Research Session – ISART 2010

1:15p – 3:15p

Session targets:

1. Overview on on-going Cognitive Radio research worldwide..
    - Europe FP7: Roberto Llorente (Technical University at Valencia)
    - UK: Maziar Nekovee (British Telecom)
    - Asia-Pacific: Tan Geok Leng (Infocomm Development Authority, Singapore)
    - USA: Jeff Reed (Virginia Tech.)
    - USA: Lei Yang, Heather Zheng (UC Santa Barbara)
2. Identify common roadblocks and strategies
3. Foster further collaboration through research programs

Spectrum sharing and coexistence: Europe's 7th Framework Program approaches

ISART 2010, Boulder, CO

July 2010

Overview

RAS

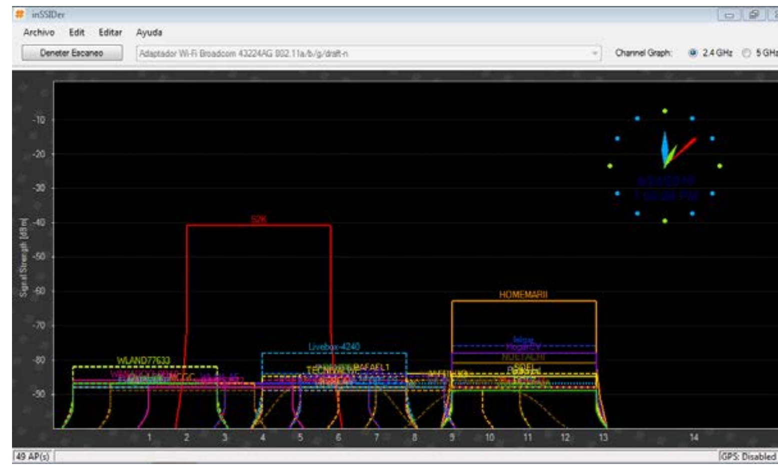
- **Introduction**
- Project Highlights
  - **E-UWB:** Coexisting Short Range Radio by Advanced Ultra-Wideband Radio Tech.
  - **SENDORA:** SEnsor Network for Dynamic and cOgnitive Radio Access
  - **E3:** End-to-End Efficiency
  - **OneFit:** Opportunistic networks and Cognitive Management Systems for Efficient Application Provision in the Future InterneT
    QoSMOS: Quality of Service and MObility driven cognitive radio Systems
  - **UCELLS:** UWB real-time interference monitoring and CELLular management Strategies
  - **FIVER:** Fully-Converged Quintuple-Play Integrated Optical-Wireless Access Architectures
- Standardisation and Regulation
  - **WALTER:** Wireless Alliances for Testing Experiment and Research
- Conclusion

FP7 views

Introduction

- **Cognitive Radio <u>is the way forward</u>**
  - Interesting for coexistence with licensed services (DFS-Radar, DSA-LMR, etc.)
  - <u>Necessary</u> in un-licensed wireless

Just an example..



One more thing..

Router-computer distance was 2-meters and it was 1 am time(!)

FP7 views

Introduction

- **More and more unlicensed radio-enabled devices are present day after day**

Typical devices..






Not so typical..



Emerging problem: guaranteed bitrate-demanding equipment

Internet TV

(bitrate)

- SD
- HD (720)
- HD (1080p)
- 3D
- **3D-AUTOSTEREO (no glasses)**

FP7 views

Introduction

RAS

Cognitive Radio (CR) targets to..

A) Maximise spectrum capacity

B) Enable QoS policy

- A) Of course!- spectrum capacity is an major economic force
- B) **QoS policies are key factors** to enable operator revenue
  - From "communist" spectrum access (equal for all), to "market" access ("premium services" are possible)
  - QoS policies enable advanced services enter the market

(3D HD streaming, on-demand GAMING, on-demand computing)

CR requires a major technological effort to solve roadblocks:

1. Techniques/algorithms
2. Security issues
3. Cost - Cost drives technical choices
4. Standardization/regulation

FP7 views

Introduction– Europe FP7

- Europe is devoting major resources to ICT in the 7th Framework Research Program

ICT Work Programme 2011- 12

- Total available budget: € 2.4 billion **($ 3.1 Billion 2011-12)**
- 8 Challenges + FET
- Challenge 1 represents a major share (≈ 25%)
- Future Internet - 2 strands under Challenge 1

Mainstream research
Continuity with new aspects

Future networks, networked media, sensor platforms, services & clouds, trust & security, FIRE experimentation, …

FI-PPP

Closing the gap between research and innovation

FP7 views

Introduction– Europe FP7

- An important share is devoted to ICT. Open calls (announced 20th July):

- FP7-2011-ICT-FI. Deadline: 2-XII-2010. Funding 90 M€
- FP7-2011-ICT-GC. Deadline: 2-XII-2010. Funding 30 M€
- FP7-ICT-2011-FET-F. Deadline: 2-XII-2010. Funding 10 M€
- FP7-ICT-2011-C. Deadline: 12-III-2013. Funding 46 M€
- FP7-ICT-2011-EU-RUSSIA. Deadline: 14-IX-2010. Funding 4 M€

FP7 views

¿Can USA (also other countries) companies/institutes participate in FP7?

-Yes, if European branch with R&D capabilities

-Yes, in specific calls. E.g.

Support Actions, Networks of Excellence
Alternative Paths to Components and Systems
New paradigms for embedded systems
(etc..)

-Yes, if foreign partner provides key technology not found in Europe

-(if none of the above) Yes, but without R&D funding

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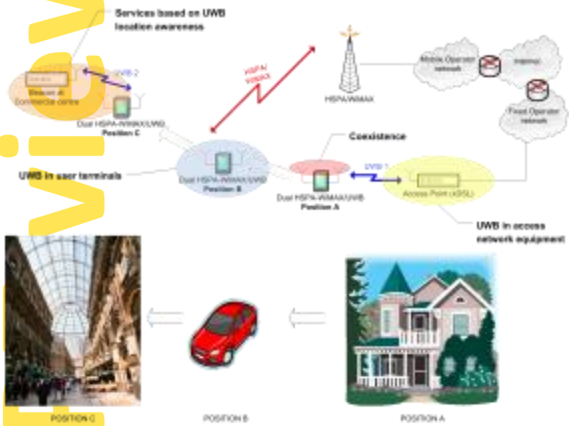
FP7 views

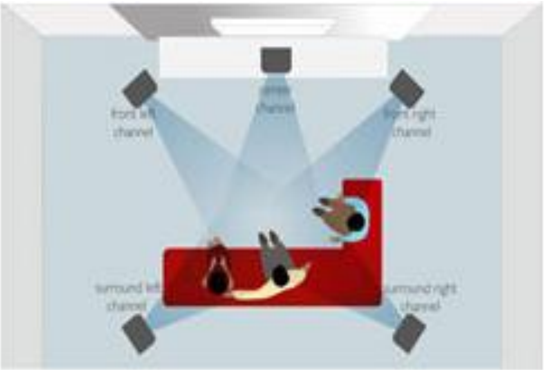
EUWB is an Integrated Project (IP) focused in UWB radio, targeting:

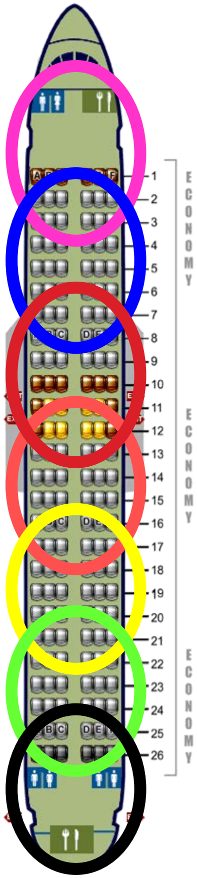
- Identify advanced UWB application scenarios
- Investigate interferers and interference impact on UWB deployment
- Future UWB requirements- coexistence
- CR-UWB [e.g. Detect and Avoid (DAA)]
- Spectrum sensing: non-data aided techniques
- Cognitive pilot channel (CPC): data-aided techniques
- Distributed Cognitive pilot channel
- Overall requirements of CPC

EUWB: Advanced UWB systems toward industries

- To provide sophisticated new highly demanded in several European key industrial application enabled by Advanced Ultra-Wideband Radio Technology (UWB-RT)
  - Home cluster - **Philips**
  - Automotive cluster- **Bosch**
  - Public transport cluster - **EADS**
  - Heterogeneous cluster - **Telefonica**







Advanced UWB systems applications in ubiquitous

- Some example of applications
  - Real time location and tracking
  - Multimedia (audio and video) communications
  - Internet services (VOIP, web surfing, etc)
  - Personal area communications
  - Real time video transmission and fire-fighter localization
  - etc.

Application requirements:

- Low data rate with long and medium distance
- Very high and high data rate standard with short and medium distance

IEEE802.15.4a
ECMA 368
ECMA 687 (60 GHz)

UWB Systems Every Where !!!:

- Home, office, car, road and vehicles, emergency, air bus, shopping mall, hospital, industry, etc collocated with other systems

Single and multi-radio interface

FP7 views

UWB will be spectrally overlapped with other radio systems

Interferers at UWB systems

Recognized interfering signals (In-Band wireless standard):

- WiFi, IEEE 802.11 a/n
- WiMax, IEEE 802. 16 d/e
- IEEE 802.15.4a (impulse radio, UWB LDR)
- ECMA 368
- Radar Communications

Out-band wireless standards:

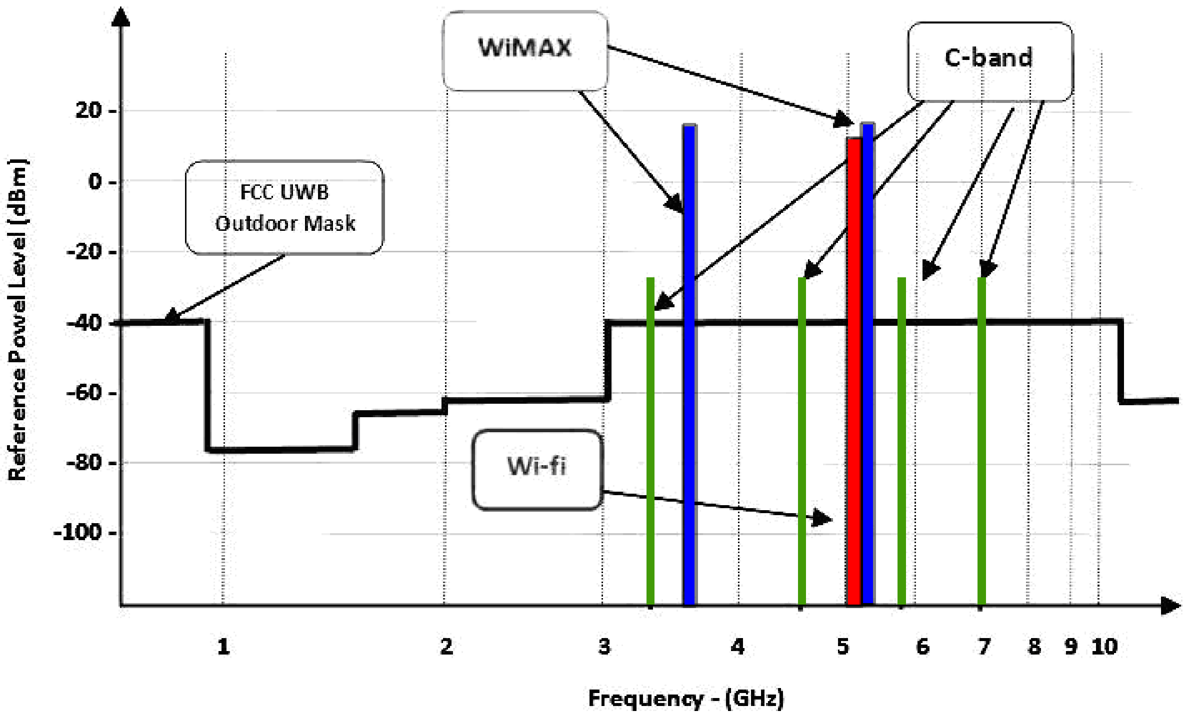
- UMTS
- HSPA/HSDP
- etc.

