Cognitive Radio Experimentation World

September 2011

Announcement of a first competitive call to select experiments for the CREW project

The project "CREW – Cognitive Radio Experimentation World" is currently active in the Seventh Framework programme of the European Community. The primary target of the project is to establish an open federated test platform, which facilitates experimentally-driven research on advanced spectrum sensing, cognitive radio and cognitive networking strategies in view of horizontal and vertical spectrum sharing in licensed and unlicensed bands. Within this Open Call the project solicits proposals to use the available CREW facilities for experimental validation or experimental performance analysis in the field of cognitive radio and cognitive networking.

Project Coordinator: IBBT

Project partners: IBBT, imec, Trinity College Dublin, Technische Universität Berlin, Technische Universität Dresden, THALES Communications France, EADS

Project website: www.crew-project.eu

1 Background information on the CREW project

The ability to implement and test new solutions in cognitive communications, from sensing and spectrum shaping at the physical layer to cooperation and coexistence among cognitive devices in a cognitive network, is critical to the development of the field. The CREW project establishes a federation of cognitive radio testbeds in Europe that aims to facilitate experimental research.

In its initial phase, depicted in Figure 1, CREW federates a software defined radio testbed at Trinity College Dublin, a heterogeneous ISM wireless testbed at IBBT, a sensor network testbed at TU Berlin, a spectrum sensing platform developed at imec, and an LTE/LTE+ cellular testbed at TU Dresden.

CREW offers the following **federation functionalities**:

- a *common portal* to all testbeds. giving a comprehensive description of the individual testbeds and the functionalities of the federated testbed and further providing clear guidelines on how to access and use the federated testbed;
- *advanced cognitive components* such as spectrum sensing agents and configurable radio platforms, by linking together software and hardware solutions from multiple partners;
- *open data sets* for spectrum sensing data and primary user activity, created under benchmarked conditions and using a common sensing data structure;
- a *benchmarking framework* for cognitive radio and network experiments, offering automated procedures for experiments and performance evaluation methodologies, enabling comparison between subsequent developments or competing cognitive solutions.

