Cognitive Radio Experimentation World

Project Deliverable D8.6
Updated report on sustainability model

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Abstract: This deliverable presents an overview of the sustainability view of the individual facilities, potential business models for the CREW facility including a general CREW exploitation plan for the upcoming last year of the project and the steps beyond, and figures concerning the numbers of experiments through open calls and open access, detailed usage statistics of the individual testbeds and their exploitation plans within the scope of the project.

Keywords:

Sustainability, testbed usage statistics, business models, access policy, exploitation plans

Executive Summary

Setting up a sustainability plan for the CREW facility is not a simple task and comprises various challenges. Sustainability means usage (or usefulness) of the infrastructure beyond the end of the project. The purpose of this sustainability deliverable was to describe the different potential business scenarios able to implement after the end of the project, and present a realistic exploitation plan with migration path for the upcoming year(s). This deliverable provides an updated and more realistic implementation view on the work presented in D8.5.

In this deliverable, we present first a summary of the results of enquiries conducted with the different project partners in 2010 and 2013 concerning sustainability topics such as openness, usage, access policies, and financial viability of the different individual testbeds. This gives us a good view on the diversity in technologies, size, complexity and strategy of the different facilities. In 2014 we conducted a last enquiry, focusing on the best practices obtained within CREW, asking the opinion of the partners about the proposed business models, and collecting usage statistics of the different testbeds and experiments conducted. The results are all presented within this deliverable.

A full section is dedicated towards statistics concerning the experiments through the three first open calls and open access, including an evaluation of both systems, as well as detailed usage statistics of the individual testbeds.

When considering what to do after the CREW project, four different business model options are presented: (i) CREW will continue to exist as an innovative brand within the FIRE and cognitive radio experimentation community, (ii) a follow-up project can be defined, (iii) CREW functionality might move into a future federation (such as Fed4FIRE), (iv) or testbeds will follow their individual strategies.

A general exploitation plan for CREW has been worked out with potential migration steps. For the last year of the project the focus will be on proceeding with the open access strategy. The first step when the project ends is keeping the CREW brand alive. This was perceived very well by all partners, certainly as this is a low effort model and especially benefits from the well-perceived project. However this business model is not sufficient and sustainable in the long run. The next step should focus on looking for opportunities to define a new CREW+ project within the boundaries of the upcoming H2020 calls and project partner's visions. Discussions concerning defining a new project and the potential focus can start when the new H2020 call texts will become available. Alternatively, migration toward a more high level federation, such as Fed4FIRE, may prove promising. Some CREW partners are already involved in the project; others have shown their interest in this model. Every partner however should develop their individual strategy alongside all previous proposed business scenarios, in order to stay unique and maintain a valid and operational testbed facility.

Besides the general exploitation plan, all partners within the project present at the end of this deliverable their individual exploitation plans within the scope of CREW.

List of Acronyms and Abbreviations

CRN	Cognitive Radio Network
CSA	Coordination and Support Action
EC	European Commission
FP	Framework Programme
FTE	Full time equivalents
H2020	Horizon 2020
HW	Hardware
IoT	Internet of Things
IPR	Intellectual Property Rights
MoU	Memorandum of Understanding
OA	Open Access
OC	Open Calls
PM	Person months
PoI	Point of Information
SME	Small and Medium-sized Enterprise
SW	Software
Steerco	Steering Committee
WINNF	Wireless Innovation Forum

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1 Introduction

This deliverable is dedicated to the sustainability model of the project. Many testbed infrastructures have been set up from a technical perspective, mainly financed by European Commission (EC), national or regional funds. However, the lifespan of technical innovation is not very long; hence additional investments must be made to keep the infrastructure up-to-date. Next to implementing updates the infrastructure must also be kept operational, maintained and supported, which also takes a lot of effort. Finding funding has been proven to be a problem for several projects in the past, and still today.

Therefore a sustainability model must be elaborated. This is a first requirement for keeping the CREW federation operational onwards, guaranteeing a certain operational level and enabling maintenance support (Figure 1). New experimenters must be attracted during this period to make use of the available infrastructure, and to indicate the benefits of the testbed infrastructures of CREW. The Open Call 3 was focused on attracting new experimenters, but compared to Open Calls 1 and 2 no funding is provided. In this third open call only support is offered. Additionally, the infrastructure is open to other experimenters at the same time as well outside the three open calls, through open access.

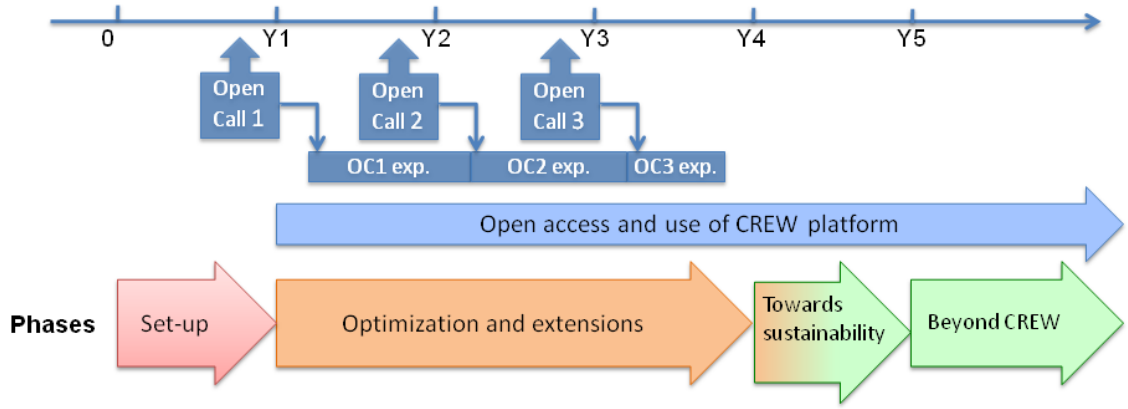

Figure 1: CREW roadmap

Within task 8.2, two main activities are considered: 8.2.1) the operation and maintenance of the CREW facility during the sustainability mode of the project, and 8.2.2) the business model.

An overview of the main conclusions from sustainability issues in the individual testbed facilities of the different project partners, as well as the best practices and main benefits gained from the CREW project are reported in section 2. We present the results from the experimenters gained through three open calls and open access, and show the usage statistics of the individual facilities (section 3).

Much attention is paid to the potential business models after the project. These are presented in section 4. The different partners within the project were consulted to present their vision and give feedback on these models. An evaluation of these models is presented in section 5. This leads to the general exploitation plan for CREW for the last year of the project, and beyond, with indication of the potential migration steps. Each partner has also indicated their individual exploitation plan, in relation to the CREW project.

An overall evaluation will be made in the last deliverable (D8.7) by the end of Y5.

2 Sustainability trends of CREW core partners

Based upon two questionnaires, one in 2010 in the early start of the project, and one in 2013 near the end of year 3, we have asked the individual CREW core partners for information concerning their testbed infrastructure (openness, usage, access policy and tariffing plan, financial availability). A comparison of the results is presented in this section. This work was presented in D8.5 [1] and is summarized below. We conclude with some best practices.

2.1 Openness

Not all test facilities in the CREW consortium are open today, but there is a trend towards making the testbeds publicly accessible (where possible). There is a shift from sharing the infrastructure with researchers of the own institution and project partners within research projects to external research institutes and in some cases industry (e.g. iMinds). Although we should mention that some of the infrastructures stay a closed environment, such as TCS. In general, we can conclude that there is mainly a shift towards more openness, but in some cases also a shift towards more protecting parts of the testbed infrastructure, for internal testing and further developments.

2.2 Usage

Next to openness, we asked the different core project partners for what purpose their testbed infrastructure was used. In 2010, the main focus was on (European) funded research projects. This was the case for all CREW core partners. Access was in nearly all cases granted to other project partners for making use of the testbed infrastructure. Only few had experience with attracting external users back then. In 2013 we saw that more partners make offers towards external users. A concern to consider is that there is less interest from the external users to use the testbed when the facility/component owner is not involved in the project!

All CREW core partners indicated that they have attracted more experimenters thanks to the CREW project. The main experimenter types are individual researchers, academic groups, research projects, SMEs and some large companies. Attracting the latter two to use the testbeds is one of the main goals of the CREW project so this is a positive conclusion.

2.3 Access policies and tariffing model

Below, some conclusions can be found concerning the access policy and tariffing model currently applied at the different facilities:

- The access policy and tariffing model proposed in D8.5 [1] are perceived very well by the different core partners and are in line with their current models.
- Not all testbed infrastructures have implemented an access policy. Some of them do not have any intention to implement such policy in the future. The main reason for this is to keep control of the situation or not wanting to have external experimenters using their facilities. In such situations, (external) research projects partners are intended to use the facilities.
- Not all partners are in favor of a premium access model. The first two access models (CREW core & open call partners, and best effort) are perceived as most “valuable” for attracting experimenters, mainly for being free of use, or relative easy procedures to implement.
- Taking part in new research projects as testbed infrastructure provider, however, is very appealing for some partners. Some guarantees should be offered such as availability of resources, advanced reservation, access to protected resources, etc. for other project partners and external experimenters to be able to use the offered testbed infrastructures.