Future wireless standards:

- IMT advanced
- LTE
- etc

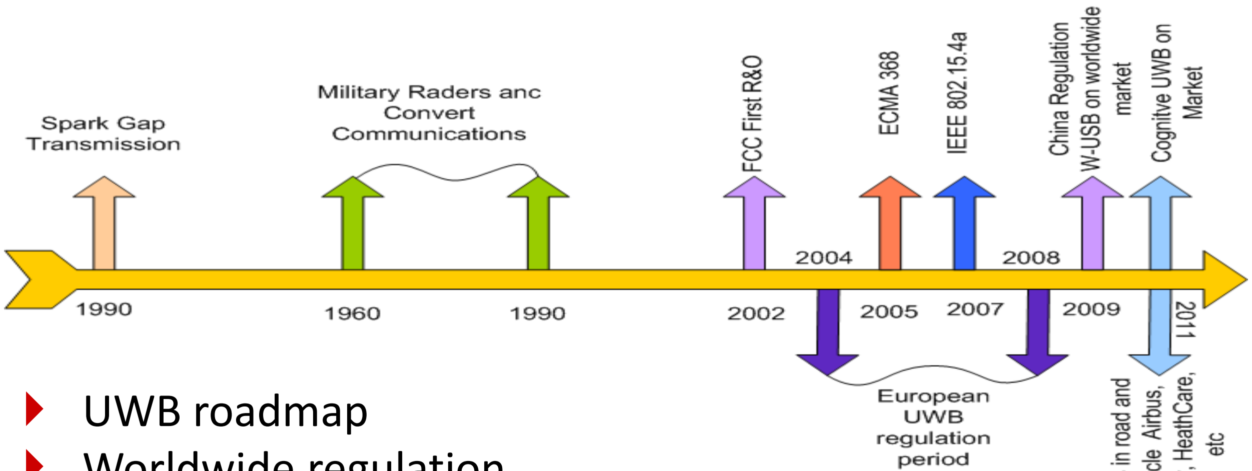
Unrecognized interfering signals:

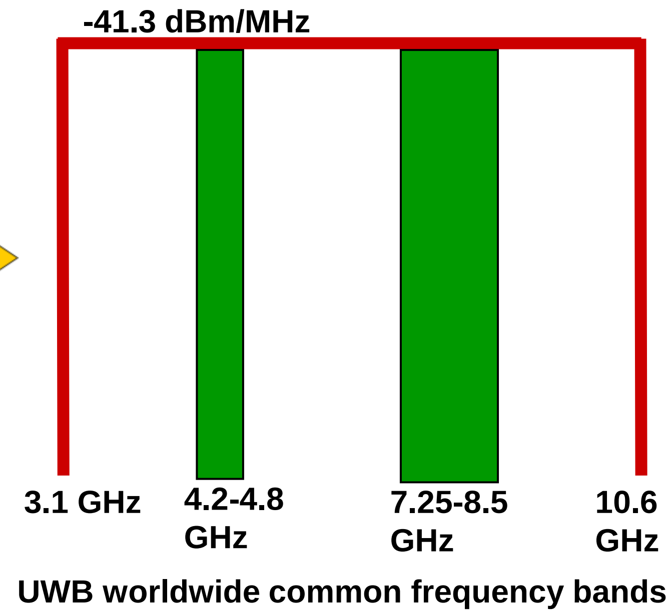
- Microwave ovens, general electromagnetic interference and any other transmitted signal (e.g. TV broadcasting)



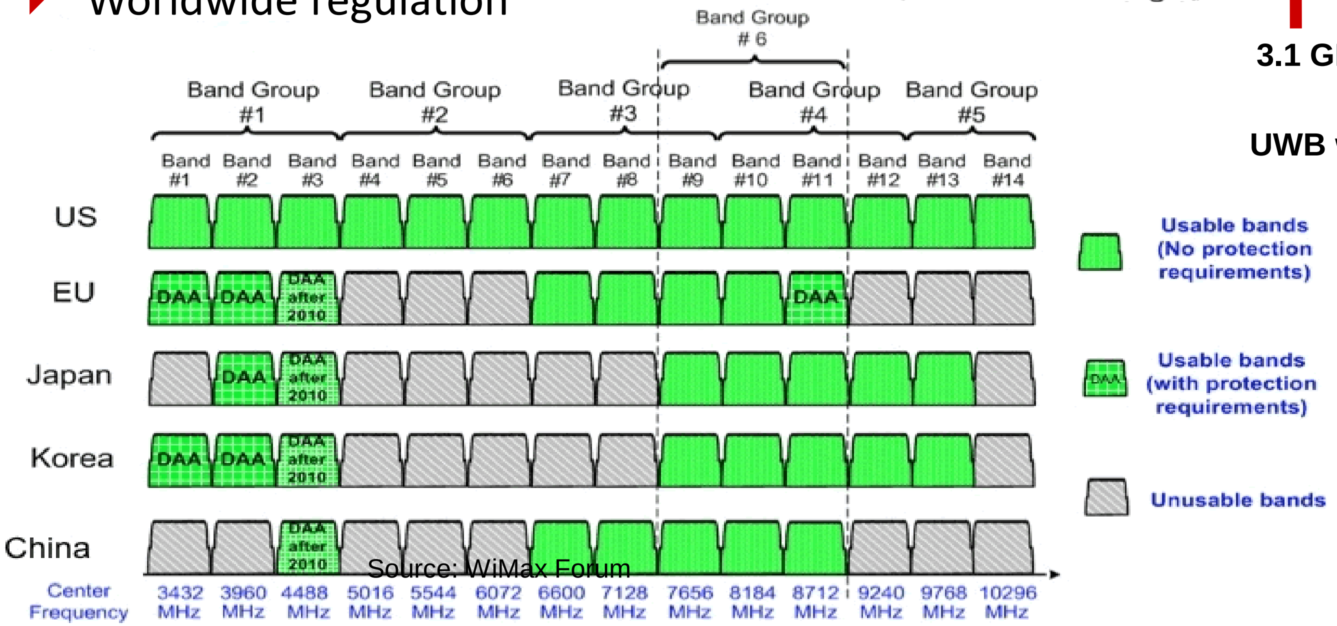
Potential interference impact on UWB system

Interference impact on UWB systems deployment!!





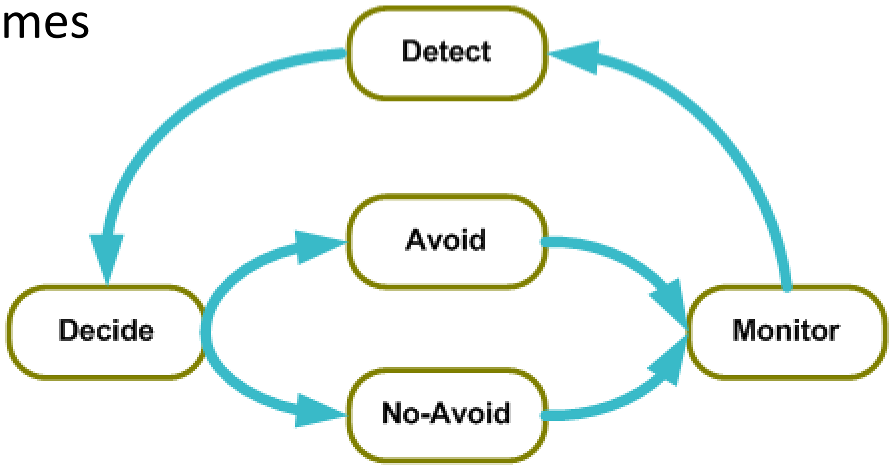
- UWB roadmap
- Worldwide regulation



Future requirements UWB systems!!

Potential UWB coexistence and interference mitigation techniques

- Detect and Avoid (DAA)
  - What is DAA?!!
  - DAA technique is mandated by regulation bodies
  - Exiting techniques must be updated to comply with DAA
  - **ETSI** is going to perform DAA compliance test
- Soft-spectrum adaptation and waveform design
- Spectrum sculpting
- Bi-orthogonal multiple-tone schemes
- Cognitive signalling



