IP CREW

Cognitive Radio Experimentation World

Workshop on TV White Spaces + CREW Training Days

Brussels, Belgium * 18-20 February 2013

Ingrid Moerman - iMinds

- **CREW - why?**
  - Which problems do we want to solve?

- **CREW - what?**
  - The CREW project at a glance

- **CREW - how?**
  - Some examples explaining the key aspects of CREW

- **CREW offer**
  - How can experimenters benefit from CREW?

The Internet plays a crucial role in interconnecting technologies and services…
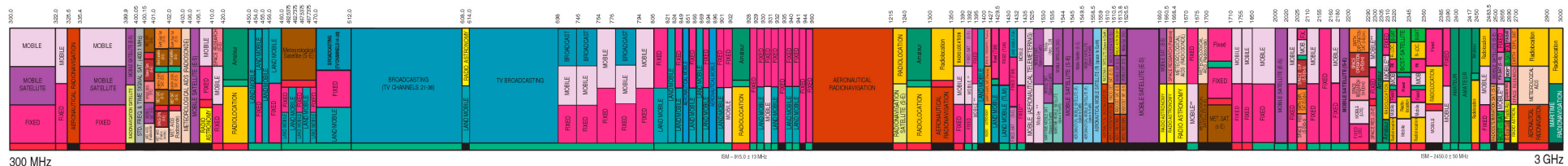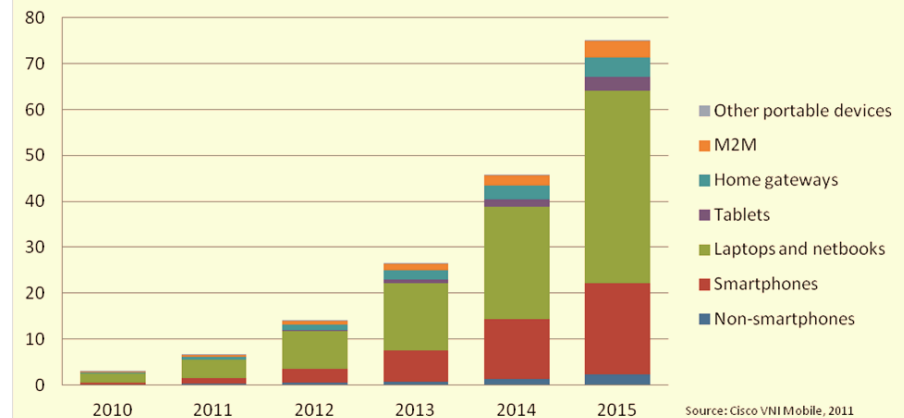

… resulting in increasing complexity

- more users, more types of users
- more devices, more type of devices (Internet of Things)
- **increasing wireless traffic demand!**

BUT… radio spectrum is limited!

- big differences depending on the frequency band
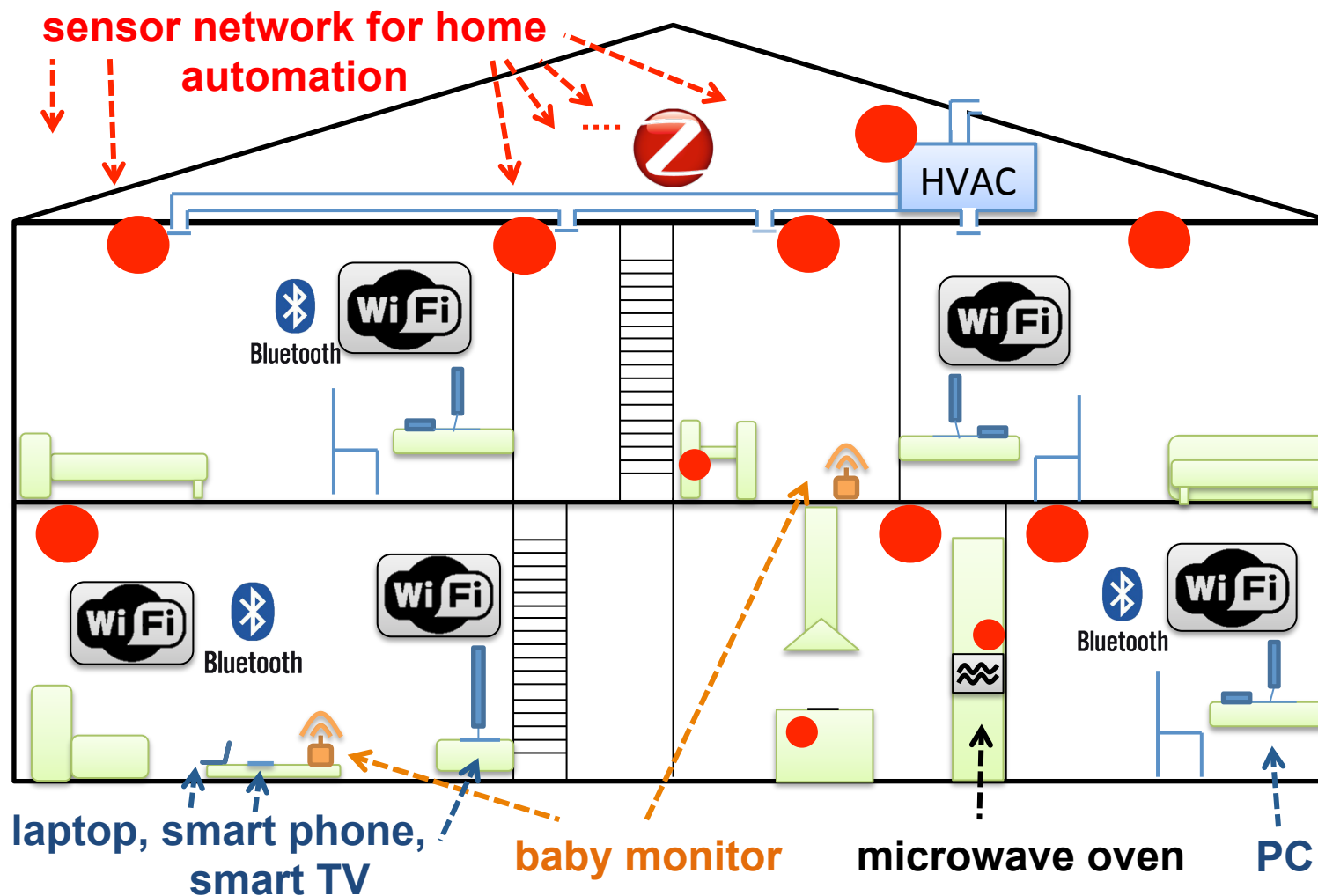 - white spaces in licensed bands versus overcrowded unlicensed bands

Mobile Data Traffic by Device (Exabytes)

- Other portable devices
- M2M
- Home gateways
- Tablets
- Laptops and netbooks
- Smartphones
- Non-smartphones

Source: Cisco VNI Mobile, 2011

CREW – Why?

- **Coexistence problem in unlicensed bands**
  - ISM bands are heavily used (lots of interference!)
  - Suboptimal use of the scarce spectral resources in ISM bands

sensor network for home automation

laptop, smart phone, smart TV

baby monitor

microwave oven

PC

- **Body Area Networks**
  - Sensors on human body measuring ECG, SpO2, heart rate...
  - Applications: medical, sports, augmented reality...
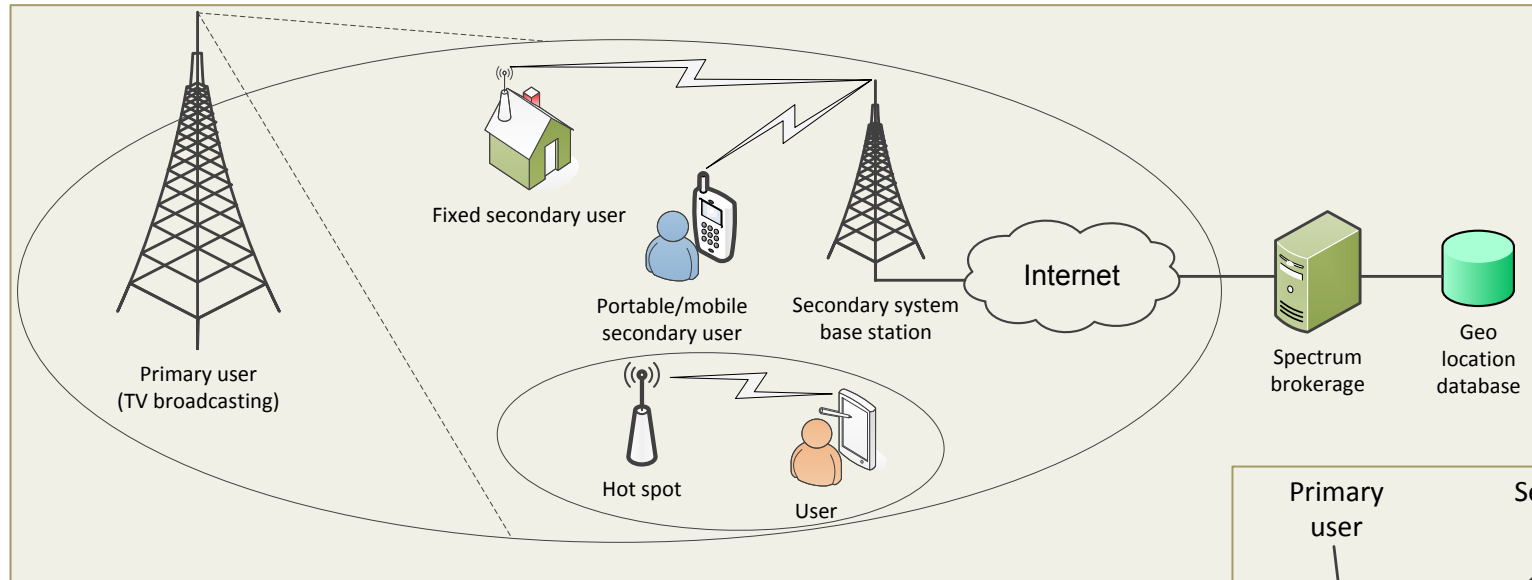 - RF communication in ISM bands is common
- **Need to coexist with other spectrum users**
  - Introduce frequency agility in BANs
  - Share spectrum utilization knowledge with other co-located BANs and stationary networks
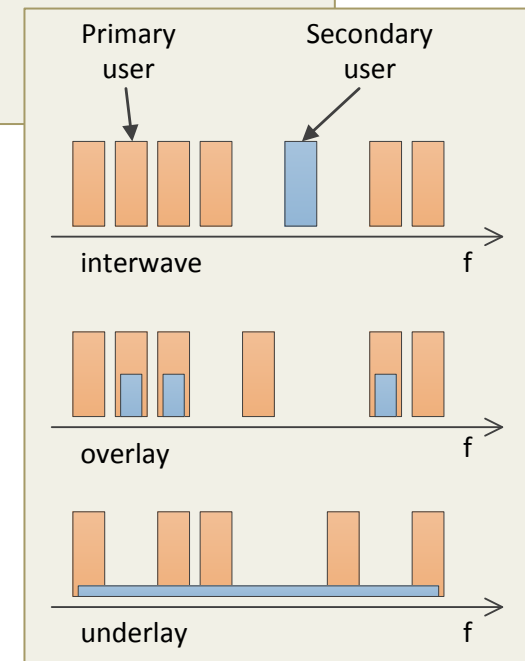- **Need for Cognitive Body Area Networks**