2.4 Financial viability

The questionnaire results show that the testbed infrastructure owners are in a constant search for funds. While funding was available for the last years thanks to the CREW project, it is worrying to see that not a single partner is sure of future funding for investments in their facility. Furthermore,

while funds may be available for operating the facilities as they exist today, there may not be room for significant expansion of functionality. This conflicts with a part of the definition of sustainability: the ability to keep testbeds up-to-date in such way that they will still be relevant tomorrow and form a solid base for further development and expansion.

The situation stays the same as in 2010, meaning (very) short-term financial viability for the different individual facilities. Testbed facilities are highly dependent on research project funding; thus, the viability depends on the success rate of projects, which is in the current economic situation not evident. The project partners seem to be pessimistic about success rate of project proposals in the pipeline and future. Conclusion is that there is definitely a need for sustainability models for sharing facilities/components with related financial compensation and a need for well-defined policies for use for long term viability of the facilities.

2.5 Best practices

We asked the CREW core project partners what has changed the most compared to the start of the project. The items in the list were gathered during a sustainability inquiry of 2013, and presented in D8.5, but lacked level of importance. This was included in the inquiry of 2014, and Table 1 presents an indication of how the different partners see the best practices. The answers are indicated in a shade of black (the darker, the more valid the answer was).

We can draw some important conclusions from this list:

- Most valued best practices include the integration of and validation of hardware and software components in broader testbed infrastructure; obtaining new research experience & facility improvements; experience, evaluate and implement different experimental methodologies; document the functionality of our testbed and its CREW extensions. This is perfectly in line with the intention of the project.
- Besides dissemination of the capabilities of the testbed, contribution to a better image & reputation of the individual facilities and ability to reach good exposure and interactions with European researchers and attracting external experimenters to the testbeds is of utmost importance to keep the testbeds used and thus sustainable.
- The value of setting up cooperation with commercial partners depends on the type of partner and testbed infrastructure. Related to this is the clarification of the access policies, as some testbeds see less value in this. This is related to the discussion of open access (OA) vs. open calls (OC) (cfr. Section 2.3).
- The usage of testbed infrastructure in classrooms was limited, which explains the low value. This work is now taken up in other EC projects, such as FORGE [2].
- Access to new funding (mechanisms) thanks to knowledge and experience gained within CREW shows dispersed value between the different partners. This also highly depends on the background of the project partners (structural funding or not) and the availability and success ratio of obtaining new (project/structural/public) funding.

Table 1: Best practices thanks to the CREW project

Thanks to CREW we could:	*None*	*Low*	*Medium*	*High*	*Very high*
Obtain new research experience & facility improvements					
Improve our existing testbed					
Realize the integration of and validate of hardware and software components in broader testbed infrastructure.					
Experience, evaluate and implement different experimental methodologies.					
Document the functionality of our testbed and its CREW extensions					
Disseminate the capabilities of the testbed					
Attract external experimenters to our testbed					
Think about or further clarify the access policies to our testbeds.					
Reach good exposure and interactions with European researchers.					
Contribute to a better image & reputation of the individual facilities					
Promote the use of open software and remote access					
Use testbeds in classroom demonstrations to increase the enthusiasm of students to pursue higher studies in wireless communications.					
Set up cooperation with commercial partners					
Access to new funding (mechanisms) thanks to knowledge and experience gained					

3 Testbed usage statistics related to CREW

Within CREW, we focused on gaining knowledge and experience on setting up experimentation in the field of cognitive radio and cognitive networking. Two mechanisms have been set up in order to attract experimenters within the field of cognitive radio networks. Open calls (funded or non-funded) and open access have been offered. The results are described in section 3.1.

We asked the different project partners to give information about the usage of their testbed facility over the last four years, regarding number of experiments (CREW and non-CREW), duration, resource consumption, reservation time versus actual usage, support, type of experimenters, etc. This is described in the tables per project partner in section 3.2.

3.1 Open call versus Open Access

3.1.1 CREW

Two mechanisms have been set up in order to attract experimenters within the field of cognitive radio networks: open calls and open access [3]. Both are evaluated in the paragraphs below.

a. Open Call

Three open calls have been launched throughout the duration of the project.

The first open call closed on October 19, 2011 at 17:00 Brussels time. The CREW project received 18 proposals, (co-)submitted by 24 proposers. Although most proposals were sent by universities and research institutes, we also received 2 proposals from industry and 1 from a governmental department. However, due to the limited budget, only three proposers, those that were ranked highest after a thorough review process by external independent reviewers, received funding

The second open call closed on October 3, 2012. The CREW project received 21 proposals, (co-)submitted by 24 proposers. Among the proposers are 13 universities and 5 research institutes. 3 proposals were submitted by SMEs, and 3 by industry. Some proposers were involved in multiple proposals. Due to budget limitations, only 4 proposals received funding.

The third open call closed on October 2, 2013. The CREW project received 10 proposals, (co-)submitted by 11 proposers. Among the proposers, 8 are universities, 2 are SMEs and 1 is industry. One proposer was involved in two proposals. The proposers could not apply for funding, but only for guaranteed support by the CREW consortium to aid in their experiment. After a thorough review process by external independent reviewers, 7 proposals were selected.

b. Open Access

CREW, since 2014, is in a continuous open access phase, offering 2 modes for the use of the CREW facilities:

- *Best effort access & basic support*: CREW offers best effort access to the facilities free of charge for non-commercial use, including basic support (i.e. information from portal, guidelines, tutorials, handbooks, and limited technical support). The CREW portal guides the experimenter to find the most suitable test facility for his experiment along with further information on how to get started.
- *Guaranteed access & advanced support*: If more guarantees are required on the availability of infrastructure and more advanced technical support is needed, it is possible to submit a proposal application for an open access experiment with guaranteed availability & support. If the request is granted, CREW commits to provide the necessary facility resources and manpower to the experimenter, free of charge.

More information about the call can be found on http://www.crew-project.eu/opencall.

Proposals can be submitted at any time and will be evaluated on a monthly basis. Proposals will be selected by the CREW steering committee and approved by the EC taking into account (1) the quality of the experiment in terms of technical novelty and/or industrial relevance, (2) the feasibility of the experiment, and (3) the availability of resources (both infrastructure and manpower resources) within the CREW federated platform.

Experimenters from successful proposals in this call will receive no EC funding and will not become official partners in the CREW project. However, this 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. This call will implement a fast evaluation process based on a simple proposal template. The administrative burden will be kept minimally for the experimenters.

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).

c. Evaluation of both channels

We have seen that the Open Calls within the CREW project have been very popular. In call 1 and 2, where funding was available for the different experimenters, there was an oversubscription rate of 5.39 and 5.08, respectively. In call 3, the proposers could not apply for funding, but only for guaranteed support by the CREW consortium to aid in their experiment. Still 10 proposals were submitted, of which 7 were granted. However we should mention that other projects are still offering experimenter funded Open Calls (e.g. Fed4FIRE) where some of the CREW experiments also could be executed. This had a direct effect on the number of submitted proposals within the third call of CREW. A proposal (standard EC template in Open Call 1 & 2, lightweight template in Open Call 3) needed to be filled out within all calls in order to be eligible for selection.

The open access mode is available since the end of last year. For guaranteed access and advanced support, a simple template (similar to Open Call 3) needs to be filled out for each experiment proposal. However we see that this is not very popular, even as it is free of charge. Several experiments use the first mechanism (best effort, no proposal submission) but don't bother with the second mechanism (proposal submission). Experimenters should be motivated to submit an application.

3.1.2 Other projects

A literature study has been conducted to analyse the other FIRE projects concerning their sustainability plan and open calls/open access strategy. A short list has been drawn up from the most interesting projects that also studied these topics. In most cases as described below it is clear that both mechanisms for attracting experimenters have their benefits and drawbacks. Further analysis needs to be conducted which mechanisms are sustainable in the long run, and how this should be organized.

a. BonFIRE

BonFIRE allows users to evaluate the effects of converged service and network infrastructures; assess the socio-economic impact of new Cloud services; and to combine Cloud computing and data storage with novel networking scenarios. Essentially, BonFIRE enables developers to research new, faster, cheaper or more flexible ways of running applications [4].

Following two successful Open Calls that have given academic researchers, developers and SMEs access to the Cloud infrastructures in BonFIRE, the Open Access initiative was launched to give more people the opportunity to get involved and test innovative ideas for free! By far, this project has created the most detailed sustainability plan of all FIRE projects [5]. The project has created their own sustainability plan with special attention for the estimation of the real cost of experimentation.

The BonFIRE foundation is currently up and running. The open access is successful, with low administration and light decision structure. However the problem existing today is the question of how to keep the foundation and underlying infrastructure funded in the short and longer time frame.

b. OFELIA

The project creates a unique experimental facility that allows researchers to not only experiment "on" a test network but to control and extend the network itself precisely and dynamically. The OFELIA facility is based on OpenFlow, a currently emerging networking technology that allows virtualization and control of the network environment through secure and standardized interfaces. The project ended end of 2013. [6]

Two successful Open Calls were launched offering experimenters additional funding for conducting experiments in the OFELIA project.

Currently a number of projects are supporting the OFELIA infrastructure (FELIX, SmartFIRE, FIBRE), with opportunities to improve furthermore the framework. Most federation projects such as Fed4FIRE are using the control framework.

c. Fed4FIRE

Fed4FIRE delivers open and easily accessible facilities to the FIRE experimentation communities, which focus on fixed and wireless infrastructures, services and applications, and combinations thereof.