Detect and Avoid ➡ Cognitive Radio ➡ Cognitive Signalling

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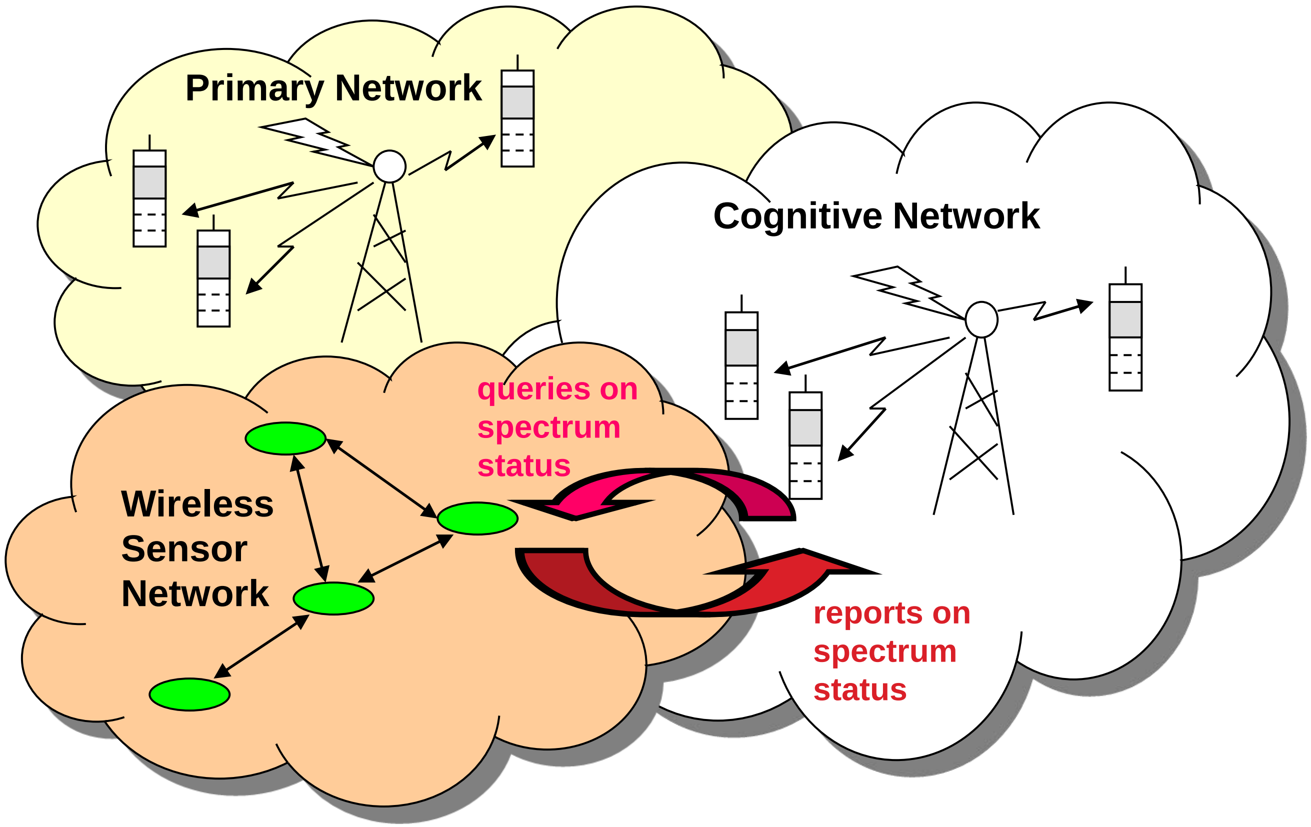
FP7 views

- Motivation: radio spectrum is a scarce resource that is paradoxically under-utilized
- Objective: develop a technology able to **reuse licensed but unused spectrum** in an opportunistic manner, in frequency-planned environments
- Challenge: **detect and use spectrum holes, without interfering harmfully with the licensed network**, with fine granularity of allocation in time and frequency

FP7 views

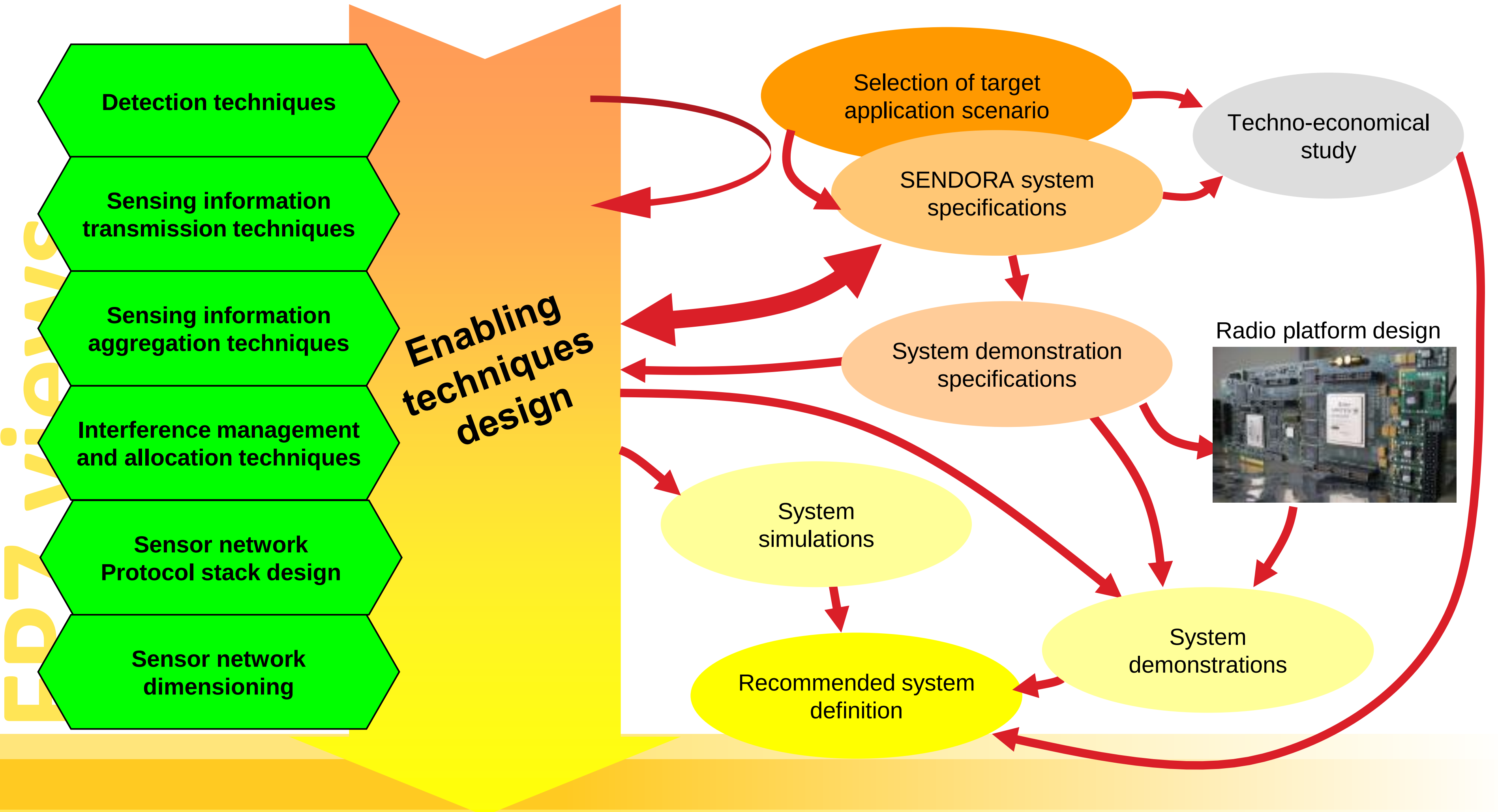


SENDORA concept consists in studying and developing a **"Sensor Network aided - Cognitive Radio"** technology

Target scenario: provide cognitive nomadic broadband communications in urban areas

FP7 views

SENDORA implementation follows a system design approach towards system simulations and demonstrations, and including techno-economical studies:



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FP7 views

Objectives and Goals of E^3

Goal

- To **transform** current wireless system infrastructures into an **integrated, scalable and efficiently managed Beyond-3rd-Generation (B3G) cognitive system framework**, which ensures **seamless access to applications and services** and **exploits the full diversity of corresponding heterogeneous systems**
- Introduce **cognitive systems in the wireless world**

FP7 views

Objective 1

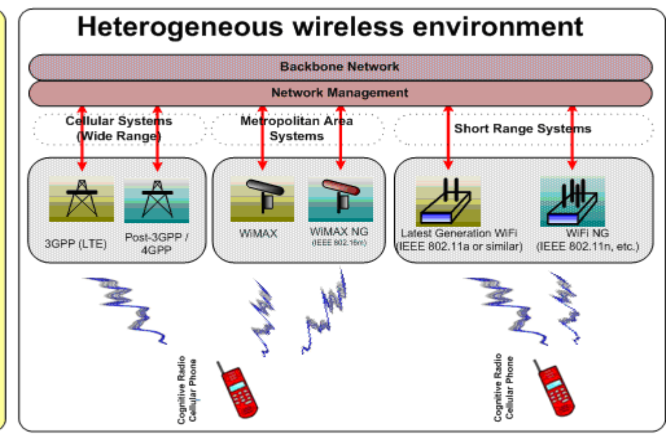
Cognitive Radio System design ***exploiting the capabilities of reconfigurable networks and self-adaptation to a dynamically changing environment.***

Objective 2

Gradual, non-disruptive evolution ***of existing wireless networks in accordance to user requirements***

E^3 Top Level Objectives

- Exploitation of Diversity
- Maximise Network Management Efficiency
- Maximise Access Network Efficiency
- Non-disruptive Evolution



Objective 3

Increased efficiency of wireless network operations, ***in particular by optimally exploiting the full diversity of the heterogeneous radio eco-space: Increase system management efficiency for network operation and (re-) configuration building on cognitive system and distributed self-organisation principles***

Contact: wolfgang.koenig@alcatel-lucent.com, pdemest@unipi.gr

More Information: www.ict-e3.eu

End-to-End Efficiency

RAS

Network operators (4)

Deutsche Telekom Laboratories

Telefónica

france telecom

TELECOM ITALIA

Alcatel·Lucent

Bell Labs Germany
project coordinator

Equipment manufacturers (6)

ERICSSON

THALES

NOKIA

NEC

TOSHIBA

E3

Jan. 08 - Dec. 09

22 Organizations (11 Countries)

Resources: 1413 PM (~59 PY/Y)

Agentschap Telecom

Bundesnetzagentur

Ofcom

Agence Nationale des Fréquences

Regulators (4)

University of Surrey

IDATE Consulting & Research

UPC

BUPT

University of Piraeus

Vrije Universiteit Brussel

Fraunhofer FOKUS Institut für Offene Kommunikationssysteme

ΕΘΝΙΚΟΝ & ΚΑΠΟΔΙΣΤΡΙΑΚΟΝ ΠΑΝΕΠΙΣΤΗΜΙΟΝ ΑΘΗΝΩΝ
NATIONAL & KAPODISTRIAN UNIVERSITY OF ATHENS

Academia / research institutes (8)

FP7 views

Cognitive Radio System Features

- Cognitive Radio Network supporting:
  - Full exploitation of Heterogeneous access systems with Joint Radio Resource Management
  - Flexible, more efficient spectrum management
  - Self-X functionality, Knowledge based, self-learning
  - Autonomous or collaborative decision making
  - Reconfigurable and dedicated terminals
  - Flexible Multistandard Basestation
  - Dynamic Spectrum Access
- Therefore improved performance and capacity – reduced OPEX

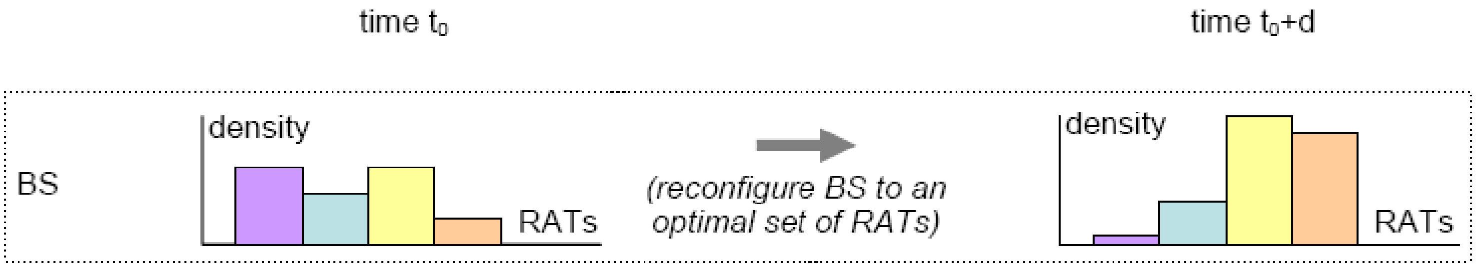


Fig. 1. Dynamic reconfiguration to an optimal RAT distribution profile.

