NEWCOM#
Network of Excellence in Wireless Communications#

FP7 Contract Number: 318306

WP2.2 – Networking technologies for the Internet of Things (IoT) with mobile clouds

D22.2
Preliminary tests over the lab infrastructures

<table>
<thead>
<tr>
<th>Contractual Delivery Date:</th>
<th>October 31, 2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Delivery Date:</td>
<td>November 16, 2013</td>
</tr>
<tr>
<td>Responsible Beneficiary:</td>
<td>CNIT/UniBo</td>
</tr>
<tr>
<td>Contributing Beneficiaries:</td>
<td>Bilkent, CNIT/UniBo, CTTC, CNRS/Eurecom, SUPELEC, UPC</td>
</tr>
<tr>
<td>Estimated Person Months:</td>
<td>10</td>
</tr>
<tr>
<td>Dissemination Level:</td>
<td>Public</td>
</tr>
<tr>
<td>Nature:</td>
<td>Report</td>
</tr>
<tr>
<td>Version:</td>
<td>1.0</td>
</tr>
</tbody>
</table>
Abstract: This document illustrates the development of the EuWIN@CNIT-BO site platforms set up and the first tests performed on them. The JRAs, consolidated during the Track 2 meeting in Bologna, are also described in addition to the planned activity for the second year.

Keywords: EuWin, Laboratory description, Experimental research, CNIT-BO site, Internet of Things, Smart City, Delay Tolerant Networks, Routing.

Authors

IMPORTANT: The information in the following two tables will be directly used for the MPA (Monitoring Partner Activity) procedure. Upon finalisation of the deliverable, please, ensure it is accurate. Use multiple pages if needed. Besides, please, adhere to the following rules:

- Beneficiary/Organisation: For multi-party beneficiaries (CNIT) and beneficiaries with Third Parties (CNRS and CTTC), please, indicate beneficiary and organisation (e.g., CNIT/Pisa, CNRS/Supelec).
- Role: Please, specify: Overall Editor / Section Editor / Contributor.

<table>
<thead>
<tr>
<th>Full Name</th>
<th>Beneficiary / Organisation</th>
<th>e-mail</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Davide Dardari</td>
<td>CNIT/Bologna</td>
<td><a href="mailto:davide.dardari@unibo.it">davide.dardari@unibo.it</a></td>
<td>WP 2.2 Leader</td>
</tr>
<tr>
<td>Roberto Verdone</td>
<td>CNIT/Bologna</td>
<td><a href="mailto:roberto.verdone@unibo.it">roberto.verdone@unibo.it</a></td>
<td>EuWin Director</td>
</tr>
<tr>
<td>Melchiorre Danilo Abrignani</td>
<td>CNIT/Bologna</td>
<td><a href="mailto:danilo.abrignani@unibo.it">danilo.abrignani@unibo.it</a></td>
<td>Task 2.2.1 Leader</td>
</tr>
<tr>
<td>Chiara Buratti</td>
<td>CNIT/Bologna</td>
<td><a href="mailto:c.buratti@unibo.it">c.buratti@unibo.it</a></td>
<td>Task 2.2.2 Leader</td>
</tr>
<tr>
<td>Andrea Stajkic</td>
<td>CNIT/Bologna</td>
<td><a href="mailto:andrea.stajkic@unibo.it">andrea.stajkic@unibo.it</a></td>
<td>Software developer</td>
</tr>
<tr>
<td>Flavia Martelli</td>
<td>CNIT/Bologna</td>
<td><a href="mailto:flavia.martelli@unibo.it">flavia.martelli@unibo.it</a></td>
<td>Software developer</td>
</tr>
<tr>
<td>Florian Kaltenberger</td>
<td>CNRS/Eurecom</td>
<td><a href="mailto:Florian.kaltenberger@eurecom.fr">Florian.kaltenberger@eurecom.fr</a></td>
<td>Contributor</td>
</tr>
<tr>
<td>Miquel Payaro</td>
<td>CTTC</td>
<td><a href="mailto:miquel.payaro@cttc.es">miquel.payaro@cttc.es</a></td>
<td>Contributor</td>
</tr>
<tr>
<td>Sinan Gezici</td>
<td>BILKENT</td>
<td><a href="mailto:gezici@ee.bilkent.edu.tr">gezici@ee.bilkent.edu.tr</a></td>
<td>Contributor</td>
</tr>
<tr>
<td>Anna Umbert</td>
<td>UPC</td>
<td><a href="mailto:annau@tsc.upc.edu">annau@tsc.upc.edu</a></td>
<td>Contributor</td>
</tr>
<tr>
<td>J. Pérez-Romero</td>
<td>UPC</td>
<td><a href="mailto:jorperez@tsc.upc.edu">jorperez@tsc.upc.edu</a></td>
<td>Contributor</td>
</tr>
<tr>
<td>Vincenzo Zambianchi</td>
<td>CNIT/Bologna</td>
<td><a href="mailto:vincenzo.zambianchi@unibo.it">vincenzo.zambianchi@unibo.it</a></td>
<td>Contributor</td>
</tr>
<tr>
<td>Francesca Bassi</td>
<td>CNRS/SUPELEC</td>
<td><a href="mailto:francesca.bassi@lss.supelec.fr">francesca.bassi@lss.supelec.fr</a></td>
<td>Contributor</td>
</tr>
<tr>
<td>Michel Kieffer</td>
<td>CNRS/SUPELEC</td>
<td><a href="mailto:kieffer@lss.supelec.fr">kieffer@lss.supelec.fr</a></td>
<td>Contributor</td>
</tr>
<tr>
<td>Gianni Pasolini</td>
<td>CNIT/Bologna</td>
<td><a href="mailto:gianni.pasolini@unibo.it">gianni.pasolini@unibo.it</a></td>
<td>Contributor</td>
</tr>
<tr>
<td>Carles Fernandez</td>
<td>CTTC</td>
<td><a href="mailto:carles.fernandez@cttc.es">carles.fernandez@cttc.es</a></td>
<td>Contributor</td>
</tr>
<tr>
<td>Pau Closas</td>
<td>CTTC</td>
<td><a href="mailto:pau.closas@cttc.cat">pau.closas@cttc.cat</a></td>
<td>Contributor</td>
</tr>
</tbody>
</table>
### Reviewers

<table>
<thead>
<tr>
<th>Full Name</th>
<th>Beneficiary / Organisation</th>
<th>e-mail</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roberto Verdone</td>
<td>CNIT/UniBO</td>
<td><a href="mailto:roberto.verdone@unibo.it">roberto.verdone@unibo.it</a></td>
<td>October 16, 2013</td>
</tr>
<tr>
<td>Marco Luise</td>
<td>CNIT</td>
<td><a href="mailto:marco.luise@cnit.it">marco.luise@cnit.it</a></td>
<td>October 29, 2013</td>
</tr>
</tbody>
</table>

### Version history

<table>
<thead>
<tr>
<th>Issue</th>
<th>Date of Issue</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>July 1, 2013</td>
<td>TOC definition – D. Dardari</td>
</tr>
<tr>
<td>0.2</td>
<td>August 25, 2013</td>
<td>Contribution from partners</td>
</tr>
<tr>
<td>0.3</td>
<td>September 5, 2013</td>
<td>First editing step – C. Buratti – D. Dardari</td>
</tr>
<tr>
<td>0.4</td>
<td>September 18, 2013</td>
<td>Contribution from partners</td>
</tr>
<tr>
<td>0.5</td>
<td>September 20, 2013</td>
<td>Editing – D. Dardari</td>
</tr>
<tr>
<td>0.6</td>
<td>September 28, 2013</td>
<td>Contribution - R. Verdone</td>
</tr>
<tr>
<td>0.9</td>
<td>September 30, 2013</td>
<td>Final version for internal review – D. Dardari</td>
</tr>
<tr>
<td>1.0</td>
<td>October 29, 2013</td>
<td>Included reviewers’ comments – D. Dardari</td>
</tr>
</tbody>
</table>
Executive Summary

The document describes the activities performed within WP2.2 after M6. The last 6 months have been dedicated to the finalization of the EUWin@CNIT-BO platforms and their functional validation. In particular, some preliminary tests have been done, with a down-scaled testbed developed using FLEXTOP, in order to compare the results with those obtained in a smart city real test bed deployed in a small town of Italy. Preliminary tests on external facilities offered by other partners are described as well. The EuWIn facilities have been officially presented during the inaugural event held in Bologna on July 8, reported in this Deliverable.

The Track 2 meeting took also place in Bologna, on July 9-10; it has been a precious occasion to refine the preliminary JRAs, defined at the beginning of the project, and add new ones, according to the actual platforms capabilities. All such JRAs are described in this document.

The activities planned for the second year are finally illustrated at the end of the Deliverable.
Table of Contents

1. Introduction ............................................................................................................. 7
   1.1 Glossary ............................................................................................................. 8

2. EuWin Activities .................................................................................................... 10
   2.1 Introduction ..................................................................................................... 10
   2.2 EuWin Inauguration Event .............................................................................. 10
   2.3 Emerging Topics Workshop ........................................................................... 14
   2.4 Track 2 meeting .............................................................................................. 14
   2.5 Co-Organization of Training Schools ............................................................. 15
   2.6 Industry Liaisons ............................................................................................. 15
   2.7 Demonstration Activities ............................................................................... 15
   2.8 Experimental Tours ......................................................................................... 15
   2.9 The EuWin Website ......................................................................................... 15

3. Preliminary testing of the EuWin facilities at CNIT/Bologna and other testbed sites ......................................................................................................................... 16
   3.1 Flexible Topology Testbed (FLEXTOP) ........................................................... 16
      3.1.1 Post-deployment test .................................................................................. 17
      3.1.2 Benchmarking of NS-2 Simulations ............................................................. 22
   3.2 Data Sensing and Processing Testbed (DATASENS) ........................................ 24
   3.3 Preliminary Tests on UWB facilities .................................................................. 25
      3.3.1 Breath Detection Tests using UWB Wireless Sensor Radar ....................... 25
      3.3.2 Preliminary Tests on UWB Radar Equipment for Passive Localization .... 30
      3.3.3 Preliminary Tests on UWB Instrumentation for Active Localization ......... 32
   3.4 Preliminary Tests on Software Radio HW for Dynamic Spectrum Selection .. 34
      3.4.1 Hardware component: basic building block ................................................. 34
      3.4.2 Software Component ............................................................................... 35
      3.4.3 Platform architecture ............................................................................... 36
      3.4.4 Signalling procedures .............................................................................. 37
      3.4.5 Example Tests .......................................................................................... 39

4. Joint Research Activities ......................................................................................... 45
   4.1 Task 2.2.2 ....................................................................................................... 45
      4.1.1 JRA#1 (Joint WP21/WP22) “Design and experimental validation of algorithms for active and passive indoor positioning” .................................................. 45
      4.1.2 JRA#3 “Experimental activity on data sensing and fusion” ......................... 48
      4.1.3 JRA#4 "Reducing Traffic Congestion in Wireless Mesh Networks" .......... 50
      4.1.4 JRA#6 "Testing IP-based Wireless Sensor Networks for the Internet of Things" 53
   4.2 Task 2.2.3 ....................................................................................................... 55
      4.2.1 JRA#5 "Socially-aware protocols for wireless mesh networks" .................. 55
      4.2.2 Potential future JRA on "Spectrum selection in opportunistic networks" .... 56

5. Plans of Activities for Year 2 .................................................................................. 58
   5.1 Introduction ..................................................................................................... 58
   5.2 Plans of Activities ............................................................................................ 58

6. Conclusions ............................................................................................................. 61
1. Introduction

The activity carried out between M6 and M12 in WP22 is described in this report. Most of the effort has been devoted to the final set up and test of the platforms available at the EuWIn lab at the Bologna site. Specific test results have been compared with those obtained from simulations and real world scenarios with the purpose to validate the theoretical research using experimental measurements. Some of WP22-related activities have been performed in external affiliate laboratories at the University of Bologna as well as at partners’ premises, thus enriching the availability of experimental platforms and opportunities for the researchers involved in WP22.

The inaugural event of EuWIn took place in Bologna on July 8. It was a successful event attended by 65 people, out of which more than half not involved in Newcom#.

The Track 2 workshop, held in Bologna on July 9-10 at EuWIn@CNIT-BO, represented an important occasion for refining the JRAs already defined during the first 6 months and to introduce new ones. Both the inauguration and the Track2 meetings are described in this document.

Finally, the Deliverable includes the description of the activities planned within EuWIn for the second year; they have been agreed after many interactions between the EuWIn Director and the WP2.x Leaders.