■ Licensed bands

- **Exclusive use, low utilization (white spaces)**
  - Digital TV switch-over freed up large parts of UHF band
- **Interweave mode**
  - Spectrum brokerage + geo location database
  - Secondary user location
- **Overlay / underlay mode**
 - Spectrum sensing + transmission format

- **Solution: cognitive radio – cognitive networking**
  - Use the available spectrum resources as efficiently as possible, by adapting the radios (transmitters and receivers) to the wireless environment and the user needs
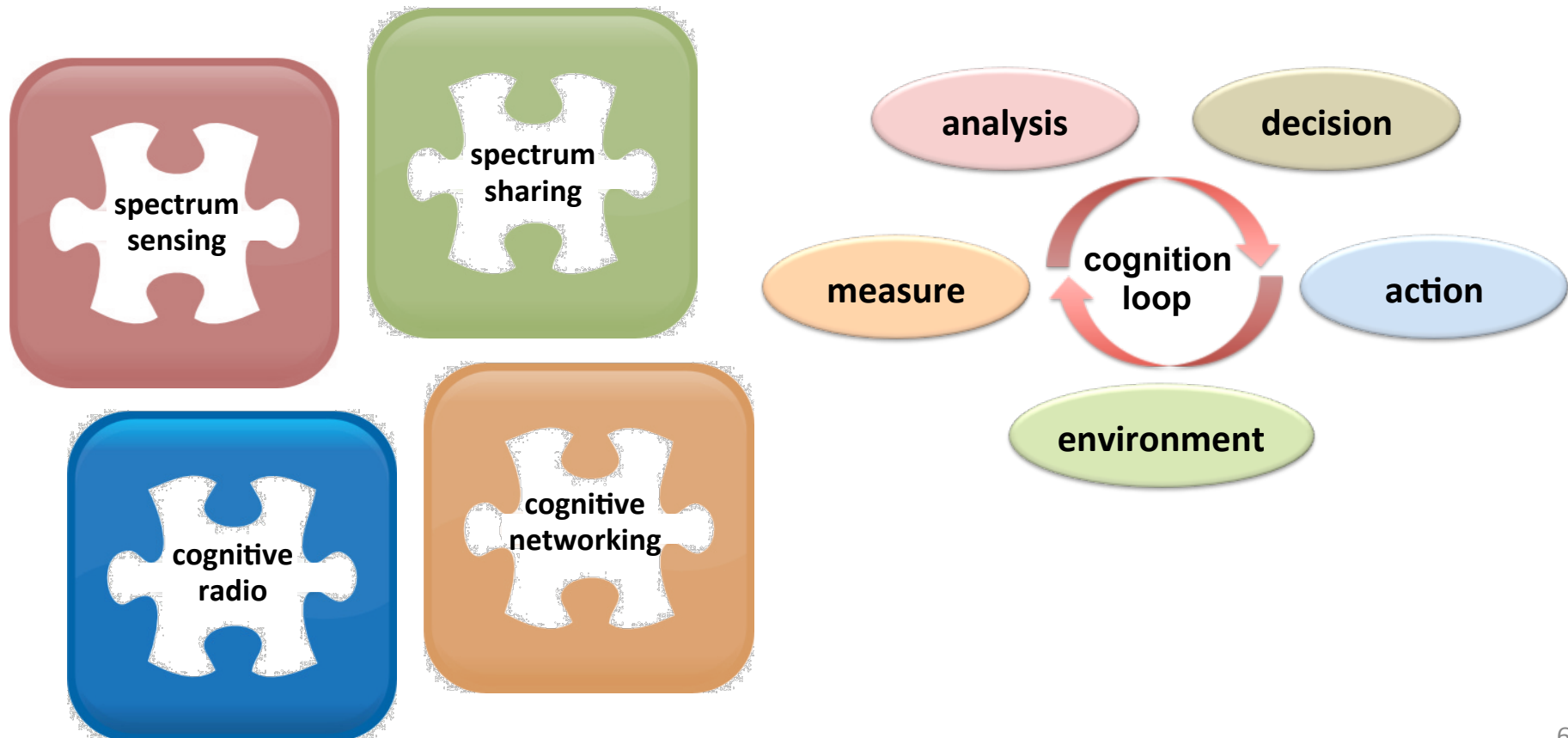
From novel idea to commercial use …

… experimentally-supported research is crucial for validation of new CR/CN concepts
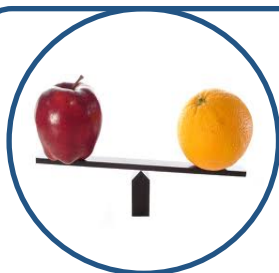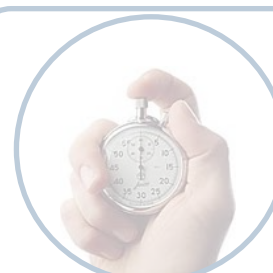

compare the performance of multiple solutions
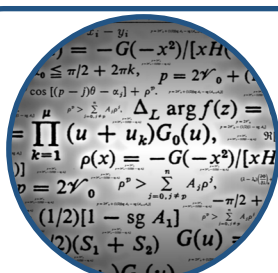
theory vs. reality: impact of real-life deployment

showcase for industry, regulators and government

reduce the time to market

understand how people experience and use technology

- **Wireless developer's questions**
  - **How to evaluate cognitive radio / cognitive networking solutions?**
    - … in a configurable environment
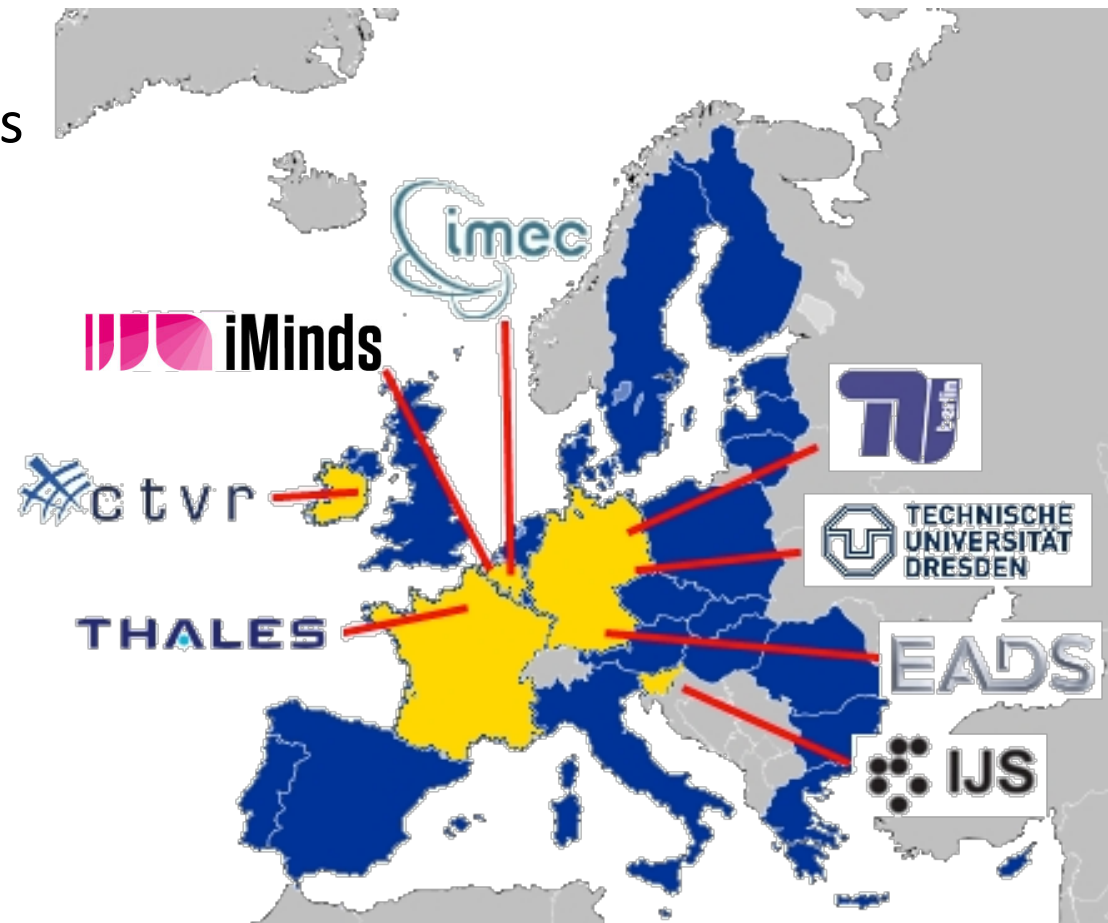   - … in a repeatable way
    - … allowing fair comparison of results