FP7 views

Innovation brought about by the project

Enablers

- Cognitive Pilot channel (CPC)
- Spectrum Sensing
- Cognitive Control Radio

Prototype

- The E^3 prototyping environment
- Demonstration Scenarios

Standardisation Work

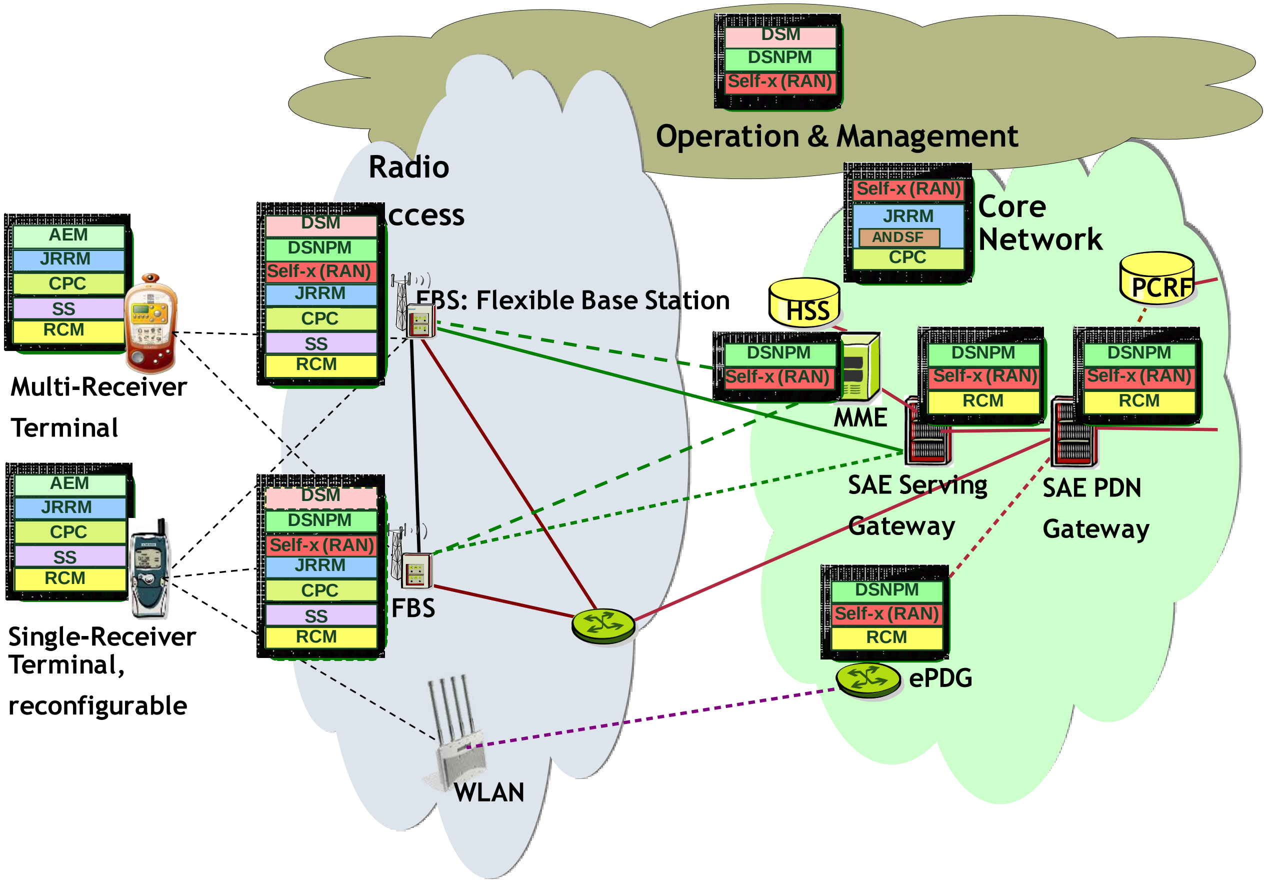
- ETSI
- IEEE
- SDR Forum

Regulation Work

- Influence on regulation (ITU-R, CEPT)

Architecture: System View

- Mapping of functional architecture on the LTE network architecture
- Impact on network elements
  - Base Stations
  - Terminals,
  - Gateways and core network elements
  - Operation and management domain
- Impact on interfaces
  - Standard interfaces enhanced
  - Additional content identified
  - Contributions to standardisation



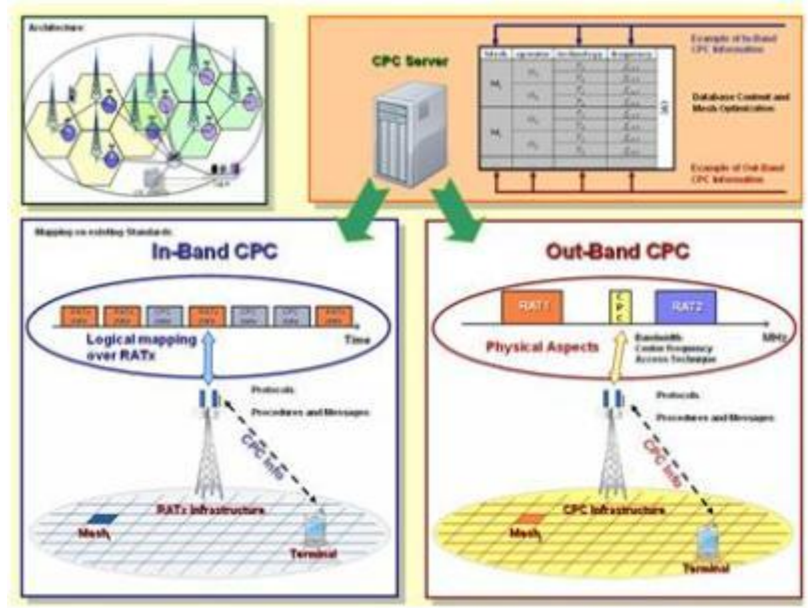
- Studies reveal acceptable impact in terms of signalling load (for example [1]) and processing power for the support of the additional functionality

[1] A. Galani, K. Tsagkaris, N. Koutsouris, P. Demestichas, "Design and Assessment of Functional Architecture for Optimized Spectrum and Radio Resource Management in Heterogeneous Wireless Networks", International Journal of Network Management, Accepted for Publication

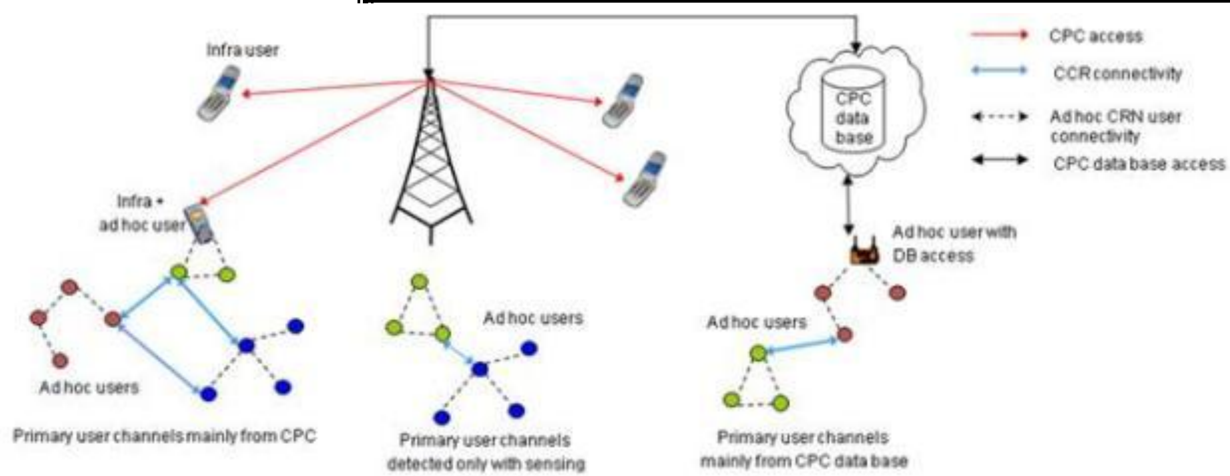
FP7 views

Enablers: cognitive pilot channel (CPC) – cognitive control radio (CCR)

- CPC for transferring information among networks and terminals in a cognitive network context
- Technical approach
  - Information specification
  - Mapping to outband and inband
  - Bit-rate calculations
  - Mesh optimisations



- CCR for direct communications of cognitive networks in limited spectrum band
  - Unlicensed access
  - Lightly licensed access
  - Primary systems may be present
- Very low power consumption



FP7 views

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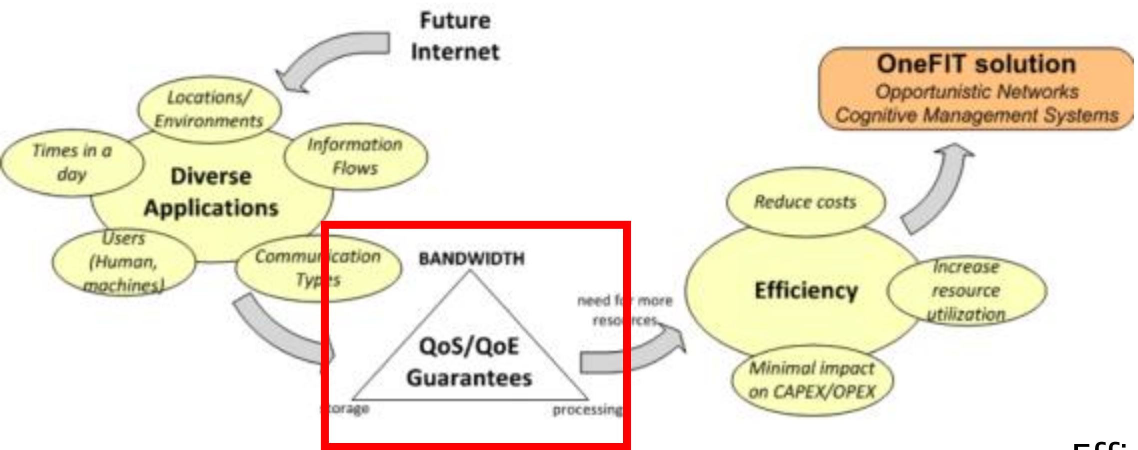
Objectives of OneFIT

*“The **main objective of the project is to design, develop and validate the concept of** applying opportunistic networks and respective **cognitive management systems** for efficient application/service/content provisioning in the Future Internet”*

Motivation for OneFIT



- <u>FI era requirements:</u>
  - Applications: numerous, diversified, often characterized by a "localized" interest
  - QoE/QoS
  - Increased need for wireless
  - Need for efficiency in application provision

- Applications
  - Growing interest for more application areas (FI penetrating every facet of our lives)
  - Social networking and prosumer concepts, communication and entertainment, management of critical infrastructures, environment (eco-system) protection, product manufacturing, digital services
- Diversification
  - Information flows, area and time of provision, end points can be users or machines, communication types
  - Quality of Service – Quality of Experience
  - Networks under stress for resources

- Efficiency in resource provision
  - Worst-case based planning, leads to over-provisioning of resources in non-peak times.
  - Intelligent resource management (e.g., spectrum reuse) is a solution, e.g., recent step is the addition of WiFi access points and femtocell nodes.
  - User expectations increase and so do the resource requirements posed onto communication networks.
  - Quest for further efficiency in resource provisioning.
  - Efficiency coupled with: (i) the higher utilization of resources; (ii) the reduction of transmission powers and energy consumption (in general, having decisions with a "green" footprint); (iii) the reduction of the total cost of ownership, which will be assumed to comprise the operational expenditures (OPEX), capital expenditures (CAPEX), and costs associated with the management of customer relations.