The Sections 2 and 5 of this Deliverable are thus common to the respective sections of WP2.1, WP2.2, and WP2.3 documents delivered at the same date.
1.1 Glossary

AD – analog/digital
ADC – analog/digital converter
AODV - ad hoc on demand distance vector
API - application programming interface
CMS - cognitive management system
CPU – central processing unit
DA – digital/analog
DAC – digital/analog converter
EIRP - effective isotropic radiated power
FCC - Federal Communication Commission
FPGA - field programmable gate array
GLRT - generalized likelihood ratio test
GMSK – Gaussian minimum-shift keying
GNSS - global navigation satellite system
GPL - general public license
GUI – graphical user interface
HAL – hardware abstraction layer
IoT – Internet of things
IP – Internet protocol
ISM – industrial, scientific, medical
JRA – joint research activity
LAMP - Linux Apache MySQL PHP
LEO - localization error outage
LQI – link quality indicator
MAC – medium access control
MIH - media-independent handover
ML – maximum likelihood
MRM - monostatic radar module
MSE – mean square error
MTI - moving target indicator
NLOS - not line-of-sight
NS – network simulator
ON – opportunistic networks
OTA - over-the-air
pdf – probability density function
PHY – physical layer
POMDP - partially observable Markov decision process
PRF - pulse repetition frequency
PRP – pulse repetition period
QoS – quality of service
RAN – radio access network
RF – radio frequency
RMSE - root mean square error
RREP – route reply
RREQ – route request
RSS – received signal strength
SDR – software defined radio
SDWN - software defined wireless network
SLAM - simultaneous location and mapping
SOI - spectrum opportunity identification
SPI – serial port interface
SWIG - simplified wrapper and interface generator
TOA – time-of-arrival
TW-TOA - two-way-TOA
USB – universal serial bus
USRP - universal software radio peripherals
UWB – ultra-wide bandwidth
VPN – virtual private network
ZZLB - Ziv-Zakai lower bound
2. EuWIn Activities

This Section describes the activities carried out in the first year of project.

2.1 Introduction

According to the DoW, the first six months of activity within Track2 of Newcom# have been dedicated to the laboratory set-up. The outcome of such activity has been described in the three Deliverables released at M6, i.e. on April 2013. After that date, EuWIn started organizing the inaugural event, held in Bologna on July 8-10, 2013, whose structure and attendance is described below. During those days, Track2 also organised an emerging topic workshop and a project meeting where the plan for future activities was discussed and many JRAs defined. Industry liaisons have been created, both during the days of the inaugural event in Bologna (participated by several industries) and on June 7 when the first Newcom# dissemination event at the premises of an industry was held, at Issy-Les-Moulineaux, France, in Orange Labs. The set of activities carried out during the six months after April 2013 is described in this Section.

2.2 EuWIn Inauguration Event

The Track2 of Newcom# organized in Bologna, on July 8--10, 2013, at the premises of the School of Engineering, a meeting composed of three events:

- the official inauguration of the EuWIn laboratory (Opening Ceremony),
- an Emerging Topic Workshop dedicated to the theme of experimental research,
- a Track2 internal meeting.

The event was participated overall by 65 people (including students, researchers, hosts from industries and other EC projects). About 60% were not involved in Newcom#.

The Opening Ceremony was open to the public and included a small exhibition where both research labs and local industries showed their products/projects. Pictures of the exhibition are included below. The official inauguration was chaired by Prof. Verdone, EuWIn Director, and included a speech from Dr J. Bacquet, EC, DG CONNECT, who reported on the future activities within Horizon2020 in terms of experimental research. In particular, he reported on the general scopes of FIRE+, the successor of FIRE in Horizon2020, and discussion followed on the possible submission of project proposals by EuWIn.

The Opening Ceremony was recorded by a professional video company, with the goal of producing two trailers to be used afterwards for dissemination purposes: a short one (about one minute) and a longer one (about ten minutes) to be used during talks and at exhibitions/fairs, respectively. Their finalization are still underway at the date of delivery of this document, and are expected by November 2013.
The list of institutions who participated to the overall event is reported below (an institution is listed if at least one representative was attending the meeting); industries, as well as non-Newcom# institutions, are highlighted in the list:

<table>
<thead>
<tr>
<th>Institution</th>
<th>Country</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>CNIT@University of Bologna, Italy</td>
<td>Italy</td>
<td></td>
</tr>
<tr>
<td>EG, DG CONNECT, Belgium</td>
<td>Belgium</td>
<td></td>
</tr>
<tr>
<td>CN2S, France</td>
<td>France</td>
<td></td>
</tr>
<tr>
<td>Laboratoire SATIE, France</td>
<td>France</td>
<td>(industry)</td>
</tr>
<tr>
<td>Supelec, France</td>
<td>France</td>
<td></td>
</tr>
<tr>
<td>Huawei, Germany</td>
<td>Germany</td>
<td>(industry)</td>
</tr>
<tr>
<td>CNIT@Politecnico di Torino, Italy</td>
<td>Italy</td>
<td></td>
</tr>
<tr>
<td>IASA, Greece</td>
<td>Greece</td>
<td></td>
</tr>
<tr>
<td>Telecom Italia, Italy</td>
<td>Italy</td>
<td>(industry)</td>
</tr>
<tr>
<td>CTTC, Spain</td>
<td>Spain</td>
<td></td>
</tr>
<tr>
<td>EURECOM, France</td>
<td>France</td>
<td></td>
</tr>
<tr>
<td>Poznan University of Technology, Poland</td>
<td>Poland</td>
<td></td>
</tr>
<tr>
<td>CNIT@University of Catania, Italy</td>
<td>Italy</td>
<td></td>
</tr>
<tr>
<td>University of Cantabria, Spain</td>
<td>Spain</td>
<td>(non Newcom#)</td>
</tr>
<tr>
<td>UPC, Spain</td>
<td>Spain</td>
<td></td>
</tr>
<tr>
<td>UCLouvain, Belgium</td>
<td>Belgium</td>
<td></td>
</tr>
<tr>
<td>Thales Group, France</td>
<td>France</td>
<td>(industry)</td>
</tr>
<tr>
<td>Telecom ParisTech, France</td>
<td>France</td>
<td>(non Newcom#)</td>
</tr>
<tr>
<td>TU Dresden, Germany</td>
<td>Germany</td>
<td></td>
</tr>
<tr>
<td>MIT, US</td>
<td>US</td>
<td>(non Newcom#)</td>
</tr>
<tr>
<td>CNIT@University of Pisa, Italy</td>
<td>Italy</td>
<td></td>
</tr>
<tr>
<td>CNIT@University of Parma, Italy</td>
<td>Italy</td>
<td>(non Newcom#)</td>
</tr>
<tr>
<td>Datalogic, Italy</td>
<td>Italy</td>
<td>(industry)</td>
</tr>
<tr>
<td>Embit, Italy</td>
<td>Italy</td>
<td>(industry)</td>
</tr>
</tbody>
</table>

*Figure 2-1: Picture taken during the Opening Ceremony*
Figure 2-1 and Figure 2-2 show pictures taken during the inauguration. The overall program of the three-day event is reported below.

July 8
9h00 – 14h30 Demo stands by: Embit, Small, Datalogic, RadioNetworks, WILab, Eurecom

Opening Ceremony

11h00 R. Verdone, UniBo Welcome
11h10 R. Verdone, UniBo EuWin: Organization and Scope
11h20 J. Bacquet, EC, DG CONNECT The Role of Experimental Research in Horizon2020
12h00 M. Payaro, CTTC EuWin@CTTC
12h20 D. Dardari, UniBo EuWin@UniBo
12h40 R. Knopp, Eurecom EuWin@Eurecom
13h00 LUNCH

Emerging Topic Workshop: “Experimental Research for the Future Internet”

14h30 R. De Bonis, Telecom Italia Wireless Comm. for Smart City Applications: From Theory to Practice
15h00 J. Peron, Thales C&S Experimental Activities in TCS: Past Results and Future Perspectives
15h30 S. Beker, Huawei Resource and Function Orchestration and Federation in Future Networks
16h00 BREAK
16h30 L. Navarro, UPC Community-Lab: a Community Networking Testbed
17h00 L. Munoz, UniCanabria SmartSanterde: An Internet of Things Experimentation and Innovation Platform in the Context of the City
17h30 A. Sibille, Telecom ParisTech The Backscattering Channel in an UWB RFID System of Tags and Readers

July 9
09h00 C. Buratti, UniBo From Smart Lighting to Smart City: Lessons Learnt from a City Test Bed
09h20 G. Pasolini, UniBo Building a Smarter Future: the WILAB Experience
09h40 F. Dovis, Polito Receivers Study of Anti-Jamming and Anti-Spoofing Techniques for Satellite Navigation

Security: Public
10h00  C. Fernandez, CTTC  Experimental Activities With GNSS-SDR
10h20  BREAK
11h00  C. Oestges, UCL  Multi-Dimensional Channel Sounding: Methods, Challenges and Recent Results
11h20  M. Payaro, CTTC  Recent Experimental Activities With the GEDOMIS® Demonstrator
11h40  F. Kaltenberger, Eurecom  Lessons Learnt From the OpenAirInterface
12h00  P. Giaccone, PolITO  Investigating the Efficiency of D2D Comm. Through the WiFi Direct Platform
12h20  LUNCH

July 9-10

Track2 meeting (ending on July 10, 2 pm)
2.3 Emerging Topics Workshop

The first Newcom# Emerging Topic Workshop (ETW) was dedicated to the theme that represents the motto of EuWIn: “Fundamental Research Through Experimentation”. It was held in Bologna, at the premises of the EUWIn site, on July 8-9, as shown in the program reported above. The TPC of the workshop included the three Track #2 WP Leaders, the EuWIn Director and Dr. Florian Kaltenberger of EURECOM. The workshop intended to group together separate experiences carried out in Europe, showing how experimental testbeds can be useful to fundamental research and the development of new techniques/protocols. The final programme has been posted on the EuWIn website under “EVENTS”.

The Emerging Topic Workshop included four sessions. During the first one, speeches from industry representatives were given (Thales, Huawei, Telecom Italia). In the second session presentations were given by representatives of other EC projects with experimental results discussed. The last two sessions included talks given by Newcom# researchers on experimental platforms and activities carried out prior to the EuWIn inauguration. The Workshop was attended by 65 people and the feedback received by the non-Newcom# participants was very positive. The opportunity to hold a similar workshop yearly was discussed.

2.4 Track 2 meeting

The internal Track2 event held on July 9-10 in Bologna after the Newcom# Emerging Topic Workshop was managed by the three EuWIn WP Leaders and was mainly devoted to the coordination of the many joint research activities defined within Track #2. This part of the meeting was only open to Newcom# researchers and attended by about 40 people (see Fig. 2-3).

Figure 2-3: Pictures taken during the event: Emerging Topic Workshop & Track2 Meeting
2.5 Co-Organization of Training Schools

The first Newcom# Training School, organized by WP3.2, has been dedicated to the topic of interference management. It was held in May 28-31, 2013 in Sophia-Antipolis at the premises of the EuWIn site of EURECOM. One of the four days of the school was organized by WP2.1, WP2.2 and WP2.3, and has been dedicated to experimental activities, involving the facilities of EURECOM and CTTC. The program is available in the EURACON website www.euracon.org (EURACON is the association in charge of administration, logistics and publicity of the School). The school was participated by about 50 participants.

2.6 Industry Liaisons

On June 17, 2013 Newcom# visited the Orange Labs at Issy-Les-Moulineaux, in France. The three EuWIn sites presented their facilities in that context. In particular, they were represented by Miquel Payaro of CTTC, Raymond Knopp of Eurecom, Roberto Verdone and Andrea Stajkic of CNIT-UniBo. The latter institution presented a poster and a demo, while the demo prepared by Raymond Knopp could not be presented for logistic reasons (owing to a storm on the city, the plane carrying the material could not land on time). The presentations of the three EuWIn sites were given in front of about ten researchers from Orange Labs and an interesting discussion followed.

2.7 Demonstration Activities

No activities have been performed in this respect in the past six months. This is basically related to the summer period (EuWIn was inaugurated in July). Concerning the plans for future demonstrations/exhibits, see section 5 of this Deliverable.

2.8 Experimental Tours

No activities have been performed in this respect in the past six months. The experimental tours require a level of interaction among the three sites that make them planned for the second year of Newcom# activities.

2.9 The EuWIn Website

The EuWIn website has been kept continuously updated by CNIT. A separate Deliverable updates on the status of the website.
3. Preliminary testing of the EuWin facilities at CNIT/Bologna and other testbed sites

The technical facilities made available at the University of Bologna research unit of CNIT, are described below overall. Three testbeds will be available: FLEXTOP, DATASENS and LOCTEST. However, the third platform will be developed at a later stage, as the SW/HW components needed for its deployment are still not available from the manufacturer side. Financial resources for its purchase are already available. Although the main EuWin site is located at the CNIT - University of Bologna -, for its use especially in WSNs and positioning experimentations, facilities made available by partners participating to intra- and inter-WP JRAs are being “federated” under the same hat of common research themes (lab of labs), as will be described in the following sections. These facilities will be useful to complement the JRA within EuWin at UniBo as well as to enforce the synergies among EuWin laboratories.

