemblies, and also at workpackage level, providing updated information on the standardization work items.

3.6.2 Task 7.2

The major achievements of Task 7.2 during this third year (M24-M31) are described hereafter:

- In 2012 (Year 3): **12 papers** have been contributed to first line international conferences and workshops and **5 papers to major journals**.
- Monitoring of the correct use of the **dissemination infrastructure** (similar to the standardization infrastructure in T7.1) composed with **Dissemination plan**, **Dissemination register** and **Dissemination repository [9]**. Update to the BeFEMTO partners on the organized dissemination actions, sponsorships of events (including 2 workshops, 1 training school and 1 panel session).
- Organization of **one (1) Winter School**, including **7 presentations from BeFEMTO** partners
  - **Joint BeFEMTO & Freedom Winter School (Barcelona, Spain)**: 6-10/02/2012: http://femtoschool.cttc.es/
- Organization of **3 collaborative workshops:**

  - BeFEMTO Workshop co-organized with King's College IEEE WCNC 2012 (1-4 April 2012 - Paris France), including **2 presentations from BeFEMTO** partners
  - BeFEMTO Workshop in conjunction with IEEE ICC 2012 (11/06/2012, Ottawa, Canada)
  - Second Workshop on Cooperative Heterogeneous Networks (coHetNet) in conjunction with ICCCN 2012, 30/07/2012
- Collaboration in the writing of three books chapters
- One presentation from CTTC at the LTE World Summit, 25/05/2012
- **BeFEMTO web site**: The BeFEMTO webpage (www.ict-befemto.eu) is the website for the dissemination of public project results, as public reports, along with any other relevant material, as the promotion of BeFEMTO organized events.
- BeFEMTO dissemination over Internet. A BeFEMTO interest group was been created in a social network (**LinkedIn**) and also a link to BeFEMTO was been included in the **Wikipedia**, in the terms: 4G, LTE-Advance and Femtocell, supposing a noticeable source of BEFEMTO web page visitors.

4. Project Management

Over this second project period (M13-M31), major activities of the Project Management (PM) have been to ensure gaining momentum to reach the right innovation pace whilst ensuring good quality and timely release of all deliverables (public and internal) thanks to tight cooperation and crystal clear, flexible processes.

The following activities and achievements are thus worth being mentioned whilst synthesizing efforts spent in PM:

- **Reporting Period 1Audit by EC in Brussels: 16th of March 2011**
    - Audit Preparation Meeting with PMT, hosted by TTI in Santander, Spain, on 2nd of March 2011
    - Audit Reviewers' comments: Coordination for agreed actions w.r.t requests to validate Year 1 technical work
- **Consortium Agreement (CA)**
    - Amendment #2: signature finalized, scanned version available to all partners under secured server
- **Grant Agreement (GA) Amendment #2**:
    - Grant Agreement (GA) amendment due to corporate legal changes in Sagemcom. The R&D entity carrying the RTD contribution is now part of a subsidiary, SAGEMCOM Energy & Telecom, under umbrella of the Holding SAGEMCOM coordinating the project. Proposal from EC was to introduce this subsidiary as a new partner within the project. Legal, Financial and accounting actions have been undertaken to address this issue, and make the corresponding amendment to the Grant Agreement, under guidance from EC.
    - The budget released by Sagemcom due to Accounting changes, was re-allocated to two partners, mimoOn and CTTC for additional Proof-of-Concepts investigations
    - This action was finalized in February 2012.
- **Grant Agreement (GA) Amendment #3**:
    - A new amendment (#3) was performed and finalized in June 2012.
    - This implemented mostly two (2) partners (UOULU, PTC) effort and budget re-allocation.
    - A minor 1 Month Extension (till M31), was approved by EC mainly to allow some partners to claim costs related with FuNEMS participation (in July 2012). On the other hand, it's worth being noted that NO changes regarding delivery Deadlines were never asked by the consortium.
- **Quarterly Management Reports** (QMR): five (5) QMRs have already been delivered on time to Project Officer. The sixth (6th) for Reporting Period 2, and last QMR#10 will be released by mid of July (16th) as planned. (*QMR are released maximum 1 month after end of the period to take into account Man Month indications*).
- **General Assemblies** (GA): 5 plenary meetings have been organized
    - GA#4: 6-7 April 2011, hosted by CEA in Grenoble, France,
    - GA#5: 8 – 9 Sept. 2011, hosted by NEC in Heidelberg, Germany
    - GA#6: 1-2 Dec. 2011, hosted by TID in Madrid, Spain,
    - GA#7: 20-21 March 2012, hosted by SC in Paris, France
    - GA#8: 20-21 June 2012, hosted by mimoOn in Duisburg, Germany

