Amplifying Future Internet Research and Experimentation for a Sustainable Future

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CONCLUSIONS AND RECOMMENDATIONS FOR FIRE'S FUTURE

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Author(s):	Hans Schaffers, Paul Grace, Stefan Bouckaert, Sathya Rao, Jan van Ooteghem, Annika Sällström, Martin Potts
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Executive Summary

This deliverable presents key elements of FIRE's strategy towards 2020 in the form of conclusions and recommendations. The work draws from ongoing discussions as well as earlier papers and deliverables, and discussions during events (co-)organised by AmpliFIRE. The conclusions and recommendations are currently being discussed within the FIRE community during the months February – March 2015.

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1. Introduction

This deliverable presents key elements of FIRE's strategy towards 2020 in the form of conclusions and recommendations. The work draws from ongoing discussions as well as earlier papers and deliverables, and discussions during events (co-)organised by AmpliFIRE. The conclusions and recommendations are currently being discussed within the FIRE community, including the FIRE Board, during the months January – March 2015. A final report will be made available by April 2015.

The conclusions and recommendations encompass three categories: 1. vision and positioning, 2. Strategic direction, and 3. action plans. The vision level is the highest level and reflects FIRE's longer term situation, the broad sense of direction, and its future positioning in terms of broad relationship to other actors and initiatives. The strategy level indicates the priority areas and thrusts of FIRE for the next years, aimed at realizing the vision and positioning. The main elements at this level are: impact creation; sustainability; servitization, users engagement, competences and other. The actions level captures the concrete activities, within these dimensions, that collectively realize the strategies and bring FIRE closer to the vision and positioning.

The deliverable is structured as follows. Chapter 2 provides a mapping of conclusions and recommendations, presenting their interrelations. Chapter 3 presents the summary list. In Chapter 4, the conclusions and recommendations are explained concisely. Recommendations for the next work programme 2016-2017 are described in section 5. As a summary, we propose the future development of FIRE in section 6. Finally, the Appendix in section 7 presents some longer elaborations.

AmpliFIRE's findings presented here have been communicated to the Commission Unit E4 as input for the current development of Workprogramme 2016-2017 as regards Future Internet research and experimentation priorities.

2. Mapping the Conclusions and Recommendations

This document describes what FIRE (and its stakeholders) should do; this is based upon an overall and consistent picture of conclusions and recommendations made by the AmpliFIRE project. As there are many interrelations among the various aspects and topics of FIRE, the next picture presents these in a visual manner. It is an unfolding layered structure where subsequent layers provide more detail, but relations between aspects can have different meanings. The following layers are proposed (Fig. 1):

I. **The Vision level** is the highest level and reflects FIRE's longer term situation, the broad sense of direction, and its future positioning in terms of relationships to other actors and initiatives.

II. **The Strategy level** indicates the priority areas and thrusts of FIRE for the next years, aimed at realizing the vision and positioning. The main elements at this level are: impact creation; sustainability; service orientation, user engagement, competences, etc.

III. **The Actions level** captures the concrete activities, within these dimensions, that collectively realize the strategies and bring FIRE closer to the vision and positioning.

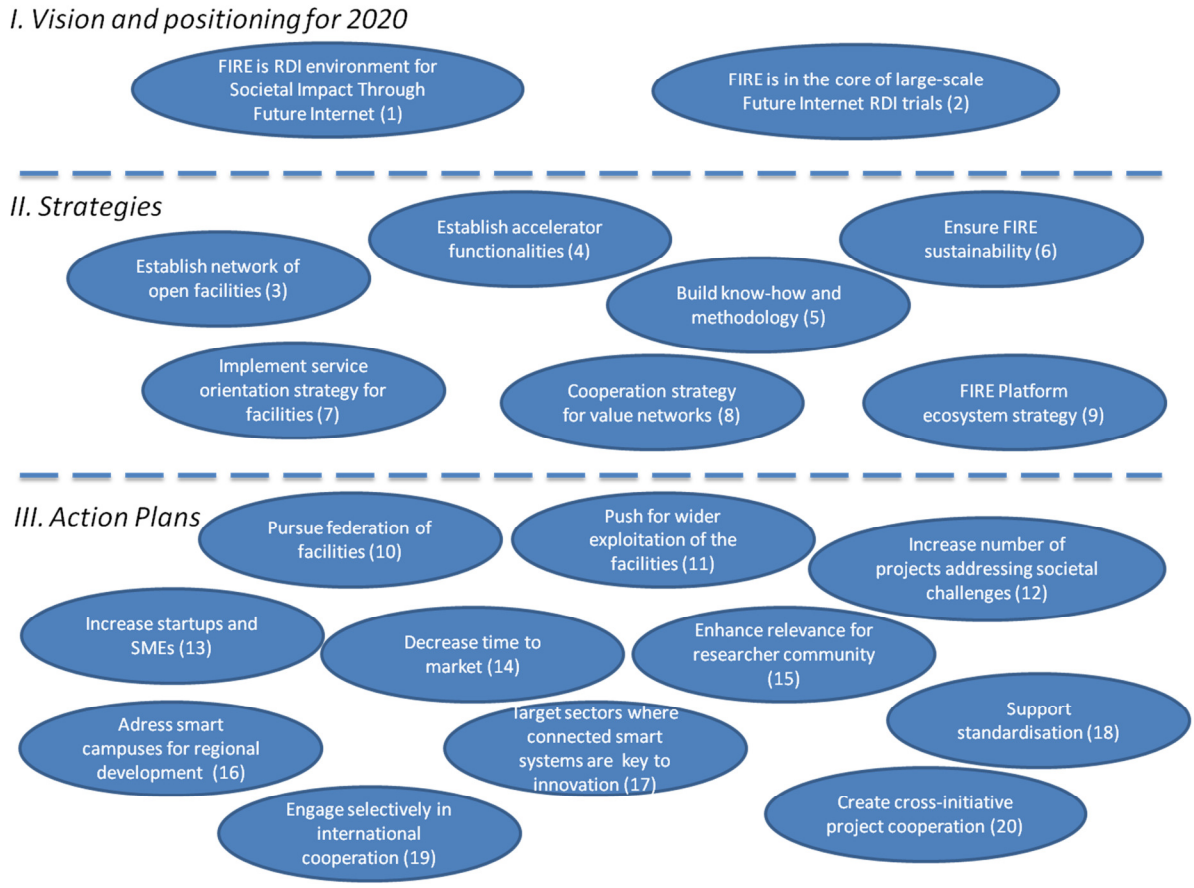

Fig. 1 Main conclusions presented in layers

This document is built upon previous AmpliFIRE deliverables and White Papers. The added value of this document is that it concentrates on formulating short and clear conclusions and recommendations. To create a self-standing document, short explanations are added. The Actions level is explained in more detail in AmpliFIRE's Roadmap document (D1.3).

3. Summary of Conclusions and Recommendations

I. FIRE VISION AND POSITIONING

1. FIRE's strategic vision for 2020 is to be the RDI environment for the Future Internet, creating business and societal impact and addressing societal challenges.
2. FIRE must position itself - and more generally the concept of experimental testbeds - at the core of the experimental large-scale trials of other Future Internet initiatives and thematic innovation domains of Horizon 2020.

