Cognitive Radio Experimentation World

July 2013

Announcement of the third 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: iMinds

Core project partners: iMinds, imec (IMEC), Trinity College Dublin (TCD), Technische Universität Berlin (TUB), Technische Universität Dresden (TUD), THALES Communications & Security (TCS), EADS Deutschland GMBH (EADS), Institut Jozef Stefan (JSI)

Project website: www.crew-project.eu

1 Background information on the CREW project

The ability to move cognitive radio research from a theoretical or simulation phase to an experimental phase is crucial to make further advances in the field: cognitive experiments will help the international research community, industry, and regulatory bodies to understand the possibilities and limitations of spectrum sensing, spectrum sharing, coexistence and cooperation between wireless networks. The CREW project establishes a federation of cognitive radio testbeds in Europe that aims to facilitate experimental research. To reach this goal, the CREW project brings together and builds further on the hardware (wireless testbeds and cognitive components such as dedicated sensing hardware), tools and extensive expertise of eight European partners. The consortium holds expertise from the physical to the application layer, and has years of experience building and operating its heterogeneous wireless testbeds and cognitive components.

Diverse existing wireless testbeds were complemented with state-of-the-art cognitive sensing platforms (see Figure 1):

- heterogeneous ISM wireless testbed at iMinds (Ghent)
- software defined radio testbed at TCD (Dublin)
- cognitive sensor network testbed at TUB (Berlin)
- LTE-advanced cellular testbed at TUD (Dresden)
- Heterogeneous outdoor testbed LOG-a-TEC at JSI (Ljubljana)
- spectrum sensing platform developed at IMEC

Figure 1 depicts the CREW federation as it exists today: five different 'islands' are (often remotely) accessible by external experimenters. The CREW portal website (www.crew-project.eu/portal), provides both uniform high-level descriptions of the available hardware and software components, and in-depth information on how to get access to and how to use the federation components.