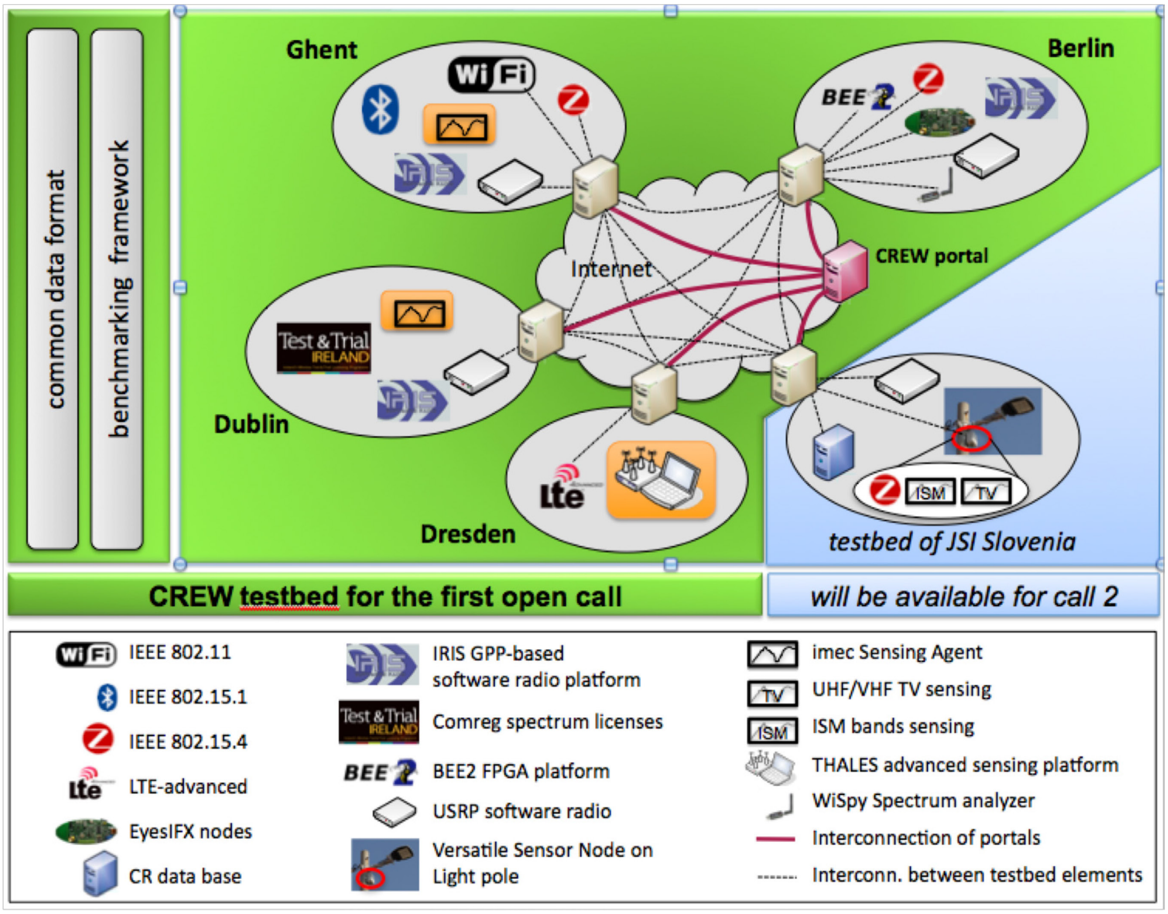

Figure 1: The CREW federation of cognitive radio testbeds

We envision three primary **operating modes** for the federation (see Figure 2):

- In *mode 1*, experimenters access an individual testbed in the federation using the information available on the common CREW portal.
- *Mode 2* will enable the hosting of nodes from one testbed in another and the creation of new nodes from combinations of hardware and software components developed in different testbeds of the federation.
- *Mode 3* defines the sequential use of testbeds, capturing data and behaviours observed in one testbed and replaying those in a different testbed, emulating the joint operation of multiple testbeds.

Possible **usage scenarios** for experiments using the CREW federation include:

- *Context awareness for cognitive networking*: new techniques for context awareness in unlicensed (ISM) and licensed bands (TV white spaces, cellular systems);
- *Robust cognitive networks*: applications that require robust communications though avoiding harmful interference and using frequency agility to improve communication quality;
- *Horizontal resource sharing in the ISM bands*: algorithms, protocols and networking architectures for coexistence of and cooperation between independent heterogeneous network technologies;
- *Cooperation in heterogeneous networks in TV bands*: new ideas for opportunistic spectrum access to underutilized licensed TV bands;
- *Cognitive systems and cellular networks*: the impact of dynamic spectrum access by secondary users on LTE cellular primary systems.