Four open calls have been launched, 2 calls for experimenters and testbed infrastructures, and 2 specifically targeted towards SMEs. The responses were very positive in terms of number of submitted proposals. More information can be found at [7].

The creation of a sustainability and exploitation plan for this federation is still work in progress. A first sustainability plan was presented [8].

d. AmpliFIRE

AmpliFIRE is an FP7 support action, continuing much of the work previously done by FIRE Station. The FIRE Radar provides a range of visions, discusses the gaps that must be bridged to reach them from the present portfolio, and describes the changes in mission and philosophy that will affect the FIRE program in the coming decade. Part of the study focused on the different Open Call mechanisms set up and run during the FIRE projects [9].

Conclusion is that the process was initially unfamiliar by most partners and considerable extra time was consumed as each project developed its own procedures, besides the obligatory aspect set by the EC. Main benefits related to the use of (not commercially available) testbed infrastructure, training and support for experimenters (incl. funding), low administration (e.g. relative ease of preparing proposals), and visibility and publicity. Challenges should focus on the need for better usage metrics and measurements so that the costs of external experimentation can be fairly allocated or anticipated, focused services towards SMEs, more clear legal implications (mostly related to IPR), standard methods monitoring experiments and saving result data to permit best practices comparisons.

e. CI-FIRE

The ultimate goal of CI-FIRE is to help establish mechanisms to translate outstanding research results into innovation to boost European competitiveness. Their overriding objective is to foster new multidisciplinary experimental research and the implementation of sustainable business models for FIRE facilities. This project supports the sustainable use of FIRE testbeds and platforms such as Fed4FIRE, BonFIRE, OFELIA, Sunrise and many others [10].

Whereas initially predominantly the instrument of Open Calls was applied for attracting experimenters and testers from academic, research and industry sectors, nowadays more and more experimenters are given free/Open Access to FIRE research infrastructures [11]. Further analysis needs to be conducted whether funding experimenters is the best idea, how to support infrastructure providers, and how this should be organized.

3.2 Usage statistics per project partners

We asked all project partners to give information about the usage of their testbed facility over the duration of the project. This is described in the tables below.

3.2.1 Usage statistics per testbed infrastructure

The results are presented in following tables (2 till 9).

a. iMinds

Table 2: Usage of iMinds testbed infrastructure

How much requests for experiments have you received on your testbed throughout the duration of the CREW project?
60 account requests
Of those, how many were as a result of the CREW project?
15
How much of those CREW request were granted for execution? How is this related to the overall approval of experiment request (over all experiments within your facility)?
100%. At the time, no requests for experiments are denied. Experiments might be denied in the future if they require too many resources for a long period. For example: all nodes cannot be reserved for an entire month, because lots of other projects use the testbed.
How many new accounts (excluding OC3 accounts) are created since open access is offered? How frequently is the testbed used by these new accounts?
32. These accounts are responsible for about 50% of the total number of reservations on the testbed.
What was the average resource consumption per experiment? Was there a difference between the average number of nodes used versus reserved? If so, why (e.g. for interference reasons)? Could you indicate the average duration of experiment?
Average resource consumption: 10 nodes/experiment (17% of total capacity in Zwijnaarde testbed) We have no stats on difference between reserved and used nodes. We estimate that this will (on average) be below 50%. Average duration of reservation slot: 10 hours (mostly from 8am to 6pm, some slots can take up to a week, some only 1 hour).
What was the ratio in time between reservation time and actual usage of the resource?

No actual stats available (estimated around 50%). We do plan to monitor & penalize this in the future.
What was the ratio in type of experimenters (academic research, education, industry, own usage)?
60% for academic research projects (national, EU, PhD (internal + external)) 5% for educational use 35% for demand-driven research projects in collaboration with SMEs and industry (industry/SME ratio: estimated 50/50)
What was the ratio in type of experimenters (CREW related versus non CREW related)?
15/60 users originate in CREW (25%), which means they found out about the testbed through the CREW portal (or other CREW related events). Further detail on these users: 4/15 are PhD students (U.S./U.K./France/Netherlands) 10/15: CREW Open Calls (including industrial partners) 1/15: academic research (CREW-OpenLab collaboration)
What was the average time required to help experiments to get started (can depend on type of experimenter)?
Experienced FIRE users (with wireless expertise) can start to use the testbed based on the available documentation. Estimated time for answering some questions during their first experiments: 2 hours. New FIRE users/ Users requiring specific functionalities (e.g. mobile nodes): 1 day up to 1 week. New users requiring the installation of custom hardware: 3 days up to several weeks.
How much support did you need to provide to experimenters (in terms of manpower, JIRA items, etc.) during the experiment?
Open call experiments: 2 tot 4 weeks/experiment (new hardware/new functionalities needed).
Other experiments: 1 day/experiment (estimated average, including support for non-testbed related issues (e.g. setting up a wireless network, configuring NAT/DHCP/DNS on the experiment network).
If you have further information, please note them below.
On average, 86% of the w-iLab.t testbed is used during day time. On one day, up to 8 experiments can run simultaneously.

b. IMEC

Table 3: Usage of imec testbed infrastructure

How much requests for experiments have you received on your testbed throughout the duration of the CREW project?
6 (UDUR, TUIL, UTH/NICTA, SIRI, national projects QoCon and CoPlaSM,)
Of those, how many were as a result of the CREW project?
4 (UDUR, TUIL, UTH/NICTA, SIRI)
How much of those CREW request were granted for execution? How is this related to the overall approval of experiment request (over all experiments within your facility)?
6
How many new accounts (excluding OC3 accounts) are created since open access is offered? How frequently is the testbed used by these new accounts?

NA (access to IMEC spectrum sensing engine happens via the iMinds test facilities)
What was the average resource consumption per experiment? Was there a difference between the average number of nodes used versus reserved? If so, why (e.g. for interference reasons)? Could you indicate the average duration of experiment?
NA
What was the ratio in time between reservation time and actual usage of the resource?
NA
What was the ratio in type of experimenters (academic research, education, industry, own usage)?
67 % academic research (CREW open call experiments)
33 % industrial research (QoCON and CoPlaSM are collaborative projects with industry)
What was the ratio in type of experimenters (CREW related versus non CREW related)?
50 % CREW related (Open Call 1,2,3)
What was the average time required to help experiments to get started (can depend on type of experimenter)?
1 day for WARP based experiments
1 to 5 days SCALDIO based experiments, depending on required flexibility.
How much support did you need to provide to experimenters (in terms of manpower, JIRA items, etc.) during the experiment?
5 days for WARP based sensing experiments
15 days for SCALDIO based sensing experiments
If you have further information, please note them below.

c. TCD

Table 4: Usage of TCD testbed infrastructure

How much requests for experiments have you received on your testbed throughout the duration of the CREW project?
Approximately 10 requests
Of those, how many were as a result of the CREW project?
Approximately 5
How much of those CREW request were granted for execution? How is this related to the overall approval of experiment request (over all experiments within your facility)?
All, this is typical
How many new accounts (excluding OC3 accounts) are created since open access is offered? How frequently is the testbed used by these new accounts?
1 account created, not used since
What was the average resource consumption per experiment? Was there a difference between the average number of nodes used versus reserved? If so, why (e.g. for interference reasons)? Could you indicate the average duration of experiment?
Typically an average of 3 nodes is reserved for 4 weeks.

What was the ratio in time between reservation time and actual usage of the resource?
Resources are used for 25-50 percent of the reservation time
What was the ratio in type of experimenters (academic research, education, industry, own usage)?
75 % - own 12.5 % - industry 12.5 % - academic research
What was the ratio in type of experimenters (CREW related versus non CREW related)?
75% - non-CREW 25% - CREW
What was the average time required to help experiments to get started (can depend on type of experimenter)?
On average a few hours, but up to 4 days for non-experienced users
How much support did you need to provide to experimenters (in terms of manpower, JIRA items, etc.) during the experiment?
Typically less than1 day for experienced users, but up to 4 weeks for more complex experiments and less experienced users.
If you have further information, please note them below.

d. TUB

Table 5: Usage of TUB testbed infrastructure

How much requests for experiments have you received on your testbed throughout the duration of the CREW project?
126 new account requests
Of those, how many were as a result of the CREW project?
13 experiments (not accounts, this information is not available)
How much of those CREW request were granted for execution? How is this related to the overall approval of experiment request (over all experiments within your facility)?
8 requests were granted. Overall 68 accounts where granted, it is 100% of those that in the end accepted the TWIST access rules and followed the whole registration correctly
How many new accounts (excluding OC3 accounts) are created since open access is offered? How frequently is the testbed used by these new accounts?
10
What was the average resource consumption per experiment? Was there a difference between the average number of nodes used versus reserved? If so, why (e.g. for interference reasons)? Could you indicate the average duration of experiment?
The TWIST testbed allows only for reservation of all nodes in a given technology. There is no statistics how many nodes where used. The average duration of an experiment is 11.5 hours. However most of them are shorter than 10 hours, few lasting up to 2 weeks, many less than hour.
What was the ratio in time between reservation time and actual usage of the resource?