Some External actions have been also handled by the Project Manager in order to disseminate the outcomes of the project, together with increasing its reputation and visibility:

- Participation and presentation to **EU-Canada Future Internet Workshop**, hosted by CRC in Waterloo, Canada on 23-24th of March 2011
    - http://www.futureinternet-internetdufutur.nrc-cnrc.gc.ca/eng/index.html
    - Presentation available Online: http://iitfrdextprd01.iit.nrc.ca/FutureInternet/Archives_Future_Internet_Workshop.htm
- **Chairing of 3 International Workshops**
    - IEEE VTC spring 2011
        - 2 Keynote Speakers
            - Prof. Mérouane Debbah, Head of ALU Flexible Radio chair, Supélec, France
            - Frédéric Pujol, Head of Wireless & spectrum practice, IDATE

        - Member of the BeFEMTO's Advisory Board
    - ICT FuNEMS 2011 (jointly with FREEDOM)
        - 2 Keynote Speakers
            - Prof. Simon Saunders, Chair Femto Forum
                - Member of the BeFEMTO's Advisory Board
            - Rupert Baines, VP Marketing, Picochip
    - IEEE WCNC 2012
        - 2 Keynote Speakers
            - Dr. Holger Claussen, Alcatel-Lucent Bell Labs UK
            - Dr. Dino Flore, Qualcomm, 3GPP RAN3 Chairman
- **Femto/WiFi Panel Session:** hosted within IEEE PIMRC 2011, Toronto, Canada:
- **Keynote Speech** during the **4th International Workshop on Femtocells,** hosted by King's College, London
- **EURASIP Journal Special Issue on 'Femtocells in 4G Networks'**
    - Joint editor with Prof. Josep Vidal (Freedom PM), and Sergio Barbarossa (Freedom)

Besides the above usual organizational activities, continuous efforts are spent to elaborate an efficient, attractive and fruitful strategy thanks to tight cooperation and discussions with all Board members, WP Leaders (WPL) within the PMT, and WP7 partners.

Practical outcomes of such discussions and decisions, can be seen mostly as WP7 results, by tightening links with some industry groups (e.g. Femto Forum), other FP7 projects (e.g. workshops and Winter school with FREEDOM, summer school with EARTH), and gaining momentum in terms of focused contributions (e.g. 3GPP).

5. Produced Deliverables & Milestones

5.1 Internal/Interim Reports

Although non contractual, these Internal/Interim Reports (IR) are indeed keystone of the overall project progress status, since they represent intermediate milestones. They are also thus very useful for gaining momentum, tightening relation, strengthening cooperation among partners, whilst allowing to identify potential issues and confirm strategy and workplan.

During this 2nd Period, **seven (7) IRs** have been released, among them, **six (6) Technical IRs** have been shared with the Project Officer on a timely manner.

Del. No	Deliverable Name	WP No.	Lead Bene-ficiary	Nature	Dissem-ination level	Delivery date (Annex I)	Actual Deliv-ery date
IR4.2	Preliminary integration & optimisation of SON techniques	4	mimoOn	R	CO	M15	M15
IR6.2	Selection of Key algorithms and technologies for proof of concept testbeds	6	NEC	R	CO	M15	M15
IR2.4	First Report on System concept and its performance	2	UniS	R	CO	M18	M18
IR5.2	Preliminary femtocell access control, networking, mobility and management mechanisms	5	NEC	R	CO	M18	M18
IR6.3	Integration of selected algorithms into platforms	6	SC	R	CO	M18	M18
IR7.2	Dissemination action based on BeFEMTO international Workshop	7	SC	Event	PU	M24	M24
IR3.3	Promising Interference and Radio Management Techniques for Indoor Standalone Femtocells	3	CEA	R	PU	M24	M24