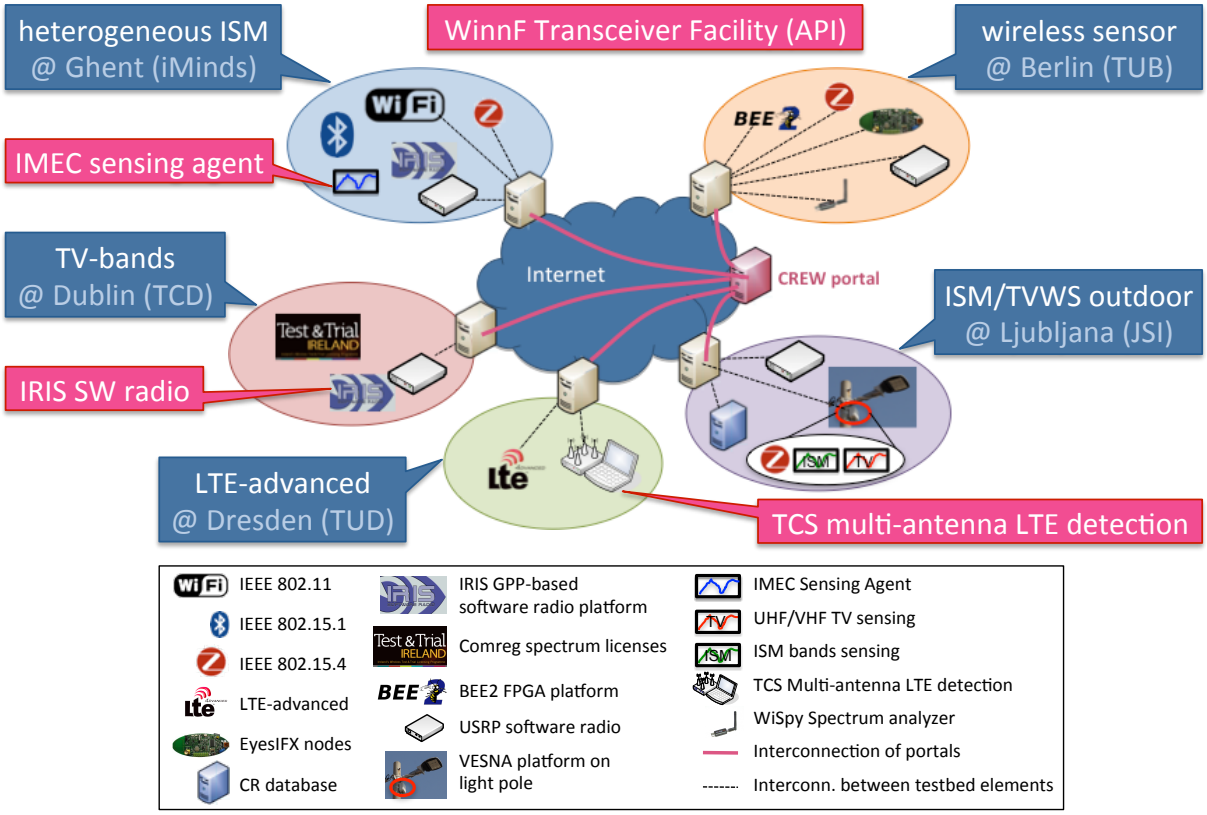

Figure 1: The CREW federation of cognitive radio testbeds

In addition to the common portal, CREW offers three other **federation functionalities**:

- *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, primary user activity, background traffic, packet traces, etc. created under benchmarked conditions and using a common sensing data structure;
- a *benchmarking methodology and framework* for cognitive radio and network experiments, offering credible and rigorous methods and automated procedures for experiments and performance evaluation, enabling objective comparison between subsequent developments or competing cognitive solutions.

Possible **usage scenarios** for experiments using the CREW federation include, but are not limited to:

- *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.

CREW is a five-year project, which started in October 2010 (see CREW roadmap in Figure 2). Its first year was dedicated to the formation of the federation and experiments by the project partners. In the following three years, the consortium is expanded through three open calls for proposals. During this time, the testbeds in the federation are enhanced with demand-driven extensions. The final year 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.

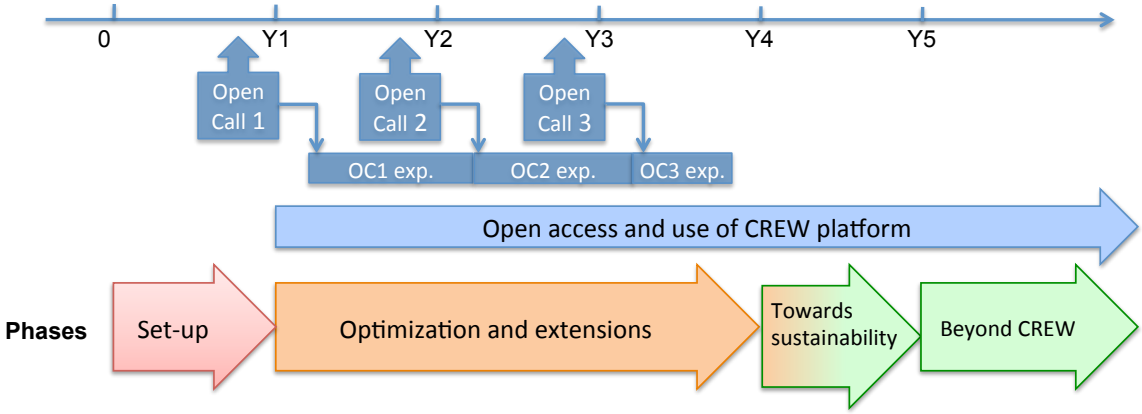

Figure 2: CREW roadmap

For more information on the CREW usage scenarios and federation functionality we refer to the following project deliverables, publicly available at the CREW website:

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/deliverables/CREW_D2.2_TCD_R_PU_2011-03-31_final_PRC.pdf)
D2.3 - Definition of use of the Federation (http://www.crew-project.eu/sites/default/files/CREW_D2.3_IMEC_R_PU_2011-09-30_final.pdf)
D2.4 - Definition of internal usage scenarios, federation functionality and the use of federation as applicable to the VESNA-based testbed (http://www.crew-project.eu/sites/default/files/deliverables/CREW_D2.4_JSI_R_PU_2011-12-30_v1.pdf)
D3.1 - Basic Operational Platform (http://www.crew-project.eu/sites/default/files/CREW_D3.1_TCF_R_P_2011-09-30_final.pdf)
D3.2 - Optimized operational federated platform (http://www.crew-project.eu/sites/default/files/CREW_D3.2_TCD_R_P_2012-09-30_final_v1.0_0.pdf)
D4.1 - Definition of Test Configurations and Benchmarks (http://www.crew-project.eu/sites/default/files/CREW_D4%201_TCD_R_PU_2011-09-30_final.pdf)
D4.2 - Methodology for performance evaluation (http://www.crew-project.eu/sites/default/files/CREW_D4.2_IBBT_R_PU_2012-09-30_final.pdf)
D4.3 - Definition of Test Scenarios and Benchmarks for VESNA Testbed (http://www.crew-project.eu/sites/default/files/CREW_D4.3_JSI_R_PU_2012-03-01_v1.0_0.pdf)

2 Call information

Target number of experiments to be supported: The CREW project expects to support at least 4 and at most 8 experiments.

Number of partners per experiment: The target number of partners per proposal 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.

Duration of the experiment: The maximum duration of an experiment is 6 months.

Earliest start date of experiment: 1 January 2014

Latest end date of experiment: 30 September 2014

Call deadline: Wednesday, October 2, 2013 at 17:00h CET (Brussels time)

Address for proposal submission: info@crew-project.eu

Call identifier (used as subject in email for proposal submission): CREW2013-OC3

Language of the proposal: English

Contact for information on this call: Ingrid Moerman (iMinds),
email: Ingrid.moerman@intec.ugent.be,
phone: +32 9 33 14 925

Terms and conditions

Each experiment must make use of the CREW facilities: implementation and validation of the proposed experiment must happen on the CREW facilities. Please be aware that CREW hardware cannot be moved outside the CREW test facilities. The proposed experiment must lead to a public demonstration on the CREW platform and/or a scientific publication.

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 the feasibility of the proposed experiment with 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/).

The template for proposal writing can be found in Annex II of this document. Proposals are accepted based on technical novelty, on the extent they make use of the CREW facilities and on availability of resources. Proposal evaluation will follow a blind peer review process by external experts. Final proposals will be selected by the CREW steering committee and approved by the EC taking into account (1) the recommendations from the external experts, (2) the feasibility of the experiment, and (3) the availability of resources (both infrastructure and manpower resources) within the CREW federated platform.

Unlike the first and second open calls, experimenters from successful proposals in this third open call will receive no EC funding and will not become official partners in the CREW project. However, this open call offers free access to the CREW facilities and guaranteed training & support by CREW partners covering guided training, technical assistance, and necessary extensions to experimentation tools. Compared to open call 1 and open call 2, this third open call will implement a fast evaluation process based on a simple proposal template (see Annex II). Unlike the first and second open calls, the

administrative burden will be kept minimally for the experimenters (only a short final report with main conclusions and findings of the experiment)

Detailed terms and conditions for access to the CREW facilities and collaboration between successful proposers and the CREW project partners will be formalized through a Memorandum of Understanding (MoU), of which a template can be found in Annex III.

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 functionality. The experiments should exploit the unique features of CREW facilities and address one or more (the quality is much more important than quantity) of the federation functionalities listed below:

- *Combination of (*at least) two *cognitive components* (from different testbeds)
  This can be either usage of cognitive components from different individual CREW testbeds or bringing own components into the federated testbed, e.g.:
  - Use of imec spectrum sensing agent in iMinds testbed.
  - Use of Iris software radio architecture for dynamic adaptations for coexistence (developed by TCD) in another testbed in the federation (e.g at iMinds testbed of JSI testbed)
  - Comparing experimental results obtained in two different testbeds (e.g. iMinds and TUB experimental facilities)
- CREW *advanced spectrum sensing* functionality:
  - Combination of different sensing solutions (hardware and/or software) of the CREW federation.
  - Comparison of own sensing algorithms/hardware with sensing algorithms/hardware available in the CREW federation.
- *Benchmarking features*:
  - Run and compare novel cognitive solutions in a reproducible "reference" test environment offered by CREW (e.g. home/office reference scenario at iMinds)
  - Use and validation of available metrics and scores for performance evaluation of cognitive solutions. These metrics can be found in the repository on the CREW portal (see http://www.crew-project.eu/repository/metrics_scores)
  - Definition of new or more advanced metrics and scores for performance evaluation of cognitive solutions
- Use the *CREW Common Data Collection and Storage Methodology*:
  - storing of measurement results in a common format
  - using the CREW facilities to make the traces publically available
- 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.
  - Analyzing and exploiting other available interfaces, such as the aforementioned for dealing with benchmarking configuration and data storage