![Figure 3-1: The EuWin@UniBO site platforms](image)

3.1 Flexible Topology Testbed (FLEXTOP)

The FLEXTOP platform is composed of 100 nodes equipped with IEEE 802.15.4 radios distributed inside the Telecommunication Laboratory at the University of Bologna, as shown in Figure 3-2. Devices are located in fixed positions within some message boards on the walls (see Figure 3-3), creating a regular layout. Different network topologies may be realised, through proper software setting of nodes’ characteristics such as the transmit power and the receiver sensitivity, and through switching on only part of the available nodes.

This platform is based on over-the-air (OTA) implementation of software, meaning that NEWCOM# partners will have remote access to the platform and may upload their own software.

The main objectives of the platform are:
1. Testing of separate protocol stacks in realistic settings, and their performance comparison under a certified environment, with known propagation conditions
2. Performing pre- and post- deployment tests, i.e. industries developing IoT or smart city applications
3. Benchmark for those research groups developing 802.15.4 network simulators
4. Performance indicator for specific algorithm implementations w.r.t. mathematical models.
We refer to [1] for an exhaustive description of FLEXTOP. Two JRAs will exploit the FLEXTOP facility, in particular, JRA#4 and JRA#6, described in section 4. However, apart from the JRAs, other activities will be performed on FLEXTOP, with reference to the objectives stated above. In the following some preliminary results, achieved though tests on the platform and related to objectives number two and three, will be presented.

![Figure 3-2: The FLEXTOP Map](image)

![Figure 3-3: FLEXTOP devices location at UniBO](image)

### 3.1.1 Post-deployment test

As stated above, one of the objectives of FLEXTOP is to perform pre- and post-deployment tests, mainly with reference to testbeds developing IoT or smart city applications. To this aim some preliminary tests have been done at UniBO, in order to compare a smart city real testbed, deployed in the small town of Casalgrande (Italy), with a down-scaled testbed developed using FLEXTOP. The development of a testbed deployed into a laboratory, that is in a stable and controllable environment, precisely reproducing a real testbed deployed outdoor, may drastically reduce the costs of the testing and parameter tuning phases in the real deployment. Results shown in this paragraph demonstrate that EuWln, and FLEXTOP in particular, is a useful tool with reference to the above mentioned objective. For this reason, in the case of
industrial projects (e.g., liaison with industrial partners) EuWIn could be a useful tool to reduce the time-to-market.

The real testbed runs a smart city application, with the aim of developing a smart lighting system, able to properly manage the luminosity generated by the lamp posts, in order to reduce the energy consumed by the municipality. The smart lighting system may also provide some additional services to people or cars or other objects in the street. To this aim a Wireless Sensor Network (WSN) has been deployed in an area of the small town of Casalgrande in Italy. In particular, 24 lamp posts have been equipped with: i) an IEEE 802.15.4-compliant transceiver; ii) two light sensors each, in order to measure the light intensity provided by each lamp post and the light intensity coming from other sources (e.g., banners, shops or houses); iii) a dimmer each, to change the level of luminosity generated by the lamp.

The measurements made by light sensors are sent through the multi-hop WSN to a Gateway, that is the Coordinator of the IEEE 802.15.4 network. The Coordinator will then process the received data and it will send out unicast commands to specific nodes in the network to dim the level of luminosity generated by the lamp.

Nodes are deployed as shown in Figure 3-4. The red dots indicate the lamp posts, numbers near red dots are the IDs of the devices, and the blue square represents the Coordinator.

Furthermore, lamp posts are densely distributed in the city, hence it is possible to reuse that system as low data-rate backhaul for other Smart City services.

Figure 3-4: The Real Testbed in Casalgrande

Figure 3-5 shows the entire architecture installed in Casalgrande, which consists of four layers:

- **Layer1 (L1) - Server**: it could be a typical LAMP (Linux Apache MySQL PHP) installation. The main functionalities are: setting of a Web Server for accessing the data coming from the WSN, management of the VPN (Virtual Private Network) connection, storing the data on the Database. Furthermore, it is responsible of the status of L2 devices; it can send commands to each L2 device and alert to the
operator if some problems show up. An L1 device could be connected to several L2 devices in a star topology network.

- **Layer2 (L2) - Gateway:** it is a single board computer, in the installed testbed it is based on ARM920T CPU. It runs a minimal Linux distribution; it is designed to communicate (e.g., via serial port) with the Coordinator, and it handles a VPN session to the Server using a 3G Data Modem or any other kind of high speed internet connection. A single L2 device is intended to be connected with hundreds of L3 devices in a multi-hop topology. L2 devices are smart enough to send commands directly to L3 devices, to maintain the L3 network and to take decisions.

- **Layer3 (L3) - WSN:** this part is made of all the nodes that are installed on the lamp posts, plus the Coordinator. As stated above, nodes are equipped with a wireless transceiver, sensors and actuators, collect data and receive commands. The number and behavior of L3 devices could influence the number of L4 devices. Some L4 devices can connect to a L3 device through a star topology network.

- **Layer4 (L4) - External device:** some applications send few bytes, for example in a tracing application a L4 device sends its position to the L3 devices or a gas meter sends periodic data with an interval of some hours. L4 devices might connect to the nearest L3 device and use it as relay for sending their data towards the Server (L1). The traffic produced by L4 devices is very low, they do not need a bidirectional communication in most cases.

![The testbed architecture](image)

**Figure 3-5: The testbed architecture**

In this document we refer to level three, that is the WSN of devices deployed on the lamp posts and transmitting/receiving data to the Coordinator, which is the Gateway at level 2.

In order to create a down-scaled version of the real testbed on FLEXTOP, only 24 devices of the platform have been switched on, and some of them have been moved in order to reproduce as much as possible the Casalgrande’s deployment. Moreover, the transmit power has been reduced, in order to have a multi-hop communication to reach the Coordinator as in the real testbed. The position of the devices during the experiment is depicted in Figure 3-6.
Nodes on the two testbeds run the application and implement the same protocols stack, based on Zigbee Pro on top of the IEEE 802.15.4, and using many-to-one routing. The comparison between the results achieved through the real and the down-scaled testbeds has been performed in terms of packet loss rate and topologies. With reference to the packet loss rate, in both cases no packets were lost. While for what concerns the topologies the following metrics have been evaluated:

i) Average number of hops for a node to reach the Coordinator;

ii) Probability of being a router for a node, that is the percentage of paths, connecting all nodes to the Coordinator, passing through the router;

iii) Probability mass function (PMF) of the distance among topologies: considering each topology as a graph, the distance is defined as the number of basic operations (insert or remove a link, change a node position) needed for a topology to became equal to the other under examination.

In Figure 3-7 the average number of hops that a packet needs in order to reach the Coordinator is shown. As can be seen, despite the different environments where testbeds are deployed, it is possible to reproduce almost the same number of hops needed by nodes to reach the Coordinator, through simple parameter settings on FLEXTOP.
Figure 3-7: Comparison of the average number of hops per node

Figure 3-8: Comparison of the Probability of a node being a Router

Figure 3-9: Comparison of the Probability Mass Function of the Distance among Topologies

Looking at the Figure 3-8 it can be noticed that the probability of being a router is fairly distributed amidst almost all the nodes, except for those at the 'border' of the network, that is nodes from 1 to 5 in Casalgrande and from 1 to 4 in EuWln; the differences between these
peaks are due to the positioning of the nodes that is not perfectly matched between the two testbed, that is nodes 5, 7 and 16 are the most used in EuWIn while 6, 9, 11 and 17 are the most used in Casalgrande.

Finally, Figure 3-9 represents the PMF of the distance among topologies defined as the number of basic operations (insert or remove a link, change a node position) needed for a topology to became equal to the other under examination. This figure shows that the trend in both cases is very similar, that is EuWIn reproduces almost the same topologies created in the Casalgrande testbed, despite the difference of the environments. The reason is that the randomness of the topologies generated in the network is not due to the randomness of the radio channel (i.e., the environment), but to the randomness of the medium access control protocol (MAC). The latter, in fact, affects the way routing control packets are forwarded in the network, therefore the generated topologies. Being the MAC and routing protocols implemented in the two testbeds exactly the same, the resulting topologies are very similar.

3.1.2 Benchmarking of NS-2 Simulations
With reference to the third objective of FLEXTOP, that is benchmarking of IEEE 802.15.4 simulators, some tests for comparing FLEXTOP results with an IEEE 802.15.4/Zigbee simulator, implemented in NS-2 were performed.
Such work is part of the JRA#4 on “Reducing Traffic Congestion in Wireless Mesh Networks”, presented in paragraph 4.1.2.

The aim of this work is to: i) validate the network simulator implemented in NS-2; ii) investigate and discuss the differences between the results, due to the practical issues normally not accounted for in simulations.

Both the NS-2 and the FLEXTOP platform run Zigbee on top of the IEEE 802.15.4. The AODV-based routing protocol defined by Zigbee is considered. The reference scenario studied and set up on FLEXTOP is shown in Figure 3-10: 4 sources, 32 routers and the Coordinator, that is the receiver of all data generated by the source nodes. The same application was reproduced both in the simulator and in the testbed: sources transmitted packets to the Coordinator, with different data generation rates.

In order to reduce the overhead generated in the network, therefore collisions, in our implementation (both in FLEXTOP and NS-2) we try to separate the route discovery phase (that is RREQ/RREP transmissions) from the data transmission phase. Each source sends a RREQ and waits an interval of time, called timeout before starting the transmission of a burst of data packets. Time between two subsequent RREQ is denoted as round. Depending on the delay with which the RREQ are propagated in the network and RREP is received by the source, the two phases could be perfectly separated or not.
Performance has been evaluated in terms of packet loss rate (PLR) and total overhead generated in the network, that is the total number of RREQ and RREP transmitted in the network.
Figure 3-10: Experimental Setup

Figure 3-11 shows the PLR for different data generation rates, achieved with FLEXTOP and with the NS-2 simulations. As can be seen, the PLR obtained with the real network is larger with respect to the simulated, and the latter is particularly true for high data generation rates. This is mainly due to the overhead generated in the real network, which is much larger with respect to the one simulated in NS-2. The latter is shown in Figure 3-12 (see below). The reason why the difference between the two curves changes with the data generation rate is mainly because, depending on the data generation rate, in the FLEXTOP testbed we were not able to properly distinguish the route discovery phase from the data transmission phase, while in NS-2 these two phases are always well separated. In particular, in FLEXTOP when the data generation rate is large, the two phases are not separated and this generates many losses due to collisions. Due to the latter, in the simulator the PLR starts increasing for a data generation rate larger than 20 packets per second, while in FLEXTOP it is always increasing. It can be concluded that the simulator can be considered as reliable only when we deal with specific range of data rates, as both curves converge to the same value.

Figure 3-11: Packet Loss Rate for the AODV-based protocol

Figure 3-12 presents the total overhead generated by the network layer and averaged over the number of rounds for both simulations and experiments. As in the case of PLR, simulation results are quite stable, while experimental results vary with the data generation rate. It can be seen that the overhead increases as the data generation rate decreases. At
the same time, it has been shown that PLR decreases when the data generation rate decrease. This is due to the fact that in the case of higher data generation rates, sources have more difficulties with the path discovery that implies that they should transmit more RREQs, attempting to find the path. But these control packets are not forwarded by relay nodes, since they are busier with forwarding data packets already existing in the network. On the other hand, when the data generation rate is lower, sources generate less overhead, but at that point all relay nodes are able to "hear" and retransmit those packets. Therefore, the total overhead in the network becomes larger.

Apart from the differences underlined above, also the following issues should be introduced, to understand the differences among the results. The connectivity among devices, not exactly reproduced in the simulator, since devices in these preliminary measurements were not located on the walls but on the ground (see Figure 3-10). Moreover, the ZigbeePro software used in FLEXTOP, meaning that link costs are updated depending on the LQI with which Link Status packets are received. In fact, while in NS-2 Link Status packets are not transmitted, during the experiments these packets are exchanged, providing the link costs between the transmitter node and all its known neighbors. The existence of these packets affects the path selection in the network.

In conclusion, it has been shown that for a specific range of data generation rates the NS-2 simulator can provide proper insight, while some issues arise when it comes to larger data rates. However, as stated above, some issues for a fair comparison have been raised and as a next step in the JRA#4 these issues will be fixed, in order to complete the certification of the NS-2 software.

![Figure 3-12: Total overhead for the AODV-based protocol](image)

3.2 Data Sensing and Processing Testbed (DATASENS)

DATASENS is an infrastructure of approximately 100 nodes using IEEE 802.15.4 radios deployed inside one of the University of Bologna buildings, in rooms and corridors, implementing sensors able to monitor/emulate physical instances, like light intensity, temperature, equipped with LEDs that will ease the management and control of application tasks. In addition to the nodes composing the fixed infrastructure, approximately 50 battery-supplied mobile nodes (with 802.15.4 devices) carried by people moving around (roaming nodes), are part of the testbed.
An important advantage of this testbed is the possibility to enlarge the number of devices used in the experiments by including FLEXTOP devices with some necessary modification. The exhaustive description of DATASENS is presented in [1].