There is no such statistics available
What was the ratio in type of experimenters (academic research, education, industry, own usage)?
90% academic experiments versus 10% industry/SME. It is hard to count as some people register with public email address, and it is the only source of such information. Also there is still some user account sharing amongst people.
What was the ratio in type of experimenters (CREW related versus non CREW related)?
There is no such statistics available
What was the average time required to help experiments to get started (can depend on type of experimenter)?
Estimated couple of hours to 1 day to familiarize with the tutorials for TWIST user and 1 week for the users using advanced CREW functionalities.
How much support did you need to provide to experimenters (in terms of manpower, JIRA items, etc.) during the experiment?
Experiments that need advanced CREW functionalities 1-2 weeks per experiment
If you have further information, please note them below.
Using pure TWIST testbed is relatively easy. In order to use advanced CREW functionalities more training is required

e. TUD

Table 6: Usage of TUD testbed infrastructure

How much requests for experiments have you received on your testbed throughout the duration of the CREW project?
27
Of those, how many were as a result of the CREW project?
4
How much of those CREW request were granted for execution? How is this related to the overall approval of experiment request (over all experiments within your facility)?
2. The other non-CREW requests were realized by other projects.
How many new accounts (excluding OC3 accounts) are created since open access is offered? How frequently is the testbed used by these new accounts?
1 (Eurecom for 1 week)
What was the average resource consumption per experiment? Was there a difference between the average number of nodes used versus reserved? If so, why (e.g. for interference reasons)? Could you indicate the average duration of experiment?
2 BS/AP and 2 UEs/Terminals, 1 week
What was the ratio in time between reservation time and actual usage of the resource?
2:1
What was the ratio in type of experimenters (academic research, education, industry, own usage)?
Academic 15% industry 48%

Education 11% own usage 26%
What was the ratio in type of experimenters (CREW related versus non CREW related)?
11% / 89%
What was the average time required to help experiments to get started (can depend on type of experimenter)?
3 days
How much support did you need to provide to experimenters (in terms of manpower, JIRA items, etc.) during the experiment?
1 FTE for the respective period for all experiments
If you have further information, please note them below.

f. TCS

Table 7: Usage of TCS testbed infrastructure

How much requests for experiments have you received on your testbed throughout the duration of the CREW project?
1
Of those, how many were as a result of the CREW project?
1
How much of those CREW request were granted for execution? How is this related to the overall approval of experiment request (over all experiments within your facility)?
1
How many new accounts (excluding OC3 accounts) are created since open access is offered? How frequently is the testbed used by these new accounts?
NA
What was the average resource consumption per experiment? Was there a difference between the average number of nodes used versus reserved? If so, why (e.g. for interference reasons)? Could you indicate the average duration of experiment?
3 PM Duration of OC1 experiment
What was the ratio in time between reservation time and actual usage of the resource?
What was the ratio in type of experimenters (academic research, education, industry, own usage)?
Research institute experimenter
What was the ratio in type of experimenters (CREW related versus non CREW related)?
100% CREW related
What was the average time required to help experiments to get started (can depend on type of experimenter)?
1.5 week
How much support did you need to provide to experimenters (in terms of manpower, JIRA items, etc.) during the experiment?

2 PM
If you have further information, please note them below.

g. EADS

Table 8: Usage of EADS testbed infrastructure

How much requests for experiments have you received on your testbed throughout the duration of the CREW project?
1 (Channel measurements by UDUR in scope of Open Call 1)
Of those, how many were as a result of the CREW project?
1
How much of those CREW request were granted for execution? How is this related to the overall approval of experiment request (over all experiments within your facility)?
1
How many new accounts (excluding OC3 accounts) are created since open access is offered? How frequently is the testbed used by these new accounts?
NA
What was the average resource consumption per experiment? Was there a difference between the average number of nodes used versus reserved? If so, why (e.g. for interference reasons)? Could you indicate the average duration of experiment?
2 days
What was the ratio in time between reservation time and actual usage of the resource?
100 %
What was the ratio in type of experimenters (academic research, education, industry, own usage)?
100 % academic research
What was the ratio in type of experimenters (CREW related versus non CREW related)?
100 % CREW related (Open Call 1)
What was the average time required to help experiments to get started (can depend on type of experimenter)?
1 day for set-up of equipment
How much support did you need to provide to experimenters (in terms of manpower, JIRA items, etc.) during the experiment?
2 days hands-on support during installation of equipment and conduction of measurements
If you have further information, please note them below.

h. JSI

Table 9: Usage of JSI testbed infrastructure

How much requests for experiments have you received on your testbed throughout the duration of the CREW project?
We received 11 requests for experiments requiring access to the testbed. 7 of those progressed to the stage where access to the testbed was granted.
Of those, how many were as a result of the CREW project?
All.
How much of those CREW request were granted for execution? How is this related to the overall approval of experiment request (over all experiments within your facility)?
All. The granted proposals in funded Open Calls were below 50% (more like 30-40%) while the ones accepted and supported in unfunded Open Calls were 70% or more (much less proposals in this case).
How many new accounts (excluding OC3 accounts) are created since open access is offered? How frequently is the testbed used by these new accounts?
7 new accounts were opened granting access to the LOG-a-TEC testbed to users from 4 different organizations, a Slovenian SME Xlab (commercial users), Jozef Stefan International Postgraduate School (one teaching stuff, one PhD student), TU Cluj-Napoca (undergraduate students that spent an internship at JSI) and JSI (external to CREW project). The frequency of use of the testbed varied between experiments but generally there were several short term experiments. Cumulative use for none of the users exceeded 3 days.
What was the average resource consumption per experiment? Was there a difference between the average number of nodes used versus reserved? If so, why (e.g. for interference reasons)? Could you indicate the average duration of experiment?
A typical experiment requiring only remote access to the testbed reserved in total 10 hours of testbed time. One long-term observation experiment reserved the testbed for a total of 50 hours over a 4 month period. One experiment requiring local access and special preparations required in excess of 100 hours of dedicated testbed time.
What was the ratio in time between reservation time and actual usage of the resource?
This information has not been logged.
What was the ratio in type of experimenters (academic research, education, industry, own usage)?
All academic research
What was the ratio in type of experimenters (CREW related versus non CREW related)?
100% CREW for wireless experimentation
What was the average time required to help experiments to get started (can depend on type of experimenter)?
1 week
How much support did you need to provide to experimenters (in terms of manpower, JIRA items, etc.) during the experiment?
A typical experiment involving only remote access to the testbed required on the order of 10 hours of support from our side. An extreme case was an experiment requiring local access to the testbed, extensions to the testbed functionality and on-site preparations that required 1 month of support.

If you have further information, please note them below.
/

3.2.2 Evaluation of testbed statistics

When analyzing the statistics of the five testbed owners (excluding IMEC, EADS, TCS), we see that since test facilities have been opened at the end of Year 1 of the CREW project, these facilities are not only used for CREW related experiments, but also for other experimenters not directly related to CREW. This is an indication that the test facilities are not only useful for CREW, but also for other research activities in a broader wireless community. Although the Open Access formula (with the lightweight proposal) is not really a success, many new accounts have been created in different CREW testbeds since the start of the Open Access period (early Year 4), showing that there is still interest in the CREW facilities, even when no CREW funding is available for the external experimenter.

Specific HW and SW (like IMEC spectrum sensing engine and TCS transceiver API) can only be made available through incorporation in one of the 5 testbed islands and it is important to further promote such HW/SW functionality integration.

Support (for getting started, and during the experiment) is very important, and depends on the use of advanced features and flexibility needed: more complex experiments require more support. There seems to be a lot of interest from external experimenters (in particular from industry and SME) to integrate new hardware in the CREW testbeds. Experiments that need the integration of external hardware generally require more support than experiments that use CREW hardware only.

Training of experimenters seems to be very important, certainly for experimenters that have not yet experience with FIRE.

4 Potential business models for CREW after the end of the project

As stated in the DOW *"the CREW project will implement a sustainability business model for exploitation of the federated testbed from year 4 on and beyond the project"*.

We will first describe the different models, presenting the potential value, but also indicating the possible effort and costs related. Next some questions regarding the business potential of those models will be asked.

We indicate four potential options that are possible beyond the CREW project: (i) CREW will continue to exist as an innovative brand within the FIRE and cognitive radio experimentation community, (ii) a follow-up project can be defined, (iii) CREW functionality might move into a future federation (Fed4FIRE), (iv) or testbeds will follow individual directions as implemented by the different partners. There are possible migration scenarios in between, as can be seen in Figure 2, meaning that depending on one scenario, others are not excluded e.g. keeping CREW as an innovative brand will not exclude the possibility to define a new follow-up project.