II. STRATEGIC CHALLENGES FOR EVOLUTION OF FIRE

3. FIRE should help establish a network of open, shared experimental facilities and platforms in co-operation with other Future Internet initiatives.
4. FIRE establishes accelerator functionality, by itself or in co-operation with other Future Internet initiatives, to boost SME research and innovation and startup creation.
5. FIRE's core expertise and know-how should evolve: from offering facilities for testing networking technologies towards offering and co-developing the methodologies, tools and processes for research, experimentation and proof-of-concept testing of connected smart systems.
6. FIRE should ensure longer term sustainability building upon diversification, federation and professionalization.
7. FIRE should develop and implement a service provisioning approach aimed at customized fulfilment of a diverse range of user needs. FIRE should establish clear channels enabling interaction among providers, users and service exploitation by collaboration partners.
8. FIRE should become part of a broad Future Internet value network, by pursuing co-operation strategies at multiple levels.
9. FIRE should evolve towards an open access platform ecosystem.

III. ACTION PLANS TO REALIZE THE STRATEGIC DIRECTIONS

10. Federation of testbeds should be strongly pursued, as it is a key requirement now and in the future.
11. FIRE should strengthen the activities aimed at wider exploitation of its testbed resources by increasing the scope and number of experiments and experimenters using FIRE facilities.
12. FIRE should increase the number of projects and experiments that lead to resolving societal challenges.
13. FIRE should initiate actions to leverage its resources to startups and SMEs.
14. FIRE should initiate activities aimed at decreasing the time to market for experimenters.
15. FIRE should maintain and strengthen its relevance for the researcher community.
16. The potential capability of FIRE facilities and resources for regional development, to support technology development and product and service innovation, should be exploited.

17. FIRE should expand its range of facilities to also address research and innovations in sectors where “networked, smart systems” are crucial for innovation.
18. FIRE facilities are to be exploited for standardisation activities (proof-of-concept).
19. FIRE should selectively engage in international co-operation, based on reciprocal and result oriented actions.
20. Create co-operation across Future Internet related initiatives and stimulate alignment of EC units.
21. FIRE should establish a professional community to lead its development toward 2020.

4. Conclusions and Recommendations Explained

4.1 Vision and Positioning for 2020

1) FIRE's strategic vision for 2020 is to be the RDI environment and accelerator for the Future Internet, creating business and societal impact and helping to resolve societal challenges.

FIRE must shift its scope and focus from primarily researching and experimenting with networking technologies towards being a RDI environment for the facilitation of research, experimentation and innovation on connected smart systems in the Future Internet. This without losing, but adding to, FIRE's traditional core expertise in networking technologies. Research on networking technologies is a key domain within the new 5G-PPP, hence FIRE has the opportunity to move upwards towards the connected smart systems enabled by advanced networking technologies.

This changing scope and focus is complemented with a changing role of FIRE itself. FIRE should transform from a portfolio of projects to a longer term "programme" bringing more sustainability and coordinated development of testbed facilities, eventually becoming an innovation ecosystem and platform for Future Internet research, experimentation and innovation. This way FIRE acts as an "accelerator" of technologies for connected smart systems boosting start-ups and advanced SMEs. For this, FIRE's ecosystem must be grounded in an open and sustainable actor network bringing together researchers, developers, industry users, advanced SMEs and European Commission units. FIRE's ecosystem and platform strategy requires opening up its facilities, services and tools for other initiatives, developers and innovators. Current experiences made with Open Access and Open Calls are a first step.

2) FIRE must position itself and more generally the concept of experimental testbeds at the core of the experimental large-scale trials of a) other Future Internet initiatives and b) selected thematic innovation domains of Horizon 2020.

FIRE should realize new and wider opportunities for exploiting its testbeds and know-how resources. Opportunities exist in current Future Internet initiatives, but also in thematic domains addressing industrial leadership and societal challenges. Relevant initiatives suitable for further (co-)developing and using testbed facilities include FI-PPP, 5G-PPP, EIT ICT Labs and e-Infrastructures. This also includes the recently started Big Data PPP initiative. Areas where FIRE facilities and services promise a high contribution potential on the short term include Internet of Things, cloud-based systems and Big Data, as areas that drive innovations in a range of application domains. Based on core competence in testbeds and experiments for advanced networking topics (SDN) FIRE should bridge towards services and applications.

Wider exploitation and further development of FIRE resources has started with the FI-PPP (several FIRE facilities are part of the FIWARE nodes) and Smart Cities (a number of Smart City projects are part of FIRE) and should be selectively strengthened both downstream and upstream with the 5G-PPP (networks), with e-Infrastructures, and with important thematic innovation domains representing societal challenges.

4.2 Strategic objectives to be pursued by FIRE

3) FIRE should establish a network of open, shared experimental facilities and platforms in co-operation with other Future Internet initiatives.

Experimental facilities should become easily accessible for any party or initiative developing innovative technologies, products and services based on Future Internet technologies, including SMEs and startups and European, national and regional research and innovation initiatives. FIRE should work with other initiatives in the Future Internet to establish such easy and open access.

For this to happen, several actions should be implemented:

- Federation of facilities to facilitate the sharing of tools and methods, provide single access points and support cross domain experiments.
- Facilities should employ recognized global standards
- At the level of facilities, implement Open Access structures as a fundamental requirement of any FIRE facility.
- Formal arrangements with exploitation partners and initiatives including on programme level should be established.

To extend open facilities beyond FIRE, concrete co-operation opportunities should be identified, building upon a clear value proposition with other programs and initiatives. In particular 5G-PPP (networking technologies), Géant/NRENs (e-Infrastructures), EIT ICT Labs (education, business innovation), FI-PPP, initiatives in Internet of Things and Smart Cities, and regional innovation clusters building on smart campuses[1]. Conditions hindering such co-operation opportunities, such as the need for continuous upgrading of facilities, the alignment with demands of co-operating initiatives, the sustainability of facilities, resolving differences in technical characteristics, capacity to offer services to external actors under specific conditions (SLA, confidentiality, security, ease of access and use), should be established in next phase projects within the 2016-2017 timeframe.

4) FIRE establishes Future Internet accelerator functionality boosting SME's research and innovation and start-up creation.

The long-term goal of FIRE is to realize a sustainable, connected network of Internet experimentation facilities providing easy access for experimenters and innovators across Europe, and offering advanced experimentation and proof-of-concept testing services. This way FIRE could act as a technology and service oriented "accelerator" of research and innovation. Several actions should be deployed to realize this goal:

- The number of startups and SMEs leveraging FIRE can be increased by providing a professional highly supported facility and service offering (such as EaaS, shortening learning time and decreasing time to market for experimentation) and by providing direct incubation support.
- Projects can be prioritized that consider wider engagement with industrial activity, for example through tailored open calls and open access, point of contact, and professional service delivery.

[1] Opportunities for collaboration with initiatives regarding regional innovation strategies for smart specialisation (RIS3) could be explored here.

- A FIRE Broker initiative can be implemented providing broker services across the FIRE portfolio or via exploitation partnerships.
- FIRE can be made accessible to wider communities by offering community APIs.