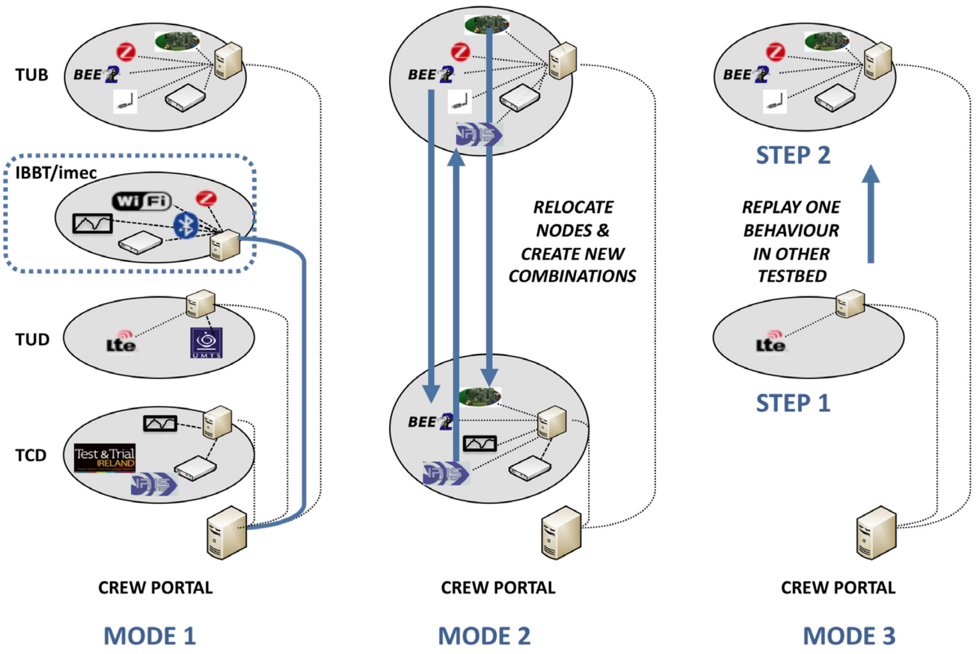

Figure 2: Operating modes of the CREW federated platform

CREW is a five-year project, which started in October 2010 (see CREW roadmap in Figure 3). Its first year is dedicated to the formation of the federation and experiments by both academic and industrial partners (Thales and EADS). In the following two years, the consortium will be expanded through two open calls for proposals. During that time, the testbeds in the federation will be enhanced with demand-driven extensions. The final years of the project will allow the transition to a sustainable usage model for the federation, which is expected to evolve into a self-sustaining platform for cognitive radio experimentation.

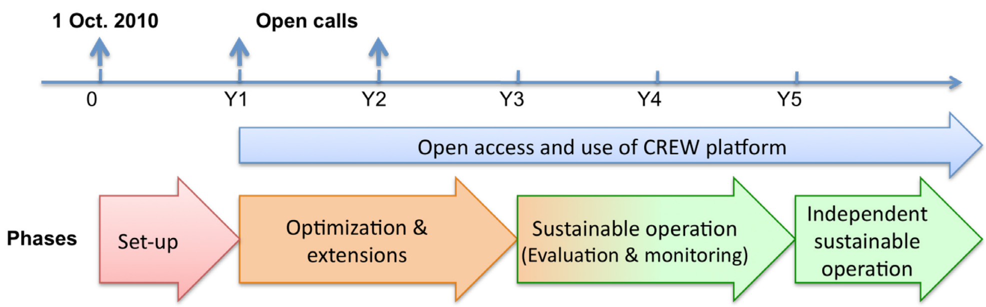

Figure 3: CREW roadmap

For more information on the CREW usage scenarios and federation functionality we refer to:

- D2.1 - Definition of Internal Usage Scenarios (http://www.crew-project.eu/sites/default/files/CREW_D2.1_TUD_R_PU_2011-01-31_final_v1.0.pdf)
- D2.2 - Definition of Federation Functionality (http://www.crew-project.eu/sites/default/files/CREW_D2.2_TCD_R_PU_2011-03-31_final.pdf)

2 Call information

Budget of this call: € 400,000

Minimum Commission funding per experiment: € 50,000

Maximum Commission funding per experiment: € 200,000

Number of experiments to be funded: The CREW project expects to fund at least 3 and at most 5 experiments.

Number of partners per experiment: The target number of partners per experiment is 1 or 2.

Type of participants: The profile of participants is both academics and companies active in the domain cognitive radio or cognitive networking, that need to run experiments to further test, evaluate and optimize their cognitive solutions. The rules of participation are the same as for any FP7 project.

Duration of the experiment: The maximum duration of an experiment is 12 months.

Language of the proposal: English

Call deadline: Wednesday, October 19, 2011 at 17:00h CET (Brussels time)

Address for proposal submission: ict@ec.europa.eu

Call identifier (used as subject in email for proposal submission): CREW2011-OC1

Contact for information on this call: Ingrid Moerman (IBBT),
email: Ingrid.moerman@intec.ugent.be,
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Each submitted experiment should address at least 2 of the CREW federation functionalities defined in Section 3. We strongly encourage potential proposers to discuss their ideas for experimentation with the CREW consortium prior to submission of their proposal, so as to ensure maximal exploitation of the CREW facilities and functionalities.