FP7 views

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QoSMOS: At a glance

- Quality of Service and MObility driven cognitive radio Systems
- Is an FP7 Integrated Project
  - Call 4 objective ICT-2009.1.1; The Network of the Future, part (b): Spectrum-efficient radio access to Future Networks
  - Duration is 36 months from January 2010
- Budget
  - 1198 PMs
  - Total = 14.5M€, EC contribution = 9.4M€
- 15 partners (**BT**, TEL, CEA, UOULU, TUD, IT, NTUK, AGILENT, TCF, UNIS, NEC, Fraunhofer, TST, ALD, BME
  + External Advisory Board for project steering
    (regulators, broadcasters,..)
- Contact: Michael Fitch; michael.fitch@bt.com
- More information: www.ict-qosmos.eu

QoSMOS: Motivation

- To develop a framework to **improve utilisation of radio spectrum, consistent with co-existence** with other services and opening up of the mobile broadband value chain,
- A cognitive approach to align with the strategies of the regulators
- A pan-European effort with a range of partners is needed to bring all the pieces together and move them close to market

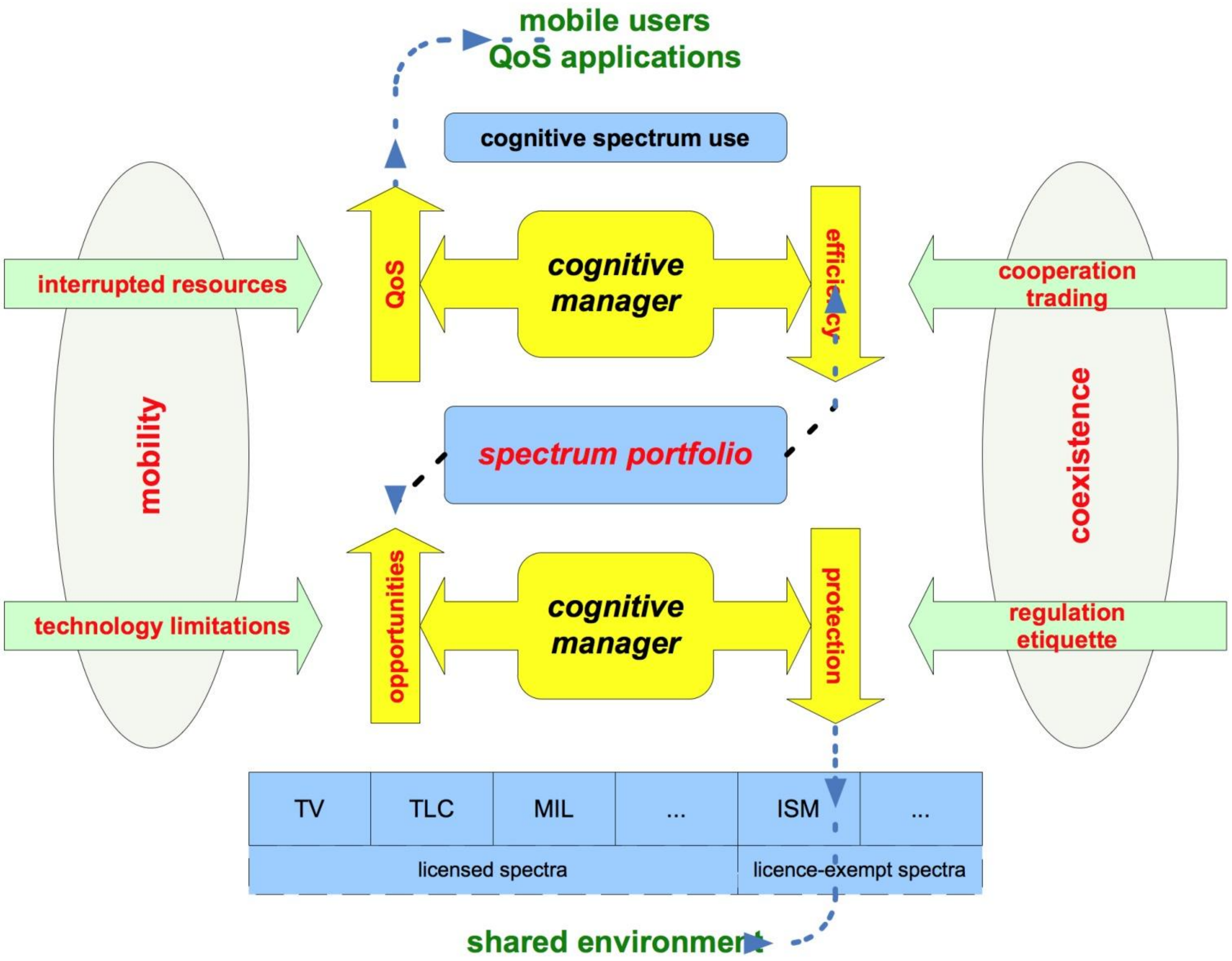
FP7 views

QoSMOS: Objectives

- The main objective is to provide a set of solutions for efficient radio access to future networks
- Under this are two S & T objectives
  - Cognitive Wireless Access Provision [measurable criteria]
    - Platform aspects
    - Intelligence aspects
  - **Network Support Provision [measurable criteria]**
- And two non-S & T objectives
  - Use-case development [guidelines on marketing]
  - Preparation of regulatory policies [response of regulators]

FP7 views

QoSMOS: Concept



An upper cognitive manager that allocates resource

A lower cognitive manager that manages the spectrum portfolio

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- UCELLS targets ultra-low power radio sensing and managing
  - New power-efficient radio transmission systems (e.g. UWB)
  - Cognitive radio clusters and advanced radio architectures
  - Security, public safety and emergency application scenarios
    - (e.g. people localization in disaster areas)

FP7 views

RAS

UCELLS main TARGET: **UWB sensing to enable cellular UWB**

- Spectral management of UWB signals
- Power-flow control techniques introduction in UWB terminals

FP7 views

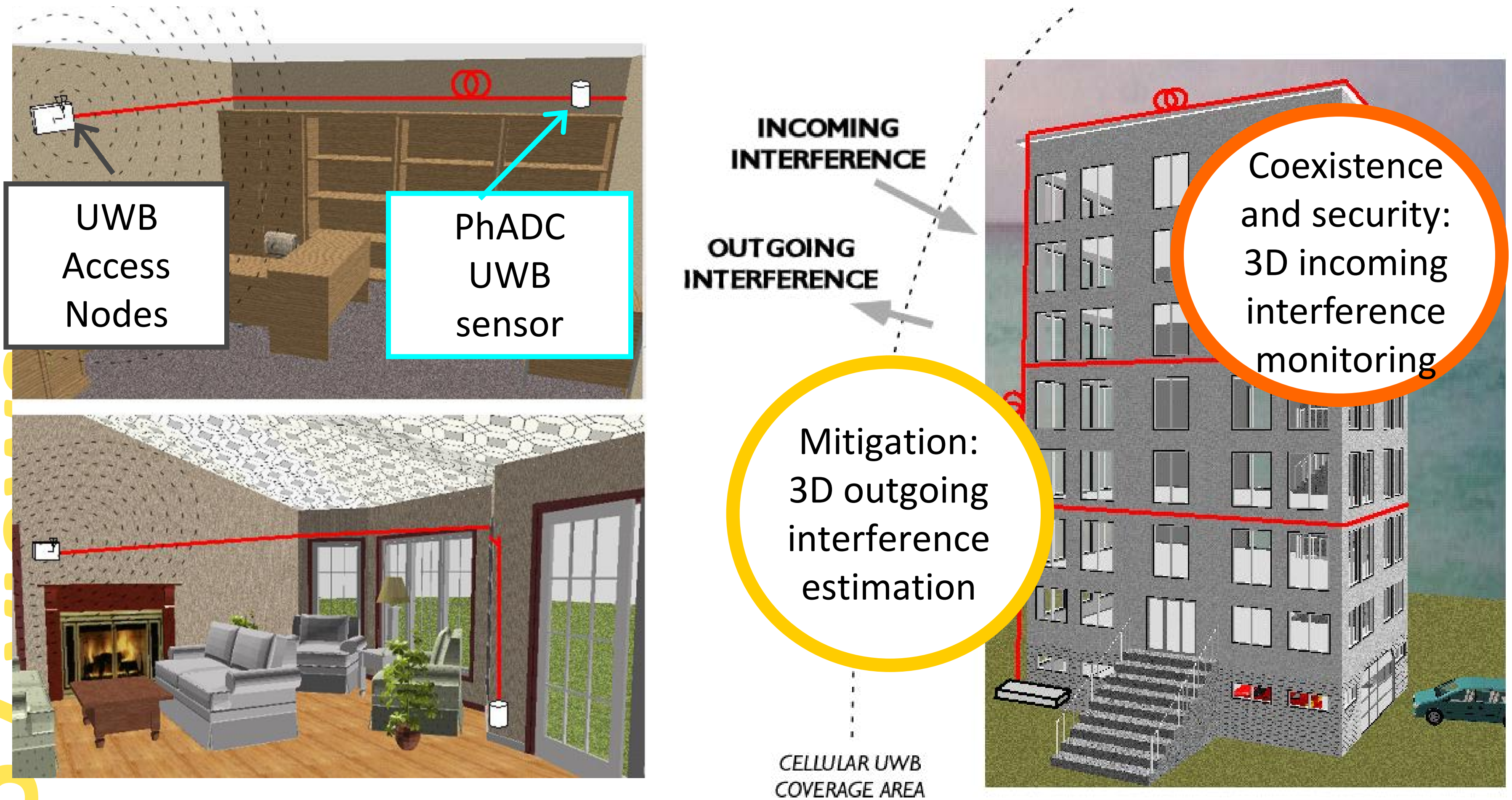
Enabling TECHNOLOGY:
UWB wireless spectrum monitoring is possible by ***multichannel high- performance photonic ADC (PhADC)***