5) FIRE's core expertise and know-how should evolve: from offering facilities for testing networking technologies towards offering and co-developing the methodologies, tools and processes for research and experimentation on connected smart systems and infrastructures.

Future Internet research and innovation requires testbed facilities, methodologies, processes and tools that are suitable to the studied objects and contexts. These should take into account the complexity characteristics of large-scale, smart connected systems, and should address the full scope from technological components to complex socio-technical systems, and should cover the stages of research, experimentation and innovation. Several actions should be considered to reach this goal:

- Experiments and innovations increasingly take place in real-life environments (human behavior, connected objects, cities, buildings, wireless environments), hence FIRE experiment methodologies should leverage living labs oriented methodologies.
- FIRE should also establish a knowledge community, for example by setting up a range of smaller projects aimed at knowledge and methodology development (similar to activities within Géant; possibly FIRE could work together with Géant in this respect).
- FIRE must promote common tools and methodologies to perform experiments. Essentially, FIRE must provide Experiment-as-a-Service i.e. an experimenter can utilise FIRE facilities from a single point using the same technologies without having to learn all the heterogeneous technologies. The added value of such a service is the reduced time to experiment deployment, which in turn will lower barriers to both the research and industrial experimenters and help grow the user base.

6) FIRE should ensure longer term sustainability building upon diversification, federation and professionalization.

Given the trends, i.e. Internet of Services, Things and People, FIRE should continue to broaden its range in meeting experimental needs. It should also better support the transition from research and experimentation to innovation and adoption. FIRE should evolve from the single area oriented Future Internet research and experiment facilities towards **cross-technology, cross-area facilities** which can support the combined effects and benefits of novel infrastructure technologies used together with emerging new service platforms (clouds, IMS, content distribution) enabling new applications in media, health, manufacturing, smart cities and other domains.

For this to be realized several conditions must be established and further pursued:

- A broad set of facilities that capture the complexity of the Future Internet and meet the often interdisciplinary needs of experimental users.
- Continue standards driven federation to ensure research is not constrained to so-called experimental silos.
- Align with global facilities within the Future Internet research landscape, e.g. XIFI and GENI. Ensure that transitions between one another is either seamless or simple.

- Facilities and federations within FIRE should seek to be self-sustaining (as far as possible), implementing new financial models that encourage projects to be successful rather than support own experiments.
- Increased professionalization of FIRE's internal organization, contracting, services marketing.

7) FIRE should develop and implement a service provisioning approach aimed at customized fulfilment of a diverse range of user needs. FIRE should establish clear channels enabling interaction among providers and users.

FIRE's offer should transform towards a service-oriented framework where the concept of **Experimentation as a Service** is central. The concept of "servitization[2]" should have greater prominence in FIRE facilities. Facilities should make a transition towards professional service provision to its customers. For this to happen, technical, organizational and cultural bottlenecks need to be addressed, and facilities' traditional operational and business models need to adapt. A transition should be made from facilities which are used primarily by researchers, lacking a clear service interface, towards offering customized services in making the facilities easily accessible and usable for product and service innovation by different actors such as other Future Internet initiatives, industry parties, and advanced SMEs.

To realize this goal of sustained services, the following actions should be considered further:

- In targeting a wide range of customers, FIRE should offer a portfolio of services, instead of technologies and tools (these can continue to be delivered to researchers). Channels should be established through which services can be provided and consumed.
- FIRE should manage the delivery of services effectively. This requires that FIRE meets future experimenter demands and be demand-driven—federating diverse facilities for this purpose.

8) FIRE is to become an essential part of a broad Future Internet value network, by pursuing co-operation strategies at multiple levels.

FIRE is part of a network of value creation for the Future Internet encompassing different initiatives and actors. It should establish linkages and concrete co-operation with other actors and initiatives in order to realize its ambitions. Co-operation strategies must cover different levels: federating and sharing of testbed facilities, Access and interconnection of infrastructures, joint provision of service offerings, partnering with actors in specific sectoral domains. FIRE should target both strong ties and loose ties collaboration. By strong ties we refer to relationships that are and have developed throughout many years, while loose ties collaboration is represented by more dynamic relationships. Both are of equal importance. By close collaboration between different actors within the FIRE value-network we can capitalize on what exists and foster FIRE to become more dynamic and user-driven to attract and serve a wider base of partners.

To begin to realize this strategic goal:

[2] The term "servitization" denotes the increasing attention to the service component attached to products. Instead of selling "products" the trend is towards selling "product-services" and adding more and more services to products. Within FIRE this corresponds with the ongoing development towards experimentation related services offering.

- FIRE should co-operate with other initiatives within the landscape of Future Internet research, innovation and experimentation: 5G, FI-PPP, Internet of Things, Smart Cities. For this, FIRE must show a clear position on its offerings and uniqueness.
- A key co-operation is with the future 5G-PPP. For example, FIRE experimental facilities could potentially be of use for the 5G PPP initiative (cellular networks, WiFi and sensor based networks, cognitive radio networks, but also SDN and cloud facilities). For such co-operation to happen, mutual benefits should be identified and FIRE should address the conditions that need to be in place in order to engage in co-operation, such as organisational and financial sustainability, and the ability to modernize its testbed facilities over a longer time period.

9) FIRE should evolve towards an open access platform ecosystem.

Ecosystem strategy, including how to attract and establish sustainable relations with SMEs and developers, will become a more and more important aspect of FIRE strategy and future business model. Unlike a value chain or supply chain, a platform-based activity brings together and enables direct interactions within a value network of customers, suppliers, developers and other actors. The portfolio of FIRE facilities and services are constituting a platform ecosystem facilitating multi-sided interactions. Developer communities may use the FIRE facilities to directly work with business customers on technology and product development, whereas the current FIRE service model focuses on giving researchers and experimenters access to FIRE facilities. It implies creating mutually beneficial relations over a longer time horizon: creating a platform ecosystem around the FIRE activities.

First steps towards forming a platform ecosystem are to:

- Encourage federation, set up open access and open call structures, and stimulate developer activities.
- Promote developer activities to: address enhancements in brokerage platforms (facility offers – user demands), build tools to support SMEs interacting with facility providers and other.
- Establish additional roles for facility exploitation by new actors with clear responsibilities and expertise as facility 24/7 operators and include them in the sustainability models (this might not be the similar actors as those in the initial testbed development initiatives).
- Setting up a knowledge community in experimentation (as in Géant) could also attract both researchers, developers and users.

4.3 Action Plans

10) The ongoing development towards federation of testbeds should be supported. Federation is a key requirement for experimenters, now and in the future.

In the prior strategy it is clear that FIRE needs to better sustain relevant resources, and better support cross domain experimentation via a common European platform. Fed4FIRE is a first step in this direction; however, consideration must be taken into account as to how such activities can be carried on.

If a central cross facility experimentation federation is to continue, the following solutions can be considered:

- Sustain federation activity: fund a support action to continue the operation of Fed4FIRE, i.e. the management of the federation operation (e.g. tool maintenance and portal

services), the support of new experiments and experimenters (open call management), and day-to-day upkeep.