Table 5-1: Non-contractual Deliverables status: Internal Reports, Reporting Period 2 (Year 2 and Year 3)

5.2 Contractual Deliverables & Milestones

During the **Reporting Period 2 (M13 – M31)**, the **fourteen (14) contractual Deliverables** (listed below in Table 55-2) have been **produced, and released on time**.

Del. No	Deliverable Name	WP No.	Lead Bene-ficiary	Estimated Indicative Person Months	Nature	Dissem-ination level	Delivery date (Annex I)	Actual Deliv-ery date
D4.2	SON enabling techniques (final)	4	DOCOMO	60	R	PU	M21	M21
D1.3	Evaluation of progress status of the project, issue 2	1	SC	8	R	CO	M24	M24
D2.2	The BeFEMTO system architecture	2	NEC	25	R	PU	M24	M24
D3.1	RF front-end solutions	3	TTI	20	R	PU	M24	M24
D4.3	Multi-cell RRM for networked femtocells (final)	4	UOULU	100	R	PU	M24	M24
D5.2	Femtocell access control, networking, mobility and management mechanisms (final)	5	CTTC	50	R	PU	M24	M24

D6.2	Integration of selected algorithms into platforms & interfaces finalization	6	SC	80	R	PU	M24	M24
D1.4	Final project report	1	SC	5	R	PU	M30	M30
D2.3	The BeFEMTO system concept and its performance	2	DOCO MO	11,5	R	PU	M30	M30
D3.2	Interference and RRM solutions for indoor standalone femtocells	3	UNIS	88	R	PU	M30	M30
D4.4	Integrated SON techniques for femtocells radio access	4	CEA	49	R	PU	M30	M30
D5.3	Evaluation report of femtocells networking, mobility and management solutions	5	UNIS	18,62	R	PU	M30	M30
D6.3	Final proof of concepts validation, results and analysis	6	SCET	105	R	PU	M30	M30
D7.2	Final report on the standardisation and dissemination activities of the project	7	TID	29,82	R	PU	M30	M30

Table 5-2: Contractual Deliverables status, Reporting Period 2 (Year 2 and Year 3)

In parallel to Deliverables**, three (3) major Milestones** were identified within the DoW (Table 55-3), and both of them have been successfully achieved.

Miles -tone No	Milestone Name	WP(s) Invol-ved	Lead Benefi-ciary	Expe-cted Date	Achieved Yes/No	Comments
MS3	Selection of solutions for: • Proof of concepts implementation Analytical / simulation analysis	3, 4, 5, 6	UNIS	M18	YES	Down selection of promising networking, RRM and SON techniques for further analysis and proof of concepts implementation.
MS4	BeFEMTO check point against targets: • Final BeFEMTO system architecture • Detailed simulation results versus project targets of 8 b/s/Hz/Cell and 10 mW output power Integrated platforms version 1.0 ready	2, 3, 4, 5, 6	UNIS	M24	YES	Checking the progress towards project objectives and adjustment of studies accordingly. Architecture is finalised and hardware platform is ready for proof of concepts.
MS5	Final BeFEMTO solutions and results: ▪ Overall system concept ▪ Proof of concepts Validation against project objectives	2, 3, 4, 5, 6	NEC	M30	YES	This milestone leads to tangible results of the project towards achieving its stated objectives.

Table 5-3: List of Milestones, Reporting Period 2 (Year 2 and Year 3)

6. Dissemination Activities

This section summarizes the results reached by the partner's contributions to dissemination activities during the 30 months of the project duration. BeFEMTO has focused its dissemination activities in broadcasting the objectives and results of the BeFEMTO research to a wider external audience (industrial, scientific and non-scientific public) ensuring wide-spread familiarization of BeFEMTO's technologies.