Topics for experimentation proposals include (but are not limited to):

- Advanced spectrum sensing algorithms
- Coexistence of wireless networks in unlicensed bands: realization of the cognition loop
- Coexistence of wireless networks in licensed bands

1. Advanced spectrum sensing algorithms

The focus of this type of experiment is on validation of novel spectrum sensing algorithms in one (or more) of the CREW testbeds, e.g.

- Heterogeneous distributed sensing;
- Local versus distributed spectrum sensing techniques;
- Simple versus advanced spectrum sensing techniques, e.g. energy detection, matched filter detection, cyclostationary feature detection...;
- Impact of the quality of the sensing hardware on spectrum sensing resolution and accuracy when using simple COTS (Commercial Off The Shelf) hardware versus advanced CREW spectrum sensing hardware;
- The effect of controlled mobility (via mobile robots) on spectrum sensing.

For this type of experiment, CREW offers the following tools:

- Access to different types of sensing hardware (see table 1 in Annex I);
  - API to IMEC sensing agent offering access to reconfigurable front-end (see http://www.crew-project.eu/sites/default/files/SensingEngine_UserManual.pdf);
  - Transceiver Facility API implementation for the USRP2 platform (more info, see http://www.crew-project.eu/sites/default/files/CREW_D3.2_TCD_R_P_2012-09-30_final_v1.0_0.pdf)

- Repository containing traces (see http://www.crew-project.eu/repository/traces) that can be used to create reproducible wireless test environments (e.g. LTE primary user traces, ISM environments such as home/office/conference…);

2. Coexistence of wireless networks in unlicensed bands: realization of the cognition loop

The focus of this type of experiment is evaluating cognitive networking protocols (not only focusing on spectrum sensing, but also on layer 2 and higher layer aspects). In this category of experiments (possibly basic) spectrum sensing is a means, rather than the goal.

Possible experiments and evaluations are:

- New algorithms, protocols and networking architectures for solving the spectrum bottleneck in ISM bands enabling coexistence between wireless devices and (heterogeneous) technologies.
- Cognitive networking monitoring techniques (physical, link layer, network layer, transport layer, application layer) and understanding of the complex and dynamic wireless environment through intelligently combining the distributed local information.
- 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. iMinds versus TUB 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 higher layer cognitive radio / cognitive networking protocols

For this type of experiment, CREW offers the following tools:

- Repository containing traces (see http://www.crew-project.eu/repository/traces) that can be used to create reproducible wireless test environments (e.g. LTE primary user traces, ISM environments such as home/office/conference…);
- Repository containing methodologies (see http://www.crew-project.eu/portal/methodology) and measurement tools for performance evaluation and comparison of cognitive networking solutions (see http://www.crew-project.eu/portal/crew-benchmarking-tools);

- API to access real-time (distributed) spectrum sensing information using available CREW hardware (see http://www.crew-project.eu/sites/default/files/CREW_D5.2_TUB_R_PU_2012-09-30_final_v1.0.pdf and http://www.crew-project.eu/sites/default/files/rabaey2010cbrokerage%20Connectivity%20Brokerage%20White%20Paper_v1.0.pdf);
- Cognitive network protocol architecture, enabling focused experimentation on specific protocol components (MAC, routing…) (see for example IDRA architecture developed by iMinds http://idraproject.net);

3. Coexistence of wireless networks in licensed bands

In coexistence scenarios, interference between primary and secondary networks can usually not be avoided completely. Key questions that need to be answered in order to support the feasibility of cognitive radio solutions in licensed frequency bands revolve around the interference caused to an incumbent system by an overlay network and vice versa.