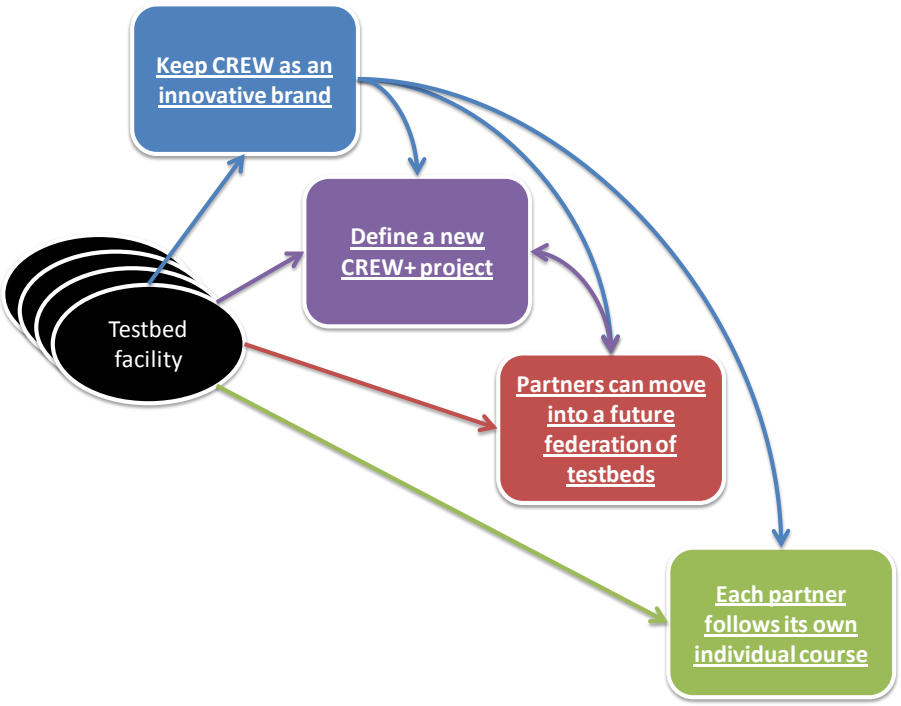

Figure 2: Potential models beyond the CREW project

4.1 Keep CREW as an innovative brand within the FIRE and cognitive radio experimentation community

The CREW project is well known within FIRE, and has a very good connotation in terms of innovation and experimentation. Also within the cognitive radio experimenter community the project has a very good reputation, thanks to the experience and knowledge gained during the project. The idea of this first model is to keep "CREW" beyond the end of the project as an innovative brand for cognitive radio experimentation.

Within Table 10 we present the potential value proposition for this business model. We used the canvas model from Osterwalder [12].

Table 10: Value proposition for CREW brand

<table>
<tr><td rowspan="2">Key partners

Individual wireless testbeds incorporating diverse wireless technologies and SW radio platforms augmented with cognitive radio hardware</td><td>Key activities

Facilitate experimentally-driven research</td><td rowspan="2">Value proposition

Open federated platform for Cognitive Radio (Networking) experimentation

Offering common methodology for wireless experimentation</td><td>Customer relationships

First point of contact for cognitive radio (networking) experimenters

Providing advice on most suitable testbed(s) for their experiment</td><td rowspan="2">Customer segments

Experimenters in the field of cognitive radio / cognitive networking (focus on academics, education purpose and industry)</td></tr>
<tr><td>Key resources

Knowledge on experimentally-driven research

Documentation about the individual testbeds, how-to tutorials and best practices</td><td>Channels

Portal

Newsletter

Academy (tutorials / webinars)

FIRE newsletter and activities</td></tr>
<tr><td colspan="3">Cost structure

Portal: keep it up and running, and up to date

Marketing and PR: giving tutorials and webinars, providing documentation, representing CREW on conferences and FIRE events

Support: single point of contact (SPOC)

Management: decision structure with representation from the different partners</td><td colspan="3">Revenue streams

None directly towards CREW</td></tr>
</table>

a. <u>What could we "sell" as our main competences and knowledge within this CREW brand?</u>

- Developed hardware and software components
- Developed methodology for replication of experiments in cognitive radio / cognitive networking environments.
- Knowledge and experience gained through experiments combining different partners and facilities
- Repository (experiment descriptions, traces, background environments, processing scripts, performance metrics & benchmarking scores...)

b. <u>What can we offer to the experimenter?</u>

- Portal that acts as first point of information (PoI) for cognitive radio / cognitive networking experimenters
- Provide advice on most suitable testbed(s) for their experiment
- (Pointers to) documentation (hosted and updated by the different testbeds that are part of CREW) about how experiments could be set up. This can be through hands-on video guidance, written out tutorials, etc.

- More interactive sessions on how to set up and use the different facilities joined through the CREW brand
    - Through online demonstrations and presentations (webinars)
    - Presentations at conferences and events

c. What can we offer to the testbeds (still) wanting to take part of this model?

- In more general promotion of cognitive radio / networking experimentation
- Increased visibility would lead to
    - Potential to retain or attract new experimenters
    - Increased usage of your facility
    - Image and trust in your facility
    - Potential of new collaborations with other partners and facilities

d. What do we need to keep this model operational?

- The portal (http://www.crew-project.eu)
    - The server and website needs to be kept up and running (backend and front-end software updates, keeping DNS name, etc.)
    - Content: improvement of the information shown about the testbeds (likely to be a link to an up-to-date local website)
    - Point of contact: the website should act as first point of contact, possibly extended with some SPOC person responsible in case of more information or questions.
- Marketing and PR
    - Creation of how-to tutorials (presentations, videos) to be published on the portal, for new as well as advanced experimenters, and basic as well as advanced experiments.
    - Promoting the CREW brand at local and international events, or in publications
        - Integrated: oblige an experimenter or joined testbed when presenting their own work which was being made possible through the CREW methodology or platform, to integrate some link to CREW and report this (e.g. reference in publication, logo on their presentation, or general slide about the purpose of CREW to be included, or other type of reference)
        - Dedicated: special tutorial, demo or presentation given about CREW (e.g. at a FIRE event where CREW is represented in the FIRE forum or at the conference)
    - CREW academy: organizing interactive sessions
        - Online: e.g. dedicated webinar on specific topic, experience on using the methodology, …
        - Optional: dedicated sessions, workshops or training days at a physical location.
    - Newsletter: an idea is to have a final newsletter: what did we do during the project, what we have achieved, and how we will move on beyond the end of the project.
    - PR within FIRE: an aggregated summary of tutorials, events, experiments, usage of the facilities, etc. could be published in the general FIRE newsletter
- Governance board that can decide on new initiatives and upcoming steps
    - This board would include one member of each testbed
    - Tasks and responsibilities
        - Manage current memberships, but also set up rules and guidelines to evaluate and approve new members
        - Communication plan regarding marketing and promotion
        - Decide on new opportunities: taking the lead on setting up new projects, aligning with other projects or organizations, etc.
    - A bi-monthly conference call meeting would suffice. Other conference calls or meetings may be set up in an ad-hoc manner, depending on the topic to be discussed (e.g. new project definition, elaboration of tutorials, etc.)

e. Potential migration strategies

- This framework could be used for defining new projects within the domain of cognitive radio / networking.
- Some partners might also continue their work within other projects and domains, certainly with the link to Fed4FIRE
- Follow an individual course next to this business model

4.2 Define a follow-up project CREW+

A possibility could be to continue the work and extend the expertise gained throughout the project within a newly defined project within H2020. The next call is to be later this year. The specific topics should be discussed within the consortium and between the partners.

4.3 CREW functionality will move into a future federation of testbeds (Fed4FIRE)

Fed4FIRE is delivering a common federation framework for Future Internet Research and Experimentation facilities that hopefully will

- be widely adopted by different communities (experimentation facilities, experimenters, academia, industry)
- support powerful experiment lifecycle management (including tools for discovery and reservation, experiment control, measurements, etc.)
- support key aspects of trustworthiness (federated identity management and access control, accountability, SLA management)

This project is bringing together a lot of experimentation facilities, in order to attract more experimenters and save costs (economies of scale). This IP project is now in its second year, and several decisions concerning the structure and functionality are currently taken. A first version of their sustainability plan has been published.

Partners of the current CREW project could take part in this future federation (some already are or plan to via the open calls). Experimentation across different testbeds might not be the most important motivation for CREW partners. Single sign-on, same look and feel by using common experimentation tools, access to multiple (wireless) testbeds, and extension of the Fed4FIRE community by connecting them with wide user base is of greater importance.

a. What could we offer this future federation of testbeds (beyond Fed4FIRE)?

- Unique wireless testbeds with advanced cognitive radio components
- Developed a methodology for controlled and replicable experiments in various radio environments.
- Knowledge and experience gained through experiments combining different partners and facilities (best practices)

b. What is the benefit for the experimenter?

- The ‘standardized’ tools provided by the federation could be used on wireless testbeds
- Potential to replicate experiments on different testbeds
- Possibility to combine CREW testbeds with other testbed facilities

c. What is the benefit to the CREW partner?

- In more general promotion of cognitive radio / cognitive networking experimentation
- Increased visibility would lead to

  - Potential to retain or attract new experimenters
  - Increased usage of your facility
  - Image and trust in your facility
  - Potential of new collaborations with other partners and facilities
- Make use of tools provided by the federation
- Support of common tools and common APIs by the federation

d. What does a federation partner (testbed facility) need to provide?

- To be compliant to several APIs for some functionalities
  - Authentication & authorization
  - Resource description and discovery, soft reservation and provisioning
  - Facility monitoring
  - Experiment control
  - Experiment measurement
- Provide documentation to the experimenters how to set up an experiment

4.4 Each partner follows its own individual course

Each partner can also follow its individual course as its strategy, strengthened by the knowledge, tools, methodologies, hardware that are a direct and/or indirect result of CREW. For instance it can stay completely independent, or can join other testbeds and projects, or make liaisons with other partners or joining groups such as the Wireless Innovation Forum (WINNF).