Photonics enables…

1. UWB interference mitigation (required for range extension): 3D evaluation of external interfence produced
2. Identification and monitoring of wireless interferers disturbing

… because PhADC gathers UWB spectrum information simultaneously from a set of sensors

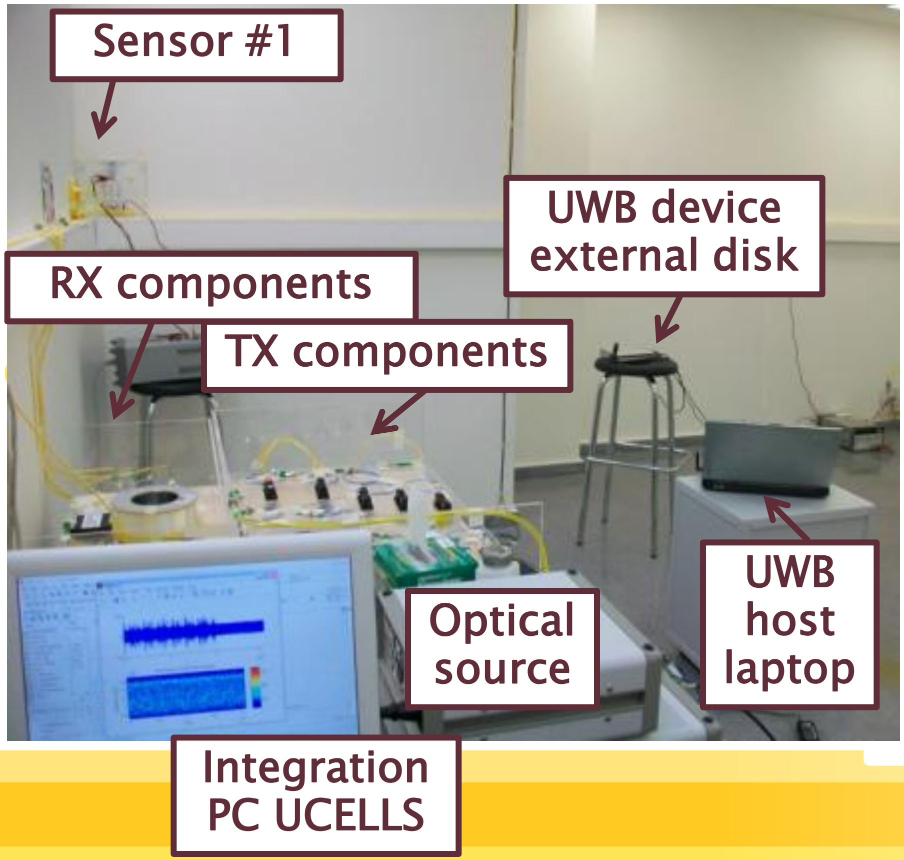
Scenarios: UCELLS deployment

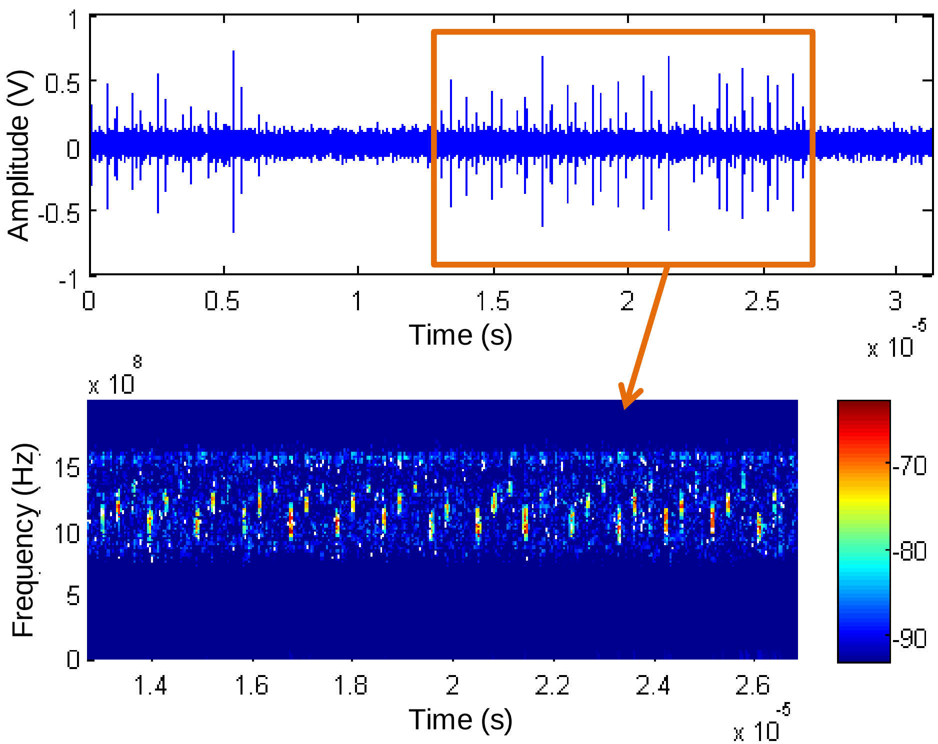


UCELLS
interference
monitoring

Demonstration

- **UWB communication (ECMA-368) are actually:**
  1. Fingerprinted
  2. Localized
  3. Managed





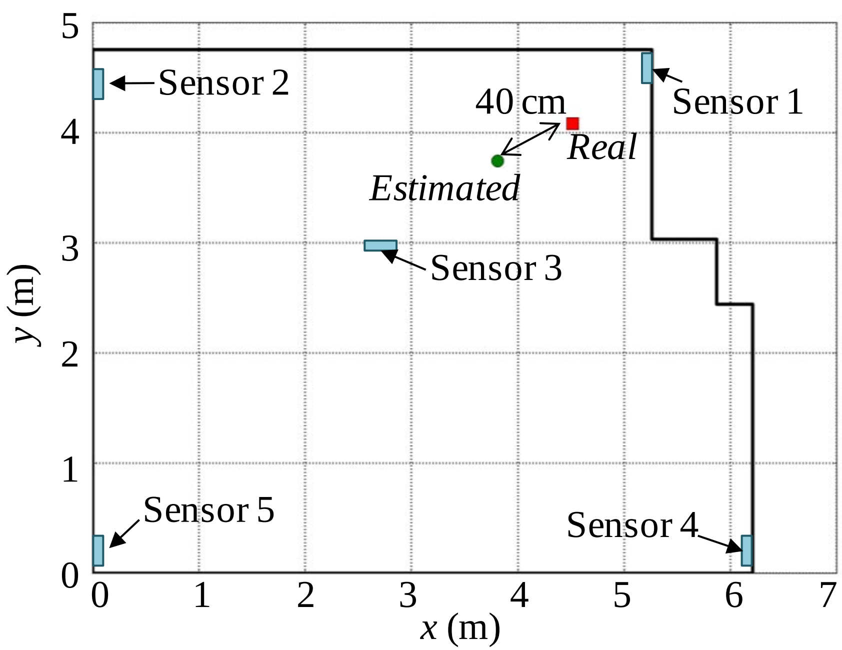
Experimental results

FP7 views

- Fingerprinting

Time42:	1.276733e+001µs	-100dB	-100dB	59dB
Time43:	1.307660e+001µs	60.7dB	-100dB	-100dB
Time44:	1.338588e+001µs	-100dB	74.9dB	-100dB
Time45:	1.369515e+001µs	-100dB	-100dB	51.3dB
Time46:	1.400442e+001µs	67.7dB	-100dB	-100dB
Time47:	1.431369e+001µs	-100dB	64.7dB	-100dB
Time48:	1.462296e+001µs	-100dB	-100dB	54.2dB
Time49:	1.493224e+001µs	67.6dB	-100dB	-100dB
Time50:	1.524151e+001µs	-100dB	64.6dB	-100dB
Time51:	1.555078e+001µs	-100dB	-100dB	52.5dB
Time52:	1.586005e+001µs	70dB	-100dB	-100dB
Time53:	1.616932e+001µs	-100dB	55.7dB	-100dB
Time54:	1.647860e+001µs	-100dB	-100dB	63dB
Time55:	1.678787e+001µs	77.2dB	-100dB	-100dB
Time56:	1.709714e+001µs	-100dB	67dB	-100dB
Time57:	1.740641e+001µs	-100dB	-100dB	-100dB
Time58:	1.771568e+001µs	62.9dB	-100dB	-100dB
Time59:	1.802495e+001µs	-100dB	67.5dB	-100dB
Time60:	1.833423e+001µs	-100dB	-100dB	62.1dB
Time61:	1.864350e+001µs	67.2dB	-100dB	-100dB
Time62:	1.895277e+001µs	-100dB	60.1dB	-100dB
Time63:	1.926204e+001µs	-100dB	-100dB	65.8dB
Time64:	1.957131e+001µs	61.5dB	-100dB	-100dB
Time65:	1.988059e+001µs	-100dB	68.5dB	-100dB
Time66:	2.018986e+001µs	-100dB	-100dB	-100dB
Time67:	2.049913e+001µs	76.4dB	-100dB	-100dB
Time68:	2.080840e+001µs	-100dB	68.1dB	-100dB
Time69:	2.111767e+001µs	-100dB	-100dB	66.8dB
Time70:	2.142695e+001µs	80.4dB	-100dB	-100dB
Time71:	2.173622e+001µs	-100dB	63.1dB	-100dB
Time72:	2.204549e+001µs	-100dB	-100dB	-100dB
Time73:	2.235476e+001µs	62.3dB	-100dB	-100dB
Time74:	2.266403e+001µs	-100dB	58.3dB	-100dB
Time75:	2.297331e+001us	-100dB	-100dB	63.4dB