Currently, there are no preliminary results achieved through this platform. However, the first experiments are planned for November 2013, mainly in the framework of JRA#3 and JRA#5 described in Chapter 4.

### 3.3 Preliminary Tests on UWB facilities

With technological progress, it is possible to develop short-range radar systems for uses in biomedical, industrial and safety applications, where one of the main objective is the detection and localization of human presence through the observation of vital functions such as breathing and heart beating. Examples can be found in the detection of moving human target in a specified surveyed area and vital functions monitoring of patients in the medical field. Another application of interest is the ground penetrating radar where a detailed vision through the ground is made possible with the purpose to search people or objects buried under debris or other materials.

The recent UWB technology applied to radar systems is very promising thanks to its high spatial and temporal resolution.

#### 3.3.1 Breath Detection Tests using UWB Wireless Sensor Radar

CNIT-UniBO makes available other facilities related to ultra-wide bandwidth (UWB) devices at Cesena Campus premises. These devices can be used to set up experiments in the field of active and passive (radar) localization. Preliminary tests have been performed with the purpose to detect human vital sign based on breath activity detection.

Breath activity detection is based on the identification of slow changes that can be observed from the signal backscattered by the person caused by the quasi-periodical chest movements. The nominal rate of these variations typically falls in the range \([0.2 - 0.7]\) Hz.

In addition, through the measurement of the time interval elapsed between the instant when the radar sounding signal is transmitted and the instant when the signal backscattered by the chest is received, it is possible to estimate the distance (ranging) of the person.

This opens the door to the possibility to localize with high accuracy the position of the person \((\text{target})\) when multiple ranging estimates obtained using more radars are collected. Unfortunately, both the detection and ranging processes are impaired by the propagation effects caused by multipath, obstacles, and the presence of unwanted signal components scattered by the rest of the environment \((\text{clutter})\). Therefore there is the need to design robust detection and estimation schemes and test them in real environments.

To this purpose an extensive measurement campaign was performed at CNIT-UniBO (Cesena campus) in different scenarios and target displacements with the purpose to create a sufficiently large database to allow for the performance assessment of the breath detection and distance estimation.

Successively, the time-variant channel response model accounting, for pulse distortion due to non-ideal propagation effects, and the Generalized Likelihood Ratio Test (GLRT) based detector introduced in [2] have been applied to the measured data. In addition to the detection of breathing activity, the GLRT detector returns the maximum likelihood (ML) estimates of the breathing frequency as well as of the pulse response delay, from which it is
possible to obtain the ranging information. This information can be exploited to determine the target position when multiple radars are employed. The robustness of the detector and the accuracy of distance estimation have been assessed using experimental data even in the presence of obstacles.

![Diagram of radar functionality](image)

*Figure 3-13: Diagram of radar functionality*

The commercial device adopted for the measurement campaign was the Novelda NVA R640 radar development kit, based on the NVA6100 chip, operating in the 2 - 6 GHz band. It is equipped with a low power RF pulse generator with first order Gaussian pulse shaping and pulse width <1ns. The power spectral emission mask is compliant with the FCC Part 15 limit. Specifically, the radar sends periodically UWB pulses at frequency $PRF=6 \text{ MHz}$ and collects the samples of the signal backscattered by the surrounding environment in a limited observation window of duration $T_f=15.3 \text{ ns}$ (corresponding to about 2 meters at the minimum radar sampling time of 26ps) starting from a selectable time offset. Therefore, the total number of samples collected per observed window is $K=512$. By changing the time offset, operating ranges up to about 15 m can be achieved. In addition to the radar control circuit, two sinuous antennas with removable dielectric lens have been used. Experimental data were collected in different scenarios in the main building of the Faculty of Engineering at the University of Bologna, Cesena campus. The first scenario considered is a small conference room where the radar and target were deployed in line-of-sight (LOS).
The second scenario is a garage, with walls made of brick with 13 cm of thickness (see Figure 3-14).

Figure 3-14: Measurement set up in the garage

The third scenario is a typical office environment with plasterboard walls of 15 cm of thickness, whereas in the fourth scenario the obstacle is composed of a reinforced concrete column of 60 cm of thickness. In each scenario the radar was placed on a pedestal at about 1 meter from the ground. The antennas were deployed in a quasi-monostatic configuration, separated by 15 cm. The isolation between the transmitting and receiving antennas is carried out by the internal circuitry of radar. In the last 3 scenarios, the target was located behind the obstacle thus resulting in NLOS condition.

Figure 3-15: Measurement scenario considered

With reference to Figure 3-15 various measurements were taken with the target at different distances $d$ from the radar with steps of $\Delta d$ cm. In Table 3.0 the distance interval as well as the steps $\Delta d$ used during the measurement campaign are summarized.
In each configuration, the person sat in front of the radar and breathed normally, with an almost constant rate. His chest was at the same height as that of the antennas. For each scenario $N=500$ channel response waveforms were collected continuously, for a total measurement time of 7.2 seconds. Three different body orientations were considered: The person with his chest faced to the radar, the person rotated of 90 degrees, and the person back faced to the radar. Additional measurements were taken with the person holding his breath. The total number of measures collected is 200, each of them containing 500 waveforms.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Range $d$ (cm)</th>
<th>$\Delta d$ (cm)</th>
<th>Distance $r$</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOS</td>
<td>[90 – 470]</td>
<td>20</td>
<td>--</td>
</tr>
<tr>
<td>Brick</td>
<td>[90 – 470]</td>
<td>20</td>
<td>65</td>
</tr>
<tr>
<td>Plasterboard</td>
<td>[90 – 470]</td>
<td>20</td>
<td>65</td>
</tr>
<tr>
<td>Concrete</td>
<td>[90 – 470]</td>
<td>20</td>
<td>25</td>
</tr>
</tbody>
</table>

Table 3.0: Measurement parameters

As first test, in Figure 3-16 an example of 2D spectrogram (frequency – TOA) is reported. Since the breathing component is expected to be in the range 0.2-0.7 Hz, the presence of a strong peak due to breathing movements is evident.
In Figure 3-17 the 1D spectrograms (with fixed TOA) associated to a case with the person breathing, and one with the person in the same position but holding his breath, are reported. The difference between the two situations is clearly visible, and the breathing rate is easily estimable to be 0.35 Hz.

Regarding the detection rate, in the LOS scenario, all configurations analyzed gave a correct detection, whereas in the presence of a wall between the target and the radar the detection rate decreases but it is still good, especially for the plasterboard case. Due to the bad propagation conditions, the measured data collected in the reinforced concrete scenario were too confusing to be successfully used in the detection process.

![Figure 3-17: 1D spectrograms: breathing and not breathing person](image1)

![Figure 3-18: Estimated target distance vs real distance](image2)
Once the presence of the target has been detected, both the breathing frequency and discrete delay ML estimates can be obtained by looking for the location of the largest element of the 2D spectrogram.

In **Figure 3-18** the estimated distance versus the actual distance $d$ between the target and the radar for the brick wall is reported. Three different body orientations have been considered (front, back and 90 degree rotation). In NLOS conditions the distances are in general overestimated. This might be caused by the extra propagation delay introduced by the different materials encountered by the electromagnetic wave. However, apart from this offset, the trend is almost linear confirming a good performance of the estimator up to about 5 meters.

Among the 3 body orientations considered, that corresponding to the worse ranging accuracy is the 90 degrees rotation. This behavior can be explained by considering that when in front and back positions, chest movements happen in the same direction of the radar and hence variations in the backscattered signals are in general larger. When the body is rotated by 90 degrees, chest movements are partially shadowed by the shoulder and are orthogonal to the direction of the radar thus leading to weaker variations.

Future tests in JRA#1 foreseen experiments in more complex scenarios in which the target is not stationary and more targets are present. One of the main channeling aspects to be investigated is the required time resolution of the radar.

**3.3.2 Preliminary Tests on UWB Radar Equipment for Passive Localization**

Bilkent University has TimeDomain PulsOn 410 Monostatic Radar Modules (MRMs) [11], which are coherent UWB radar modules with 1.4 GHz of RF bandwidth (see **Figure 3-19** and **Figure 3-20**). There are 4 transceiver (radar) units, which can be used to transmit UWB pulses and receive reflections from the objects in the environment. The units operate at a center frequency of 4.3 GHz.

![Figure 3-19: Components of TimeDomain PulsOn 410 Monostatic radar Module (MRM)](image-url)
In passive localization applications, moving targets can be detected by eliminating the clutter via moving target indicator (MTI) filters. Then, positions of targets can be estimated based on estimates from multiple MRM devices.

Figure 3-20: TimeDomain PulsOn 410 Monostatic Radar Module (MRM)

The initial scenario considered for testing is as follows: Four UWB sensors are constantly transmitting signals and reflected signals from moving objects (in our case single person/multiple people are walking in an indoor environment) are collected by each of these sensors as shown in Figure 3-21.

The output of each sensor is range measurements of moving objects. It is assumed that the locations of the sensors are known to the fusion center and each sensor sends its measurement to the fusion center. The state vector of a target at time $k$ is

$$\mathbf{x} = [x_k, y_k, \dot{x}_k, \dot{y}_k]^T$$

where $[x_k, y_k]$ is the position, $[\dot{x}_k, \dot{y}_k]$ is the velocity of the target and $T$ denotes the transpose operation. The target dynamic is modeled by linear Gaussian constant velocity model [11]:

$$x_k = F_{k-1}x_{k-1} + v_{k-1}$$

where $F_k = \begin{bmatrix} I_2 & \Delta t_2 \\ 0_2 & I_2 \end{bmatrix}$ and $Q_k = \sigma_v^2 \begin{bmatrix} \frac{\Delta^4}{4} I_2 & \frac{\Delta^3}{2} I_2 \\ \frac{\Delta^3}{2} I_2 & \Delta^2 I_2 \end{bmatrix}$.

$F_{k-1}$ is the state transition matrix, $v_{k-1} \sim N(0, Q_{k-1})$ is the white Gaussian process noise, $Q_{k-1}$ is the process noise covariance, $\Delta$ is the sampling interval, $k$ is the discrete time index, $\sigma_v$ is the standard deviation of the process noise, $I_n$ and $0_n$ denote $n \times n$ identity and zero matrices, respectively.
Range measurements are collected by each sensor, $i = 1, \ldots, N_s$, in the area. The measured range measurement from a sensor located at $[x_i, y_i]$ is given by

$$Range = \sqrt{(x_k - x_i)^2 + (y_k - y_i)^2}$$

In the initial phase of the project, random finite sets based filtering techniques [12]-[16] are being tested on the data collected from the setup in Figure 3-21. In particular, probability hypothesis density filter implementation is being investigated.

### 3.3.3 Preliminary Tests on UWB Instrumentation for Active Localization

#### 3.3.3.1 CTTC ultra-wideband equipment

The following wideband instrumentation is available at CTTC premises:

- Network Analyzer 67GHz Agilent E8361A
- Pulse generator Picosecond 10050A
- TDR/TDT Pulse generator Picosecond 4022-TDRT
- Oscilloscope Infinium Agilent DSO81004A
3.3.3.2 Preliminary statistical assessment of UWB measurements

In order to assess the validity of some of the statistical assumptions made by most of the tracking/positioning algorithms, we analyzed the results from an extensive Ultra-Wideband (UWB) measurement campaign made with A Timedomain PulseON 220 UWB node. The measurement campaign was performed in an indoor environment with a network of \( N = 20 \) static UWB sensors deployed in the area. The scenario was an office-like environment, and the nodes location were accurately measured. Note that all nodes were located at a same height of 1:13 m, with the ceiling being at 3 m. The deployed nodes provided range estimates between any pair of node positions. A Timedomain PulseON 220 UWB node computes a range estimate using a proprietary TOA estimator, whose implementation is not public. The experiment of computing ranges between pairs of nodes was performed 700 times per node.

We stored the measurements in a database composed of (i) the accurately measured locations of each node, which would be used as the true positions for algorithms assessment; and (ii) pair of range estimates from node \( i \) to node \( j \). After a quick inspection of the measurements in the database, one could suspect that the Gaussian assumption cannot be made in general. We applied an Anderson-Darling test for normality, finding that the Gaussian assumption was not realistic \[40]\). That fact justified the search for other approaches not based on the Gaussianity of ranging measurements, and the assessment of the impact of that false assumption in practice.

Working with signal samples instead of direct measurements of ranging, we have derived a lower bound for the mean-square error (MSE) of the TOA estimation error when a interfering pulse is present. The novelty of the bound is in considering that no knowledge of the channel is available, and hence, the estimation is performed as if there was no interference. The bound has been derived from the Ziv-Zakai Lower Bound (ZZLB) by including the interference in the system model. A compact expression that depends on the time delay and amplitude of the interference has been obtained. This bound enables us to compute the estimation error as a function of the delay from the interference and plot the so-called multipath error envelopes. The bounds on the multipath error envelopes can be compared with the ML estimation. The bound is easily extended to more interfering pulses, and, by taking the expectation of the bound respect the distribution of all the paths, a bound over a realistic channel can be derived.