  - **Should/can I build my own heterogeneous testing environment?**

- **Cognitive Radio Experimentation World**
  - FP7 call 5
  - Project started October 2010
  - 8 core partners
  - 3+6 open call partners
    - UDUR (UK)
    - TUIL (DE)
    - TECNALIA (ES)
    - UTH (GR)
    - NICTA (AT)
    - IT (PT)
    - CMSF (PT)
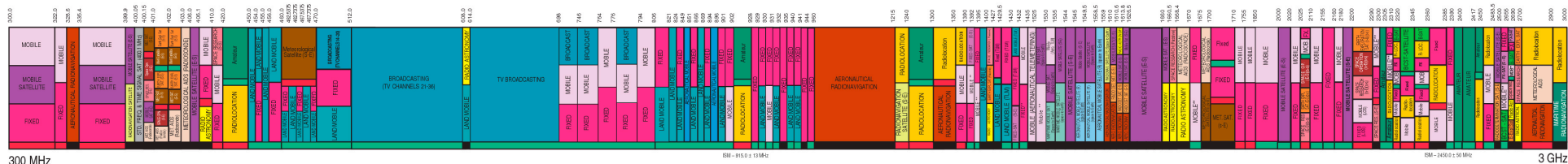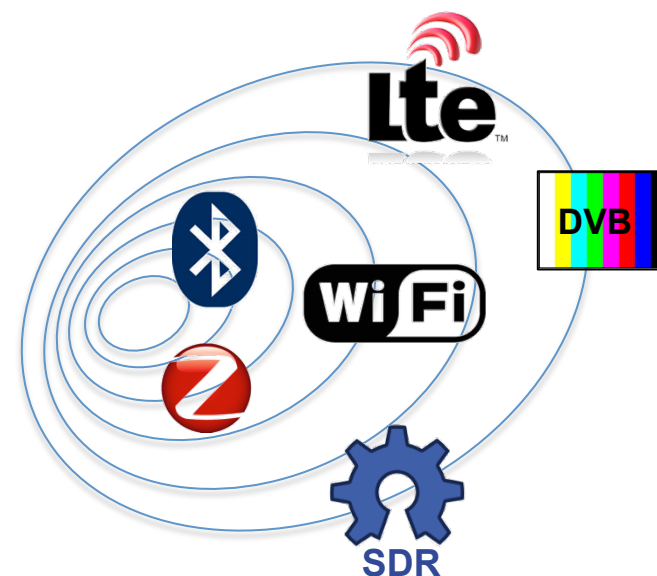   - CNIT (IT)
    - WINGS (GR)

- **CREW is NOT …**
  - doing research on spectrum sensing, cognitive radio & cognitive networking
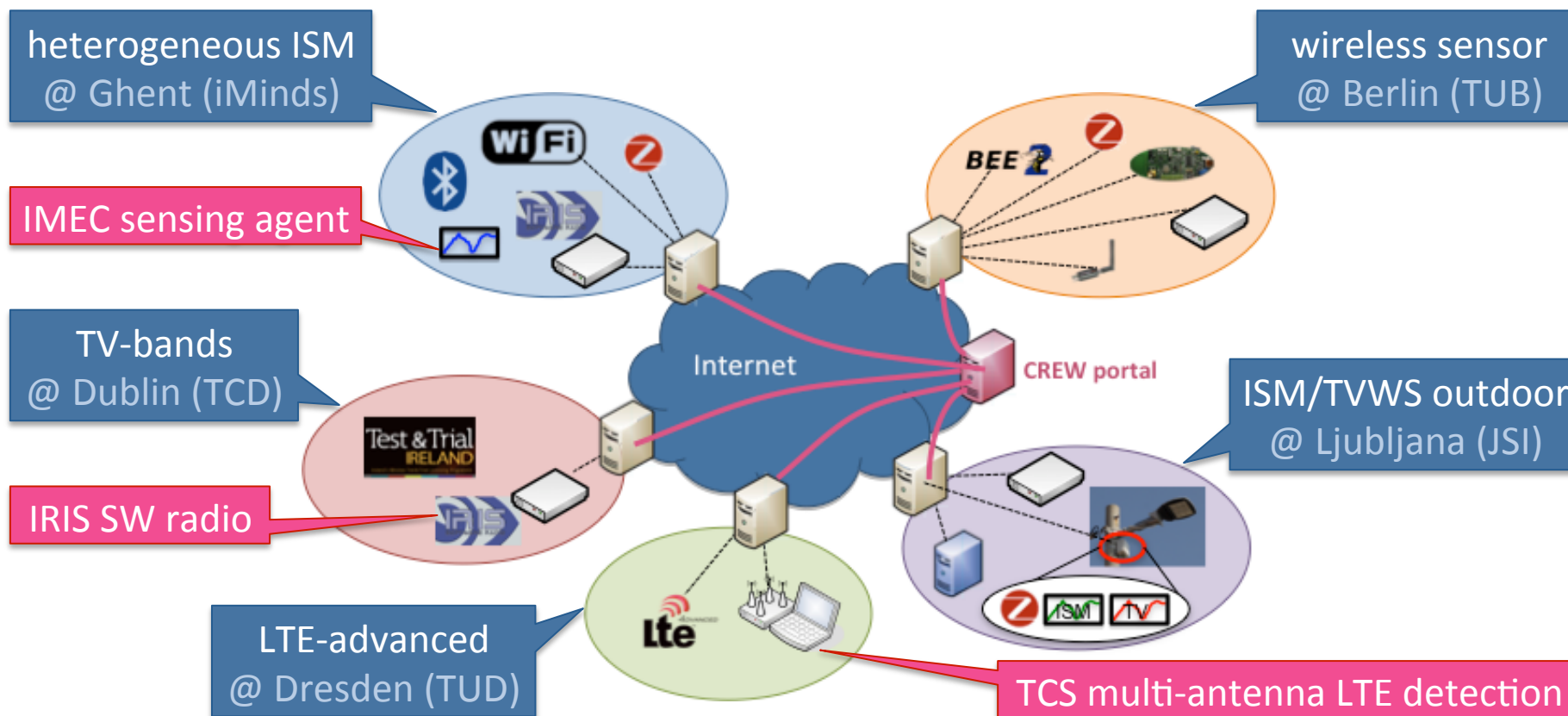 - designing new algorithms

- **CREW is …**
  - bringing together test facilities for supporting research on spectrum sensing, cognitive radio & cognitive networking
  - augment existing facilities with novel cognitive components
  - bringing together expertise on experimentation
  - facilitating access to heterogeneous test facilities
  - offering better methodologies for experimentation (repeatability, reproducibility, comparability)
  - validate advanced cognitive solutions using CREW facilities and CREW methodologies

- **establish an open federated test platform, facilitating experimentally-driven research on**

  - advanced spectrum sensing
  - cognitive radio
  - cognitive networking
  - spectrum sharing
    in licensed and unlicensed bands

CREW platform

heterogeneous ISM
@ Ghent (iMinds)

wireless sensor
@ Berlin (TUB)

IMEC sensing agent

TV-bands
@ Dublin (TCD)

ISM/TVWS outdoor
@ Ljubljana (JSI)

IRIS SW radio

LTE-advanced
@ Dresden (TUD)

TCS multi-antenna LTE detection

Internet

CREW portal

WiFi	IEEE 802.11	**IRIS**	IRIS GPP-based software radio platform	**IMEC**	IMEC Sensing Agent
Bluetooth	IEEE 802.15.1	Test&Trial IRELAND	Comreg spectrum licenses	**TV**	UHF/VHF TV sensing
Z	IEEE 802.15.4			**ISM**	ISM bands sensing
lte	LTE-advanced	**BEE2**	BEE2 FPGA platform		TCS Multi-antenna LTE detection
	EyesIFX nodes		USRP software radio		WiSpy Spectrum analyzer
	CR database		VESNA platform on light pole		Interconnection of portals
				-------	Interconn. between testbed elements

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CREW Federated platform: key aspects

- **common portal**
  - comprehensive **description** of the individual testbeds
  - **guidelines** on how to access and use the federated testbed

- **novel cognitive components**
  - **relocation** of components
  - **linking together** software and hardware **entities** from the different partners
  - **standardized API** for SDR architectures (developed within WINNF)

- **creation of open data sets**
  - a **common data structure** based on IEEE 1900.6 standard enabling
    - sharing of experiment descriptions, traces, data processing scripts…
    - spectrum sensing using heterogeneous sensing hardware

- **benchmarking framework**
  - enabling experiments under controlled and **reproducible test conditions**
  - allowing **fair comparison**
  - offering **automated procedures** for experiments and performance evaluation