- Require integration of new facilities under the Fed4FIRE umbrella. Project budget to reflect man power required for integration.
- Arrange central open calls for cross FIRE experiments. Increase the funding for cross FIRE experiments (i.e. those that utilise multiple testbeds).
- Arrange funding for facility providers to support experimenters via Open Access.
- Ensure transparency of multiple testbeds for experimenters in accessing a service.
- Arrange for a proportion of a facility budget for open calls to be made available for the central collaborative experiments. A CSA can manage the awarding of cross project funding.
- Fund relevant new testbeds. Allocate proportion of open call budget for collaboration and integration of new facilities.

Hence we recommend a Support Action to continue the operation and management of a central FIRE federation, and also manage a central budget for cross domain experimentation. This should be funded after the conclusion of Fed4FIRE, i.e. in 2016.

11) FIRE should strengthen the activities aimed at wider exploitation of its facilities. It should increase the scope and number of experiments and experimenters using FIRE facilities.

A broker service can dramatically decrease the effort for performing experimentation and attracting new users to FIRE. A new experimenter contacts the broker service to discuss what is and isn't possible, the broker provides advice as to how FIRE resources can be leveraged to perform the experiment. While not necessarily important for the traditional FIRE community, SMEs and users with little knowledge about FIRE will be better supported. "One of the key challenges for collaboration with industry and SMEs is that there must be a set of communication tools and mechanisms that can adapt the "language" and the "message" to audiences often consisting of quite diverse groups (industry vs research)."

- Implement a small action (potentially as part of a wider FIRE support action) to provide broker services across the FIRE portfolio, including partners with significant expertise and interest in testbed exploitation.
- Prioritise projects with a strong set of external stakeholders beyond computer science researchers, stimulating multidisciplinarity in experimentation.
- Prioritise facility projects that underpin experiments with the latest (and most demanded) technologies.
- Require that a facility project funded within the FIRE+ programme operates an open access for a minimum period of time. For a new facility after 2 years; for an ongoing facility after 1 year (until the end of the project). Make it possible for facility providers to apply for grants for service operation.
- Focus on Interoperability solutions between FIRE and GENI (and potentially CENI) resources. Fund integration activities; this is provided through Fed4FIRE's budget at the moment and funding should be considered when this is no longer available.
- Implement interoperability solutions between FIRE and FI-PPP (and potentially 5G-PPP) resources; consider a small action to investigate the issue in greater depth (rather than the ad-hoc approach currently employed).

12) Increase the number of projects and experiments that lead to resolving societal challenges.

FIRE should increase community involvement as opposed to i) singular experimenters, and ii) academic and industry participants including customers of Future Internet solutions. It is needed to bring end-users into the FIRE community such that they can also innovate for the social good. Promote open source community building methods such as hackathons and open source code.

- Promote FIRE as an important R&D&I facility in the quest to solve tomorrow's grand challenges.
- Increase collaboration globally and within Europe.
- Promote FIRE as a collaboration environment to support high-quality cross-disciplinary societal research and innovation actions.
- Increasing FIRE's societal impact also implies that testbeds in the domain of software and services are prioritised. Facilities should be prioritised that balance the Future Internet resource offering, i.e. software and services resources that match the current experimenter demands.

13) Increase the number of start-ups and SMEs leveraging FIRE

One of the examples where FIRE facilities are already used in collaboration with SMEs and industry is iMinds iLab.t. The iLab.t facilities are used in many FIRE projects and as such have been used by industry and SMEs as part of open calls. Interestingly, the iLab.t facilities are also used by industry and SMEs outside funded research programs: SMEs and industry are collaborating with iMinds iLab.t on a bilateral basis, and are prepared to pay for the use of the facilities and especially for the technical/scientific support layer that is added on top (see also http://ilabt.iminds.be/offer). From this example it can be seen that FIRE facilities can certainly be of use to SMEs and industry.

The key to making this combination work is to add a "service" layer on top of the testbed: guide interested "experimenters" from industry and SMEs from A to Z during a particular project: assist in defining the added value of experimentation/testing for their product or service, help to install and set-up an initial experiment, potentially also run experiments for the customer and report on the outcome. Providing such support to industry and SMEs is not trivial, and testbeds interested in offering such support may expect a significant impact on their day to day operations compared to when only offering or using testbeds as part of "traditional" research projects. Hence, FIRE should consider the following actions:

- Provide a professional, highly supported facility to attract commercial partners. Fund activities in terms of improving the service offering. It should follow industry standards and SLA models for service management. The learning time and start-up time for using facilities should be drastically reduced. Also, open access to trial FIRE should be provided, i.e. to discover if it is fit for purpose.
- Prioritise projects that consider wider engagement with industrial activity. Not as project partners, but through direct and hassle free engagement mechanisms: tailored open calls and open access, point of contact, professional service delivery.
- Directly (or indirectly via partners) support incubation of SMEs and start-ups e.g. using initial funding via refundable loans. Select startups that could potentially access finance, coaching, investment forums, partners, etc. through a 3-6 months programme. It should more probably be a virtual accelerator, relying on specific partners in Europe, such as existing accelerators, incubators, etc. offering similar support. This FIRE accelerator

being an additional layer but addressing specifically the use of FIRE facilities and development throughout FIRE partners.

14) FIRE should initiate activities aimed at decreasing the time to market for experimenters.

The positioning of FIRE as the RDI environment of Future Internet technologies and services requires the capability to efficiently and effectively run cycles of invention, testing, scaling up to trials, and go to market.

- To accomplish this goal, FIRE should build a strategic and technological relationship with PPP initiatives to ensure that rapid transfer from idea to initial validation to trialing can occur with minimal cost to commercial participants.
- FIRE should foster "spinouts" including use-cases and technologies from FIRE experiments, and should provide continued support of start-ups e.g. further free use of facilities.

15) FIRE should maintain and strengthen its relevance for the researcher community.

It should increase the number of high-level research publications for experiments that have employed FIRE facilities. High quality computer science publication venues require rigorous and repeatable hypothesis evaluation typically involving real-world experiments.

- FIRE should be promoted as a facility to provide a recognized platform for such evaluation.
- Fund activities for developing FIRE tools with preference given to services supporting reproducibility. This can either be as a funded project in the Work Programme or through centrally managed open calls.

16) The potential capability of FIRE facilities and resources to support technology development and product and service innovation for regional development should be exploited.

FIRE should be positioned as a backbone infrastructure of experimental facilities supporting urban and regional development. For example in supporting product and service innovation activities in regions or smart campuses, and through providing accelerator and incubator support. This interest in "innovation clusters" is shared with e-Infrastructure activities. FIRE and e-Infrastructure activities could work together on this priority.

17) FIRE should expand the range of facilities to also address research and innovations towards sectors where "networked, smart systems" are crucial for innovation.

Such sectors include, for example, advanced manufacturing, smart homes and buildings, and water and energy management including vendors and service providers. FIRE testbeds for testing critical infrastructure (e.g. monitoring systems) are also needed.

18) FIRE facilities are to be exploited for standardisation activities.

Standardisation is the cornerstone of the FIRE federation and open access strategies, and hence there is a need to ensure that standardisation activities are executed in a coordinated

manner and in a timely fashion across FIRE. Additional standards-based stakeholders, e.g. ETSI and ITU may benefit from experimental facilities that can be offered by FIRE.