Also in the same context, a receiver that takes into account the a priori available information of the probability density function (pdf) from the channel is envisaged. Current state of the art estimators do not take this information into account. For this goal, a Bayesian estimator will be designed. The performance of the estimator will be evaluated first in a situation where only one interfering pulse is present and it will be compared with the multipath error envelopes explained above. In this way we will compare the estimation performance when no channel knowledge is used against the use of the a priori pdf. Afterwards, the estimator will be implement for realistic multipath channels.

Future activities within JRA#1 will be devoted to the development of specific algorithms for UWB positioning and tracking, as well as the integration of UWB measurements in configurations with multiple technologies.
3.4 Preliminary Tests on Software Radio HW for Dynamic Spectrum Selection

UPC makes available Universal Software Radio Peripheral (USRP) boards that are intended to be used as a real-time environment for testing the behaviour of dynamic spectrum selection algorithms whenever a radio link needs to be opportunistically established between two terminals. The demonstration platform was originally developed for the evaluation of spectrum selection in Opportunistic Networks (ONs), and now it is envisaged that it can be used in NEWCOM# for testing new spectrum selection techniques either related to ONs or to other scenarios in which a number of terminals need to communicate making use of dynamic spectrum selection techniques.

In the original concept of the platform, ONs are defined as temporary, localised network segments created under certain circumstances and comprising both infrastructure nodes and infrastructure-less devices. In this vision, ONs are governed by the radio access network (RAN) operator (which provides the resources, the policies, the knowledge, etc.), therefore they can be considered as coordinated extensions of the infrastructure [3]. ONs have been investigated to provide efficient solutions for a wide range of possible scenarios and use cases, such as [4]. (1) “Opportunistic coverage extension”, which describes a situation in which a device cannot connect to the operator’s infrastructure, due to lack of coverage or a mismatch in the radio access technologies. The proposed solution includes an additional connected user that, by creating an opportunistic network, establishes a link between the initial device and the infrastructure, and acts as a data relay for this link. (2) “Opportunistic capacity extension”, which depicts a situation in which a device cannot access the operator infrastructure due to the congestion of the available resources at the serving access node. The solution proposes the redirection of the access route through an ON that avoids the congested network segment. (3) “Infrastructure supported opportunistic ad-hoc networking”, which considers the creation of a localised, infrastructure-less ON among several devices for a specific purpose (peer-to-peer communications, home networking, etc.). Infrastructure governs the ON creation, benefits from the local traffic offloading and develops new opportunities for service provisioning. A common technical challenge in the above scenarios is to decide the proper spectrum to be used for the transmission of data and control flows in any communication link in accordance with the requirements for this link depending on the applications to be supported. This functionality is referred to as spectrum selection and it envisages a dynamic and flexible use of the available spectrum that ensures an efficient usage of this resource. The spectrum management process should be divided in two differentiated steps. First, spectrum opportunity identification (SOI) will find out the set of possible frequency bands that are available for the link. Second, and based on the results of the previous step, spectrum selection will decide the most adequate band for the communication.

In the following a description of the main characteristics of the implemented testbed platform, including the details on the hardware and software components, is provided. This platform is going to be used in the planned JRA#2 described in chapter 4.

3.4.1 Hardware component: basic building block

The platform is made of Universal Software Radio Peripheral (USRP) boards, each one controlled by a laptop, as shown in Figure 3-22. A total of 6 USRPs are available. Each USRP integrated board incorporates AD/DA Converters (ADCs/DACs), a Radio Frequency
(RF) front end, and a Field Programmable Gate Array (FPGA) which executes some pre-processing of the input signal [5]. A typical setup of the USRP board consists of one mother board and up to four daughter boards. On the mother board, there are four slots, where up to 2 receivers and 2 transmitters daughter boards can be plugged in. The daughter boards are used to hold the RF receiver and the RF transmitter. There are 4 high-speed 12-bit ADCs and 4 high-speed 14-bit DACs. All the ADCs and DACs are connected to the FPGA that performs high bandwidth math procedures such as filtering, interpolation and decimation. The DACs clock frequency is 128 Msample/s, while ADCs work at 64 Msample/s to digitize the received signal. A Universal Serial Bus (USB) controller sends the digital signal samples to a PC in I/Q complex data format (4 bytes per complex sample), resulting in a maximum rate of 8 Msample/s. Consequently, the FPGA has to perform filtering and digital down-conversion (decimation) to adapt the incoming data rate to the USB 2.0 and PC computing capabilities. The maximum RF bandwidth that can be handled is thus 8 MHz.

There exist different kinds of daughter boards that allow a very high USRP reconfigurability and working at several frequency bands. The daughter boards integrated in the USRP motherboard of this testbed are XCVR2450 Transceivers. They work in the frequency ranges 2.4 - 2.5 GHz and 4.9 - 5.9 GHz.

![Figure 3-22: USRP and controlling laptop](image)

### 3.4.2 Software Component

The software component includes the programs needed to control the different functionalities of the USRP nodes, and also to implement the spectrum selection algorithms under test. Identification of spectrum opportunities is performed by both a hardware platform (i.e., USRP) and a software component implemented with GNU Radio toolkit. GNU Radio is a free and open source software for learning about, building and deploying software radios [6]. It provides a library of signal processing blocks and the glue to tie it all together. In GNU Radio, the programmer builds a radio by creating a graph where the vertices are signal processing blocks and the edges represent the data flow between them. All the signal processing blocks are written in C++ and Python is used to create a network or graphs and glue these blocks together. Simplified Wrapper and Interface Generator (SWIG) is an open source package used by GNU Radio as glue such that the C++ classes can be used from Python. SWIG has the ability to convert the C++ classes into Python compatible ones. As a result, the whole GNU Radio framework is capable of putting together and exploiting the benefits of both C++ and Python. GNU Radio has been used to develop the modules that implement the spectrum opportunity and spectrum selection algorithms and to enable the data and control
communication between USRP transceivers.

### 3.4.3 Platform architecture

To illustrate the architecture of the platform, Figure 3-23 represents in the upper part a possible scenario that can be evaluated by means of the demonstration platform. In the lower part of the figure the corresponding implementation by means of USRPs is also shown. The objective of this testbed is to show the behaviour of the spectrum opportunity identification and spectrum selection procedures. For that purpose, in the considered scenario two devices need to communicate through an ON link controlled by the infrastructure, as graphically illustrated in the upper part of Figure 3-23. Both spectrum opportunity identification and spectrum selection functionalities reside in the infrastructure node. The result of executing these functions, with the specific frequency block assigned for the ON link between the two terminals is notified using a Cognitive Control Channel [7]. Moreover, and given that the assigned spectrum can belong to different bands, some of them being assigned opportunistically (e.g., the ON terminals acting as secondary users), or being license-free, we assume the existence of other external interferers operating in the same spectrum band that may degrade the communication between the terminals.

The corresponding testbed implementation of the infrastructure node and the terminals by means of USRP transceivers is shown in the lower part of Figure 3-23. USRP#1 implements the infrastructure and the associated spectrum identification and selection functionalities, while USRP#2 and USRP#3 are the terminals exchanging data. Moreover, the external interferers can be either implemented by means of other USRPs (e.g., USRP#4 in the figure) or can be other devices such as an access point.
3.4.4 Signalling procedures

The platform implements the required signalling procedures for supporting the creation of the ON and associated establishment of the radio link between the two devices (e.g., USRP#2 and USRP#3 in Figure 3-23) under the control of the infrastructure node (e.g., USRP#1 in Figure 3-23), as well as the procedure for reconfiguring the ON by changing the assigned frequency whenever the quality in the communication between the two devices falls below a specific threshold due to e.g. interference.

The implemented signalling is based on the Control Channel for the Cooperation of the Cognitive Management System (CMS) protocol using the implementation option based on IEEE 802.21 “Media-Independent Handover (MIH) Services” [8]. The physical support for this signalling makes use of a specific channel in the 4.9 - 5.9 GHz band.

Figure 3-24 presents the detailed message exchange among the involved USRPs for the creation of the ON. It consists of two different stages. The first one is the negotiation phase that is in charge of identifying and selecting the adequate spectrum block that will be used for the communication between the two devices. Correspondingly, it is at this stage where the relevant algorithms for spectrum selection are implemented. The second stage is the establishment of the communication link between the two USRPs based on the selected spectrum block.
The signalling procedure for the ON reconfiguration is depicted in Figure 3-25. It is triggered whenever one of the terminals detects that the quality of the communication has been degraded, due to e.g. interference in the assigned spectrum block. The detection of degradation is based on measuring the efficiency, defined as the ratio between successfully transmitted packets with respect to total transmitted packets including retransmissions. Whenever the efficiency is below a certain threshold, the reconfiguration procedure is triggered. As seen in Figure 3-25, in the first stage the USRPs acting as terminals communicate with the USRP acting as infrastructure to request a change in spectrum block. The spectrum opportunity identification and the spectrum selection algorithms are executed and another spectrum block is selected. It is communicated to the terminals and then during the second part of the procedure the link is reconfigured to the selected frequency.
3.4.5 Example Tests

In the following some sample experiments that have been executed with the previously described platform are presented, in order to illustrate the capabilities and the type of results that can be obtained.

3.4.5.1 Example Test 1: Adaptation to dynamic interference conditions

The aim of this subsection is to illustrate the operation of the spectrum selection functionality based on the results of the spectrum opportunity identification in a scenario with dynamic interference conditions. The scenario depicted in Figure 3-23 is considered where a communication is being established between USRP#2 and USRP#3. The system operates in the ISM 2.4 GHz band.

The spectrum opportunity identification algorithm that identifies the available spectrum block is executed at USRP#1 and consists in two different procedures, namely the measurement procedure and the spectrum block formation. In the measurement procedure, the total analysed band is subdivided into $N$ smaller portions of equal band $\Delta f$. The measurement algorithm performs an energy detection sensing (during a period of time $\Delta t$) for each $\Delta f$ portion until measuring the total band, starting from frequency $F_{\text{min,band}}$. The measurements are repeated during a period $T$. Then, based on the multiple measurements carried out, the spectrum opportunity index is obtained for each portion, defined as the fraction of measurements during the period $T$ in which this portion has been detected as available. In the spectrum block formation procedure, the consecutive spectrum blocks with spectrum opportunity index above a certain threshold are grouped in blocks. Each block is constituted by a maximum of $P_{\text{max}}$ portions. For each block, the algorithm returns the 2-tuple $SB_k=(f_k,BW_k)$, where $f_k$ is the central frequency of the block and $BW_k$ the bandwidth.
The configuration of the spectrum opportunity identification in this test assumes that the measured band goes from 2.4 GHz to 2.5 GHz subdivided in $N=1000$ portions of $\Delta f=100$ kHz. The energy detection sensing time is $\Delta t=100$ms. The measurements are averaged during the period $T=10$s. The power threshold to decide if a portion is free is set based on [9]. In particular to determine the threshold the USRP antenna was replaced with a matched load (i.e., a 50 Ohm resistor), then the Cumulative Distribution Function (CDF) of the thermal noise was calculated, and finally a threshold between thermal noise and signal energy was selected considering a false alarm probability equal to 1%. Finally, $P_{\text{max}}=50$ portions is considered in the formation of the spectrum blocks.

*Table 3-1* illustrates the result of the spectrum opportunity identification in the environment where the system is operating, and where one Wi-Fi access point exists at 2.412 GHz. A total of 7 spectrum blocks are available. Then in this test the spectrum selection algorithm chooses the spectrum block #6 centered at 2.447 GHz for the communication between USRP#2 and USRP#3. After the link between the two terminals has been created, the transmission of data between USRP#2 and USRP#3 starts on this spectrum block with the characteristics given in *Table 3-2*. At this stage, USRP#2 periodically monitors the efficiency in the data transmission as the ratio between successfully transmitted data packets and total number of transmitted data packets including retransmissions. This is computed based on the received acknowledgements for each packet.