Details on the objectives of the present call including some examples for possible experiments can be found in Section 3 of this document. Information on the available CREW facilities, hardware components and software can be found in Annex I of this document. A detailed description of the characteristics of the individual testbeds is available on the CREW portal (http://www.crew-project.eu/portal/reference).

Guidelines for proposal writing can be found in the “Guide for Applicants” available in the open call section of the CREW project website (http://www.crew-project.eu/opencallinfo). Guidelines for the experiment work plan and timing can be found in Annex II of this document. We expect sufficient details for the different phases of the work plan.

The partners of the experiments will become members of the consortium and therefore accept the normal responsibilities of effort reporting, consortium meetings, project reviews and so on. Within the CREW project, we aim to make software tools and experimentation methodologies as much as possible available to the research community. Basic guidelines on Foreground/Background/Sideground information and access rights are dealt with in the CREW Consortium Agreement, signed by all partners of the CREW consortium. The new partners will also have to sign the CREW Consortium Agreement, which is available in the open call section of the CREW project website (http://www.crew-project.eu/opencallinfo).

3 Objectives of the present call

We are looking for exciting experiments and evaluations in the cognitive radio and cognitive networking research domain that make use of the CREW facilities and its federation function functionality.

The experiments should maximally exploit the unique features of CREW facilities, where each proposal has to address at least 2 of the federation functionalities listed below:

- *Combination of* at least two *cognitive components* (from different testbeds)
  This can be either bringing own components[1] into the federated testbed or usage of cognitive components from different individual CREW testbeds, e.g.:
  - Use of imec spectrum sensing agent in IBBT testbed.
  - Use of Iris software radio architecture for dynamic adaptations for coexistence in another testbed in the federation.
  - Comparing experimental results obtained in two different testbeds.
- CREW *advanced spectrum sensing* functionality:
  - Combination of different sensing solutions (hardware and software) of the CREW federation.
  - Comparison of own sensing hardware with sensing hardware available in the CREW federation.
- *Benchmarking features*:
  - Run and compare novel cognitive solutions in[2] a reproducible "reference" test environment offered by CREW (e.g. home/office reference scenario at IBBT)
  - Use and validation of available metrics and scores for performance evaluation of cognitive solutions. Available metrics in CREW include spectrum occupation, overall throughput, reliability (packet error rate), energy efficiency, delay, jitter and round-trip time (RTT).
  - Definition of new or more advanced metrics and scores for performance evaluation of cognitive solutions
- Use the *CREW Common Data Collection and Storage Methodology* for
  - Storing measurement results in a common format and using the CREW facilities to make the traces publically available
  - Sequential use of individual CREW testbeds (e.g. replay of behaviour from one testbed in another testbed for the definition of new realistic test scenarios)
- Using the *interfaces* proposed and promoted by CREW for linking together software and hardware solutions to build advanced cognitive components.
  - Taking full advantage of the Transceiver Facility API implementation for the USRP2 platform (available for Linux hosts)
  - Combining and integrating cognitive algorithms performing sensing, physical layer radio access, multi-channel medium access control, or any other cognitive radio feature with existing hardware platforms.
  - Analysing and exploiting other available interfaces, such as the aforementioned for dealing with benchmarking configuration and data storage

[1] When bringing in a new hardware component, there should be sufficient sustainable benefits for the overall CREW federation, meaning that there should be an added value for the CREW federation, even after the new partner has left CREW upon completion of the experiment.

[2] The development of new cognitive solutions is not covered by this open call. The open call only covers the efforts for designing experiments and deploying solutions on CREW test infrastructure, not for designing new cognitive solutions.

Examples of experiments include but are not limited to:

1. Context awareness approaches

Many of the example scenarios for cognitive networking require some form of context awareness, spectrum occupancy information or spectrum sensing. A first range of example experiments for cognitive radio is hence related to this important research field:

- Local sensing performance for various frequency bands and signals: various ISM band signals in the ISM bands, TV signals in the TV bands and LTE signals in the 2.6 GHz LTE bands.
- Characterization of sensing performance of different hardware solutions.
- Comparison of local versus distributed sensing. Distributed sensing approaches for various bands and scenarios.
- Context awareness performance of database versus local or distributed sensing. Study/comparison for ISM bands with packet-based traffic, for LTE bands with voice/data traffic and for TV bands with broadcast traffic.