Although some activities have been launched there is opportunity for stronger collaboration with standardization organisations:

- FIRE to participate in global activities concerning testbed APIs, standard EaaS frameworks, etc.
- FIRE to promote standards, and to ensure new FIRE testbeds (funded by FIRE+ programme) and external testbeds (those joining a FIRE federation).
- FIRE testbeds to offer "proof-of-concept" services for validating standards.
- Funded support actions are needed to prioritize the coordination of standards implementation across both the FIRE federation and the facility projects.

19) International co-operation is essential for FIRE, however the current bilateral international co-operation should be more reciprocal and result oriented.

Work done by other EU bodies e.g. trade agreements with other countries outside EU could be used as stepping stone to enhance cooperation between FIRE and related initiatives in these countries. FIRE should also strengthen its international presence and cooperation by aligning with other European initiatives such as 5G-PPP and technology platforms such as NetWorld2020 and NESSI.

20) Create co-operation across Future Internet related initiatives and align EC units.

Based on FIRE's know-how in design, set up and management of experimental testbed facilities and in provision of testbed services for various contexts, FIRE should identify concrete co-operation opportunities building upon a clear value proposition with other programs and initiatives. The following table identifies the key co-operation actions.

Initiative	Potential for co-operation
eInfrastructures (Géant, NRENs)	Géant/NRENs offer high-bandwidth connectivity for interconnection of testbeds. FIRE facilities are users of Géant building blocks. FIRE adds services such as testbed access. FIRE may leverage Géant facilities and improve Géant services.
EIT ICT Labs	FIRE may benefit from ICT Labs activities in education, business outreach and entrepreneurship support. EIT ICT Labs can be an exploiter of FIRE facilities and experimentation services. Collaboration between FIRE and EIT ICT Labs is explored in CI-FIRE.
FI-PPP	FI-PPP offering may include FIRE experimentation facilities, services and experiments; these should meet FI-PPP demands such as migration and interoperability.
5G-PPP	FIRE facilities could potentially be of use for 5G-PPP but this needs further exploration. Fed4FIRE, CREW and OFELIA could offer relevant testing environments.
Smart Cities, Internet of Things	FIRE includes several projects in the IoT domain that are highly relevant for Smart Cities and communities. SmartSantander and the recently started Organicity are key examples of FIRE opportunities.

To achieve such global co-operation, and address the potential bottlenecks, the following actions can be considered:

- FIRE must collaborate with initiatives (via necessary Support Actions) to align technical differences; offer services to external actors under specific conditions (SLA, confidentiality, security, ease of access and use), and sustainability should be established in next phase projects within the 2016-2017 timeframe. This might also include to be part of a multi-lateral initiative ("Future Internet Alliance") to coordinate efforts among programmes and organisations and to address joint challenges faced by the broader segment.
- FIRE can be seen as overlapping with other initiatives and even competing - and with similar targets – with other testbed service providers. FIRE must strengthen its position to be a forerunner as a developer and supplier of large scale interconnected novel cutting edge testbed facilities for both future networking technologies R&D and the service innovation economy.
- To expand FIRE beyond the existing largely scientific experimenter community, FIRE should seek in a more structured way to tap into established business partnerships to exploit future opportunities. The ETP´s are such examples (NESSI, NetWorld, NEM, etc). The testbed users should actively be encouraged to involve potential customers of their solutions as partners when using the testbeds.
- Exploit the open call mechanism to be more focused on developing and validating the testbed usefulness rather than an instrument to attract testbed users. Use them also to invite partners for testbed exploitation as well as engaging partners providing complementary facilities and services. In this way, FIRE would better prepare the facilities for market release and usage on a wider scale. This would also include to elaborate on sustainable business models.
- And finally, to foster long-term collaboration the sustainability of FIRE is a crucial aspect to convince collaboration actors to invest in the relationship. FIRE must be able to show clearly how longer term collaboration can be supported that goes beyond individual project timescales.

21) FIRE should establish a professional Board and Community to lead its development toward 2020.

The FIRE community should be professionally organised around a FIRE Board, Working Groups, and regular community meetings continuing the FIRE Forum and opening up to related Future Internet initiatives.

- The FIRE Board governance should be professional with 2-year elected key roles such as FIRE Board Chair, and include Working Groups for Technical Vision, Dissemination and Knowledge. The key roles should form the Board Management Committee (BMC). The FIRE Board key roles are to be fulfilled by FIRE Facility project representatives. The BMC prepares the FIRE Board meetings.
- The FIRE Board's Charter should clearly identify and define permanent members, invited guests. Permanent members: representatives from CSAs; IPs, STREPs (FP7); RIAs and IAs (H2020). All projects should be represented, but voting rights could be weighted. Invited guests: EC, representatives from related initiatives (Géant, FI-PPP, 5G-PPP, Smart Cities, Living Labs, …) and specific experts.

- For the future, the FIRE Board should establish a legal entity (FIRE Office) comparable with the ENoLL Office.
- CSAs should assume a supporting role for the FIRE Board and FIRE Community, including a role in Vision development, INCO, dissemination and other. The role of CSAs to support the FIRE community should be part of the (2016-2017) Work Programme text.

5. Recommendations next Work Programme 2016 - 2017

The above actions should be reflected in the Work Programme 2016-2017. AmpliFIRE recommends several immediate priorities to consider and implement during 2016-2017:

1) Support action to sustain a FIRE federation

With Fed4FIRE approaching its conclusion, the future of this cross-domain facility must be considered. The federation path should be continued with emphasis on targeted integration: integration of new and existing projects (networking, computation and data resources cf. SDN technologies) into a FIRE federation. Importantly, a collaboration budget should be reserved within new projects to carry out the federation integration.

We recommend that a support action is proposed to operate FIRE experiments on the federation (based upon the information gathered from the sustainability year of the Fed4FIRE project. Such a support action would manage day-to-day operation; manage a pot of money for experiments and new federation resources accessible via open calls; and support open-access users.

2) Balance the Future Internet pillars towards converged federation

Testbeds in the domain of software and services should be prioritized. The Work Programme should consider prioritising service-based resources, such as IoT facilities and Big Data resources, especially those integrated with cutting edge networking facilities e.g. SDN and 5G networks. Facilities must also place greater emphasis on the persistent storage of experimental results and Knowledge-as-a-Service (KaaS) captured from previous experiments.

Additionally, cutting edge facilities should be funded in several areas to meet gaps in the FIRE offering e.g.:

- 5G relevant testbeds to support experimentation with new 5G air interfaces and hardware. Additionally testbeds to support experimentation with resource optimisation e.g. wireless communication optimisation and spectrum sharing.
- A large-scale IoT federation supporting highly heterogeneous Things that are openly accessible and geographically dispersed.
- Testbeds to support Big Data experimentation, particularly for new data processing technologies, and the provision of novel resources such as large open data sets.

3) Increased alignment with relevant initiatives

Put instruments in place to investigate and deliver strategic, technical and operational alignment with initiatives such as the FI-PPP and 5G-PPP.

Several other priorities for WP2016-2017 can be found in the D1.3 “FIRE Ecosystem Progress Report”.

6. How FIRE should transform over the next years

Based on conclusions and recommendations presented above, the next table summarizes the envisaged future evolution of FIRE towards 2020.