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CREW federated platform: key aspects

- **common portal**
  - www.crew-project.eu

- description of the facilities & cognitive components
- usage policies
- requesting accounts
- getting started: tutorials

CREW federated platform: key aspects
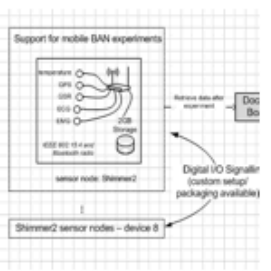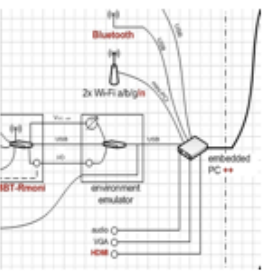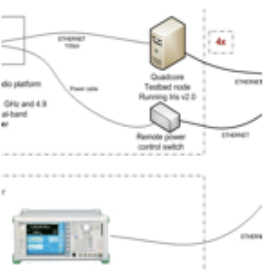
■ common portal

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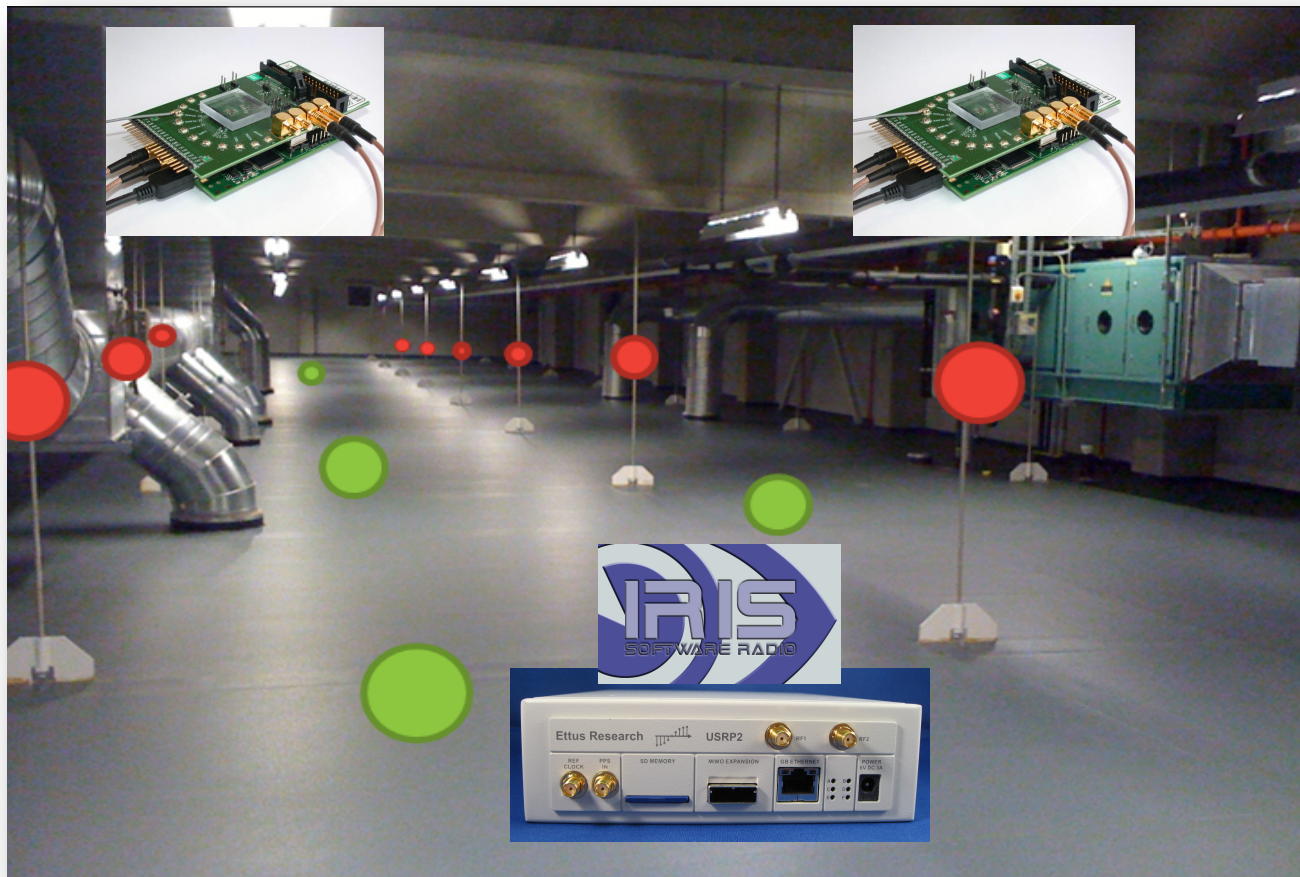
- **Novel cognitive components: transceiver API**
  - **standardized API** for SDR architectures (developed within WINNF)
  - functional specification for command and control of RF hardware platforms

Applicative Functionalities   **Platform Functionalities**   **PHY**

Upper Layers — Modem — Transceiver — Antenna

Air interface

Transceiver API

Linux PC

USRP2

CREW Federated platform: key aspects

- **Novel cognitive components: imec Sensing Agent (1)**

- **Versatile spectrum sensing engine building on reconfigurable radio elements**
- **Low power/area/cost targeted to enable use in mobile devices**
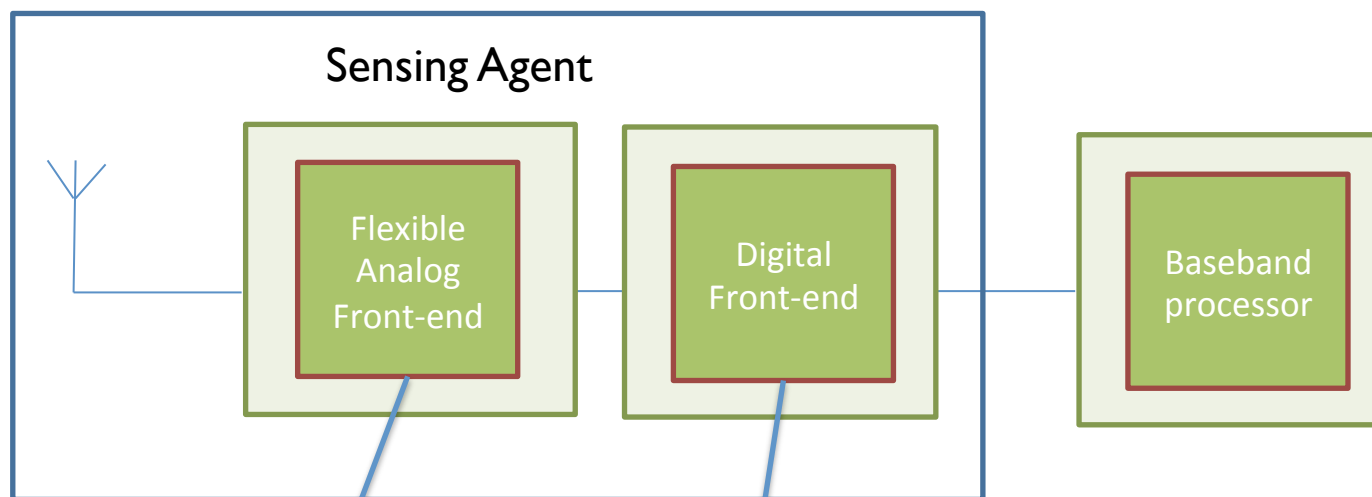
imec's Scaldio2b   imec's DIFFS

CREW Federated platform: key aspects
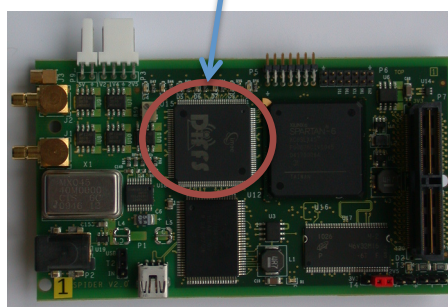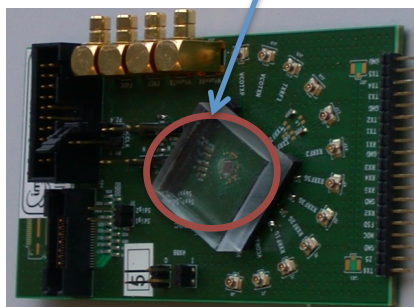
- **Novel cognitive components: imec Sensing Agent (2)**

- **Flexible analog front-end**
  - imec's Scaldio2b (100 MHz – 6 GHz tunable)
  - Rice University's WARP (2.4 GHz - 2.5 GHz and 4.9 GHz - 5.875 GHz tunable)
- **Digital front-end**
  - imec's DIFFS (DIgital Front-end For Spectrum Sensing)
- **Software API running on host PC for Sensing Agent control**
  - Configuration of Sensing Agent
  - Configuration of components (Scaldio, WARP, DIFFS, ...)
  - Raw data handling
- **OMF for experiment control**
  - Initialization of Sensing Agent platform
  - Control of Sensing Agent application
  - Database communication for storing Sensing Data

