Cognitive Radio Experimentation World

July 2012

Announcement of the second 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

Core project partners: IBBT, 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 IBBT (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.

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 methodologies and automated procedures for experiments and performance evaluation methodologies, enabling comparison between subsequent developments or competing cognitive solutions.

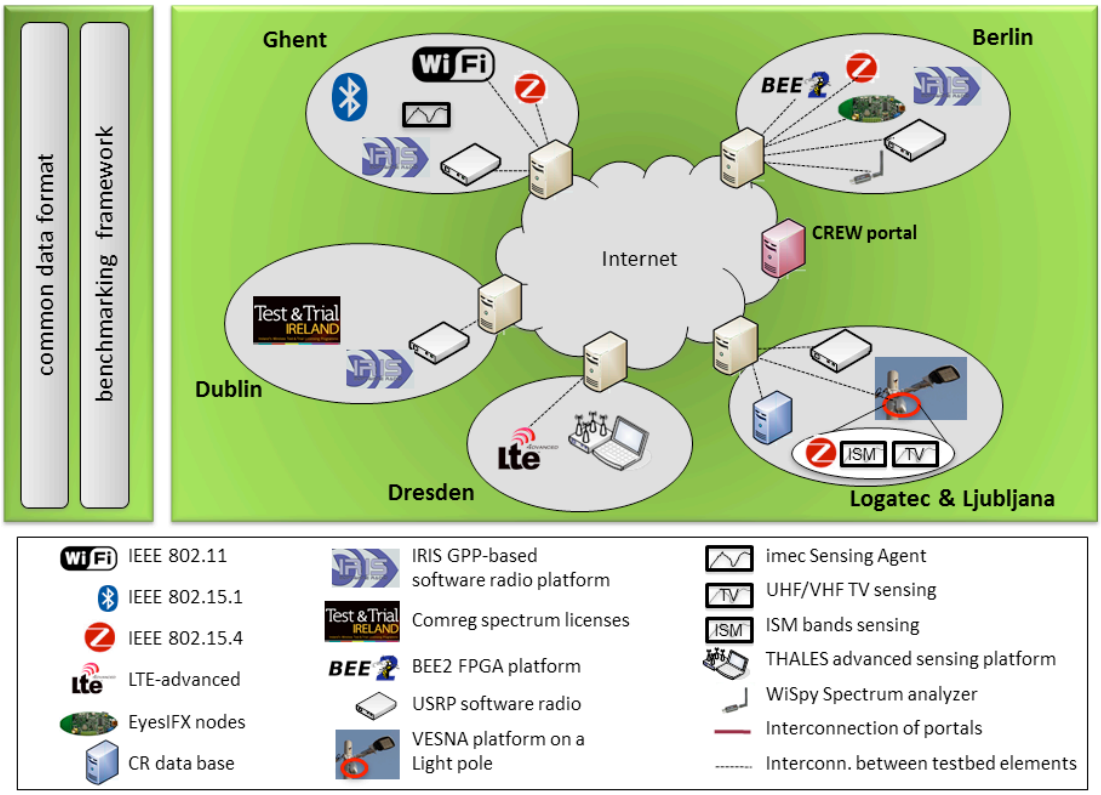

Figure 1: The CREW federation of cognitive radio testbeds

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 two years, the consortium is expanded through two open calls for proposals. During this time, the testbeds in the federation are 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.

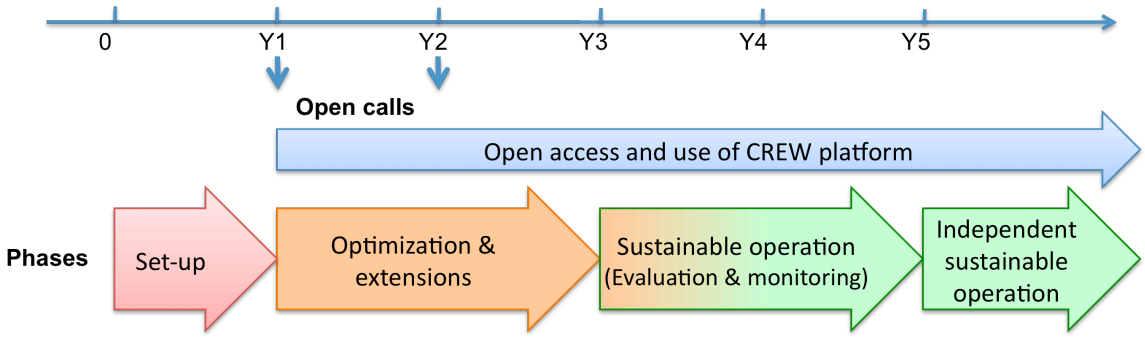

Figure 2: CREW roadmap

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)
- D3.1 - Basic Operational Platform (http://www.crew-project.eu/sites/default/files/CREW_D3.1_TCF_R_P_2011-09-30_final.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)

2 Call information

Budget of this call: € 440,000

Minimum Commission funding per experiment[1]: € 50,000

Maximum Commission funding per experiment: € 120,000

Number of proposals to be funded: The CREW project expects to fund at least 4 and at most 8 proposals.