Possible experiments and evaluations are:

- Analysis of interference in a primary system (e.g. LTE, DVB-T), caused by a cognitive radio solution;
- Analysis of robustness of a secondary system towards interference from a primary system (e.g. LTE, DVB-T);
- Impact of erroneous and/or inaccurate sensing information;
- Techniques/protocols to deal with harmful interference from both primary and secondary side;
- Flexible PHY for cognitive radio
- Design of geo-location database architecture (communication between sensing nodes and decision node, data storage format, update frequency for sensing…)

For this type of experiment, CREW offers the following hardware and tools:

- Primary system hardware and spectrum licenses for experiments in the corresponding frequencies (see http://www.crew-project.eu/portal/IRISdoc and http://www.crew-project.eu/portal/ltedoc);
- Access to different types of sensing hardware (cf. table 1 in Annex I);
- Repository containing traces (see http://www.crew-project.eu/repository/traces) that can be used to create reproducible wireless test environments;

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 I). 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(s) is strongly recommended during proposal preparation.

Contact persons for local testbeds are:

- iMinds: Daan Pareit (Daan.Pareit@intec.ugent.be)
- IMEC: Lieven Hollevoet (lieven.hollevoet@imec.be)
- TUB: Mikolaj Chwalisz (chwalisz@tkn.tu-berlin.de)
- TCD: Paul Sutton (suttonpd@tcd.ie)
- TUD: Rohit Datta (rohit.datta@ifn.et.tu-dresden.de)
- JSI: Carolina Fortuna (carolina.fortuna@ijs.si)

Table 1: Characteristics and capabilities of CREW individual testbeds

Individual testbed locations → / **Features ↓**	**iMinds**	**TUB**	**TCD**	**TUD**	**JSI**
Wireless technologies/spectral bands					
TV-bands					
OFDM			x		
License (ComReg)			x		
License free with limited tx power allowed in UHF (e.g. 50 mW e.r.p. for BW=200 kHz)					x
LTE-bands (1.98/2.00 GHz UL, 2.17/2.19 GHz DL)				x	
License (UMTS Band VII issued by BNetzA)				x	
License (EUTRAN Band I 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		x
IEEE 802.15.4 (868 MHz)		x	x		x
COTS hardware (number of components)					
Tmote Sky sensor node	200 R	102 R			
Eyes IFXv2		102 R			
Shimmer2		16			
iMinds/rmoni RM090 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				

Cognitive radio platforms (number of components)					
imec sensing engine (ISM bands)	8 R				
imec sensing engine (100 MHz - 6 GHz)	2 R				
Iris software radio platform	8 R		8R		
BEE 2 FPGA platform, 2.4 GHz ISM transceiver		6			
USRP software radio					
Motherboards:					
USRP 1.0			5 R		
USRP 2.0			4 R		
USRP N200/N210	8 R		4 R		2
USRP E100	6 R		4 R		
Daughterboards:					
BasicTX 1-250 MHz	8 R				
BasicRX 1-250 MHz	8 R				
SBX 400-4.4GHz transceiver	2 R				
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		2
XCVR 2450 (2.4-2.5 and 4.9-5.85GHz)	16 R		12 R		
WARP Platform v2	5 R				
Signalion HALO 430 SDR equipment				2	
Signalion SORBAS (eNodeB + UE) @ 2.6GHz				3 + 3	
Signalion SORBAS (eNodeB + UE) @ 2.1GHz				3	
VESNA sensing platform					
SNE-ISMTV @ 868 MHz; LOG-a-TEC / JSI, (R)					16 / 4
SNE-ISMTV @ 2.4 GHz; LOG-a-TEC / JSI, (R)					29 / 4
SNE-ISMTV @ UHF; LOG-a-TEC / JSI, (R)					8 / 2
Commercial spectrum analyzer hardware (number)					
Wi-Spy 2.4x		8 R			
AirMagnet Spectrum XT	1				
Rohde & Schwarz / Agilent … spectrum analyzers		1			
Rohde & Schwarz FSQ				1	
Rohde & Schwarz FSH				1	
Rohde & Schwarz TSMW Network Analyzer				1	
Rohde & Schwarz FSVR Real-time Spectrum Analyser			1 R		
Anritsu MS2781B Spectrum Analyser			1 R		
Anritsu MS2721B Spectrum Master			1 R		
Anritsu MS 2690A Spectrum Analyser	1R				
Commercial signal generators					
Rohde & Schwarz SMBV Vector Signal Generator		1			1
Rohde & Schwarz SMU 200A Vector Signal Generator			1 R		
Anritsu MG3700A Vector Signal Generator			1 R		
General testbed features					
Indoor	x	x	x	x	(x)
Outdoor				x	x
Mobility		x		x	(x)
Remote control				(x)	