CREW Federated platform: key aspects

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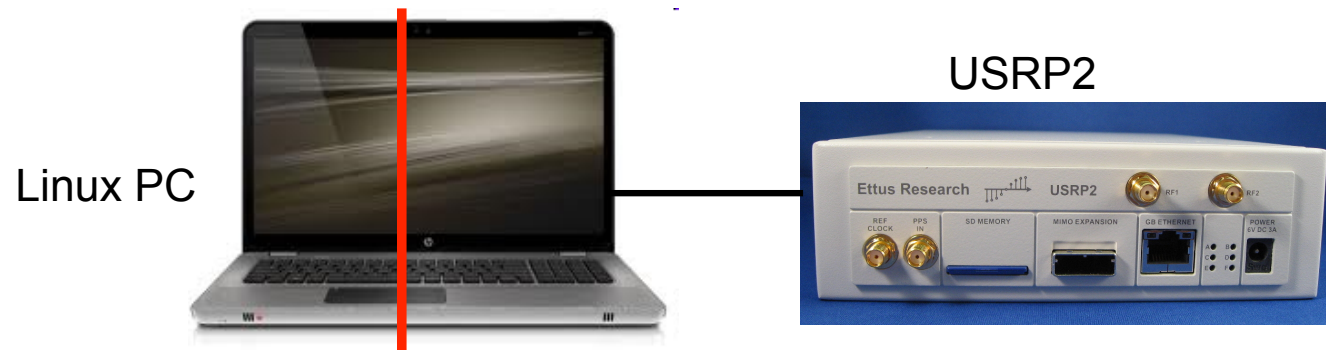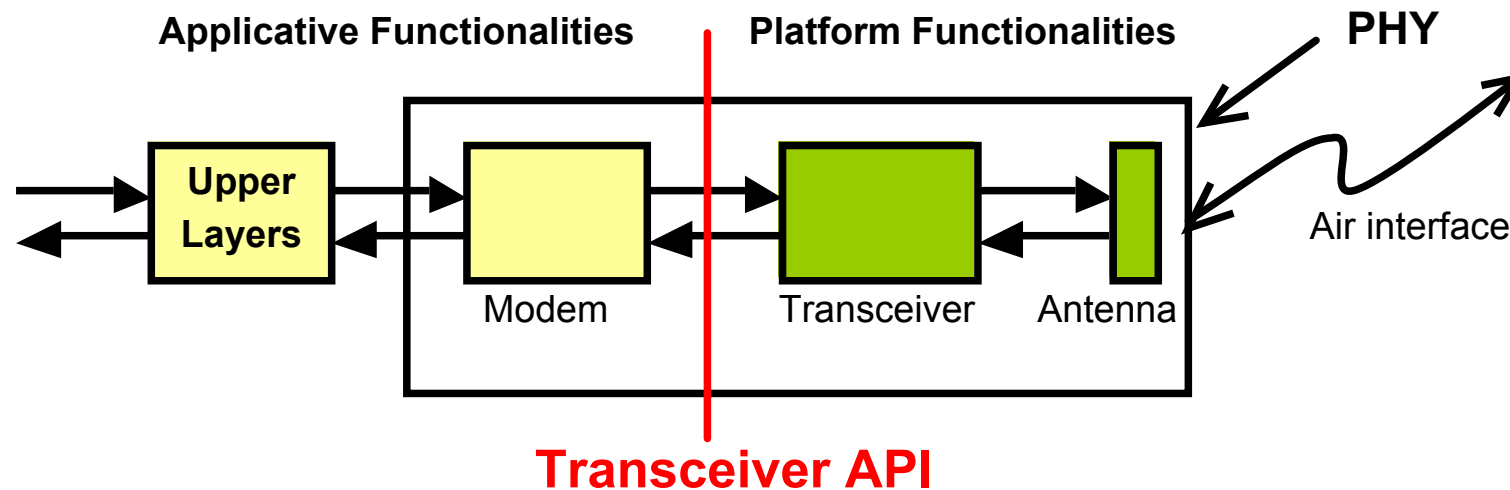 - **linking together** software and hardware **entities** from the different partners
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Creation of open data sets

- **CREW repository** (www.crew-project.eu/repository)

CREW repository

- traces
- background environments
- experiment descriptions
- scripts
- Performance metrics and scores

Home » CREW repository

scripts

Script to produce CREW common data format (CDF) for spectrum sensing

Device	Script
Airmagnet	createCDF_Airmagnet.m
USRP SE	createCDF_USRP.m
IMEC SE	createCDF_imec.m
Vesna	createCDF_vesna.m
Telos	crewcdf_wispy.m
Wispy	crewcdf_telos.m

Processing Script based on CREW CDF

A script to calculate power in certain channel based on CREW CDF can be found here.

A function to plot data based on CREW CDF can be found here.

CREW Federated platform: key aspects

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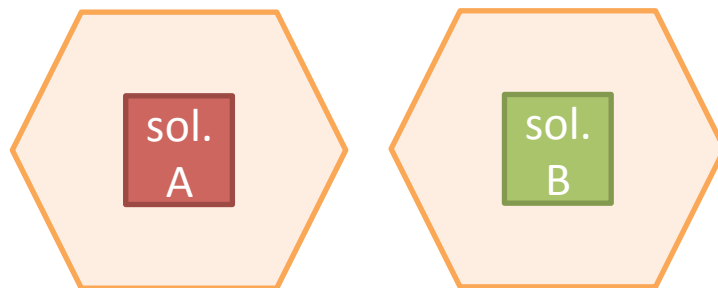## ■ Benchmarking

- is the act of measuring and evaluating
  - cognitive hardware components
  - cognitive software components
- under reference conditions
- relative to a reference evaluation

- **Primary goal**
  - Enable fair comparison
    → objective performance indication of CR/CN concepts

sol. A

sol. B

sol. A

sol. A'

Compare different solutions
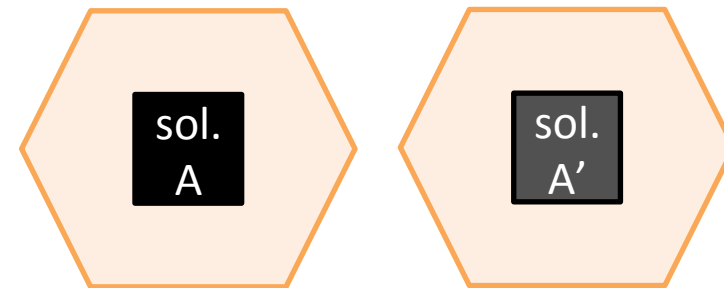
Compare subsequent developments

- **Interference avoidance in sensor networks (RDT)**

RDT = Receiver Directed Transmission
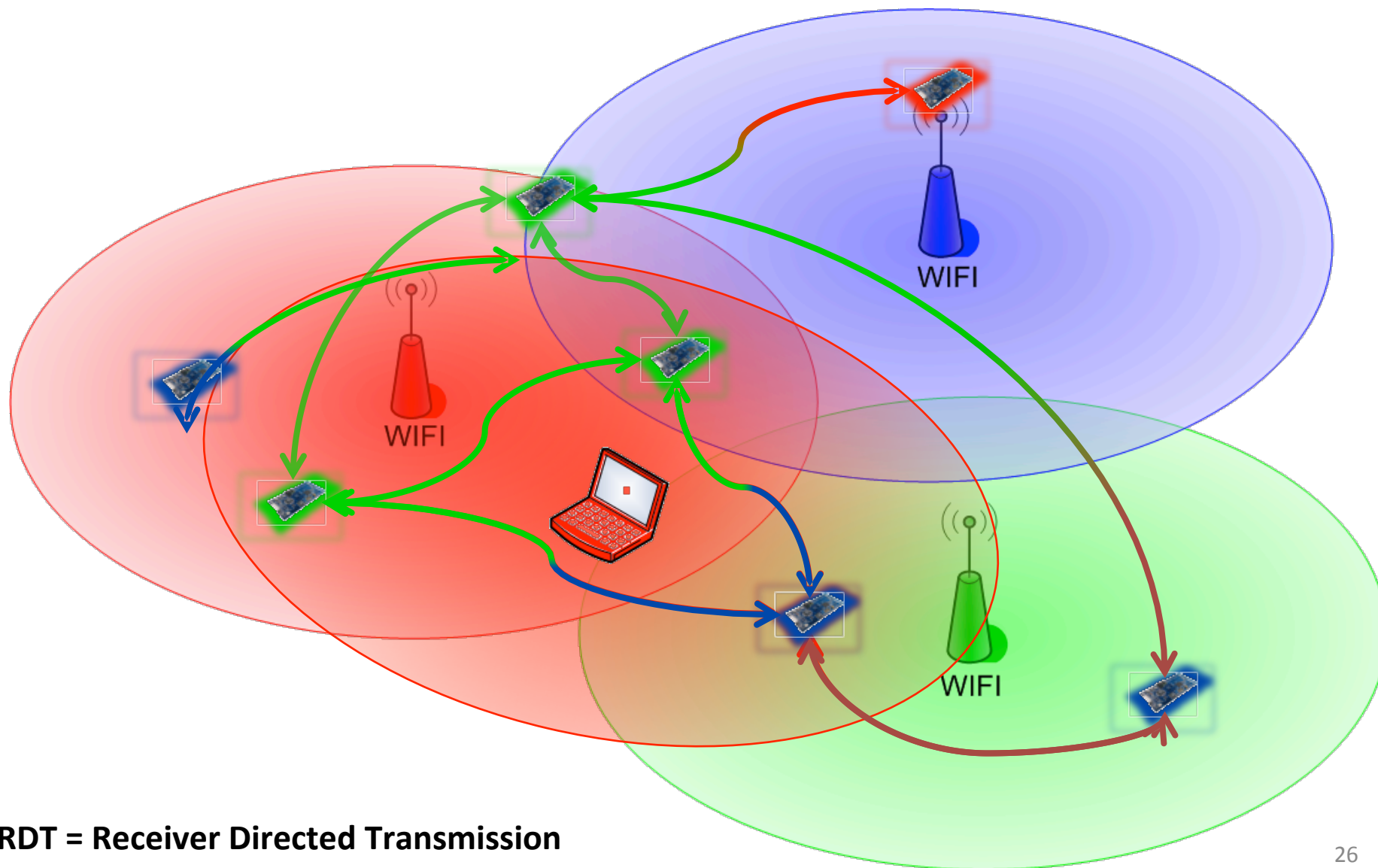
Single channel versus multi-channel
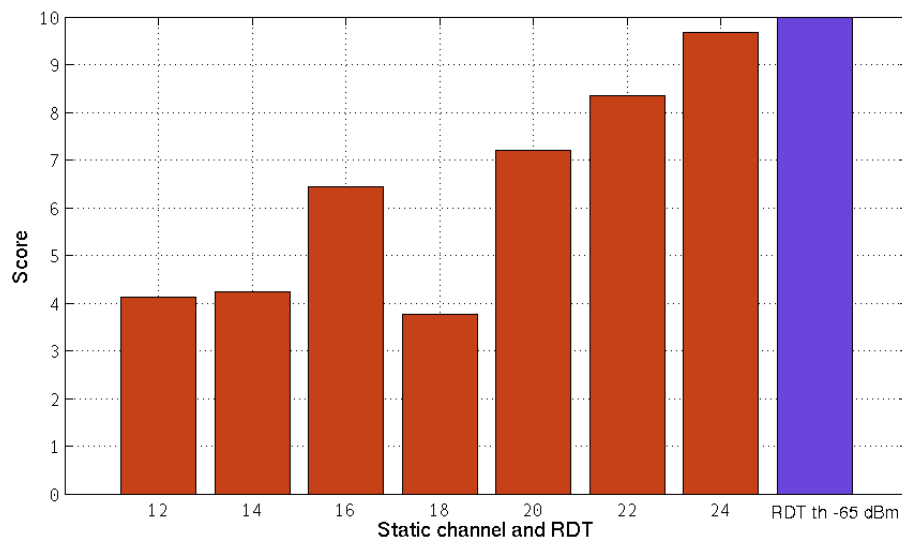
Score =