This model can be combined with one of the previous models. Being partner of the CREW innovative brand, taking part in a new EU project, or being compliant to the future federation of testbed infrastructures, will (in most cases) not disturb individual strategies.

5 Viability of the proposed business models

Within a detailed questionnaire in July/August, we presented the different project partners the four business scenarios from section 4 and asked their opinion. The results and conclusions are presented in the sections below.

5.1 Keep CREW as an innovative brand within the FIRE and cognitive radio experimentation community

The strongest points seen within this model are

- This model serves as a baseline and a reference for a potential new project based on cognitive radio network(CRN) testbeds.
- It leverages on achieved results, both technically and on operations and marketing.
- It keeps the CREW facilities open for further experimentation by external experimenters.
- It facilitates Cognitive Radio (Networking) experimentally-driven research. Platform and software offering with proven / validated methodology for wireless experimentation. It is a heterogeneity of wireless devices and test methods, with an open access infrastructure
- It maintains the achieved integration of individual testbeds and partners and facilitates future comparison and exchange of experience, results, scripts, traces, etc.
- It provides greater visibility in the experimentation and research community, especially to otherwise lesser known facilities, and increases opportunities for promotion at the European level. Keep it as an information channel on CREW facilities beyond the project's end.
- The CREW brand can be utilized to establish future collaborations with industrial and academic partners.
- The CREW portal that will still be supported can advise on most suitable testbed(s) for experimentation, with certain level of support, and basic training material (tutorials / webinars) available
- This model is a low cost, low effort solution for keeping CREW up and running

Weakest point declared is the fact there is no clear revenue stream or continuing benefit to facility provider.

According to all project partners, this model presents enough benefits for the experimenter. However, some things stay unclear or should be taken into account. The success of the model will of course depend on the level of maintenance that can be provided, and potential upgrades and extensions that can be implemented in the future in order to offer actual relevant environments to the experimenter. This model provides mainly benefits while looking for the testbed infrastructure or at the initial stage of experiment. We can see in CREW that further cooperation between experimenter and the specific testbed provider is happening anyway. Preserving the CREW brand is a first step, but is not feasible in the long run. It could be seen as a relevant transition phase until another 'brand' takes over.

A clear statement made by all partners is that they all approve and would be interested in taking part of this model in the future. This is mainly due to the fact that they would like to stay connected with the community. However, as mentioned above, this model should best be seen as an initial phase, until a more sustainable (funded) model, can be established, either by a new research project or though collaboration with industry.

Most partners are also willing to commit some effort in this business scenario (seven out of eight).

Following commitments would be made

	Yes	Maybe	No
• Bimonthly calls for general discussion	7		1
• Updating facility information	6		2
• Submitting information about upcoming events, experiments conducted, best practices, …	5	1	2
• Providing presentations, giving tutorials, webinars	3	3	2
• Support tasks	1	3	4
• Management tasks	3	1	4

In general we can state that this model shows some interesting aspects, in terms of benefits for the individual testbeds and experimenters, with a minimal amount of effort, and thus low cost. This model is excellent as an initial step before transition towards a more sustainable model is possible.

5.2 Define a follow-up project CREW+

All partners responded very well upon this business scenario. Focus could be put on larger and more complex experiments within the field of cognitive radio networking, with support of common and broadly applicable tools for flexible radio and wireless research. The different partners could contribute their testbed facilities and expertise gained throughout the CREW and other projects.

However it is very difficult to set up a CREW follow-up project, combining visions, research outlines and potential effort of the current partners. Besides, due to the large amount of proposals submitted within the H2020 calls, getting the project funded in the end is even more challenging.

5.3 CREW functionality will move into a future federation of testbeds

The Fed4FIRE project [7] has as goal to deliver a common federation framework for FIRE facilities that hopefully will be widely adopted by different communities, support experimenter lifecycle management, and key aspects of trustworthiness. This framework is based upon supporting common APIs and standards. In the end this should hopefully bring together a lot of experimentation facilities, in order to attract more experimenters and save costs (economies of scale).

Nearly all CREW partners with an individual testbed infrastructure show interest. Some of them, such as iMinds, are already part of the Fed4FIRE project; some have taken part in submitting proposals to the open calls, such as TCD.

The infrastructure of CREW partners taking part of Fed4FIRE is thus already or will be in the foreseeable future in line with the proposed standards related to authentication and standardization, resource description and discovery, (soft) reservation and provisioning, facility monitoring, experiment control and experiment measurement. Other partners already have some of the functionality (e.g. partial OMF6 and OML support) or are willing to commit some effort in migration towards some or all proposed functionalities and APIs (e.g. SFA, full OMF6 and OML support) in order to be (partially) compliant to the framework and tools offered. This way, the migration step towards such a federation in the end will be relatively small.

The main added value for them to commit this effort to become part of a larger federation would be broader visibility and promotion, access to additional users, potential of building new relationships, could serve as a reference and a stepping-stone for future research projects, more streamlines administration, increase usage of some of the specific individual testbed components, motivation for further development of the testbed access APIs and investment in infrastructure as a continuous process of improvement.

Some partners see this upgrade of functionalities as an upfront investment by themselves, however for some funding could/would be essential to make (some) functionalities compliant with the

recommended or mandatory standards. Within the current open calls, some funding is available to attract new testbed facilities with complimentary technologies and functionalities, which lowers the upfront investment cost becoming compliant.

5.4 Each partner follows its own individual course

Of course, besides all the proposed business scenarios presented in the previous section, each partner, with or without its own testbed infrastructure, has its own vision and research track planned. Some focus more on academics or education, others on SME and industry. Others want to position their facility in a unique way, or (want to) extend it towards new domains and technologies. This brings along different requirements and functionalities. This business scenario is of course valid for all partners. As most partners are always looking for new opportunities and funding, combining their own trajectory with some of the previous mentioned business scenarios is always possible.

5.5 General visions

Keeping projects such as CREW sustainable is very difficult. Each facility has its own competences and specific hardware and software infrastructure. The EC should protect this, and should discourage setting up new facilities with the same functionality as existing testbed infrastructures, or should at least push sufficient cooperation (through federation principles) between similar facilities in order to avoid duplication of developments. In view of capacity or diversity of wireless environments, the availability of more testbed infrastructures at different physical locations can be useful, but holds the risk of duplicate developments. New EC projects seeking experimentation resources should therefore be encouraged to use as much as possible existing facilities (e.g. CREW or the individual core partners) able to offer them the required infrastructure and experimentation tools, rather than setting up new facilities.

Some partners claim that, although they envision continuing to operate the testbed for the foreseeable future, they are a research center and the continued operation and expansion of the testbed depends on the continued availability of funded research projects. They hope that FIRE, within the framework of Horizon 2020, will play an important role in sustainable funding for testbed federations; this might enable them, for instance, to retain a full time person to provide support for testbed use by external researchers.

They hope CREW will not all end after the sustainability mode of the project. The results from the non-funded OC3 results were good. However we have to take into account that other projects are still offering funded open access opportunities for experimenters, underpinning the open access model currently applied, leading to few proposals. It would be good to keep the CREW federation running for publicity reasons. Finding funding in the long run will be crucial. Otherwise it will be very difficult for CREW to exist.

6 Exploitation plan

This section focuses on the concrete steps to be undertaken in Y5 and beyond. We split up between the more general plan for the federation, and the individual plans by the different project partners.

6.1 Exploitation plan for CREW in general

6.1.1 Open access

CREW, since 2014, is in a continuous open access phase, offering 2 modes for the use of the CREW facilities: *Best effort access & basic support* where CREW offers best effort access to the facilities free of charge for non-commercial use, including basic support; *Guaranteed access & advanced support* when more guarantees are required on the availability of infrastructure and more advanced technical support is needed. For the latter a simple proposal needs to be submitted. Both models are offered for free.

However we see that the second mechanism is not very popular, even as it is free of charge. Several experiments use the first mechanism (best effort, no proposal submission) but don't bother with the second mechanism (proposal submission). Experimenters should be motivated to submit an application. Therefore we should promote a *two-step approach*. Experimenters can start with best effort access, in order to get them acquainted with the different testbeds, the hardware, software and interfaces, and experimentation opportunities. In order to request extensions and advanced support for their experiment, they should submit an application.

Following steps will be undertaken in order to help to overcome this issue. First, a clear distinction must be made between the two mechanisms, indicating in detail the differences and benefits for both offers. Next iMinds will coordinate the collection of information about the new open access users. This way we could stimulate them to submit proposals, or ask them the reason why they are not proceeding with this step. Finally successes of open access experiments will be presented on the website motivating new OA experiments to proceed with the proposed two-step approach.

6.1.2 CREW brand

All partners have perceived the CREW brand scenario very well. Actions will be taken to keep this scenario operational.

- *Lead*: As iMinds was project lead, they will continue taking the lead.
- *Steerco*: all partners involved should participate in the monthly call.
- *Portal*: iMinds will keep the portal operational. All partners have committed to keep the information about their testbed infrastructure up to date. However this specific information and technical documentation will not be hosted any more on the portal, but will be moved to individual websites offered by the testbed facilities. A link to these sites will be provided on the portal. Basic information about CREW, its experimentation opportunities (e.g. open access rules) and its dissemination activities will be kept centrally on the portal.
- *CREW academy*: the different tutorials will still be presented on the website. The different partners consider a best effort strategy for new tutorials, thus depending on the effort required and dissemination opportunity.
- *Follow-up of open access proposals:* a monthly call will be organized to analyse and evaluate the received proposals.