Open VPN	x				
Web tools	x	x			x
SSH		x			
mysql	x				
Automated measurements	x				x
Runtime interaction	x	x			x

Annex II: Proposal template for an experiment using the CREW platform

Proposal application form for an experiment in Open call 3

Note: The application form has to be completed in Times pt. 11 and single line spacing. The lay-out, font type, spacing or titles should not be modified. The page limits need to be respected. The Word version of the application form can be downloaded from the CREW website (http://www.crew-project.eu/opencall3)

Proposer information
Contact information Organization 1, name: Organization 1, address: Organization 2, name: Organization 2, address: Name of the contact person[1]: Contact telephone number: Contact email:
Profile & expertise of proposers (max. ½ page for each organization) **Organization 1:** **Organization 2:**

[1] In case of two proposing organizations, the contact person should belong to the first organization

General experiment information

Full title of experiment:

Acronym of experiment:

Desired start date (DD/MM/YYYY, Earliest date: 01/01/2014):

Intended duration (maximum 6 months)[2]:

Experiment description

Concept & motivation (max. ½ page):

Which cognitive solution will be evaluated in your experiment? What does the experiment aims to test (e.g. the spectrum efficiency, primary user detection, coexistence between competing technologies, comparison of multiple solutions...)? Please note that a cognitive solution does not have to implement a full cognitive cycle, but could as well focus on a single aspect of the cognitive cycle.

Motivate the need for using the CREW facilities.

Specification of experiment (max. 2 pages):

How do you propose to set up the tests? What are the test scenarios? Which measurements do you want to perform? Which performance metrics will be applied? What is the expected output from the experiment?

Use of the CREW federation (max. ½ page):

Which CREW infrastructures/components, federation functionality will be used? How much resources will be needed (e.g. number of nodes in an individual testbed). What is the estimated occupation of the CREW infrastructures/components...(e.g. 20 runs, each with a duration of 1 hour)?

Are there specific demands for essential extensions to improve/extend the CREW federation functionality? If yes, describe the extra functionality that is indispensable for the execution of your experiment. Such extensions must be discussed and agreed upon with the core CREW partners. Please indicate who is expected to implement the extensions: CREW core partner(s) and/or proposer(s)?

[2] Please take into account that the experiment must be finalized at latest by 30/09/2014.

Impact of the experiment (max. ½ page)

How will the experiment create value to your organization or your community in general? What is your interest in the results?

Describe the measures you propose for the dissemination and/or exploitation of the results of your action?

Terms and conditions

Successful proposers in this third open call will gain access to the CREW testing facilities for a maximum duration of 6 months, free of charge and with guaranteed support. There are however some restrictions that need to be followed, as stipulated in the Memorandum of Understanding for using the CREW facilities for experimentation (see Annex III of the CREW Announcement document for Open Call 3).

☐ By ticking this box the proposers indicate that, in case this proposal is successful and when they execute their experiment using the CREW facilities, they agree with the conditions as stipulated in the "Memorandum for Understanding for using the CREW facilities for experimentation".

☐ By ticking this box the proposers confirm that, in case this proposal is successful, they have the necessary manpower resources to execute the proposed experiment.

Annex III: Memorandum of Understanding for using the CREW facilities for experimentation

The Memorandum of Understanding is still under preparation and will be published on the CREW website, as soon as available (well before the submission deadline)