Amplifying Future Internet Research and Experimentation for a Sustainable Future

AMPLIFIRE

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THE FIRE ROADMAP TOWARDS 2020

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Executive Summary

This deliverable presents a roadmap for Future Internet Research and Experimentation (FIRE) within the Horizon 2020 program. The objective of the roadmap is to identify how FIRE can move forward via a series of key developments and milestones to achieve the advancements in testbed facilities and services that will create state of the art ecosystem for future experimental research. The roadmap identifies the key objectives to be achieved in the particular phases of the roadmap (2016, 2018, and 2020), and then presents a set of recommended solutions that will achieve these objectives. We also analyse how uncertainties (e.g. levels of funding) will affect the roadmap progression, and suggest alternative pathways, i.e. follow a reduced pathway of milestones. Finally, the deliverable recommends key inputs to be included in the upcoming work programmes for FIRE calls up to 2020.

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1. Introduction

The objective of the AmpliFIRE's FIRE roadmap (presented in Figure 1) is to identify how FIRE can move forward via a series of key developments and milestones to achieve the advancements in testbed facilities and services that will create a state of the art ecosystem for Future Internet experimental research and innovation. The FIRE roadmap is influenced by emerging trends in two dimensions:

- The ***technology trends*** layer observes important research, technology and experiment directions that will directly influence FIRE moving forward. FIRE as a programme must remain useful to the research and technology communities; these emerging trends are collected from recent material regarding state of the art research in Future Internet technologies (including the AmpliFIRE Radar [1]).
- The ***Future Internet landscape*** layer observes broader trends that FIRE could and in many cases must align with to achieve objectives, e.g., providing experimental support to Smart Cities and 5G researchers. These are identifiable by large research programmes both in Europe and globally. It is important to identify that FIRE exists within an EC programme, and the Future Internet Landscape is largely driven by EC policy and strategy; and hence, solutions must be aware of this ecosystem. This also means that while knowledge about 2014-2017 exists, 2018-2020 is largely unknown.

The FIRE Roadmap is split into three phases: i) 2014-16, ii) 2016-2018, iii) 2018-2020 that are then described by a common template:

- The ***objectives*** highlight what FIRE aims to achieve before the end of the phase through a set of *solutions*. Each objective is taken from the strategy [2] proposed by AmpliFIRE.
- The ***solutions*** outline specific actions FIRE can take to meet the objectives. FIRE is a complex system of experimental facilities, therefore in order to consider solutions we break it down into sub-layers where novelties can emerge and solutions can be realised to meet the higher objectives.

We have identified four solutions core layers:

1. The *FIRE resources solutions* considers the role of the testbeds made available through FIRE, i.e., whose development is funded in part by the FIRE programme. These represent an important element in achieving objectives through making the right experimental facilities available, sustaining these facilities, and ensuring their provision meets user demands.
2. The *FIRE Experiment as a Service (EaaS) and access solutions* considers the services provided to the user to allow them to perform experiments; these can be experimental services to perform and monitor experiments (set up experiment, report on results, etc.), services to utilise facilities directly (SLA management, security, resource management), and central services managing the FIRE offering (e.g. a FIRE portal). Also the mechanisms employed to allow users to access and make use of the testbed are considered e.g. fully open access, open calls, policy-based access, etc.