average end-to-end packet reception rate (on a scale of 10)

Energy detection threshold optimization

- If threshold too high: sensor packets are interfered (and lost)
- If threshold too low: channels are not switched (too sensitive to the noise)

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Cognitive Body Area Networks
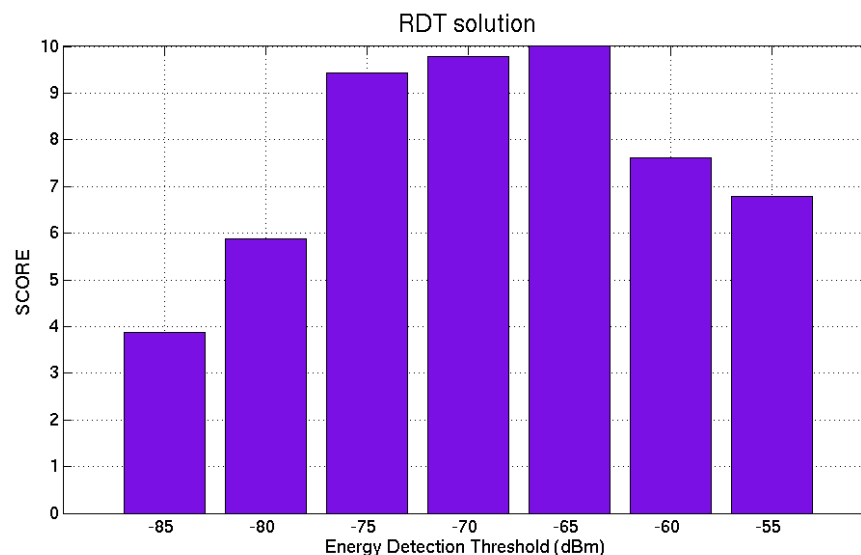
- **Simplify BAN experimentation**
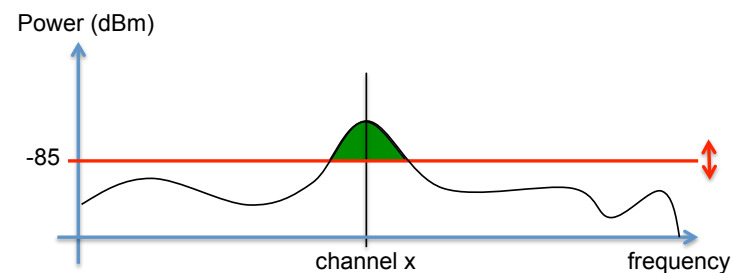- **Allow to conduct BAN experiments**
  - Repeatable
  - Automatic
  - Remote
- **Experimental infrastructure**
  - Mobile robot for BAN emulation
  - Validation and control of RF environment
  - Indoor office environment

Shimmer2r

Local Spectrum Sensing Device (IMEC)

Microsoft Kinect

iRobot Roomba
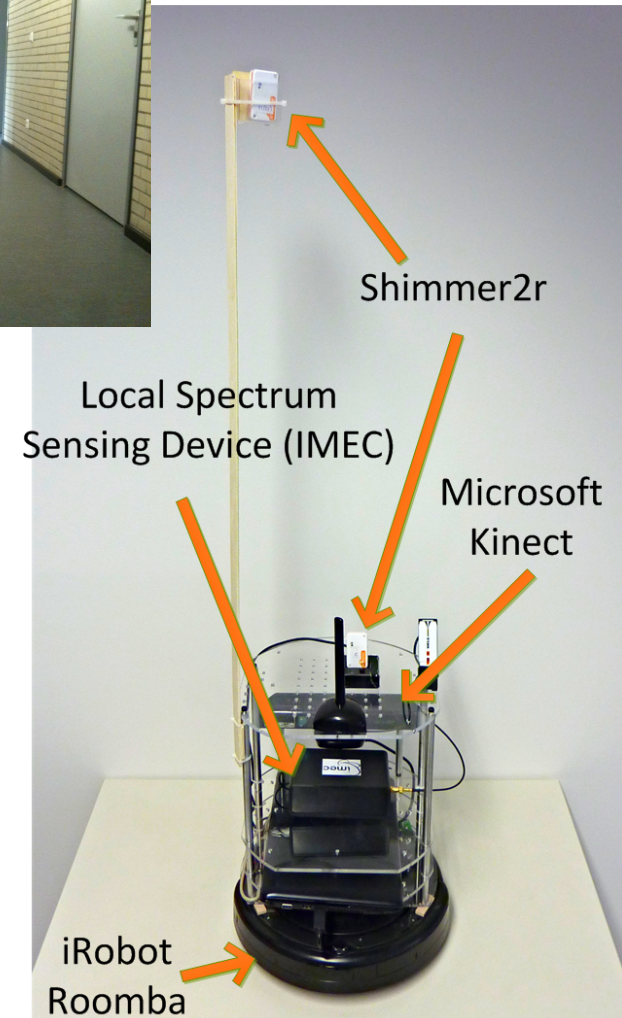
- **Heterogeneous spectrum sensing in the UHF band**
  - Outdoor experiment with **relocation** of equipment
    [1. USRP1, 2. IMEC sensing agent, 3. VESNA SNE-ISMTV-UHF]
  - Using **common data format** for easy processing and reporting
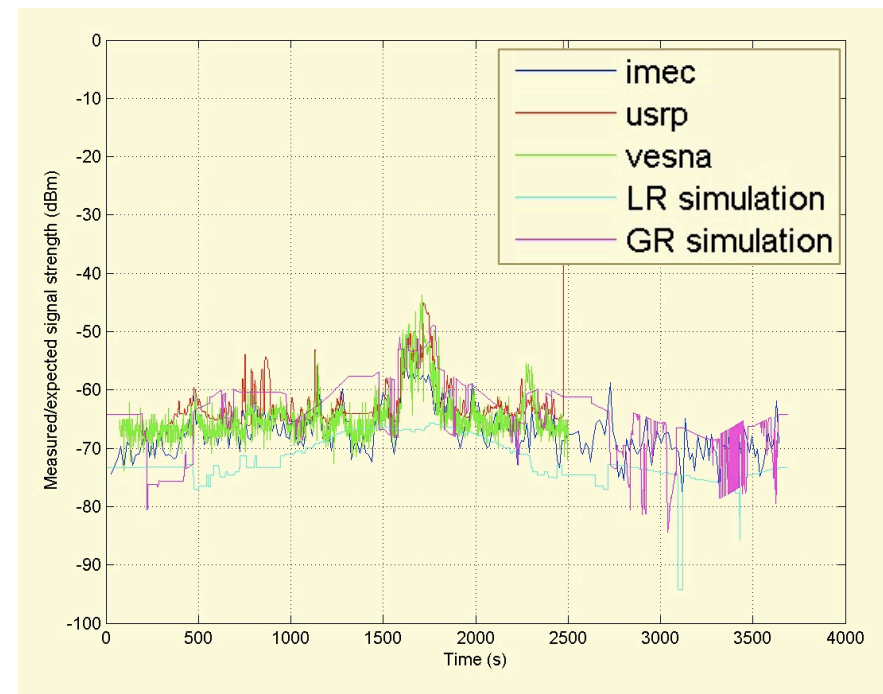 - Estimation of signal strength using **Longley-Rice channel model** and **GRASS-RaPlaT radio planning** tool
  - **Comparison** of sensing devices to estimations from channel models