- Localization



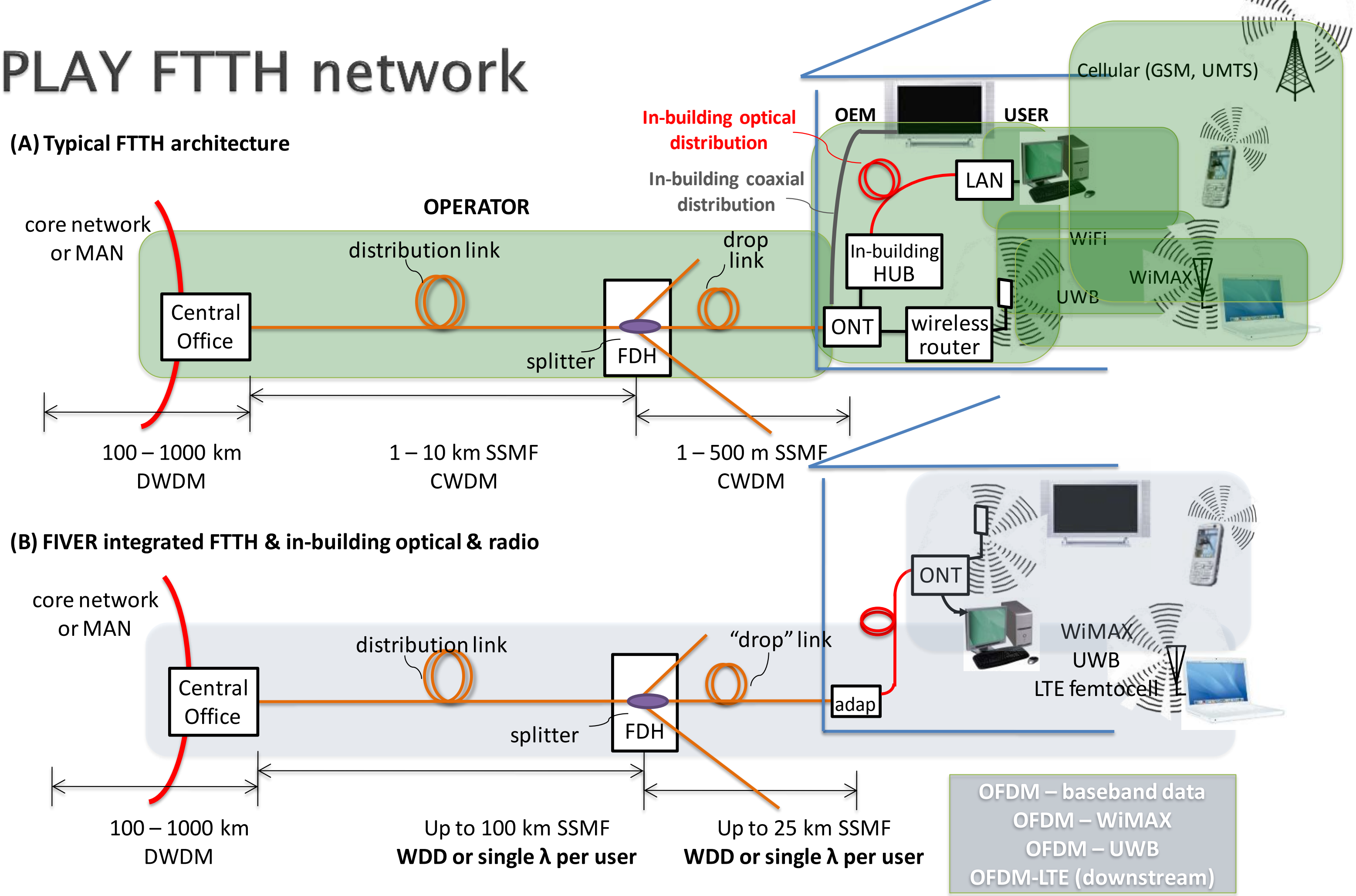
Overview

RAS

- Introduction
- Project Highlights
  - **E-UWB:** Coexisting Short Range Radio by Advanced Ultra-Wideband Radio Tech.
  - **SENDORA:** SEnsor Network for Dynamic and cOgnitive Radio Access
  - **E3**: End-to-End Efficiency
  - **OneFit:** Opportunistic networks and Cognitive Management Systems for Efficient Application Provision in the Future InterneT
    QoSMOS: Quality of Service and MObility driven cognitive radio Systems
  - **UCELLS:** UWB real-time interference monitoring and CELLular management Strategies
  - **FIVER: Fully-Converged Quintuple-Play Integrated Optical-Wireless Access Architectures**
- Standardisation and Regulation
  - **WALTER:** Wireless Alliances for Testing Experiment and Research
- Conclusion

FP7 views

FIVER 5-PLAY FTTH network



1. **QUINTUPLE PLAY implemented using FULL STANDARD RECEIVERS (UWB, WiMAX, LTE and OFDM-baseband) employed at costumer premises – ALL OFDM-BASED**
2. **COGNITIVE FIBRE-TO-THE-HOME NETWORK**
3. **Two architectures: CWDD: Conventional wavelength duplexing architecture**

   RWDD: R-EAT based (only optical source at CO)

FP7 views

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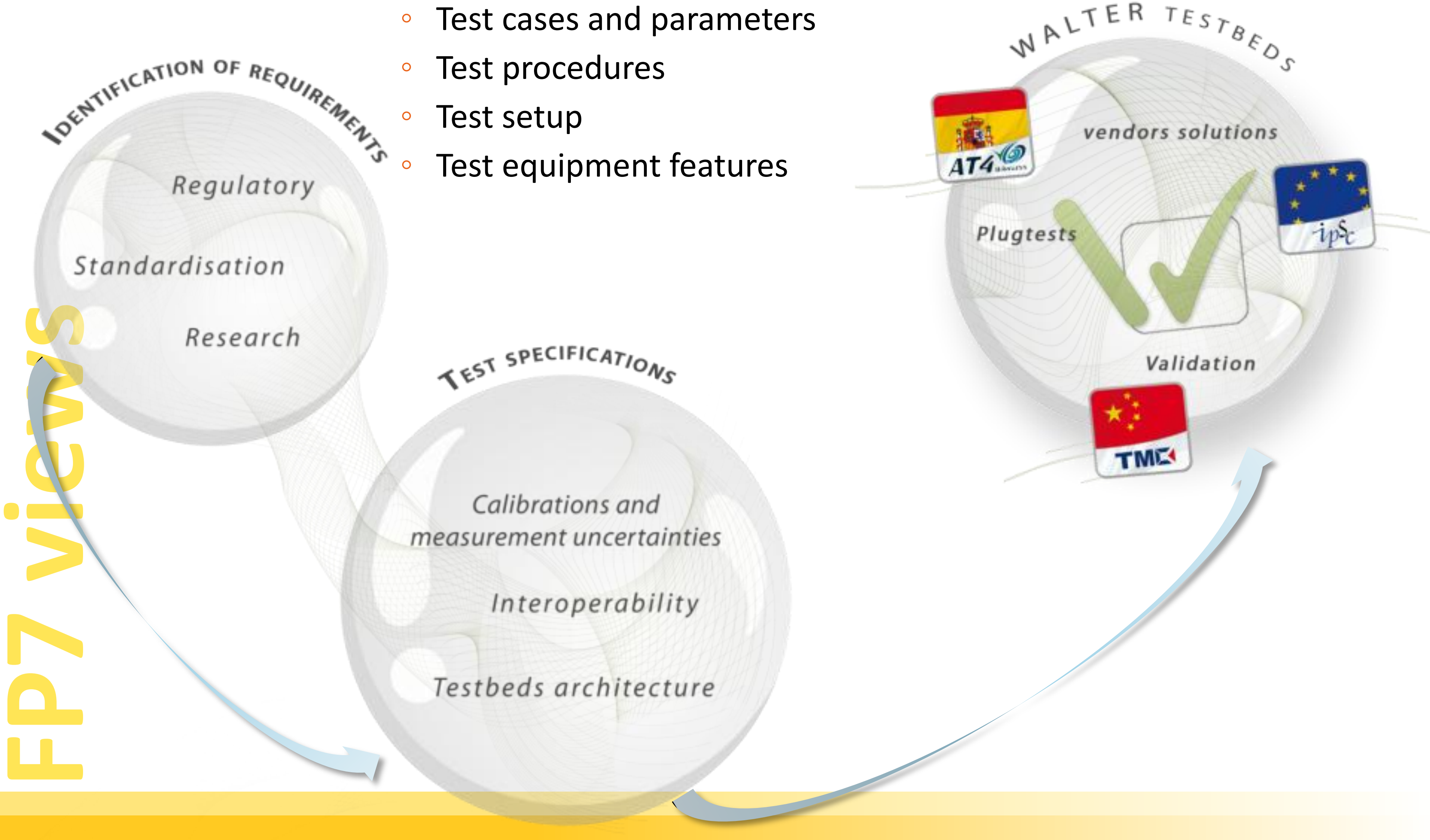
At a glance

- WALTER = Wireless Alliances for Testing Experiment and Research
- Objective: Development of an international network of test beds for emerging broadband wireless technologies
- Project focus: Coexistence of emerging wireless broadband technologies with other radio technologies and services
- Partners:
- Duration: 2 years (01.01.2008 to 31.12.2009)
- Project website: http://walter-uwb.eu

FP7 views

Overall approach

- Testbed definition
  - Test cases and parameters
  - Test procedures
  - Test setup
  - Test equipment features