	FIRE current 2014	**FIRE in the future 2020**
Vision and positioning	FIRE as collection of testbed facilities for academic researchers	FIRE experiment resources available and accessible as services to a wide range of users including SMEs, industry, other initiatives such as 5G, FI-PPP, EIT ICT Labs
Core activity	Research and Experimentation on networking technologies	Research, experimentation and innovation for smart connected systems
Expertise and know-how	Experiment lifecycle management. Experimentally driven research.	Experimentation-as-a-Service Experiment life cycle management Experimentation-based innovation services to business
Co-operation	Mostly with Géant/NRENs (bandwidth) and academic research community. Evolving towards FI-PPP, 5G, EIT ICT Labs, Smart Cities	Cooperation models agreed with major initiatives and organisations Based on easy access to, combination of, and composition of services from FIRE and other "suppliers"
Federation	Reliance on the Fed4FIRE project to manage all aspects of federation, including international co-operation	Centrally managed by a support action, for the FIRE initiative as a whole. New projects commit resources to federate
Services	FIRE offering at the level of access to testbed projects	Servitization of the FIRE offer. FIRE resources and services anywhere anytime
International	Bilateral project-based cooperation mainly with US (FIRE-GENI), Japan, Brazil, China (FIRE-CENI)	Mutually advantageous cooperation based on common projects with selected international initiatives.

7. Appendix – Background Materials

7.1 FIRE strategic vision: RDI environment for the Future Internet

FIRE's ambition for 2020 is to be the "RDI environment for the Future Internet". The FIRE initiative assumes a key role in providing open facilities, services and methodologies for research, experimenting and innovating Internet-enabled "connected smart systems".

Explanation: The Internet includes, but is more than, networking technologies. FIRE has been predominantly technology-driven, is increasingly being shaped by demand pull. This demand pull is represented by four main pervasive trends: Internet of Things, Internet of Services, Internet of Information and Internet of People. Following these trends, FIRE should shift its focus from primarily experimenting and researching on networking technologies (as research on networking technologies is the key domain of the new 5G-PPP) towards gaining a key role in facilitating experimentation and innovation on "connected smart systems".

	Current status FIRE in 2014	FIRE Vision for 2015 – 2020
Access to testbed facilities	Federation towards widely reusable and accessible facilities Open Access	Facilities on the background, services to customers and users on the foreground
Facilities' testing and experimentation focus	Networking technologies; increasing attention to IoT, Cloud computing	Networking Technologies Smart networked systems (such as IoT or using Big Data)
FIRE services	Experiment life cycle support Open Access	Experimentation as a Service; Experimentation support anytime anywhere "Servitization" of the value offer
Support role for other initiatives in Future Internet	Some FIRE testbeds are used for FI-PPP. Exploration of potential role for 5G.	Servitized facility and tool provider for 5G-PPP and other initiatives.
Application domains	Increasing interest for real-life domains (Cities, Underwater, Autonomous Vehicles)	Smart systems sectors in general High-tech industry, manufacturing Smart regions and districts, innovation clusters
Collaborations	FI-PPP 5G (emerging) NRENs (connectivity)	FI-PPP 5G (facility access and service provider) NRENs (services, facilities, connectivity) EIT ICT Labs (research, education, business) EU programmes in smart systems (services, facilities)
FIRE community governance	Collection of FIRE projects No real community governance	Professional governance with legal and organisational arrangements

Implications: Establishing itself as the "RDI environment for the Future Internet" working on (technological) solutions for the Internet of Things, Information, Services and People, implies the importance for the FIRE initiative to establish the facilities, service infrastructures,

methodologies and tools, collaboration relations and know-how enabling to experiment with technological solutions for "network-based smart systems". The "service offer" concept must be brought to the forefront of the FIRE value offerings, and FIRE's business model must be based on the "servitization" of its facility offers.

7.2 Current state of FIRE

From the perspective of the longer term vision and objectives, FIRE as it is now is characterised by a diverse portfolio of experimental facilities, increasingly federated and supported with tools, and responding to the needs and demands of a large scientific experimenter community. FIRE has developed a more diversified portfolio following new directions such as Internet of Things and Cloud. Open Access mechanisms have been implemented by various facilities, including projects that continue after their lifetime formally ended. However the main weaknesses of FIRE as programme are a lack of sustainability of facilities after a project ends (although some have succeeded in implementing Open Access after their lifetime ended), limited industry and SME involvement, and a not well-developed ecosystem (e.g. no self-organised, viable linkages with external communities such as software developers or user segments apart from researchers) and also not a well-developed internal FIRE community.

The role of FIRE within the Future Internet research and innovation ecosystem as developed by the European Commission might be affected by new initiatives such as the 5G-PPP and previously FI-PPP. Given the ambition for 2020 and the present state, a repositioning of FIRE, based on rethinking its added value, is needed.

FIRE Position

FIRE in the framework of European RTD framework is well placed addressing different research challenges which are continuously evolving. FIRE started in FP5 supporting networking solutions to address QoS, protocols across wired and wireless networks. Since then, the FIRE community has advanced the development and harmonization of experimentally-driven research methods and platforms to ensure the continuous relevance, rigor and robustness of the research and the strategic research agendas to cover the state-of-the -art technologies such as Cloud, Smart Cities, IoT, multi-media applications, 4G and 5G mobile, etc. FIRE activities have resulted in many important achievements in terms of federated testbeds, access to testbed facilities, experimental research methods and tools, and collaboration across disciplines, initiatives, communities and across geographical areas.

FIRE Relevance

With the testbeds becoming increasingly mature over time, and researchers getting more involved in use case experiment definitions, hands-on operation with the test tools, methodologies and best practice testing approaches, FIRE has become more relevant than ever before in advancing the Future Internet research in Europe. However, the sustainability of experimental facilities in FIRE has remained a matter of concern, and the stake holders are analysing different approaches for the long term sustainability of FIRE facilities to attract both the research community and industrial entrepreneurs for exploiting the solutions developed for the market place.

SWOT Analysis

Strength: FIRE is a unique initiative in the world to support the Internet researchers with experimental facilities having state-of-the-art technology. FIRE testbeds are developed and operated by consortia comprising academic, research and industrial partners which can help technology transfer across academia and industry easily. The testbeds run as projects and

have partial funding from the European Commission and hence the testbed owners have little risk in following innovative research activities. In the federated structures available currently, most of the Internet topics such as IaaS, PaaS, SaaS, TaaS and EaaS can be supported both in real and virtual scenarios spanning across Cloud Computing, Big Data, Cyber-Physical Systems, Future Networking, Data, Content-Centric Networking applications, etc. Through 'open calls', the user community can obtain further financial and technical support. Some more mature testbeds offer 'open access' to their testbeds so that researchers and entrepreneurs can access these facilities for their experiments free of cost (in consultation with the testbed owners) when the experiment proposals are of innovative nature.