2. Cognitive networking solutions[2] for coexistence / horizontal spectrum sharing / interference avoidance in ISM bands

Such scenarios occur in everyday professional and private lives, e.g. in home, office or public environments where an increasing number of wireless devices and multiple technologies compete for the same spectrum. To solve the spectrum bottleneck in ISM bands, there is a need for new algorithms, protocols and networking architectures allowing cooperation between wireless devices and (heterogeneous) technologies. Possible experiments and evaluations are:

- Local versus distributed spectrum sensing techniques;
- Context awareness performance of database versus local or distributed sensing, for ISM bands.
- Simple versus advanced spectrum sensing techniques, e.g. energy detection versus feature detection, impact of the quality of the sensing hardware on cognitive decisions when using simple COTS (Commercial Off The Shelf) hardware versus advanced CREW spectrum sensing hardware;
- Cognitive networking monitoring techniques (physical, link and network layer);
- Local versus collective cognitive decision and control;
- Cross-layer, cross-node, cross-network, cross-technology optimization strategies;
- Analysis of same cognitive solution in different physical wireless environments (e.g. IBBT versus TU Berlin test environment) or applied with different test scenarios (number of devices, type of devices, density of nodes, traffic load, external interferers…);
- The effect of controlled mobility (via mobile robots) on cognitive radio concepts, such as spectrum sensing.

3. Cognitive Body Area Networks

CREW provides several wearable sensor nodes[3] as part of the TU-Berlin testbed that can be used to run cognitive body area networks (CBAN) experiments. The sensor nodes can be attached to a person who may be exposed to a controlled interference situation. For example, interference can be generated via a signal generator or interference can be "replayed" from previously recorded sources (TWIST, USRPs, Wi-Fi...). The experiments could then evaluate different cognitive radio concepts on a BAN.

Since the wearable sensor nodes use the same communication technology as the nodes in the fixed sensor node infrastructure (TUB and IBBT) experiments can also involve communication between

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[3] We provide the Shimmer2 platform, which is similar to the TelosB platform - detailed information can be found online: http://www.shimmer-research.com

both, mobile and fixed, testbed infrastructure. Possible experiments could evaluate tasks such as network or interference discovery.

Finally, the TU-Berlin testbed includes a mobile robot that can be programmed to automatically perform movements inside the building. The robot can be instrumented with wearable sensor nodes to emulate a BAN. In contrast to the TWIST testbed, which can be used remotely via web interface, the robot requires the experimenter to be present (the API is not provided remotely).

Possible experiments include:

- Comparison of different sensing solutions for mobile scenarios
- Experimentation with link / multi-channel MAC protocols for CBANs
- Real-time / delay sensitive protocol support

4. Cognitive algorithms integration through the Transceiver API

The Transceiver API offers a generic standardized interface for the programming and management of radio sub-systems (radio heads, RF Front-ends together with the baseband last/first stages of DAC/ADC conversion and filtering). Through a set of programming operations the modem part of the physical layer is able to control RF configuration and I/Q sampled data transfer.

CREW will provide the implementation of that programming interface (reference code) for the widely available and used USRP2 platform.

This external experimentation scenario would typically be carried out in two steps.

1. The integration of the external experimenter existing solution on the USRP2 platform through the interfaces of the Transceiver Facility API. These interfaces will be provided for a host PC so the experimenter will benefit for easiness of host environment development (as opposed to embedded development). Hence, the cognitive algorithm will access the radio by means of USRP2 and the API.
2. System integration of the new device, composed by the experimenter cognitive algorithm and the USRP2 radio-subsystem in any of the testbeds. It is up to the experimenter to decide on the right testbed depending essentially on the band addressed and the cognitive algorithm purpose.