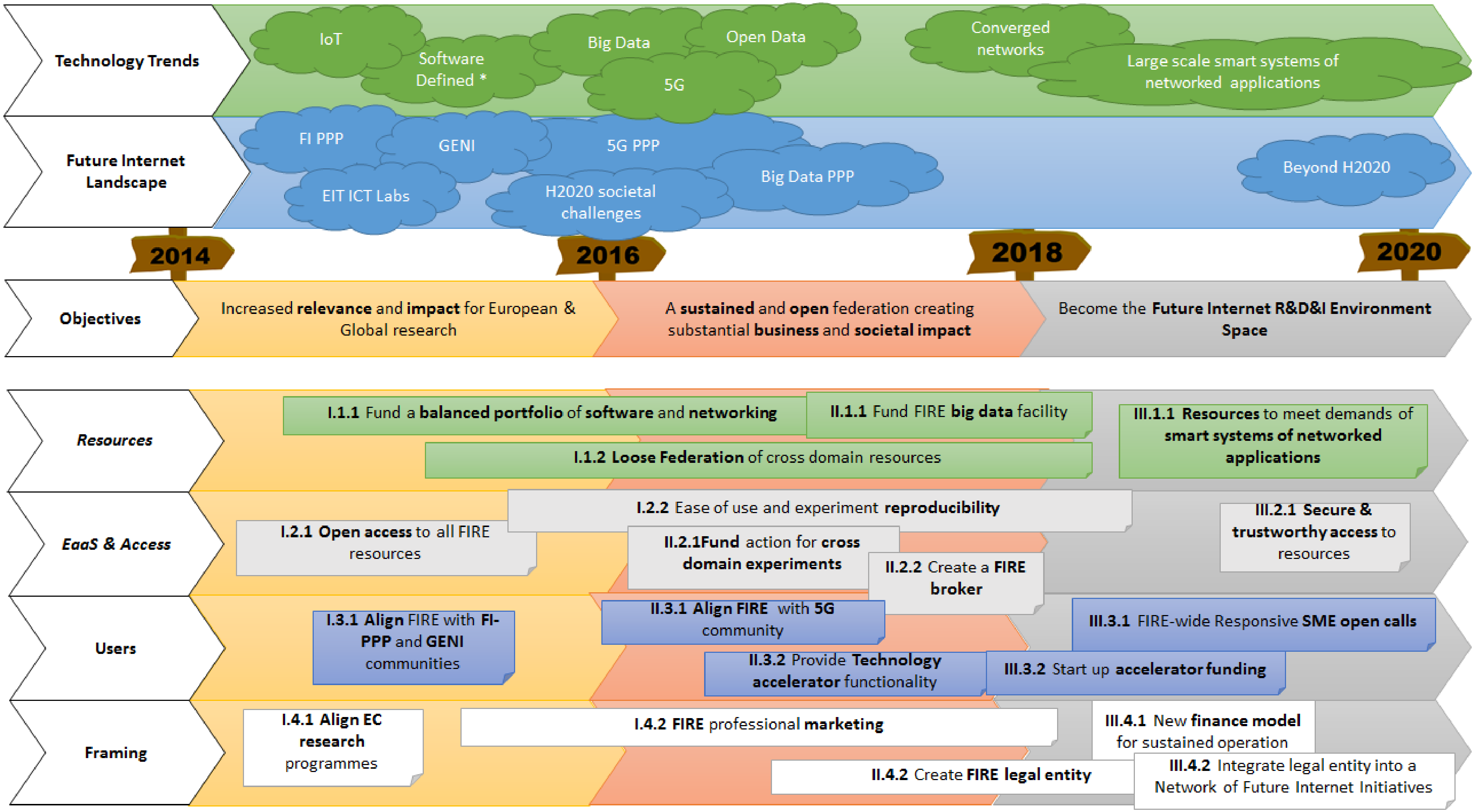

Figure 1: The FIRE Roadmap, high-level view

3. The *FIRE Users (Experimenter) solutions* considers the consumer, i.e. the overall FIRE user base who utilise the available FIRE testbed resources. Solutions in this layer will implement changes in the user base, e.g., changing from a traditional academic community in Europe, to a global community, and/or more industry and SME users.
4. The *Framing conditions solutions* consider the legal, organisational structures and arrangements for FIRE as a self-sustaining entity.

The FIRE Roadmap builds upon an assessment of trends and developments as well as the definition of the FIRE vision and objectives. These will be shortly summarized in the next sections.

2. Research and Technology Trends in the Future Internet

Pervasive trends

The *Future Internet* describes the migration from current Internet functionality towards infra-structure that is capable of supporting the next generation of applications, services, and networked systems. Traditionally this has been broken down into four pillars where research and development has focused: the *Internet of Things (IoT)* is a global, connected network of: tags, sensors, actuators, and mobile devices that interact to form pervasive systems that autonomously pursue common goals[1]; *the Internet of Services*[2] applies the vision of *service-oriented computing* to Internet-scale systems. *The Internet of Content* considers large-scale content and knowledge may be combined, mixed or aggregated to generate new content and media (such as interactive multi-media sessions and immersive complex and multidimensional virtual/real worlds); the *Internet by and for People*[3] envisages a growing number of people being connected across the *digital divide* to form diverse social networks to pro-actively build communities to exchange knowledge and blur the boundaries between systems and users (e.g. *Near-Field Communication* (NFC), *Body Networks*, *Augmented Reality*, and *Participatory Sensing)*. These pillars are then underpinned by research into advanced network communications technology (c.f. the foreseen characteristics of 5G networks).

Current research trends emphasize software and services technologies, particularly in the fields of IoT and Big Data (c.f. Gartner's Top 10 strategic technology trends for 2014[4]). However, longer term visions highlight trends towards digital convergence[1]. Hence, it is clear that future technologies will embrace the combined pillars to create truly pervasive, large-scale complex systems. This mirrors a significant software engineering initiative in the US[5] focusing on ultra large scale systems. The key technical research themes that require extensive experimentation facilities in such digitally converged systems are:

- *Scalability*. Validating scalability claims requires infrastructure with the potential to increase a system's size, workload, users, or data. Hence, substantial resources must be made available to support realistic research. A claim a system is scalable to 1K nodes is insufficient where comparative industry systems scale to 100K nodes.