*Table 3-1: Result of the spectrum opportunity identification*

<table>
<thead>
<tr>
<th>Index</th>
<th>Central Frequency (MHz)</th>
<th>Bandwidth (MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2422</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>2427</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>2432</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>2437</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>2442</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>2447</td>
<td>5</td>
</tr>
<tr>
<td>7</td>
<td>2452</td>
<td>5</td>
</tr>
</tbody>
</table>

*Table 3-2: Configuration of the communication between USRP devices*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulation</td>
<td>GMSK</td>
</tr>
<tr>
<td>Data Rate</td>
<td>256 kbps</td>
</tr>
<tr>
<td>Packet Size</td>
<td>1500 byte</td>
</tr>
<tr>
<td>Minimum Efficiency threshold</td>
<td>80%</td>
</tr>
</tbody>
</table>

In order to illustrate the capabilities of the system to react to time-varying interference conditions and to adapt the selected spectrum block to provide good QoS for the communication, the external interference source in the testbed platform (i.e., USRP#4) is...
configured to transmit at different frequencies during the experiment (see Figure 3-26). In this particular realization, after roughly 8 minutes running the testbed, USRP#4 starts transmitting on the same frequency band used for the data transmission in the ON link between USRP#2 and USRP#3. As a result, degradation in the communication is observed, as seen in Figure 3-27 that depicts the evolution of the efficiency in the communication together with the central frequencies of the spectrum blocks assigned to the ON. When the efficiency is below the threshold of 80%, USRP#2 triggers the reconfiguration procedure, requesting for a new spectrum block where data communication can be continued with improved QoS. After executing again the spectrum opportunity identification algorithm, the spectrum selection functionality decides that ON will continue operation through the spectrum block centred at 2.442 GHz, and the link is reconfigured in the new spectrum block. Then, the transmission between the terminals continues, reaching again high efficiency levels. The same process is illustrated twice during the rest of the demonstration time.

Figure 3-26: Transmission frequencies configured in the interferer (USRP#4)

Figure 3-27: Efficiency in the data transmission through the ON. The frequencies assigned to the ON are indicated in the figure.
3.4.5.2 Example Test 2: Performance of the spectrum selection algorithm

The purpose of this experiment is to evaluate the performance of a certain spectrum selection algorithm implemented in the testbed in relation to a random spectrum selection scheme. In particular, the evaluated algorithm is the fittingness factor-based algorithm presented in [10]. It makes use of the fittingness factor concept as a metric between 0 and 1 that captures how suitable a specific spectrum pool is for a specific radio link. The algorithm is based on estimating the fittingness factor for each link and available spectrum block based on a knowledge database that is maintained with different fittingness factor statistics. These statistics include the probabilities that the fittingness factor is kept to either high or low values as well as its time variability.

In this experiment, the communications’ needs between the terminals in the ON are configured to generate sessions with a certain average duration and an inactivity time between them, in accordance to the configurations indicated in Table 3-3. At each session arrival, the ON link between USRP#2 and USRP#3 is created. After creation, ON maintenance enables spectrum re-selection by means of reconfiguration procedures whenever the measured interference falls below the threshold of 80%. The duration of each experiment is 10 minutes.

For an easier illustration of the algorithm performance, and because of existing hardware limitations, this experiment considers just 2 spectrum blocks, centered at 2.472 and 2.484 GHz, respectively, both with 5 MHz bandwidth. The external interferer USRP#4 is configured to operate on the spectrum block centered at 2.472 GHz. The activity of this interference source is automatically adjusted following the transmission patterns indicated by the average activity/inactivity time durations in Table 3-3. No external interference is configured in the spectrum block centred at frequency 2.484 GHz during the experiment. However, it is subject to some spurious uncontrolled interference existing in the environment. Statistics obtained in this spectrum block indicate that it is free of interference during 99.92% of the time.

Table 3-3: Activity patterns of the ON link and the interferer USRP#4

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Average inactivity time ON</th>
<th>Average activity time ON</th>
<th>Average inactivity time USRP#4</th>
<th>Average activity time USRP#4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30s</td>
<td>60s</td>
<td>300s</td>
<td>300s</td>
</tr>
<tr>
<td>2</td>
<td>30s</td>
<td>60s</td>
<td>300s</td>
<td>60s</td>
</tr>
</tbody>
</table>

The results corresponding to the configuration of experiment 1 in Table 3-3 are plotted in Figure 3-28 and Figure 3-29 in terms of the efficiency measured in the link between the USRP#2 and USRP#3 with the random selection and the fittingness factor spectrum selection, respectively. Note that only the periods in which the link is active are plotted. Moreover, although the statistical pattern is the same for the two executions associated to the two algorithms, the actual durations of each session are different due to the randomness in the session generation. Table 3-4 presents the performance of the two algorithms in terms of the rate of executed reconfiguration procedures, required to change the spectrum block allocated to the link whenever there is degradation in the measured efficiency. This is a relevant metric in the comparison between spectrum selection algorithms since it reflects the associated signaling requirements. In experiment #1, USRP#4 is active 50% of the time, with an average duration much longer than the average activity time of the ON link (see Table 3-3). Correspondingly, in the random spectrum selection (see Figure 3-28) reconfiguration
procedures need to be carried out frequently whenever the assigned spectrum block is the one used by USRP#4. This can be observed in the figure because the efficiency falls below the limit of 80%. The resulting reconfiguration rate observed during the whole execution for experiment with the random algorithm is 2.2 procedures/min. On the contrary, with the fittingness factor based spectrum selection algorithm the efficiency is kept at a high level during the whole execution (see Figure 3-29) and correspondingly no reconfiguration procedures are required. In the configuration of experiment #2, the duration of the interferer activity is much lower (16% of the time with an average duration of 60s). As a result the reconfiguration rate of the random selection is more reduced than with experiment 1 (i.e., 0.5 modifications/min), but still the fittingness factor spectrum selection achieves a better performance.

![Figure 3-28: Efficiency in experiment 1 for the random selection algorithm](image)

![Figure 3-29: Efficiency in experiment 1 for the Fittingness factor-based spectrum selection algorithm](image)
Table 3-4: Rate of reconfiguration procedures (Procedures/min)

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Random selection</th>
<th>Fittingness factor spectrum selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.2</td>
<td>0.0</td>
</tr>
<tr>
<td>2</td>
<td>0.5</td>
<td>0.0</td>
</tr>
</tbody>
</table>
4. Joint Research Activities

In the following a brief description of the JRAs defined and discussed during the Track 2 workshop in July is given. Their further development will basically represent the activity of year 2 within WP2.2.

4.1 Task 2.2.2

This paragraph reports about the JRAs established in the framework of Task 2.2.2, dealing with “Large-scale wireless sensor networks: routing protocols, network topologies and cooperative localization”. In particular, four JRAs have been established, covering all the topics addressed by the Task and using all the three available facilities. In particular, the JRAs are:

1. JRA#1, "Design and experimental validation of algorithms for active and passive indoor positioning"
2. JRA#3, "Experimental activity on data sensing and fusion"
3. JRA#4, "Reducing Traffic Congestion in Wireless Mesh Networks"
4. JRA#6, "Testing IP-based Wireless Sensor Networks for the Internet of Things"

The first JRA deals with localization issues and will mainly use the LOCTEST platform; the second JRA is related to processing techniques and will exploit the DATASENS facility. Finally, multi-hop routing protocols and topologies are studied and tested in JRA#4 and JRA#6, both using FLEXTOP.

In the rest of the paragraph the aims and objectives of the four JRAs defined are described.

4.1.1 JRA#1 (Joint WP21/WP22) “Design and experimental validation of algorithms for active and passive indoor positioning”

Partners involved: CTTC, CNIT-BO, UCL, BILKENT, CNRS, IASA, and UTEM (Chile), a partner institution external to NEWCOM# that expressed interest in collaborating

Indoor localization remains as a challenging problem, the solution of which could trigger a myriad of new services and applications. The technology mix demanded by indoor location solutions requires a laboratory in which users can access a wide range of interfaces to an heterogeneous set of devices and form factors, and some processing capability to blend those inputs and provide the final output, that is, the device’s position. This implies flexibility in the number and type of sources, as well as the possibility to implement low-level algorithms in order to process low data, fast enough to achieve real time. Considering such requirements, we have set an open laboratory with the following main features:

- Hands-on, hardware and software oriented activities.
- Addresses the technology mix required for indoor positioning.
- Promotes collaboration and sharing by using low-cost development platforms.
- Promotes reproducible research.
- Open to industry and institutions beyond NEWCOM# members.

The specific challenges to address are:

- Channel and nodes’ position randomness
• Achieving real-time
• Hybridization of different technologies
• Robustness.

Hereafter we detail activities devoted to this research, both in the development of algorithms and in a practical implementation and experimentation.

### 4.1.1.1 Design of algorithms for indoor location

Since it is well accepted that indoor location requires information from different sources, we will test the Bayesian filtering approach for data fusion. Specifically, the following issues are being addressed:

- Development of hybridization algorithms based on Bayesian Nonlinear Filtering (namely, Extended Kalman filtering, Cubature Kalman filtering and different flavors of Particle Filtering), as well as their connection with similar approaches such as Simultaneous Location and Mapping (SLAM). This activity is carried out in a joint collaboration of UNIBO, CTTC and UTEM, a partner institution external to NEWCOM# that expressed interest in collaborating.

- Derivation of theoretical Bayesian bounds for indoor location. This activity is carried out in a joint collaboration of UCL and CTTC.

These are ongoing tasks, expected to be finished in the first trimester of 2014.

### 4.1.1.2 Design of the experimental platform

In recent years, we have witnessed the bloom of low cost, credit-card sized computers such as Raspberry Pi or Arduino. Those devices (both are under 50 €) embrace the Open Hardware and Open Software approach, building a community of developers and enthusiastic users around the World. In this approach, hardware design (i.e. mechanical drawings, schematics, bill of materials, PCB layout data, HDL source code and integrated circuit layout data), in addition to the software that drives the hardware, are all released under an open license that permits users to study, change, use and improve it.

After an analysis of the technical characteristics of different options in the market, we identified Raspberry Pi as a suitable platform for experimentation.

The Raspberry Pi is a credit-card-sized single-board computer developed in the UK by the Raspberry Pi Foundation with the intention of promoting the teaching of basic computer science in schools. The platform was designed with open source software development in mind. It has a Broadcom BCM2835 system on a chip (SoC), which includes an ARM1176JZF-S 700 MHz processor (The firmware includes a number of “Turbo” modes so that the user can attempt overclocking, up to 1 GHz, without affecting the warranty), VideoCore IV GPU, and 512 MB of RAM, a microSD slot, and two USB host ports.

<table>
<thead>
<tr>
<th>Component</th>
<th>Feature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Processor</td>
<td>Broadcom BCM2835 700MHz ARM1176JZFS processor with FPU and Videocore 4 GPU. GPU provides Open GL ES 2.0, hardware-</td>
</tr>
</tbody>
</table>
accelerated OpenVG, and 1080p30 H.264 high-profile decode.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Voltage</td>
<td>5V (microUSB powered)</td>
</tr>
<tr>
<td>RAM memory</td>
<td>512MB RAM</td>
</tr>
<tr>
<td>Storage and OS memory</td>
<td>SD card socket up to 32 GB. Boots from SD card, running a version of the Linux operating system.</td>
</tr>
<tr>
<td>Networking</td>
<td>10/100 Base-T Ethernet socket</td>
</tr>
<tr>
<td>USB</td>
<td>2 x USB 2.0 sockets</td>
</tr>
<tr>
<td>HDMI video out socket</td>
<td>YES</td>
</tr>
<tr>
<td>RCA composite video out socket</td>
<td>YES</td>
</tr>
<tr>
<td>Audio</td>
<td>3.5mm audio out jack</td>
</tr>
<tr>
<td>Video input</td>
<td>Raspberry Pi HD video camera connector</td>
</tr>
<tr>
<td>Size</td>
<td>85.6 x 53.98 x 17mm</td>
</tr>
</tbody>
</table>

Table 4-5: Raspberry PI model B features.

Figure 4-1: Raspberry PI model B board.

The aim is to use Raspberry Pi as nodes that are able to read measurements from different interfaces, to make some processing and to have communication capabilities with other nodes. Thus, we are developing software that reads those heterogeneous measurements and store them appropriately in a database, in order to test the performance of the different positioning algorithms with real data from real-life scenarios.
### Institutions involved:

<table>
<thead>
<tr>
<th>ACRONYM</th>
<th>Institution’s name</th>
<th>Activity</th>
<th>People:</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTTC</td>
<td>Centre Tecnològic de Telecomunicacions de Catalunya</td>
<td>Coordination of the activity:  - Development of signal processing algorithms for indoor location  - Setting up the laboratory and design of experiments</td>
<td>P. Closas, J. Arribas, C. Fernández-Prades.</td>
</tr>
<tr>
<td>CNIT/UNIBO</td>
<td>Università di Bologna</td>
<td>G. Calanchi, student from UNIBO, is spending 6 months (Sept 2013 – Feb. 2014) at CTTC doing research on indoor location.</td>
<td>D. Dardari, G. Calanchi, R. Verdone</td>
</tr>
<tr>
<td>UCL</td>
<td>Université Catholique de Louvain</td>
<td>A. Gusi, PhD candidate at UCL, is spending 6 months at CTTC (July 2013 – December 2013) doing research on Bayesian bounds for indoor location.</td>
<td>L. Vanderdorpe, A. Gusi.</td>
</tr>
<tr>
<td>UTEM (*)</td>
<td>Universidad Tecnológica Metropolitana de Santiago de Chile</td>
<td>Developing an application that is able to run on the Raspberry Pi and reads RSSI measurements from a TP-Link TL-WN722N Adaptador USB WiFi 802.11n, that ships an Atheros chipset, and stores such information in a MySQL-based database for further processing and statistical characterization.</td>
<td>H. Torres, R. Herskovics</td>
</tr>
</tbody>
</table>

(*) Partner institution external to NEWCOM#

At this time of writing (Sept 2013), this is an ongoing work that is expected to give place to scientific publications during 2014.