5. Reconfigurable radios and adaptation mechanisms in a cognitive network

The Iris reconfigurable radio platform at Trinity College Dublin allows experimentation with dynamic adaptations at multiple layers in the protocol stack, including the physical layer. Experimenters may make use of the Iris software defined radio to promote more efficient coexistence with legacy platforms as well as with other cognitive radios, in different bands of operation. These experiments can also take place in combination with other testbeds in the CREW federation.

Example experiments might include spectrum sculpting for better coexistence with co-located and/or adjacent systems, the implementation of a cognitive medium access control (MAC) protocol, and the use of TV white spaces through sensing and geolocation database methods

6. Impact of cognitive radio on a primary cellular system

The LTE/LTE Advanced testbed can serve as a primary (cellular) system that operates in licensed frequency bands. Cognitive radio research could revolve around how opportunistic systems can make use of white spaces in licensed bands and how that impacts on the primary system's performance.

Experiments could focus on the secondary system's physical layer properties with the aim to enhance coexistence by providing minimal interference to the primary system, as well as algorithms for the reliable detection of the targeted white spaces via energy or feature detection and the avoidance of the licensed signals.

For more information on the CREW usage scenarios, federation functionality, and additional example experiments we refer to:

- D2.1 - Definition of Internal Usage Scenarios (http://www.crew-project.eu/sites/default/files/CREW_D2.1_TUD_R_PU_2011-01-31_final_v1.0.pdf)
- D2.2 - Definition of Federation Functionality (http://www.crew-project.eu/sites/default/files/CREW_D2.2_TCD_R_PU_2011-03-31_final.pdf)

Annex I: Information on CREW facilities and components

Table 1 gives an overview of the main characteristics of the CREW individual testbeds and advanced components that will be available for experiments of the present call. 'R' refers to features that can be controlled remotely. For a detailed description of the characteristics we refer to the CREW portal (http://www.crew-project.eu/portal/reference).

Many of the experiments can be conducted remotely (as indicated by 'R' in table 1). However, some of the experiments need to be conducted during on-site visits at the individual testbed locations. In the latter case, a careful planning for site visits needs to be included in the proposal. Discussion with the local testbed owner is strongly recommended during proposal preparation.

Contact persons for local testbeds are:

- IBBT: Stefan Bouckaert (stefan.bouckaert@intec.ugent.be)
- TUBerlin: Jan Hauer (hauer@tkn.tu-berlin.de)
- TCD: Luiz DaSilva (dasilval@tcd.ie)
- TUDresden: Nicola Michailow (nicola.michailow@ifn.et.tu-dresden.de)
- imec sensing engine: Peter Van Wesemael (wesemael@imec.be)
- Thales Transceiver Facility API: Alejandro Sanchez (alejandro.sanchez@fr.thalesgroup.com)

Individual testbed locations → Features ↓	IBBT	TU Berlin	TCD	TU Dresden
Wireless technologies/spectral bands				
TV-bands (470-860 MHz GHz)				
OFDM			x	
License (license Comreg pending)			x	
LTE-bands (2.58 GHz UL, 2.63 GHz DL)				x
License (UMTS Band VII issued by BNetzA)				x
ISM				
IEEE 802.11 a/b/g (2.40-2.48 GHz, 5.15-5.35, 5.725-5.825 GHz)	x		x	
IEEE 802.11 n (2.40-2.48 GHz, 5.15-5.35, 5.725-5.825 GHz)	x		x	
IEEE 802.15.1 (2.40-2.48 GHz)	x		x	
IEEE 802.15.4 (2.40–2.48 GHz)	x	x	x	
IEEE 802.15.4 (868 MHz)		x	x	
COTS hardware (number of components)				
Tmote Sky sensor node	200 R	102 R		
Eyes IFXv2		102 R		
Shimmer2		16		
IBBT/rmoni sensor node	80 R			
Alix Embedded Linux PC (incl. 2 x IEEE 802.11 a/b/g)	200 R			
Zotac Embedded Linux PC (incl. 2 x IEEE 802.11 a/b/g/n and 1 x IEEE 802.15.4)	80 R			
iRobot Roomba mobile robot		1		
Cognitive radio platforms (number of components)				
imec sensing engine (ISM bands)	10 R			
imec sensing engine (100 MHz - 6 GHz)	1			
Iris software radio platform	8 R		x R	
BEE 2 FPGA platform, 2.4 GHz ISM transceiver		6		