6.1 Standardization & Industry Groups

This section presents the partners contributions to standardization and industry group by the project over the whole duration of the project. These 15 new contributions over Reporting Period 2 (M13-M30) have been submitted to 3GPP, Femto Forum, and ETSI. Further details can be found in [11], whilst the breakdown is given below in Table 66-1:

Standard/indusry Alliance	Group	Contributions	Total	Reporting period 1	reporting period 2
Femto Forum	LTE-SIG	3	7	5	2
	WG3	4			
3GPP	RAN-1	2	19	6	13
	RAN-3	12			
	RAN-4	1			
	SA-2	4			
ETSI	RRS	1	1	1	0
	Total	27	27	12	15

Table 6-1 Standardization contributions results

6.2 Dissemination Results

Whilst the very first period of dissemination was oriented towards setting up of tools and structures that help internal circulation of information, the cooperation amongst partners led to **fifty-nine** (**59) scientific papers** and attendance to international conferences and workshops (PIMRC, GLOBECOM, VTC, FuNEMS, WCNC, ICC, etc.), followed by the organization of **five (5) workshops** in international events (VTC 2011 in Budapest (Hungary), FuNEMs 2011 in Warsaw (Poland), WCNC 2012 in Paris (France), ICC 2012 in Ottawa (Canada) and ICCCN 2012 in Munich (Germany)), with high qualified keynote speakers from academia and industry, panel sessions and international scientific papers.

BeFEMTO academic & research partners have organized **two (2) international training schools**: one winter school hosted by CTTC in Barcelona (Spain) in collaboration with Freedom European project, and one summer school in Oulu (Finland).

Furthermore, **five (5) panel sessions** have been carried out, one of them in the PIMRC 2011 conference in Toronto (Canada) and the other ones during the international workshops organized by BeFEMTO.

Other channels of dissemination included in the project dissemination activities are presentations at events (including the Concertation process), internal meetings, the project website and internet links (**wikipedia**, BeFEMTO linkedin group, BeFEMTO YouTube channel, etc.) and the edition of **two (2) books** related to the investigations carried-out within BeFEMTO, which are foreseen in the first half of 2013 (1 book with Wiley, 1 book with Cambridge University Press).

Dissemination item		Result	Target
Standard/industry alliance Contributions	3GPP	19	
	Femto Forum	7	
	ETSI	1	
Scientific papers (Conferences, …)		59	
Journal articles		10	
Special issues (Editing)		2	
Organized Workshops		5	2
Training Schools		2	1
Panel Sessions		5	1
Presentations at events		23	
YouTube Channel	Videos	23	
	Views	10772	
Linkedin followers		222	
Books proposals		2	1
Books contributions		4	
Website visitors		13085	
Deliverables downloaded		215	

Table 6-2 Global Dissemination results of BeFEMTO (RP1+RP2)

Dissemination Results per period		RP1 2010	RP2 2011+2012	TOTAL
Standard/industry alliance Contributions	3GPP	6	13	19
	Femto Forum	5	2	7
	ETSI	1	0	1
Scientific papers (Conferences, …)		14	45	59
Journal articles		3	7	10
Special issues (Editing)		0	2	2
Organized Workshops		0	5	5
Training Schools		0	2	2
Panel Sessions		0	5	5
Presentations at events		5	18	23
YouTube Channel	Videos	0	23	23
	Views	0	10772	10772
Linkedin followers			222	222
Books proposals		0	2	2
Books contributions		0	4	4
Website visitors		3144	9941	13085
Public Deliverables and IR downloaded		19	196	215

Table 6-3 Dissemination results of BeFEMTO (per Reporting Period)

6.3 Patents filed

- mimoOn : 12 European Patents were filed in relation with the activities supported by BeFEMTO :

EP10015260
EP11002420
EP11000396
EP10016211
EP11006027
EP11006615
EP11006614
EP11005254
EP11010274
EP12000599
EP11010235

- Sagemcom: 1 patent was filed during the 2nd Reporting Period

7. Conclusions

Over this second Reporting Period (M13-M31), the BeFEMTO consortium has managed to achieve all its objectives, as agreed by Annex-I of the Grant Agreement, by releasing on a timely manner, and with quality control, ,**fourteen (14) Deliverables** as a whole, and **seven (7) Deliverables** (6 public, 1 confidential) during the 3rd year (M25-M31).