White spaces in licensed bands

- **Distributed spectrum sensing in UHF**
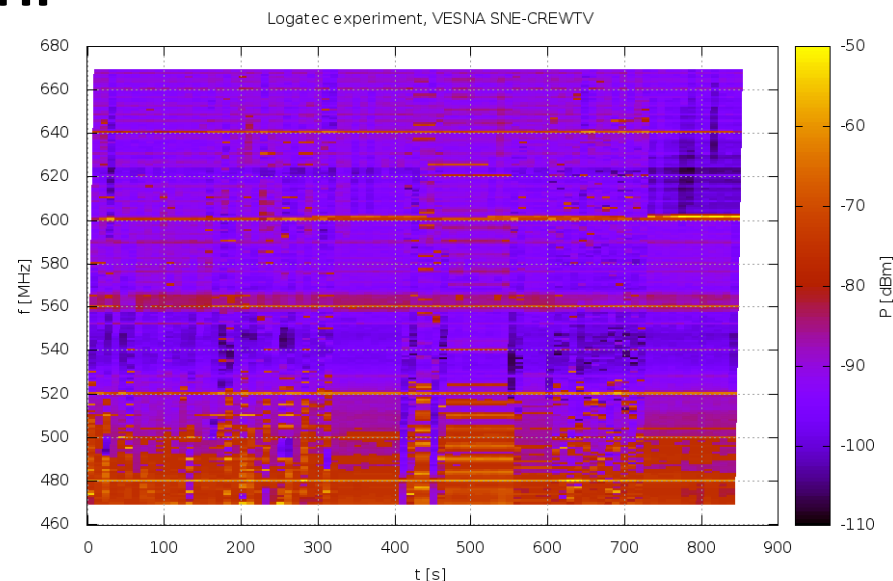 - Using multiple VESNA sensing nodes in Log-a-tec outdoor testbed to build a **radio environment map**
  - Avoiding the **hidden node problem**, minimizing primary user interference
  - **Context-awareness** experiments in licensed bands

Logatec experiment, VESNA SNE-CREWTV

Node 20 – SuperGainer antenna

Node 47 – Super ScanStick Antenna

Node 19 – Super ScanStick Antenna

DVB-T multiplex @ 562 MHz, industrial zone, node 20, SuperGainer antenna

DVB-T multiplex @ 562 MHz, kabelnet, node 47, Super ScanStick antenna

DVB-T multiplex @ 562 MHz, industrial zone, node 19, Super ScanStick antenna
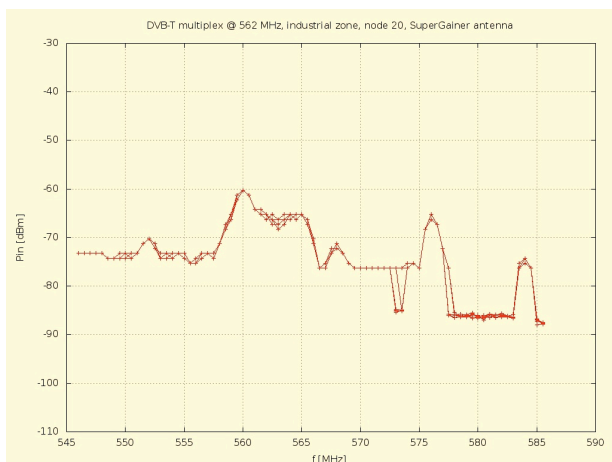
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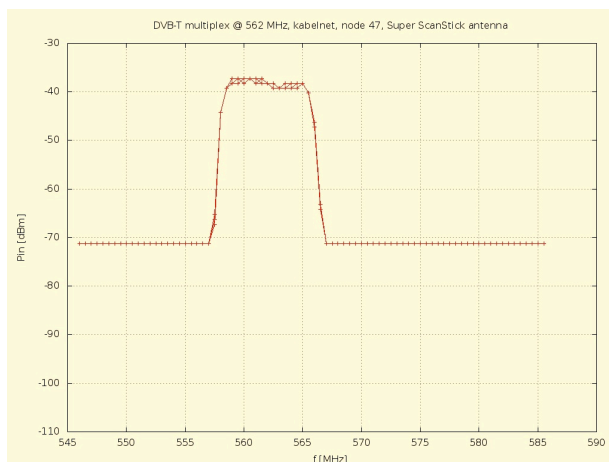
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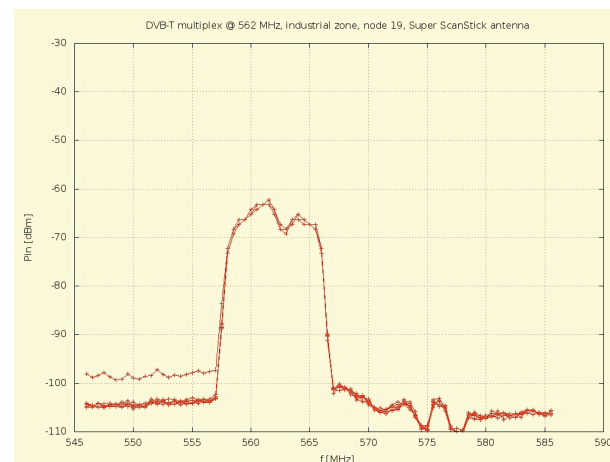 - **Context-awareness** experiments in licensed bands

Node 20 – SuperGainer antenna

Node 47 – Super ScanStick Antenna
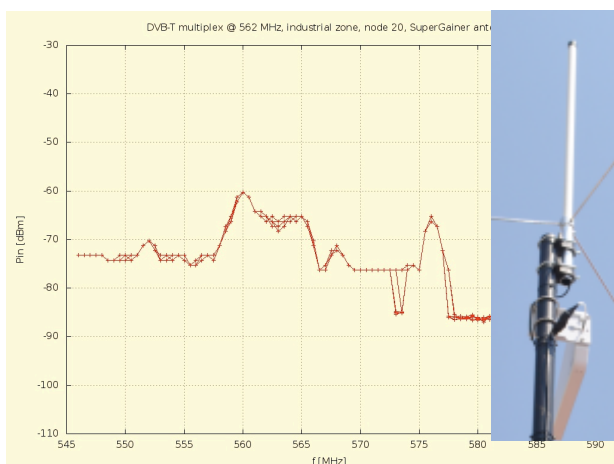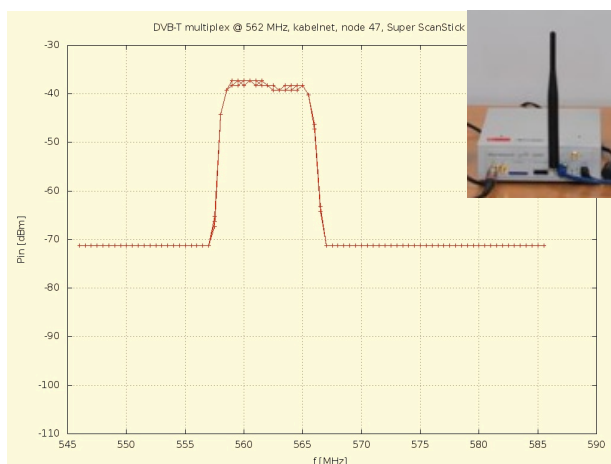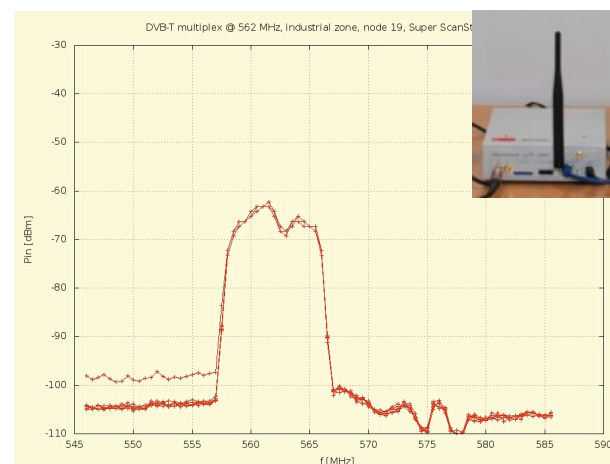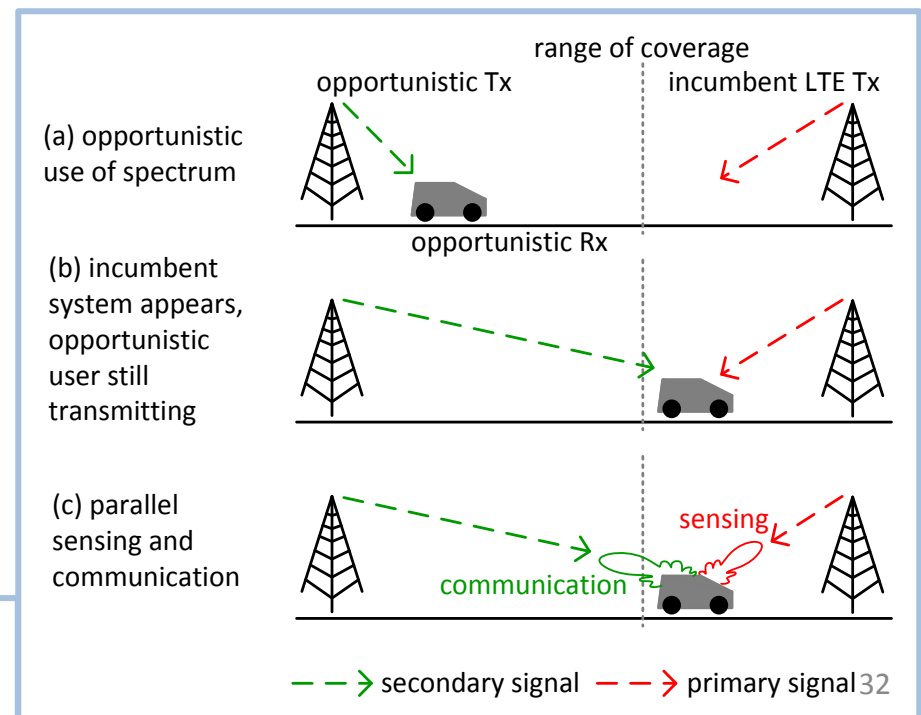
Node 19 – Super ScanStick Antenna