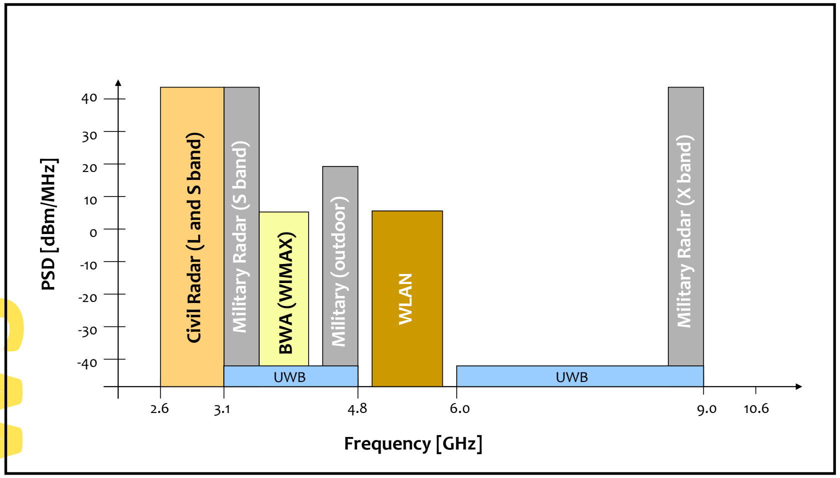


Spectral compatibility and co-existence

Example.: Ultra-Wideband radio

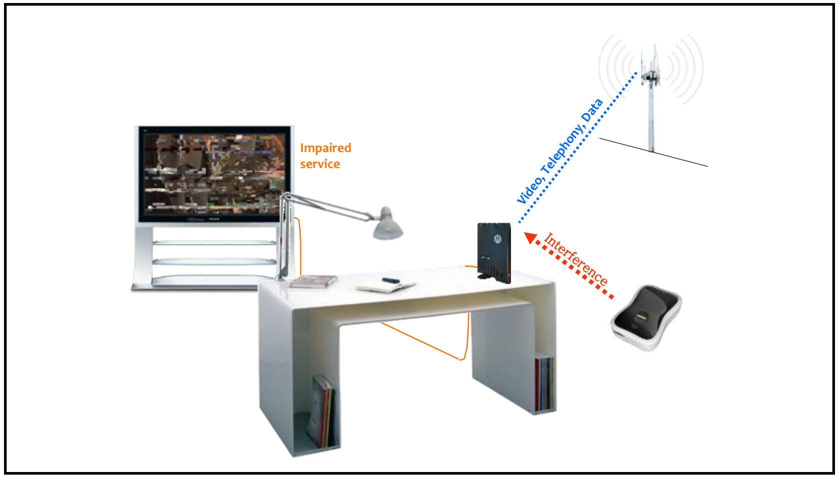
Spectrum sharing

Spectral underlay concept



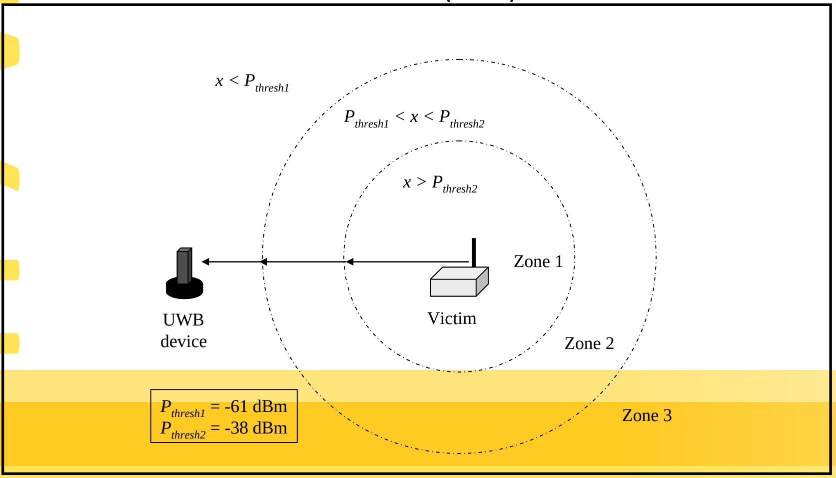
Interference scenario

Impact on licensed services



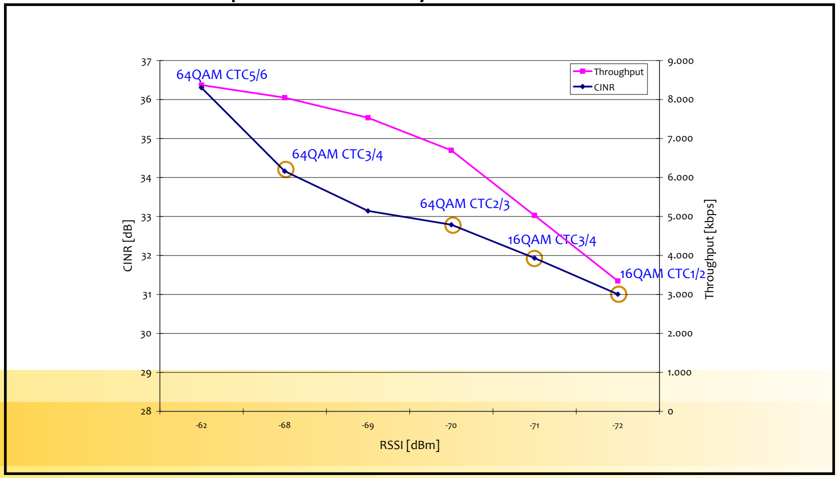
Mitigation mechanisms

Detect-and-Avoid (DAA)



Victim service protection

Impact on PHY layer and QoS



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Measurement issues and limitations

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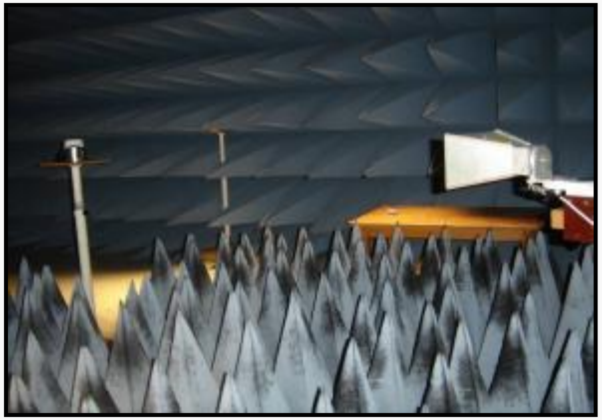
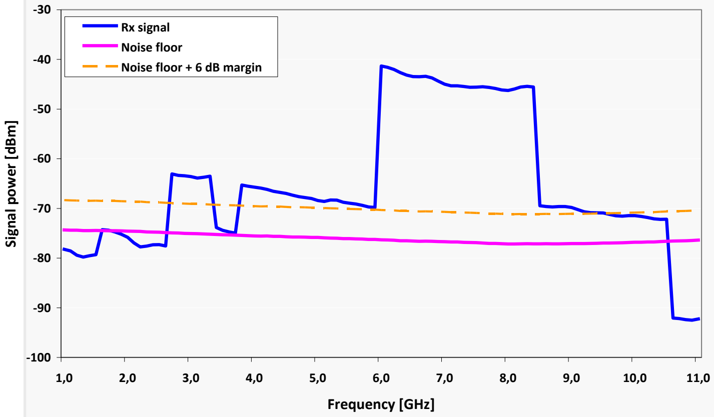
Radiated measurements

Antenna far-field, path loss, noise



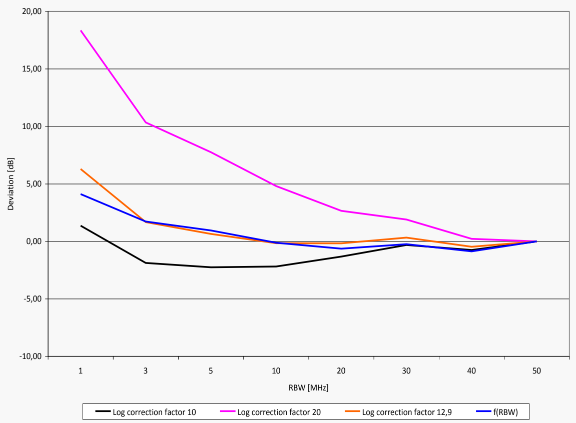
Signal-to-noise ratio

Wanted signal power < environmental noise



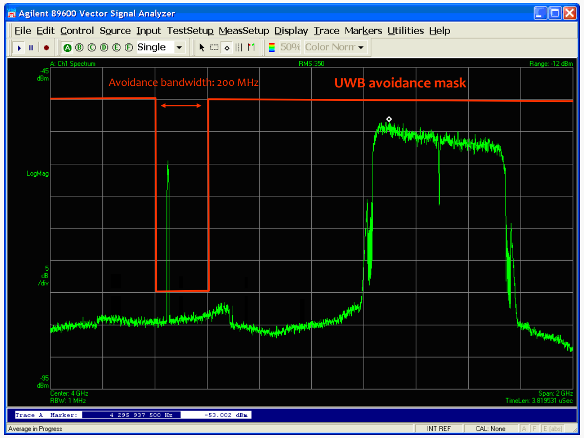
Peak power measurements

Equipment limitations, scaling factor



Functional verification

Detect-and-Avoid test procedures

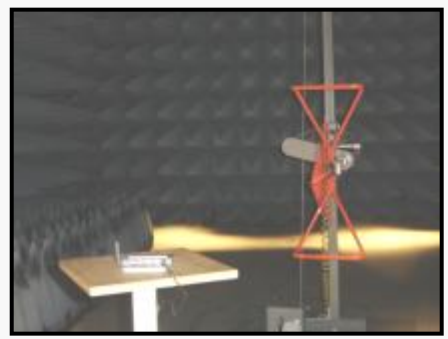


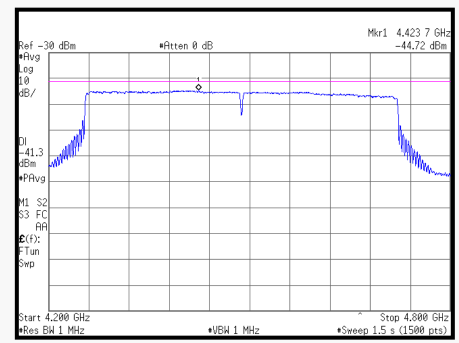
Test Categories

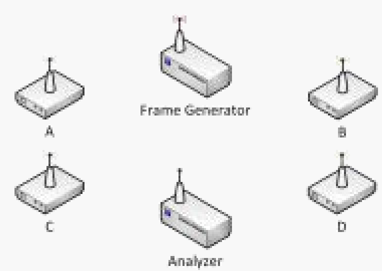
The **WALTER test beds** cover 8 test categories:

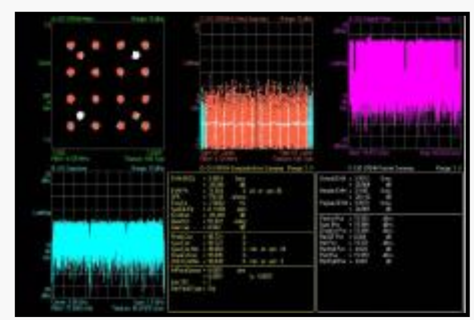
- Regulatory (REG)
- Conformance (CON)
- Interoperability (IOP)
- Radiated Performance Tests (RPT)
- Over The Air (OTA)
- Coexistence (COE)
- Performance (PER)
- Plugfests (PGF)

✓Spectrum and Power Characteristics
✓ Radiated Emissions
✓ Detect and Avoid
✓ Protocol testing
✓ and more ...









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Conclusion

RAS

- Presented Europe FP7 program – open to collaborate with USA companies/institutions
- Cognitive Radio is under major research TODAY – expect outcome tomorrow
- Presented different initiatives..
  - From high-level CR management
  - To low-level radio sensing
  - Standardization
  - Regulation

RLLORENT@NTC.UPV.ES

More information can be found in the RADIO ACCESS AND SPECTRUM (RAS) FP7 Cluster: http://www.newcom-project.eu/ras

FP7 views

Further Contact

FP7 views

- **E-UWB:**
  Dr. Abdur Rahim (abdur.rahim@create-net.org)
  Dr. Radoslaw Piesiewicz, WCB EIT + Sp.z.o.o., Poland
  Prof. Sven Zeisberg (zeisberg@htw-dresden.de)
  http://www.euwb.eu
- **SENDORA:**
  Dr. Bertrand Mercier (Bertrand.MERCIERB@fr.thalesgroup.com)
  http://www.sendora.eu
- **E3:**
  Mr. W. Koenig (Wolfgang.Koenig@alcatel-lucent.com)
  Prof. P. Demestichas (pdemest@unipi.gr)
  https://ict-e3.eu/
- **OneFIT:**
  Prof. P. Demestichas (pdemest@unipi.gr)
  J. Gebert (Jens.Gebert@alcatel-lucent.com)
  http://www.ict-onefit.eu
- **QuOSMOS**
  Dr. Michael Fitch (michael.fitch@bt.com)
  http://www.ict-qosmos.eu
- **UCELLS, FIVER**
  Prof. Roberto Llorente (rllorent@dcom.upv.es)
  http://www.ict-ucells.eu
  http://www.ict-fiver.eu
- **WALTER**
  Detlef Fuehrer (detlef.fuehrer@jrc.ec.europa.eu)
  http://walter-uwb.eu

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