### 4.1.2 JRA#3 “Experimental activity on data sensing and fusion”

**Partners involved: CNRS/SUPELEC, CNIT-BO**

Distributed estimation has emerged as the natural evolution of its centralized counterpart. Many investigations have been carried out to prove that distributing is as good as centralizing [33-38], or at least this is valid either in the number of cooperating agents or asymptotically in the number of iterations on an iterative procedure.

Within the theoretical activities of the twin JRA in WP 1.2, task 1.2.3 of Newcom#, a common node observation model of the underlying physical process to be sensed has been identified. This model is shared among the partners and accounts for different investigation scenarios.
under the privilege of being unique. This precious agreement will allow for a profitable exchange of methodologies coming from different research areas. The same model can describe both an information acquisition problem in which each node in the network observes only a limited number of the underlying quantities to be monitored, and the same problem with the acquisitions (information) coming from adjacent nodes by means of dissemination. This is summarized as follows:

\[ y_n = H_n \Theta + \xi_n \]

where \( \Theta \) is the deterministic or random input, \( H_n \) is the \( n \)-th node matrix of observation or dissemination coefficients, accordingly to the effective scenario, while \( \xi_n \) stands for additive noise. The extension to non-stationary random inputs as well as to non-linear observation models is under development.

Consensus-based algorithms have been investigated with the purpose to obtain scalable, robust, low-complexity solutions to the distributed estimation problem in which no central nodes are present and a common view of the underlying process (e.g., a spatial field) is desired at each node.

![Distributed estimation through consensus](image)

*Figure 4-2 Distributed estimation through consensus*

The theoretical activity will be focused on the optimization of the procedures that lead to the most accurate final estimation, whereas the experimental activity will rather try to validate those procedures with real hardware in realistic scenarios in order to assess the theoretical results.

During the inaugural EuWIn event, the DATASENS platform was established as the most suited structure on which to carry out the experiments to validate consensus schemes. The underlay physical process to be estimated could be the spatial distribution of interference starting from energy measurements in each portion of the radio spectrum at each node. Another possibility could be the light or temperature intensity.
Some open issues have been analyzed and some initial attempts on how to address them have been proposed: On the one hand, the time-space correlation in measurements has not been clearly investigated as a possible performance enhancing feature in strategies intermixing time scales, that is when the rate convergence of consensus among nodes in a distributed estimation algorithm is not much faster than the rate at which subsequent measurements are taken, while quantization in the transmission of information may be considered as a performance degrading factor, on the counterpart. The experimental activities will provide the way to assess the performance of asynchronous communications, this being the most natural and unregulated way to transmit information. Again, if some interesting results about convergence rate are available from theoretic investigations, the experiments will be the only way to practically demonstrate their feasibility in real scenarios.

There is one last topic that during the EuWin site inauguration in Bologna was thoroughly considered: the question is if it is possible to maintain some properties of the estimation procedures such as convergence and unbiasedness, gaining in speed and energy requirements, at the expenses of other properties (accuracy). This possibility will be directly investigated implementing some clever algorithms on the DATASENS platform. This will of course constitute an important area of interest, also with the perspective of a possibly rapid development to the market.

As an initial test bed, one interesting possibility will be the implementation of distributed estimation algorithms (e.g. based on consensus) taken from the literature, and never tried out in a real scenario, in order to prove them in practice. The DATASENS platform is really suitable to this purpose providing light sensors that can set up an unexplored alternative to the most common temperature sensing scenario.

Another possibility is interference sensing on the different Zigbee channels, that, even if more common as reference application, has not been yet studied under a distributed mixed time scale perspective. The achievable performances will be assessed in terms of mean square error and rate of convergence in the consensus procedure.

### 4.1.3 JRA#4 "Reducing Traffic Congestion in Wireless Mesh Networks"

_Parnters involved: CNIT-BO, CNRS - LIMOS lab_

This JRA is carried out by CNIT-UniBO and the LIMOS laboratory at CNRS (an external Institution which is considering to apply for becoming an Affiliate Partner of Newcom#). The aim is to design and test on the EuWin facilities at CNIT-Bologna, some proposed solutions to improve the ZigBee routing protocol, targeting at reducing traffic congestion. In data networking and queuing theory, congestion occurs whenever a link carries too much data, so that its quality of service degrades. Typical effects of congestion include an increase of queuing delays and packet losses, and an unfair use of the energy resources of nodes in the network (as the most used routers consume more energy), which shortens network lifetime, being lifetime strongly dependent on the distribution of energy across nodes. The main reason for traffic congestion in ZigBee is that paths are selected according to connectivity and hop count, without considering the level of interference on the links: we aim to improve the ad hoc on demand distance vector (AODV)-based ZigBee routing protocol by forcing paths to slightly differ from those obtained by AODV, using several approaches. As shown in _Figure 4-3_ when a congested area is present, path diversity could be useful (e.g.,
the transmitter node could select Path 2, instead of Path 1, to reach the intended receiver, avoiding the congested area).

This JRA activity is organized according to the following steps: 1) Design new protocols aiming at reducing traffic congestion in Zigbee networks, and test their performance on the NS-2 simulator implemented at the CNRS, LIMOS laboratory; 2) Implement the best solutions on EuWIn facilities at the University of Bologna, more specifically on the FLEXTOP testbed and compare them with the benchmark, that is the Zigbee AODV-based protocol.

Some work related to the protocol design has been already performed and published in [17], which is summarized below. With reference to the implementation phase, only the benchmark solution, that is the Zigbee AODV-based routing protocol, has been already implemented on FLEXTOP, while the proposed and new solutions will be implemented in the next months. Some results related to the implementation of the Zigbee AODV protocol on FLEXTOP have been already presented in paragraph 3.1.2.

![Figure 4-3: Considered Scenario](image)

Many authors focus on improving the AODV-based ZigBee routing protocol. In [17], the AODV-based ZigBee routing protocol is modified to decrease the retransmission of flooding packets in order to make routing more efficient and to avoid the broadcasting storm problem. Nodes are grouped into logical clusters, and nodes in the same clusters share a routing table, which reduces the number of RREQ packets that are broadcasted. In [18], the authors present a multipath energy aware AODV routing, where the topology is divided into logical clusters. The flooding of RREQ packets is restricted to nodes outside the cluster, in order to reduce the overhead of the route discovery. In [19] and [20] some improvements to the Zigbee tree-based topology are proposed, by applying piggybacking technique and by optimizing the number of hops to reach the destination. Further modification for Zigbee tree-based topology propose a modification able to decrease the number of hops and to better balance energy consumption in the network, by using the information contained in neighbor tables. Another study [21] proposes an enhancement to the ZigBee mesh topology, in order to find the shortest hierarchical path and to reduce routing overhead and route discovery delay. Pivot-based routing introduces diversity in routing: packets are sent from sources to
pivots, and from pivots to destinations. In [22], the author proposes a centralized approach where \( k \) paths are built from the source to the destination. Each path goes through several pivots, and the distance between pivots is limited by a threshold. The algorithm requires a global knowledge of the network, unlike our approach which is distributed (and which focuses on the case \( k = 1 \), with one pivot only on the path). In [23], the authors propose a pivot routing protocol which aims to reduce the control message overhead and extend the network lifetime. In order to select pivot, the sink propagates a query and selects candidate nodes as pivots based on the distance (for instance). A node is candidate if its distance from the sink (or from a previous pivot) exceeds a threshold. Each node maintains a return path to the previous pivot (or sink). In addition, several paths can be maintained between pivots. In our approach, we use only one pivot per path, and our objective is to select pivots so that paths from sources to destinations do not overlap and do not cause congestion. In [24], a pivot-based protocol for a tree-based network, in order to avoid congestion when several sources send data to the same destination, is proposed.

All the above mentioned works present results achieved through simulations, in most of the cases using the NS-2 network simulator, and do not implement the proposed protocols on real platforms. Moreover, most of them aim at reducing packets flooding generated during the paths discovery, and do not deal with traffic congestion. We aim at changing the paths that AODV builds, rather than optimizing the way AODV builds the paths. Furthermore, in contrast with the above-cited works, we aim at designing, implementing and verifying routing protocols through both simulations and experiments.

The proposed solution will use intermediate nodes, denoted as pivots that are selected by the data sources in order to reduce congestion on paths [17]. Pivot nodes are determined in the following way. A node is a pivot for a given couple of source-destination (S-D) nodes if it satisfies the following three rules: 1) it is not located on the shortest path from S to D, 2) it is closer to the destination than to the source, 3) it is located within the virtual rectangle having S and D as diagonally opposite angles. Following the procedure described in [17], one pivot per source node is selected, such that paths connecting the different source nodes with the intended receiver (which is the same for all the sources) do not overlap and do not cause congestion.

The proposed protocol has been simulated in NS-2 and compared with the default Zigbee AODV based protocol, as it shown in Figure 4-4, where the packet loss rate (PLR) and the average packet delay are shown, as a function of the packet transmission rate. It can be seen that the proposed solution significantly improves the performance.

The next step in this JRA activity implies implementation of this protocol on the FLEXTOP testbed and comparison with the Zigbee solution.

![Figure 4-4: Performance comparison between Zigbee and the pivots-based solution](image-url)
4.1.4 JRA#6 "Testing IP-based Wireless Sensor Networks for the Internet of Things"

Partners involved: CNIT-BO, CNIT-CT, University of Banja-Luka (Bosnia-Herzegovina, an external institution that will dedicate 10 PMs to the activities of this JRA)

The main objectives of this JRA are the implementation and testing of different upper layers protocols for IEEE 802.15.4 networks and the comparison between two different paradigms for the Internet of Things. The partners involved of this JRA are CNIT@UniBO and CNIT-UniCT and the facility that will be used is FLEXTOP.

In Figure 4-5 the two different paradigms for the Internet of Things investigated in this JRA are shown. The paradigms depicted on the right is generally referred to in the literature as the “true” Internet of Things paradigm, to emphasize that each device is directly accessible from Internet using the IP-protocol; while on the left it is reported another paradigm still under the IoT umbrella. The latter could be denoted as “Internet with Things” or “Pseudo-IoT”, to emphasize that each device is accessible by Internet but only passing through an intermediate level to translate the IP-based messages to another protocol (either standard or proprietary). Therefore, the WSN using a standard non-IP protocol (e.g., Zigbee), may access and could be accessible to/from Internet only passing through a Gateway (Bridge).

The first paradigm allows to directly access to specific nodes in the WSN, without passing through the Gateway, however it requires the use of IP addresses, which increases the overhead. On the other hand, when passing through the Gateway some delay is accumulated for the processing. The trade-off between the two above mentioned issues will be investigated and studied in this JRA.

Figure 4-5: “Internet of Things” (on the left) and “Internet with Things” (on the right)
Figure 4-6: IoT protocol stacks under examination

Figure 4-6 shows the different protocol stacks that will be implemented and tested on FLEXTOP in the next months. Two “true” IoT paradigms will be implemented and tested: i) the 6LowPAN protocols stack (depicted in green in the figure) [26] and the Zigbee IP protocol stack, using the ZigBee Smart Energy 2 profile at the application layer (in blue in the figure) [27]. Both the above protocols stacks aim at implementing the IP-protocol on top of the IEEE 802.15.4. The Pseudo-IoT paradigm is implemented using the other two protocols illustrated in the figure: ZigBee Pro [28], which is the de-facto standard for WSN and the Software Defined Wireless Network (SDWN), a framework and model designed and implemented at CNIT@UniCT. The latter is a model created by the University of Catania which should dramatically reduce the complexity of network configuration and management as well as to make the introduction of innovation in the network operations possible. SDN design and experimentation is the subject of the increasing attention of the industrial and academic research community.

The JRA is organized in three phases:
1. Implementation of the 6LowPAN, of the Zigbee/Zigbee-IP protocol stacks and SDWN on the FLEXTOP platform.
2. Comparison of the two paradigms, mainly in terms of delay needed to access to a specific node in the WSN when passing through the Gateway (IoT) or when not (IoT).
3. Comparison of the different solutions for the two paradigms in terms of: energy consumption, traffic congestion and overhead, security features, fragmentation.
4.2 Task 2.2.3

4.2.1 JRA#5 "Socially-aware protocols for wireless mesh networks"

Partners involved: CNIT-BO, CNIT-CT

This JRA between CNIT-UniBO and CNIT-CT aims at the experimental evaluation of the theoretical outcomes of the research performed in Task 1.2.2 on “Optimal design of opportunistic networks and mobile clouds” using the DATASENS platform.

The idea is to realize a mesh network composed of at most 50 mobile nodes and 150 fixed nodes.