Usage Scenario Setup

- Licensees of frequency bands, e.g., mobile operators, allow secondary use of their spectrum resources

- The secondary system must not interfere in any way with the primary system

- Tasks:

    - Find a spectrum band that is available

    - Periodically verify that the band is still available

Proposed solution

- Multi-antenna array processing enables sensing in parallel to communication

Primary user detection with spatial interference rejection:

range of coverage

opportunistic Tx   incumbent LTE Tx

(a) opportunistic use of spectrum

opportunistic Rx

(b) incumbent system appears, opportunistic user still transmitting

(c) parallel sensing and communication

sensing

communication

– – → secondary signal   – – → primary signal

Cognitive radio in cellular frequencies

Experiment Setup

- one LTE base station transmits DL signal
- in the same frequency band, an interferer transmits simultaneously
- decision threshold fixed for 80% detection probability
- signal level of the base station is gradually reduced

eNB

4-antenna array

Laptop for MMI and processing

Multi-channel receiver

Acquisition board

26 dB multi-antenna gain

- 1 antenna
- 2 antennas
- 3 antennas
- 4 antennas

detection probability

SIR [dB]

The CREW offer
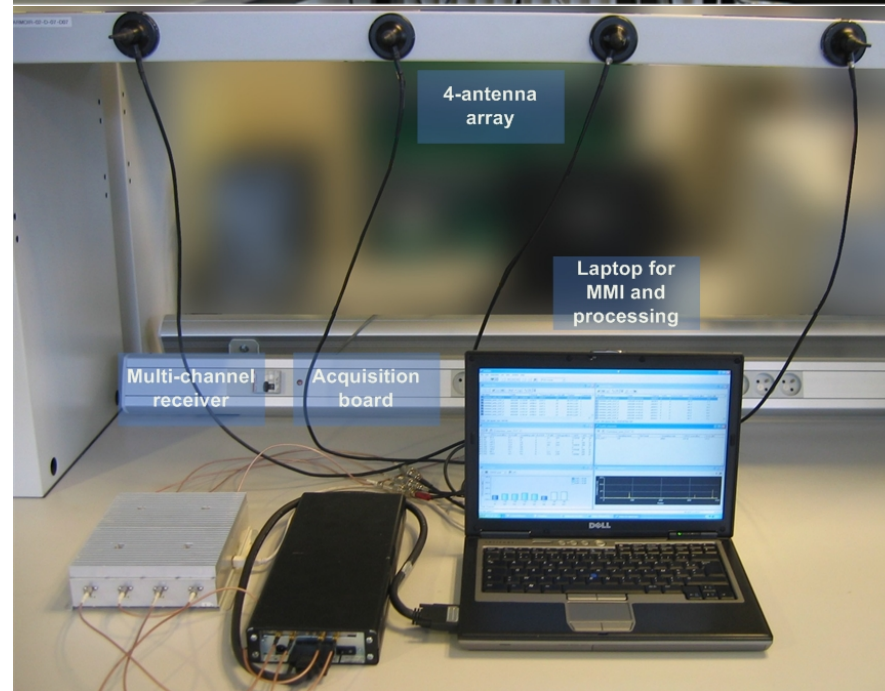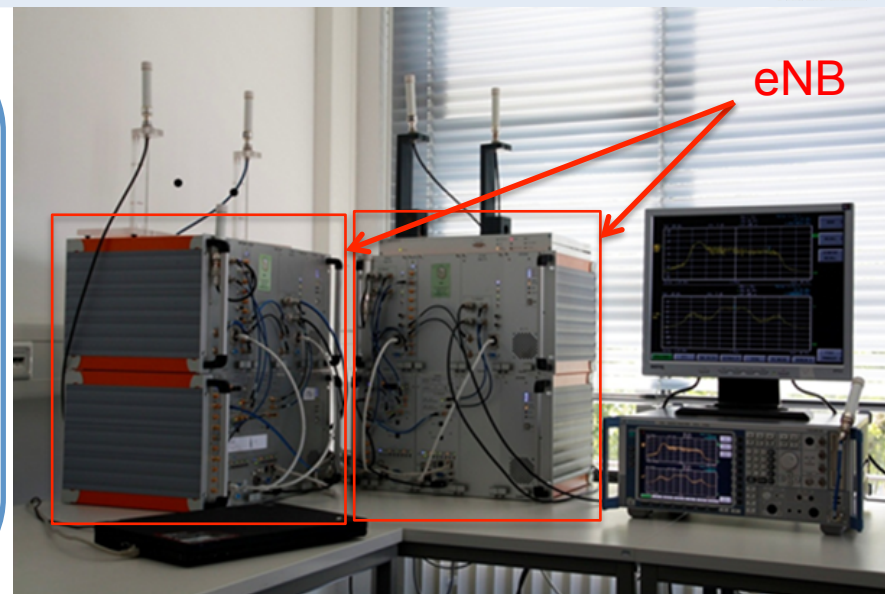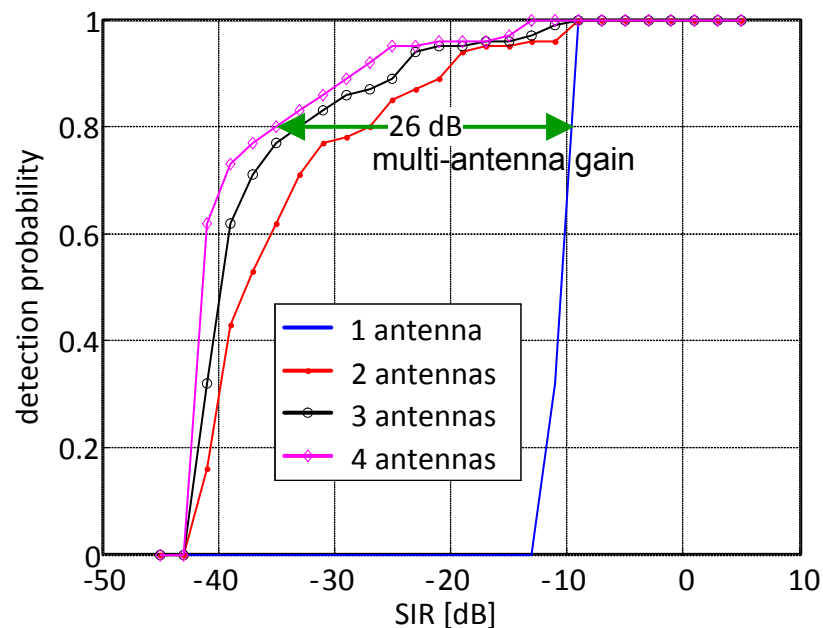
- **Open access** to 5 different testbed islands and advanced cognitive components

  - different wireless technologies
  - different spectrum bands
  - mature testbeds
  - tools for experimentation
  - reproducible test conditions
  - expertise from PHY layer to application layer
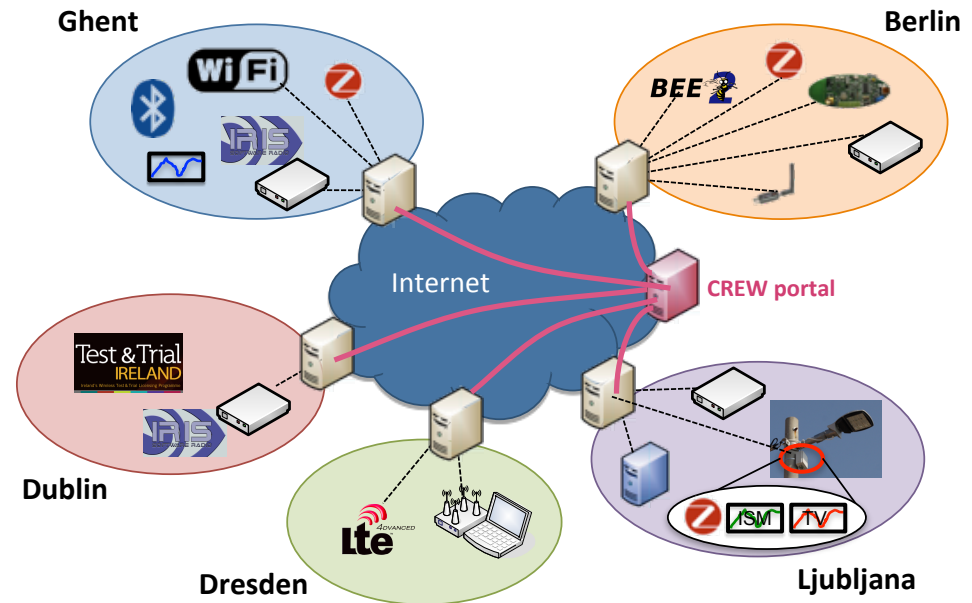
- **Portal** with detailed information and guidelines on access and use of the facilities (www.crew-project.eu)

- **Technical support & assistance** to your experiments

  - methodologies for experimentation
  - training days: 19-20 February 2013 (Brussels)
  - upcoming open call 3 for free and guaranteed support to your experiment

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Any feedback is welcome!

Contact:

Ingrid.moerman@intec.ugent.be

www.crew-project.eu