Number of partners per proposal: 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. 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 3, 2012 at 17:00h CET (Brussels time)

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

Call identifier (used as subject in email for proposal submission): CREW2012-OC2

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

Each submitted proposal should address an experiment (or a set of experiments) in one of the categories defined in Section 3. At least one proposal in each category will be funded. At least one proposal with industrial participant(s) will be funded. Each proposal must make use of the CREW facilities: implementation and validation of the proposed experiment must happen on the CREW facilities and must lead to a demonstration on the CREW platform. Please be aware that CREW hardware cannot be moved outside the CREW test facilities.

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 within 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/).

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.

[1] An "experiment" must be considered as an "accepted proposal". The maximum funding per proposal can never exceed 120kEUR, even if multiple (sub)experiments are part of a single proposal.

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 IBBT testbed.
  - Use of Iris software radio architecture for dynamic adaptations for coexistence (developed by TCD) in another testbed in the federation.
  - Comparing experimental results obtained in two different testbeds (e.g. IBBT 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[2] in 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. These metrics can be found in the repository on the CREW portal.
  - 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.
  - Analysing and exploiting other available interfaces, such as the aforementioned for dealing with benchmarking configuration and data storage

[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.

We solicit for experiments in four different categories. Three categories are focussing on a specific aspect of cognitive radio / cognitive networking solutions, while a fourth horizontal category focuses on experimentation tools. Although a single experiment may fit in more than one category, it is the responsibility of the proposer to select the best-suited category[3] for his experiment based on the primary focus of the proposed experiment. Categories cannot be changed after submission.

The four possible categories are explained below:

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;
- Repository containing 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. Layer 2 and higher layer cognitive radio / cognitive networking protocols

The focus of this type of experiment is evaluating cognitive networking protocols (layer 2 and higher). 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. IBBT 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 cognitive radio concepts, such as spectrum sensing.
- The effect of controlled mobility (via mobile robots) on higher layer cognitive radio / cognitive networking protocols

[3] Only one category can (and must) be selected.

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

- Repository containing 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 and measurement tools for performance evaluation and comparison of cognitive networking solutions;
- API to access real-time (distributed) spectrum sensing information using available CREW hardware;
- Cognitive network protocol architecture, enabling focused experimentation on specific protocol components (MAC, routing…).

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

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

- Primary system hardware and spectrum licenses for experiments in the corresponding frequencies;
- Access to different types of sensing hardware (cf. table 1 in Annex I);
- Repository containing traces that can be used to create reproducible wireless test environments;

4. Strengthening CREW experimentation tools

The focus on this type of experiment is to further advance the CREW federation experimentation tools, including a benchmarking framework, open data sets, and a common portal, ***and*** applying these to experimental research on cognitive radio using the federation testbeds.

Possible experiments and evaluations include:

- Extending the benchmarking framework being developed by CREW and conducting a series of experiments that applies the framework.
- Defining a benchmark (including test conditions and all appropriate parameters) for comparison between a selected set of cognitive radio solutions or protocols, and performing this comparison using one or more of the federated testbeds.
- Defining data structures to be used in cognitive radio experimentation, conducting a series of experiments on the CREW testbeds that produce re-usable data, and publishing the resulting data set in the CREW data repository.
- Demonstrating how data collected in a set of experiments in one CREW testbed can be published in a pre-defined data structure, and the results replayed in a separate experiment in another testbed.

For this category of experiments, proposers are encouraged to refer to:

- The CREW portal
- The description of CREW functionality in deliverable D2.2 and D2.4.
- The definition of test configurations and benchmarks in deliverable D4.1 and D4.3.

For more information on the CREW usage scenarios, federation functionality, and additional example experiments we refer to the public CREW deliverables mentioned earlier (see http://www.crew-project.eu/documents)

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 is strongly recommended during proposal preparation.

Contact persons for local testbeds are:

- IBBT: Stefan Bouckaert (Stefan.bouckaert@intec.ugent.be)
- IMEC: Van Wesemael Peter (wesemael@imec.be)
- TUB: Jan Hauer (hauer@tkn.tu-berlin.de)
- TCD: Luiz DaSilva (dasilval@tcd.ie)
- TUD: Nicola Michailow (nicola.michailow@ifn.et.tu-dresden.de)
- JSI: Carolina Fortuna (carolina.fortuna@ijs.si)

Individual testbed locations → **Features ↓**	**IBBT**	**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			
IBBT/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)	5 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		
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

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. 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.
   - Use of the CREW federation: CREW infrastructures/components to be used, federation functionality to be used and/or to be extended (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 (= implement cognitive solution(s) on CREW hardware)
   - Implementation of essential extensions to the CREW federated platform (e.g. extension of CREW measurement tools, extensions of data formats, integration of external hardware in CREW 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. **Show case**
   - Set up of show case (demonstration) to be used for further promotion of the CREW facilities
6. **Dissemination**
   - Regular dissemination actions (conferences, workshop, FIRE events, advertising of experimentation results at CREW website…)

Experiments (covering phases 1 to 5) 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' (see phase 6). More information on the expected work packages 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).

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