Strenghts	**Weaknesses**
• Diverse portfolio of experimental facilities • Increasingly connected, federated, supported with tools, and well accessible • Experimenter community	• Lack of sustainability of FIRE's facilities after project ends. This includes also the sustainability among individual facilities in federations. • Limited involvement of industry and SMEs, high entry barriers • FIRE ecosystem not well developed • FIRE community not well developed
Opportunities	**Threats**
• User support: Shortening time to market, user tools, service concepts • Benefits and enabler to Smart Cities and industry • Ecosystem development based on collaborative relations with related initiatives • Global collaboration (US, Japan, China) • More balanced funding mix (industry, national, EU, users)	• Declining programme funding by the EU after 2015 might be a possibility • Other initiatives within Future Internet might compete with FIRE

Weakness: FIRE testbeds have a major weakness of sustainability. The reasons are many fold. The testbed owners are one member of the consortium of partners from different organisations and countries, without having any commonalities in their business. The testbeds themselves are built with a particular technology and with particular experiments in sight from the partners, which may not be of much interest for commercial applications in short term. Since they are project based over a relatively short term and with only partial funding, there is no motivation to guarantee any support at the end of the project. Most of the testbed owners being research institutes, they are more interested in academic research and hence build the testbed for their needs rather than from industrial perspective to be mature and competitive. The experts involved are not full-time support staff of the testbed and very often they are learners of the usage of testbed themselves in the first phase of the project and, by the time they are ready to offer consulting on the usage to others, it is already late. Since the testbeds are not mature (at the commercial level), the user community is hesitant to try their experiments on such testbeds in which nothing is guaranteed (e.g. time slot for experiments, technical support to configure and execute, exclusive usage, SLAs, etc…). Since these testbeds are not legal entity themselves, they cannot provide any certification for the tests and results obtained, which also discourages industry and SMEs from making mature experiments

on FIRE facilities. Though open calls attracted many users, it is usually because of the financial aid they would get and very often they are part of the research community in FIRE itself. For SMEs, though it is an interesting concept, resources are necessary to study the testbed features, define the experiment scenario and prepare a proposal. Also, the time taken for the evaluation process makes it not very attractive, bearing in mind the limited success rate. The 'Open Access' has even received less attention by the research community because of only best effort support from the testbeds. All these criteria lead to sustainability problems of FIRE experimental facilities.

Opportunities: The opportunities in terms of possible scenarios are many fold, if the sustainability of FIRE experimental facilities are guaranteed. The opportunities depend on the approach taken to capitalise the assets generated over a number of years across different geographically distributed testbeds across Europe.

The current FIRE testbeds such as Fed4FIRE, SUNRISE, FLEX, CREW and others which have concluded (as projects), such as BonFIRE, OFELIA and EXPERIMEDIA, offer high usage potential if they offer matured testbeds as a service (for Iaas, PaaS. SaaS, TaaS and EaaS) with competitive technical support, cost and certification to the entrepreneurial researchers to experiment with their GoToMarket related applications.

In parallel to FIRE there are other initiatives such as FI-PPP, EIT ICT-Labs and Living Labs providing the platforms for applications and education oriented developments. The sustainability of all these initiatives and platforms will be better capitalised with a clearly defined co-operation between them for mutual benefit and extended user base. Such an approach, with the establishment of a coordinating body across the user community (researchers, SMEs and industries) and the multiple initiatives to match the users´ requirements with the testbed service offer could be considered.

With multiple studies done by the MyFIRE, AmpliFIRE, CI-FIRE and FUSION projects, it is very clear that the sustainability of research test facilities cannot be realised without partial public funding. However, the public funding should be so defined that testbeds would attract the user community, and funding would be made available only through the user community. This also will lead the testbeds to evolve in phases by forming legal entities and develop part of their testbeds as matured test facilities with certification possibility for conformance tests, and the other part as research testbeds with continuous overlap of assets used. This will also provide the competitiveness across few legal and EC certified testbeds, which can run partly as self-sustained testbeds and the other as partly public-funded testbeds.

Threats: Opportunities and Threats represent two faces of the same coin. If the European RTD community does not capitalize on the assets of FIRE, Europe will lose the competitivity and skills in the future Internet research, which will be the backbone of future economic development of the region. All developed countries including Europe and the BRIC countries are investing significantly in the area of future Internet to get the lead on the market share of ICT business. FIRE experimental facilities are unique in offering experimental facilities to the community compared to other nations, who provide grants for individual project-based funding rather than at the community level. Thus Europe is better positioned for innovation from all sectors and citizens across the society. If a proper usage model and involvement of users are not realized in short term, the investments done so far will not be well capitalized and this will have a major impact on the future technical competence of Europe in the future Internet business.

Gaps

The future Internet user community needs experiment facilities to test the products and solutions that would be of interest for market. In this context, they expect on-demand experimental platform which can offer services and applications to test their solutions easily. Experimenters need to run experiments under controlled and replicable conditions, according to specific requirements by accessing real or virtual equipment, systems and tools on demand, seamlessly and regardless of their geographical location. In general, experimenter needs are based on:

- Technical/scientific requirements: controllability, monitorability, repeatability, reproducibility, scalability, best practices
- Usability requirements: Understandability of experiment descriptions, openness of testbeds, usability,
- A Future Internet experimentation methodology
- Testbeds for the validation of specifications compliance
- Involvement of key European network equipment vendors to test the interoperability
- A web portal with the right combination of clear information, clear incentives and guidance can make FIRE facilities significantly more attractive.

AmpliFIRE has identified gaps in testbed offers in relation to the users' requirements, which should be taken into account in the future development of FIRE experiment facilities, to guarantee sustainability. The table below[3] presents a detailed overview of the identified gaps, based on analysing experimenter demands and current FIRE offers.

Experimenter Demand	FIRE Offers	Gaps
1. Experimenters need test facilities on demand	FIRE testbeds offer access to the experimenters quickly in an Open Access model, when their proposal is interesting and resources are available. Experimenters may have to pay expenses towards the consulting services.	FIRE testbeds are slow with engagement model in the competitive Open Call, as it involves integration of experimenters in the consortium 1. Awareness of capabilities and SLA guarantees are missing 2. Open call: time consuming: annual cycle
2. Minimum overhead	Open Access Model has minimum overhead.	In the Open Call model, engagement of users is a long process and involves significant overhead. The value of overhead is more than the gain achieved by funding, that too without any compliance (certification)
3. Maturity and Sustainability of testbeds	In general current testbeds are generally mature, though they may need to discuss the requirement of resources to the experimenter needs. Sustainability after the end of the project contract is not guaranteed, though many of the latest testbeds do sustain.	Most of the resources offered to the experimenters are based on open source and hence maturity is not guaranteed. Does not match with the results validation process with the operation platforms. Sustainability is not guaranteed for repeated experiments Time slots for experiments are not guaranteed
4. Professionalism in technical support	In general the testbeds are well supported for research oriented	Testing has best practice models for validating the test results. Since