USRP software radio				
Motherboards:				
USRP 1.0			5 R	
USRP 2.0	2 R		4 R	
USRP N200/N210	6 R		4 R	
USRP E100			4 R	
Daughterboards:				
TVRX (50-860MHz)			2 R	
FLEX/RFX 900 (800MHz–1GHz)			2 R	
FLEX/RFX 1800 (1.5-20.5GHz)			8 R	
FLEX/RFX 2400 (2.3-2.9GHz)			8 R	
WBX (50MHz-2.2GHz)	8 R		6 R	
XCVR 2450 (2.4-2.5 and 4.9-5.85GHz)	8 R		8 R	
Signalion HALO 430 SDR equipment				2
Signalion SORBAS (eNodeB + UE)				3 + 3
Commercial spectrum analyzer hardware (number)				
Wi-Spy (ISM: 2.4 GHz)		5		
AirMagnet Spectrum XT (ISM: 2.4 GHz & 5 GHZ)	1			
Rohde & Schwarz / Agilent … spectrum analyzers		1		
Rhode & Schwarz FSQ				1
Rhode & Schwarz FSH				1
Rhode & Schwarz TSMW Network Analyzer				1
Rhode & Schwarz FSV		1		
Anritsu MS2721B Handheld Spectrum Analyzer			1 R	
Commercial signal generators				
On request available at different locations				
General testbed features				
Indoor	x	x	x	x
Outdoor				x
Mobility		x		x
Remote control				
Open VPN	x			
Web tools	x			
SSH	x	x		
mysql	x	x		
Automated measurements	x			
Runtime interaction	x	x		

Table 1: Characteristics and capabilities of CREW individual testbeds

Annex II: Experiment work plan and timing

The work plan involves at least the following **phases:**

1. **Experiment design:**
    - Description of cognitive solution(s) that will be evaluated
    - Use of the CREW federation: CREW infrastructures/components to be used, federation functionality used (see section 3), motivation why CREW federation is needed for the experiment
    - Description of experiment(s): test scenarios, measurements, performance metrics, expected output from experiment, expected occupation of the CREW infrastructures/components…
    - Specific demands for essential extensions to improve/extend the CREW federation: description of extra functionality that is indispensable for the execution of the experiment. Such extensions need to be discussed and agreed with the core CREW partners. Please indicate who is expected to implement the extensions: CREW core partner(s) or proposer(s)?
2. **Experiment set-up:**
    - Deployment of cognitive solution(s) on CREW infrastructure
    - Implementation of essential extensions to the CREW federated platform
3. **Experiment execution**
    - Running of experiments
    - Analysis of experiments
4. **Feedback**
    - Reporting on experiments & analysis of results
    - Reporting on user experience
    - Recommendations for improvements & optimization of CREW infrastructure and components
    - Identification and specification of additional extensions for future experiments
5. **Dissemination**
    - Regular dissemination actions (conferences, workshop, FIRE events, advertising of experimentation results at CREW website…)
    - Set up of show case (demonstration) to be used for further promotion of the CREW facilities

Timing:

- Maximum duration: 12 months
- Major milestones:
    - Experiment design: no later than M2
    - Experiment set-up: no later than M4
    - Experiment execution: first successful experiment no later than M6
    - Experiment feedback: final report no later than M12
    - Dissemination:
        - first dissemination of results no later than M9
        - showcase available no later than M12

Experiments will be integrated in WP7 - 'External test cases' of the CREW project, providing a separate task for each experiment that is selected within this call. The proposer(s) will also contribute in WP8 – 'Promotion'. More information on the expected work packages and other sections in the proposal can be found in the "Guide for Applicants" available in the open call section of the CREW project website (http://www.crew-project.eu/opencallinfo).