In order to keep the CREW brand and the federation in a more structured way, and arrange all minimal intentions, we would opt for a lightweight Memorandum of Understanding (MoU). This would include the above-mentioned activities. The resources required for keeping these activities operational will be at low cost and thus minimal effort by the different project partners.

6.1.3 Path of evolution

Keeping the *CREW brand* alive is the first step to proceed after the project ends. However this business model is not sufficient and sustainable in the long run. It could be seen as a transition phase until another 'brand' takes over.

Next step should focus on looking for opportunities to define a *new CREW+ project* within the boundaries of the upcoming H2020 calls (next submission deadline is 2015, starting the project in January 2016) and project partner's visions. Topics that relate to this step could focus towards advanced SDN software defined networks (SDN) and 5G. This can be furthermore discussed during the steerco conf calls.

Alternatively to the previous proposed step is looking for migration towards *a high level federation* such as Fed4FIRE. Some CREW partners are already involved (e.g. iMinds); others have shown their interest in this model. Adaptions will be required to the different individual testbeds by implementing the different standards followed within the Fed4FIRE project. Some partners have already planned some of these functionality implementations within their roadmap, whereas others will need to be more convinced, or even funded to take this step. We should await the final business plan of Fed4FIRE (to be presented by the end of 2015) before more concrete steps could be undertaken. However different open calls have been launched towards facility providers with allocated funding to reduce this migration step.

Every partner however should develop their *individual strategy* next to all previous proposed business scenarios, in order to stay unique and propose a valid and functioning testbed facility.

The evolution path can be seen in Figure 3.

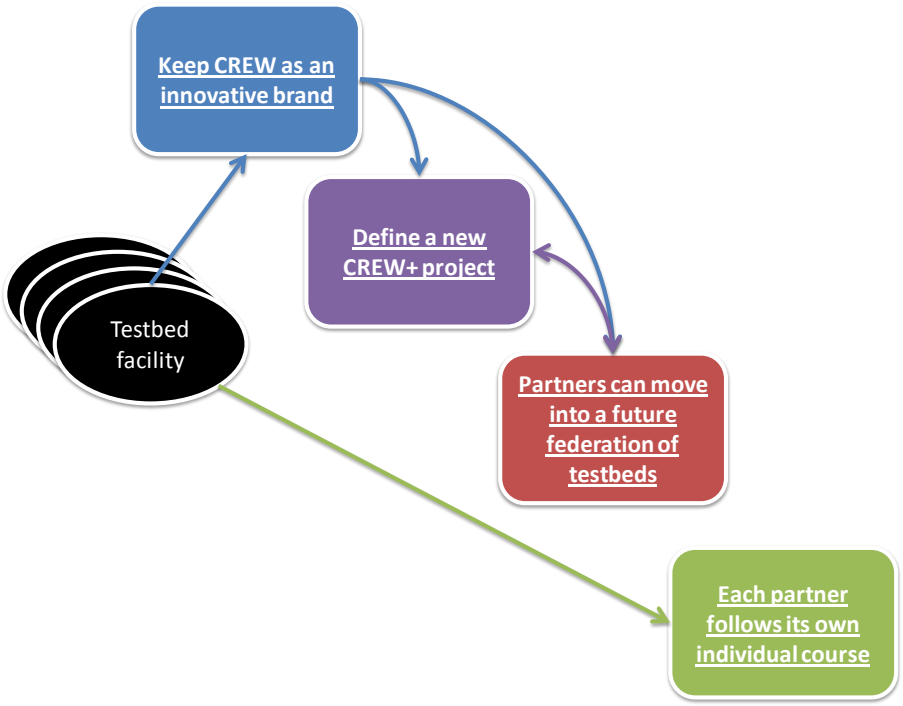

Figure 3: Evolution path of the different business models for CREW in the upcoming years

6.2 Exploitation plans of the individual project partners

In the DOW the different partners expressed their exploitation plans when the project ends. Over time, the proposed strategies of the partners have changed slightly. An update of these plans can be found below.

a. iMinds

iMinds plans to use its results obtained within the CREW project, for further enhancement of its knowledge and competence in the field of telecommunication networks, more specifically in the field of wireless networks and cognitive radio networking. The enhanced knowledge and competence obtained through the participation in the CREW project, will be exploited and used for participating in new projects and setting up partnerships in other projects, both in the academic and (national and European) industry world.

iMinds further will take the necessary actions for the sustainable operation of the common CREW portal (in support of the CREW brand) and the w.iLab.t part of the CREW federated platform. As iMinds is an academic research partner, knowledge related to cognitive radio and cognitive networking concepts will most likely not be directly commercialized. Such knowledge is mainly generated in parallel national or European research and used for validation and demonstration purposes of new experimentation tools and methodologies developed in the CREW project. iMinds is already exploiting and will further exploit its knowledge on tools and methodologies for experimentation beyond to CREW project by offering the tools and knowledge to external experimenters that are using or will be using the iMinds facilities for experimentation outside CREW. The conditions for use are described in this deliverable, D1.2 and D8.5. In the past year (year 4 of CREW) we have observed an increased use of the iMinds facilities, not only following the best effort model, but also the premium model. At the national level, iMinds has several recent collaborations (in particular in the manufacturing application domain) that use the iMinds facilities for developing innovative wireless communication strategies that are robust against interference and harsh wireless environments (obstacles, challenging propagation conditions, mobile wireless devices, etc.). One of iMinds' industrial partners has recently installed a clone of the iMinds testbed at their premises. This industrial partner is very enthusiastic about such a testbed, as they can now validate new firmware of their wireless solutions, before doing a firmware upgrade in the field. Thanks to the availability of the wireless test facility, they can speed up their development cycle. iMinds will further promote its facilities for best effort and premium, use not only at the national, but also at an European or international level.

The scientific results will also impact on the education, because the research related to wireless networks is performed at the Department of Information Technology – Broadband Communication Networks (INTEC - IBCN) of the Ghent University, where INTEC - IBCN is responsible for Bachelor and Master courses on telecommunication networks, where several practical sessions are organized using the iMinds wireless test facilities. iMinds further exploits the project results through the training of highly qualified engineers in PhD programs. Many PhD researchers are making use of the iMinds wireless test facilities and experimentation tools.

b. IMEC

Imec has been very successful in deploying this model of shared research. Imec's research bridges the gap between fundamental research at universities and technological development in industry.

Imec as a research institute valorises its R&D results to industry via 'Industrial Affiliation Programs', licensing, and occasionally the creation of spin-off companies. In the affiliation program, imec teams up with companies across the value chain of the electronic devices market, in which they get early access in new radio technologies and can use imec's know-how and prototypes to accelerate the development of their next-generation ICs. In the wireless domain industrial partners include main players in the wireless and silicon domain such as Samsung, Panasonic, Renesas, and Hisilicon (Huawei). Spin-offs launched in the wireless domain have focused a.o. on satellite communications, positioning systems (Septentrio), analog design and reconfigurable transceivers (M4S, acquired by Hisilicon). Imec is one of the few research institutes in the world, with proven experience on bringing together top-tier industry partners for cooperation into a shared research program.

c. TCD

Despite low numbers for new accounts, TCD's CREW testbed is used extensively for educational purposes and interactions with other FIRE projects. Such use, alongside future research programs are expected to support TCD's testbed for the foreseeable future.

The testbed has recently been involved in a demonstration of Internet of Things functionality at the Intel Makers fair. This activity has the potential to develop into the augmentation of the testbed with Intel Galileo boards for Internet of Things related research, extending the applicability of the facility to another research area.

Additionally, the TCD is investigating the potential to develop software control libraries for LTE, partly through use of the CREW testbed. This project aims to yield a software library (named LibLTE) to allow researchers to quickly develop LTE systems for testing alongside and integrated with Iris based SDR systems. The CREW project has provided TCD with the opportunity to pursue the development of this work with external researches, as discussed below.

The CREW testbed is also the foundation for TCD's involvement (and potential involvement) in other FIRE projects. TCD is a partner in the FORGE project, aimed at leveraging FIRE facilities for educational purposes, and much of the recent development under the CREW project has been done in close concert with this project. In this way, the CREW testbed has enabled TCD to enhance its educational capabilities. Additionally, the recent developments to the TCD's testbed support the potential direct involvement of TCD in the Fed4FIRE project for providing unified access to FIRE facilities. TCD has submitted a proposal to Fed4FIRE's second open call.

TCD plans to continue to develop the capabilities of its testbed in pursuit of future research projects and directions. Continuation of TCD's year 4 WP 6 project (discussed in the updated deliverable 6.3) is planned as a potential Open Access project involving a research team from Universidade Federal Fluminense (UFF) in Brazil. TCD also plans to pursue funding under Horizon 2020 based upon the capabilities and experiences gathered during CREW.

d. TUB

TUB, being an academic partner, will exploit the project results mainly by research and education. In the research plane, the development and the testbed environment developed within CREW will be and are used as basis for research in innovative protocols for the Internet of Things, Cognitive Radio and Intelligent Networks – all the directions in which TUB is strongly involved in strategic research areas. Specifically the deep knowledge of these areas and solid experimentation facility enables us to cooperate with industrial and academic partners. Within joint activities not only innovative solutions will be developed, but also the skills of usage of the CREW methodologies and testbeds are transferred.