In parallel, up to **seven (7) confidential Internal/Interim Reports (IRs)** were also produced during this period, and the **technical ones (6)** were delivered to the commission..

Furthermore, thanks to both a very detailed **Standardization** plan, and commitment from leading industry partners, the BeFEMTO project has already demonstrated its growing influence and impact towards **SDO**s (3GPP) and **Industry Groups** (Femto Forum) by submitting and presenting over this 2nd Reporting Period a total of **15 contributions** (standalone Local Femto Gateway, LTE eNB API definition, HetNet ICIC, Energy Saving, interference among Close Subscriber Group HeNBs, etc). As a whole, during these 2.5 years, BeFEMTO has submitted **27** contributions.

Regarding **Dissemination**, over the second period, the consortium has presented/published **45 papers** with results of the BeFEMTO research at a number of prestigious international **conferences and workshops**, such as **FuNEMS, IEEE VTC, IEEE GLOBECOM.** This gives a total of **59** publications to conferences over the whole 2.5 years.

The BeFEMTO project has also published **7 articles in international journals** and magazines and has attended several events where the project goals and scientific knowledge have been presented. As a whole, this leads to **10** journal publications over the whole lifetime of the project.

The organization of **5 international workshops** has been carried out. These workshops included paper presentations, talks by renowned international keynote speakers and panel discussions on evolved femtocell technologies with high interest to both scientific and industry communities.

Last but not least, **2 international training events** have been organized, a **Summer School** jointly with FP7 EARTH project, and a **Winter School** jointly with FP7 FREEDOM.

Finally, the overall outcomes and achievements of the BeFEMTO project during this second reporting period, demonstrate true interest, commitment and cooperation from partners, with a growing visibility, influence and impact among the whole ecosystem thanks to active contributions, and lively participations to SDOs, industry groups that are shaping the future of the related technologies.

The good amount and quality of papers, articles already disseminated are now paving the way to an increased visibility within the researchers' arena, and it is thus believed these achievements demonstrate the European Leadership in the Femtocell/Small Cell Market (e.g. **13 patents** claimed in BeFEMTO).

8. References

[1] BeFEMTO D1.3, "Year 2 - Status Report (Confidential)", ICT 248523 FP7 BeFEMTO project, December 2011

[2] BeFEMTO D2.1, "Description of baseline reference systems, use cases, requirements, evaluation and impact on business model", ICT 248523 FP7 BeFEMTO project, December 2010

[3] BeFEMTO D4.3, "Multi-cell RRM and self-optimisation for networked, fixed relay and mobile femtocells", ICT 248523 FP7 BeFEMTO project, December. 2011

[4] BeFEMTO D5.1, "Femtocell access control, networking, mobility, and management concepts", ICT 248523 FP7 BeFEMTO project, December 2010

[5] BeFEMTO D5.2, "Femtocells Access Control, Networking, Mobility, and Management mechanisms", ICT 248523 FP7 BeFEMTO project, December 2011

[6] BeFEMTO D5.3, "Evaluation report of femtocells networking, mobility and management solutions", ICT 248523 FP7 BeFEMTO project, June 2012

[7] BeFEMTO D3.2, "Promising Interference and Radio Management Techniques for Indoor Standalone Femtocells", ICT 248523 FP7 BeFEMTO project, June 2012

[8] BeFEMTO D6.3, "Final proof of concepts validation, results and analysis", ICT 248523 FP7 BeFEMTO project, June 2012

[9] [Online] Standardization registers in the BSCW folder: http://bscw.ict-befemto.eu/bscw/bscw.cgi/3151

[10] [Online] Standardization registers in the BSCW folder: http://bscw.ict-BeFEMTO.eu/bscw/bscw.cgi/3146

[11] BeFEMTO D7.2, "Final report on the standardization and dissemination activities of the project", ICT 248523 FP7 BeFEMTO project, June 2012