[3] AmpliFIRE D2.1

Experimenter Demand	FIRE Offers	Gaps
	experiments, which may not meet the requirements of business oriented SMEs.	many of testbeds are supported by research institutes and researchers, testbeds are not necessarily supported by professional test engineers.
5. Innovative experimenters need validation process	Technical validation is possible, but no certification possible.	FIRE offers only technical experimentation. Since the mission of FIRE is to support innovation oriented research, user oriented validation is not feasible.
6. Testing with real users to get a feedback on users experience	Not offered	FIRE does not have real end users
7. Professional engagements with IPR, SLA guarantees and data protection, with clearly defined usage policies	It can vary case by case basis.	Such models are typically not practiced at project level, although they might be supported by the individual institutions running the testbeds.
8 SMEs look forward TaaS and EaaS with KaaS support	These services are in discussion and hence not mature.	The concept is just being developed
9. Need sector specific usage references for credibility of testbeds	FIRE testbeds are for not built for sector specific needs, but are general and hence can support experiments of various sectors.	No such references are available, but has only some success stories with research experimentation
10. Users need a single interface to assess whether the experimenters' needs are matching the testbed capabilities.	The Open Call documents describe details of testbed features.	FIRE testbeds provide contact points at their project level. Users have to study different testbeds and choose with their perceived judgement.
11. Market promotion is the primary target of industrial (SMEs) users.	Not the mission of FIRE.	Since no end users are involved there is no possibility to address this issue FIRE does not have the mission of promoting SME products.
12. Testing following standards is important for moving towards commercialisation	Vendor specific standards are used in the testbed, but not test methodologies for commercial licence.	Most testbeds do not follow any best practice, standards based test suites for testing the system under test.
13. Support to New Technologies	FIRE testbed supports major technologies in use. New projects are being discussed to support IOT, 5G etc…	FIRE testbeds are not yet ready for IoT, Smart cities, Big DATA and 5G technologies to the matured levels
14 Security and Privacy policies should be defined	Testbeds are supposed to provide the necessary security and privacy guarantees to the user community.	The policies for SLA, security levels and privacy are not part of the present offers.

7.3 Positioning FIRE within the Future Internet innovation ecosystem

FIRE as the "RDI environment for the Future Internet" means that it positions itself as having core competence in "experimentation", being at the forefront of new networking technologies and their exploitation and use in innovative application systems. The core competence on experimenting and innovating is covering the vertical from networks to services and applications (where the services and applications in "smart systems" gets more emphasis), and addressing scale-up issues related to experimentation and large-scale trials.

It means that it offers its facilities, methodologies and tools in a professional and "servitized" way for a wide range of customers. FIRE should create, maintain and expand the know-how, facilities and methodologies to develop and test solutions in the application of (1) advanced networking technologies, and (increasingly) in the validation of (2) smart networked systems. FIRE will not overlap or compete with other Future Internet-oriented programs or initiatives but will pursue collaboration based on its core resources and opportunities for complementary value creation.

FIRE positions itself and more generally the concept of "experimental testbeds for networking technologies and smart systems" at the core of the experimental large-scale trials of other initiatives, such as FI-PPP, 5G-PPP and others e.g. Internet of Things and cloud-based systems. This has started with the FI-PPP (as several FIRE facilities are part of the FIWARE nodes) and should be strengthened with the 5G-PPP. FIRE should evolve towards becoming a key supplier (or co-developer?) of "customized" experimentation platforms, services and tools. For this to be effective FIRE should somehow establish a longer term collaborative projects-based relation with 5G-PPP to be defined in the Work Programme.

Regarding FIRE's role in "smart networked systems", FIRE should develop a foothold in this area in initiating demanding facility and research projects within FIRE making the shift from networking technologies to systems and software, in collaboration with other domains such as Big Data, Internet of Things and smart connected objects, and cyber-physical systems. Again the Work Programme should be the basis to explore collaboration with other Units, defining joint interests through concrete project collaboration.

Clearly, FIRE should seek new ways of project-based co-operation with other initiatives in network experimentation and software systems, such as Géant and NRENs, Smart Cities initiatives, and other EC Units and DGs.

International co-operation is essential for FIRE, however the current bilateral co-operation should be more reciprocal and result oriented. Work done by other EU bodies e.g. trade agreements with other countries outside EU could be used as stepping stone to enhance co-operation between FIRE and related initiatives in these countries. FIRE should also strengthen its international presence and co-operation by aligning with other European initiatives such as 5G-PPP and technology platforms such as NetWorld2020 and NESSI.

7.4 FIRE service portfolio evolution

The Future Internet Research and Experimentation (FIRE) initiative was founded to create a multidisciplinary research environment used for experimental validation. The goal of FIRE is to facilitate experimentally-driven research in the field of innovative (Internet) networking and services. This has resulted in a heterogeneous set of experimentation facilities that each target their own experimentation communities. This resulted in diverse islands with diverse types of resources offered, each with dedicated standalone APIs, which made it quite difficult for experimenters (high learning curve). Combining different (types of) infrastructures into federations was the next big step e.g. CREW, BonFIRE, Ofelia, which resulted in more successful, wider used FIRE testbed infrastructures. The focus was on more standardised procedures of experimentation, development of more generic components (e.g. authorization), tools (e.g. JFed) or APIs that could be transferred and deployed on the different sites. Nowadays, most of these FIRE experimentation facilities offer a reliable experimentation infrastructure that supports the entire experimentation lifecycle and allows thousands of researchers to do high quality experiments. This is the way forward in order to decrease the learning curve of experimenters and increase adoption of testbeds.

The evolution towards Platform-as-a-Service and Knowledge-as-a-Service will drive the evolution to Experimentation-as-a-Service. A new service paradigm allowing seamless experimentation regardless of geography, under controlled and replicable conditions with support from an experienced work force and offered via affordable access to innovators on state-of-the-art experimentation facilities.

Platform-as-a-Service (PaaS) deals with more standardized APIs and tools that help experimenters throughout their experiment lifecycle (authentication and authorization; resource discovery, specification, reservation, provisioning; experiment control; facility, infrastructure and experiment monitoring; experiment measuring). Next to this the Knowledge-as-a-Service (KaaS) component is of equal importance: facilitating experimentation with providing documentation about the facilities, tools and procedures; offering training and tutorials; sharing best practices. Besides dedicated consultancy in providing support on the experiment setup, execution and evaluation has been as valuable for some types of experimenters such as SMEs and industrial partners.

It is found that FIRE is already very relevant for certain user communities (research and education) who are, to a large degree, satisfied with the existing FIRE service offer portfolio. Other user communities' (SMEs and research projects doing complex cross-domain experiments) involvement in FIRE can be nourished by including knowledge-based services on top of the infrastructure services into the FIRE service offer portfolio (consultancy, additional support, evaluation metrics, experiment setups, etc.). The level of knowledge required also depends on the type of infrastructure, where wireless network infrastructures require more support than more common VM or cloud based testbeds. Some broker functionality including 24/7 operations and SLA provisioning should be in place in order to take care of these customized solutions.

Knowledge in terms of experimenter requirements and gaps in the FIRE offering should also be communicated back to the EC in order to take measures for future research initiatives. This is a continuous process of learning that should guarantee the continuity and innovative character of FIRE.

FIRE could provide with these broker functionalities also a link to other research initiatives such as EIT-ICT, FI-PPP. The available FIRE infrastructure could be used as underlying platform for those other initiatives, thus benefiting as well from their portfolio of potential customers.

We can conclude that there is not one "FIRE service offer portfolio". The offering will remain heterogeneous due to the support of a diverse range of infrastructures, changing experimenter requirements, sustainable funding, etc. We argue that the use of standardized protocols, APIs and tools, and knowledge sharing will increase testbed and experimentation adoption due to a lower entry barrier.