TUB can provide a record of such transfers – e.g. the management of the TWIST testbed for sensor networks developed within the EC project EYES has been transferred directly to industrial partners, including Siemens Research Center. Actually TUB has a new strong competence of technology transfer in the framework of the EIT ICT Labs KIC (European Institute of Innovation & Technology, ICT, Knowledge Innovation Center). TUB is also coordinator of the EU EVARILOS projects that builds on top of CREW facilities, as an example the interference scenarios developed within CREW where used during the EVARILOS Open Challenge, a RF-based indoor localization competition. Finally the experience in CREW helped to achieve good score and wining new project proposal WiSHFUL.

The exploitation of CREW in education will go in different areas. Obviously PhD students participate in the CREW research – but we also involve students very early in the usage of CREW testbed in form of Bachelor and Master Thesis. The development of environments and testbeds is also made available for student projects, allowing them the early contact with these technologies.

TUB traditionally does not limit its laboratory settings to own students. TUB/TKN is running the Dual Degree Master Program with Warsaw University of Technology and is participating in the EIT ICT Labs Master School in Embedded Systems within the CREW technologies will be suited. In addition TUB regularly hosts interns form India, Spain and Italy who will also benefit directly from these skills and facilities.

e. TUD

In the CREW project the TU Dresden LTE testbed has been used for experiments in the context of sensing and dynamic spectrum access. These experiments covered (1) sensing of 4G/LTE signals with multiple antennas, (2) sensing of secondary users exploiting specific characteristics of future 5G waveforms, (3) dynamic spectrum access with 4G waveforms and (4) dynamic spectrum access with hybrid scenarios of 4G and future 5G waveforms. In the course of the project, the testbed has already extended: The originally used proprietary 4G/LTE test equipment has partially been replaced by more flexible, state-of-the-art software defined radio (SDR) platform. While this process has not been fully completed due to the associated high efforts, it is expected that the testbed will further evolve to a 5G testbed. Future work will focus on the development of new waveforms and modulation schemes that meet the requirements of future applications in cellular networks. In this context, for the successful deployment of 5G systems, the coexistence of 4G and 5G systems will be important. Cognitive radio concepts are candidates to achieve this coexistence and will be considered. As for external users of the testbed, it is expected that TU Dresden will closely collaborate with partners of the newly created Dresden 5G lab (http://www.5glab.de/).

f. TCS

TCS will benefit of the testbed federation in the scope of testing and validating new cognitive radio elements and sensing agents. The different entities integrating the testbed will enable new approaches of validation and novel sensing approaches applied to emerging standards will be explored.

The heterogeneous testbed environment with its different software and hardware components will bring an excellent real infrastructure against which the WInnF Transceiver API will be verified and that very likely will lead to API upgrades. TCS expects at the end of the project that the Transceiver API will reach maturation and technologies readiness levels enabling real product implementation. In parallel the standardization activities shall increase industry acceptance and usage of the interface.

g. EADS

EADS will assess the suitability of cognitive radio and sensor networks for future aeronautic systems, such as intra-aircraft or air-to-ground communication. EDAS as the central research department of the company will spread this knowledge and experience within the EADS to make it usable by its business units (Airbus, Eurocopter, Astrium, etc.). This will facilitate the aeronautic application of the methods and techniques developed in the scope of the project.

h. JSI

JSI as a research institute is involved in many different national and international projects through which it exploits and extends the LOG-a-TEC testbed as well as the newly acquired and/or enhanced knowledge, competences and experience in experimental research and in working with large scale federated experimental facility. On one hand these experiences are exploited for acquiring and running projects in the areas of spectrum sensing, cognitive radio and cooperative networking and on the other hand for extending and promoting the use of LOG-a-TEC testbed in the areas of wireless

networking, Internet of Things and smart grids. Through such increasing use of the testbed the projects contribute to its maintenance, operational upgrading and functional enhancing. In this process we are acquiring also new testbed users beyond the needs of particular running projects both from the academia and the commercial area, however such use at the moment does not contribute to sustainable operation but rather to the increased visibility of the testbed and its utilisation, and it serves as a reference for the JSI research group.

The LOG-a-TEC testbed is increasingly used also in the education process at the Jozef Stefan International Postgraduate School, so far mostly by selected students at their research work, but with some recently implemented and planned extensions that are making advanced functionalities more easily accessible, it will be used also to make lectures more interactive, providing another dimension to teaching activities.

In order to make the testbed available to wider audience JSI also strives to become directly involved in the Fed4FIRE project for providing unified access to FIRE facilities. Some extensions of the testbed proved interesting to the industry also for piloting devices with restricted capability and testing different procedures and solutions developed for them (e.g. reprogramming, remote monitoring and control, security). This already resulted in invitations to a few bilateral and multilateral projects, proving that the value of such facility as LOG-a-TEC testbed is being increasingly recognized, and it is hoped that over time it will attract also direct commercial users. In this respect we see the largest potential in supporting experiments in wireless networking of constrained devices. Given that this area is quite popular also with new start-ups we are considering some mechanism, perhaps in collaboration with technology parks and incubators, that would allow new start-ups to use such advanced facilities for prototyping, testing and validating their solutions.

Until any of above modes of testbed operation proves sustainable JSI also pursues funding under different areas of Horizon 2020.

6.3 IPR management

The management of knowledge and the handling of Intellectual Property Rights related to the CREW project has been and is handled and managed by the overall project coordinator, this in collaboration with the Project Steering Committee. At the early beginning of the project, a consortium agreement was installed in consensus by all project members. The IPR stipulations are detailed in this consortium agreement and are based on the regulations and policies depicted in the guidelines provided by the EC. The IPR department of all consortium members have been actively involved in this process, in order to safeguard future research and valorisation strategies of the different groups involved. The Consortium Agreement has been updated in the course of the project to include special IPR regulations for new partners that have joined the Consortium as a result from Open Call 1 and Open Call 2.

Every consortium member is responsible for the definition and stipulation of the "background" knowledge they bring into the consortium in view of the project execution. The general rule will be that all partners will bring in the knowledge and efforts that are needed to make a successful project, contributing to the general objectives of the EU research area. Therefore a good balance between knowledge ownership, knowledge use, knowledge sharing, and knowledge protection has been sought by the overall project consortium.

Knowledge created within the project, in view of testbed federation techniques, methodologies and strategies is openly distributed and communicated towards the EU research community. The overall project coordinator advices and overlooks any knowledge creation that can be openly distributed to the research community. She actively motivates and follows up this process.

Detailed information on IPR management in the CREW project has been defined in D1.2 (IPR Management Report) [13]. Most access rules (related to foreground, background and sideground) and policies for use, as defined in D1.2, are still valid. An update of this report will be presented soon.

7 Conclusion

Setting up a sustainability plan for the CREW facility is not an evident task and comprises various challenges. Sustainability means usage or usefulness of the infrastructure beyond the end of the project. The purpose of this sustainability deliverable was to describe the different potential business scenarios the can be implemented after the end of the project, and present a realistic exploitation plan with migration path for the upcoming year(s).

The large diversity between the different facilities in terms of technologies, size, complexity and strategy between existed, is also reflected in the sustainability issues related to openness, usage, access policies, and financial viability. Defining a one fits all strategy was not easy.

The most valued best practices perceived by the different partners thanks to the project, include: the integration and validation of hardware and software components in a broader testbed infrastructure; obtaining new research experience & facility improvements; experience, evaluate and implement different experimental methodologies; document the functionality of the testbeds and its CREW extensions. This is perfectly in line with the intention of the project. The main conclusions for the different individual facilities are: CREW has obtained a very good reputation leading to attracting new experimenters; good exposure and interactions with European researchers; better image & reputation are etc. All partners indicated in their individual exploitation plans that they benefited from taking part in this project.

We studied the testbed usage statistics and experiments conducted during the project. We have seen that the Open Calls within the CREW project have been very popular. Although the Open Access formula (with the lightweight proposal), which is currently running is not really a success, many new accounts have been created in different CREW testbeds since the start of the Open Access period (early Year 4), showing that there is still interest in the CREW facilities, even when no CREW funding is available for the external experimenter. We see that test facilities are not only useful for CREW, but also for other research activities in a broader wireless community. Integration of specific hardware and software within testbed islands is valued highly. Support is very important, and depends on the use of advanced features and complexity of the experiment.

A general exploitation plan for CREW has been worked out with potential migration steps. For the last year of the project the focus will be on proceeding with the Open Access strategy. The first step when the project ends is keeping the CREW brand alive. This was perceived very well by all partners, certainly as this is a low effort model and especially benefits from the well-perceived project. However this business model is not sufficient and sustainable in the long run. The next step should focus on looking for opportunities to define a new CREW+ project within the boundaries of the upcoming H2020 calls and project partner's visions. Discussions concerning defining a new project and the potential focus can start when the new H2020 call texts will become available. Alternatively, migration toward a more high level federation, such as Fed4FIRE, may prove promising. Some CREW partners are already involved in the project; others have shown their interest in this model. Every partner however should develop their individual strategy alongside all previously proposed business scenarios, in order to stay unique and maintain a valid and operational testbed facility.

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