The main objective of this JRA is to evaluate the impact of the social behaviour on the performance of a mesh network composed of mobile nodes (carried by people) and fixed nodes. The presence of both the fixed and mobile nodes is motivated by the fact that a fixed network composed only of low power, low range and low data rate nodes may not fit the throughput requirement. In order to overcome this limitation, a mobile network composed of nodes carried by people (opportunistic network) will handle part of the traffic of the fixed mesh network when the requirements cannot be satisfied.

This concept can be applied to a urban environment where the fixed network is realized by devices installed on the roadside (e.g., on lamp posts) and the mobile network is composed of nodes carried by people moving on the street. When the fixed network, or part of it, is congested due to high traffic demand, a certain amount of traffic can be offloaded to mobile nodes and delivered in an opportunistic fashion.

This JRA will focus on the performance evaluation through experiments of a routing schemes for opportunistic networks that take into account the social behaviour of nodes. It can be found in the literature that taking into account the social behaviour of nodes is the effective way to improve the delivery ratio without the need of flooding an enormous amount of data across the network, which results in performance degradation [30].

The majority of the social-aware routing protocols that can be found in the literature can be defined as stateful, i.e., nodes need to collect, compute and store an high amount of information about the previous contacts with the other nodes to be able to make routing decision that will increase the performance of the network. This feature makes the cost and the complexity of devices to grow excessively, making them unsuitable for large scale deployment. Some examples of stateful social-aware routing protocols are: [31] and [32].

This JRA will focus on a stateless social-aware routing algorithm: SANE (Social-Aware NEtworking) [33]. SANE exploits a sociological observation: "Individuals with similar interests tend to meet more often". From this observation it is possible to develop a stateless routing algorithm, that is, no information about the previous contacts are needed to be collected, computed and stored. Only the interest profile of the node need to be properly characterized. When two nodes meet, data are exchanged only if their interest profiles matching is above a certain threshold. Simulation results based on synthetic mobility models and on real world traces show the effectiveness of the stateless approach compared to the stateful and social-oblivious ones.

As a step forward, we want to consider the interaction between the fixed and mobile networks in deriving useful information about the sociability and interest profile of the mobile nodes. The fixed nodes, in fact, can take advantage of their fixed position to detect social communities and derive metrics like degree centrality of each mobile nodes that detect in their communication range.

The JRA will be carried on through three phases:
1. Data collection: mobile and fixed nodes of DATASENS exchange mutual information. Examples are: inter-contact time, contact duration, contact location, speed, RSSI, etc.

2. Data processing: data collected in phase 1 will be processed in order to model the behavior of mobile users through specific metrics. These metrics may come from the social network theory, examples are: degree centrality, betweenness centrality, closeness centrality, eigenvector centrality, community detection, etc. The interest profile of the mobile nodes needs to be properly characterized in this phase.

3. Design and test of socially-aware network protocols: thanks to the analysis performed in phase 2, it is possible to design adaptive routing protocols able to improve the overall network performance (losses, delays, etc.), exploiting the social behavior of mobile nodes, and testing them on the DATASENS platform.

4.2.2 Potential future JRA on “Spectrum selection in opportunistic networks”

Even though not yet activated, a potential future JRA on spectrum selection in opportunistic networks, namely JRA#2, lead by UPC is planned. It is envisaged that this task will carry out experimental activities to test the behaviour of dynamic spectrum selection algorithms whenever a number of radio links need to be opportunistically established between different terminals under the control of an infrastructure node. An example of applicability scenario would be an opportunistic network (ON) defined as temporary, localised network segments created under certain circumstances, comprising both infrastructure nodes and infrastructure-less devices and governed by a radio access network operator, so they can be considered as coordinated extensions in which a number of links between terminals and/or infrastructure nodes needs to be established. Nevertheless, the activity may also include other more general scenarios in which a number of terminals need to communicate making use of dynamic spectrum selection techniques.

Based on the above, the main objective of this activity then is the performance validation of spectrum opportunity identification and spectrum selection functionalities for Opportunistic Networks in real environments. For that purpose, different scenarios can be considered where two or more devices need to communicate through ON links (e.g., digital home environments, etc.). The main challenge will be to demonstrate the efficiency of different spectrum selection algorithms in real environments with dynamic interference variations.

This activity is envisaged to be performed using the platform described in paragraph 3.4 implemented by means of Universal Software Radio Peripheral boards where the spectrum selected for the communication between some nodes can be dynamically modified depending on actual measurements. Moreover, different interference conditions can also be generated in different experiments to see the reactivity of the considered algorithms. Thanks to the flexibility provided by the USRP and the capability to reconfigure them by means of GNU radio, other aspects of the links to be established can also be dynamically modified apart from the operating frequency (e.g., modulation, transmit power, etc.), so that the testbed can be potentially extended to evaluate also other adaptive strategies (e.g. link adaptation, etc.).

Paragraph 3.4 has presented the type of results that can be obtained with the considered platform, together with some initial comparison of a fittingness factor-based spectrum
selection algorithm and a random selection algorithm. Evaluation can be performed in terms of both quality parameters (e.g., efficiency in the communication) as well as signaling aspects (e.g., rate of reconfigurations). Currently, the platform is being extended to include other algorithms such as a Partially Observable Markov Decision Process (POMDP). In the context of NEWCOM# it is envisaged that the considered platform can be potentially used as a support for the joint activities in which UPC is involved in WP1.1 (Task 1.1.2 - relaying and resource allocation in wireless networks) and WP1.3 (Task 1.1.3 - resource allocation for optimized radio access). However, the platform is also available for other potential activities in the network.
5. Plans of Activities for Year 2

This Section gives details regarding the plans of activities for the next year (M13 to M24) of activity of WP22.

5.1 Introduction

Track #2 intends to create a framework that will survive the end of Newcom#. Therefore, on the one hand the plan of activities has been devised as a component of the NoE; on the other, all dissemination and promotional actions are carried out under a more general perspective.

5.2 Plans of Activities

1) The Portal

The website will be updated every six months, based on the achievements at the end of each period, as already made during the previous semester.

2) Web Meetings

Web meetings will be organized based on the request of Newcom# researchers at the level of WP. Two meetings are planned during the year within WP2.1. Concerning WP2.2 and 2.3, since most of the JRAs are twinned with JRAs of theoretical nature defined within Track1, the meetings will be held at JRA level.

3) Workshops

EuWIn will participate during the next twelve months to two types of workshops: EuWIn-generated and general workshops.

By EuWIn-generated workshop it is intended an event which revolves around the EuWIn facilities, is organized and managed by the EuWIn WP leaders and Director. The 1st Emerging Topic Workshop of Newcom# was of such nature. EuWIn intends to organize a similar event in Bologna on June 23rd, within the context of EuCNC, the European Conference on Networking and Communications, flagship of the EC.

A general workshop is an event generated by some institution, to which EuWIn will contribute with results achieved through the facilities implemented at the EuWIn sites. At time of writing, one event is planned: Newcom# (both Track1 and Track2) will support the organization of the 2nd IEEE International Workshop on Advances in Network Localization and Navigation (ANLN) to be held in conjunction with the International Conference on Communications 2014 (ICC 2014), 10-14 June 2014, Sydney, Australia.

The goal of the workshop is to advance the development of new positioning algorithms based on short-range wireless communications as well as new position-aware procedures to enhance the efficiency of communication networks. This
workshop will bring together academic and industrial researchers to identify and discuss technical challenges and recent results related to short-range positioning.

The main topics of interests are:
- Cooperative localization
- Cognitive, and machine learning techniques
- Hybrid positioning and data fusion from heterogeneous technologies
- Seamless indoor/outdoor localization
- Wireless sensor radars
- Energy efficient positioning systems
- Passive localization systems for RFID
- Positioning using source-of-opportunity signals
- Field tests of location systems
- Propagation channel modeling for localization
- Performance bounds and optimization
- Simultaneous localization and mapping (SLAM)
- Navigation algorithms

Most of the workshop topics are related to WP2.2 and WP2.1 and the WP2.2 leader D. Dardari is the co-organizer of this event. More information on the workshop can be found at http://anln.spse.tugraz.at/

4) Training Schools

The third Newcom# Training School will be dedicated to the topic of experimental research. The title of the school is “B4G Networks in Cities: From Theory to Experimentation and Back”. It will be organized, jointly with the COST Action IC1004, on November 25-28, 2013 in Barcelona at the premises of the CTTC EuWIn site. The school will comprise oral and lab sessions. Its scope and structure are described below.

SCOPE - The school aims at training young researchers working in the area of B4G radio networks, with emphasis on:
- i) the role of experimentation as means to characterize the radio environment and test system performance in real contexts;
- ii) the interplay between theory and experimentation, fundamental to an accurate and efficient system design;
- iii) the relevance of a multi-disciplinary approach to research, requiring knowledge of channel, link and network aspects.

The urban environment (the 2020 City) will be considered as the common denominator for all lectures.

PROGRAM - The school program will evolve around four Tracks:
- T1) B4G networks and the 2020 City: technology bricks, requirements, applications, network scenarios, research challenges;
T2) Hybrid Localization: from satellite to distributed localization techniques for B4G networks;
T3) Multi-Hop Networks: MAC and routing aspects for the IoT component of B4G networks in the 2020 City;
T4) Channel Characterization: estimation and modeling in urban environments, with the purpose of PHY assessment.

The attendees will be exposed to theoretical lectures on all four Tracks. On the other hand at time of registration they will be asked to select which laboratory experimental session to attend on the third day (Tracks 2, 3 or 4). Alternatively, on the third day Track 1 will include seminars on various topics related to B4G and the 2020 City.

To allow efficient training during the experimental sessions, the number of attendees accepted for each of them will be limited (in Track 2, 3 and 4; Track 1 has unlimited access); a First-Registered-First-Served approach will be applied.

FACILITIES - The experimental sessions will exploit the EuWIn facilities. The CTTC and the UniBO (remotely accessible) facilities will be used during the school.

LECTURERS - The detailed program is available on www.euwin.org under “EVENTS” and on the second page of this flyer. The lecturers and Lab session tutors are from Nokia Solutions and Networks, Polytechnic of Torino, University of Bologna, Technical University of Ilmenau, CTTC, Université Catholique de Louvain, DLR, Eurecom Institute.

The TPC includes the three Track #2 WP Leaders, the EuWIn Director, Dr. Florian Kaltenberger of EURECOM, Prof. Claude Oestges of UCL. The programme will be also made available in the EURACON website www.euracon.org.

5) Industry Liaisons

EuWIn will participate to the workshops organized by Newcom# at the premises of industries. Moreover, each site will pursue a number of individual contacts with companies.

6) Demonstration activities

EuWIn will buy exhibition stands at EuCNC, in Bologna, for show of the latest achievements made possible through the EuWIn facilities.

7) Experimental Tours

One PhD student of CNIT, Danilo Abrignani, deeply involved in EuWIn/Bologna, has spent one month at EuWIn/CTTC in September 2013, discussing (among other things) about possible lines of common activities among the two sites and defining the topic for experimental tours connecting the two sites. A student from CNIT expressed the interest to perform its Master thesis in the next year at the premises of the CTTC site of EuWIn, conducting experiments in line with the plan devised.
6. Conclusions

The inaugural event of EuWIn, which took place in Bologna at the premises of the EuWIn@CNIT-BO site on July 8 2013, has been an extraordinary occasion of networking within Newcom# and outside Newcom#, in particular with industry. During this event, all EuWIn facilities have been presented to the public, both through talks and demos/posters.

The Track 2 meeting, that followed the inaugural event, has permitted the consolidation of the preliminary JRAs as well as the creation of new ones based on feedback from partners, with particular emphasis on inter-WP and inter-Track collaborations. The plan of activities for the second year has been defined. The activity carried out includes also some preliminary tests on the experimental platforms performed to assess their correct functionality.

During the next period the experimental research activity foreseen in the JRAs will take place with a strong synergy with the theoretical activity under development in Track 1. A particular effort will be devoted to demonstration activities, experimental tours, workshops, and to the organization of a training school dedicated to experimental research.

Now that the platforms are ready for use, it is time to start a solid campaign of dissemination; all the partners are invited to spread the information about the facilities made available outside the borders of the NoE. The school organised jointly with IC1004 in Barcelona for November 25-28 goes in this direction.
References

[1] D22.1 - Definition of EuWIn@CNIT/Bologna testbed interfaces and preliminary plan of activities


[26] IPv6 over Low power WPAN (6lowpan) - http://datatracker.ietf.org/wg/6lowpan/charter/

[27] Zigbee Alliance - docs-13-0200-00-sep2-smart-energy-profile-2.pdf

[28] ZigBee Alliance - http://www.zigbee.org/Products/CompliantPlatforms/ZigBeePROFeatureSet.aspx


[34] I. Schizas, G. Giannakis, S. Roumeliotis, and A. Ribeiro “Consensus in Ad Hoc WSNs With Noisy Links—Part II: Distributed Estimation and Smoothing of Random Signals”


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

project_office@newcom-project.eu

http://www.newcom-project.eu