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[1] L. Atzori, A. Iera and G. Morabito, "The Internet of Things: A survey," *Computer Networks*, 54(15),1286-1389, 2010.
[2] V. Issarny, N. Georgantas, S. Hachem, A. Zarras, P. Vassiliadist, M. Autili, M. Gerosa and A. Hamida, "Service-oriented middleware for the future internet: state of the art and research directions," Journal of Internet Services and Applications, vol. 2, no. 2, p. 23–45, 2011.
[3] D. Papadimitriou, "Future internet: The cross-etp vision document," European Technology Platforms, 2009
[4] http://futurethinking.ee.co.uk/how-mobility-cloud-and-big-data-will-dominate-the-business-it-agenda-in-2014/
[5] L. Northrop, "Ultra-Large-Scale Systems: The Software Challenge of the Future", ISBN 0-9786956-0-7 http://www.sei.cmu.edu/uls/

- *Interoperability*. The integration of highly heterogeneous technologies across a number of hardware, software, data, and networking dimensions requires new approaches to the interoperability problem.
- *Software - taming complexity*. Novel software software system, software engineering methodologies and programming abstractions are required (including autonomic ones) to support developers in building the next generation of large-scale converged systems.
- *Security, Privacy, and Trust.* The Future Internet brings new requirements and challenges with respect to the security of systems, and the privacy of users.

Trends in the FIRE Portfolio

If we examine the current FIRE portfolio we can see the extent to which it supports these research and technology challenges. Figure 2 shows the technology areas of FIRE up to 2015, e.g. IoT, Content-centric networking, and Data management. The central areas are testbed facility resources (Fed4FIRE, CREW, ORGANICITY, etc.), the areas outside are the experiment projects. As an example, IoT Lab is an experiment project researching the potential of crowdsourcing, atop of IoT testbed resources.

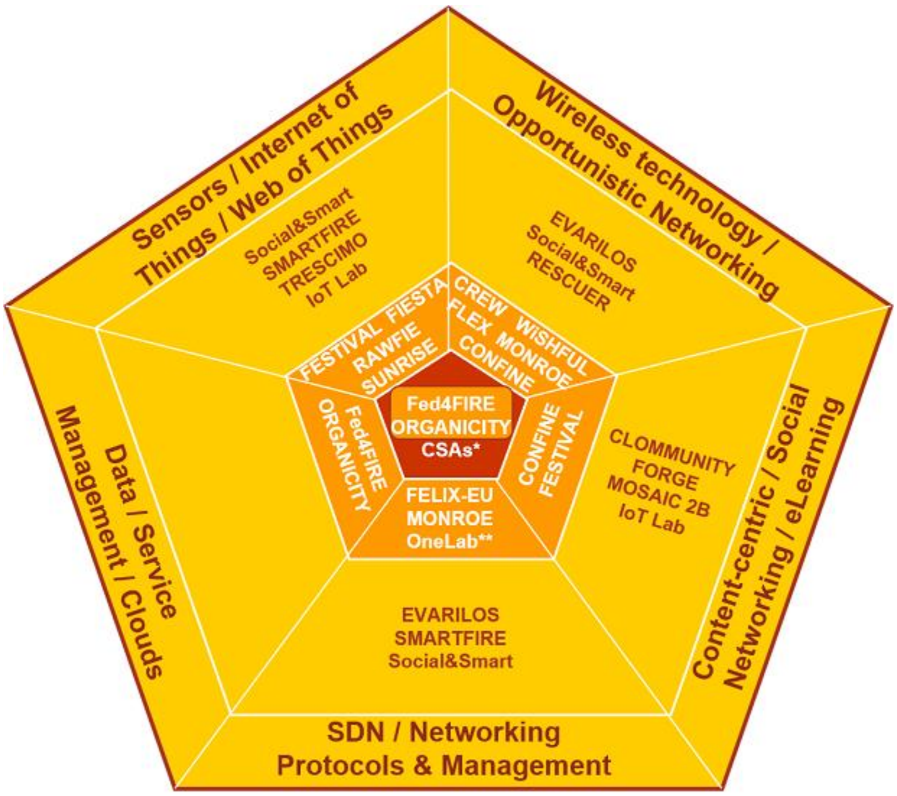


Figure 2 Current FIRE Trends

Next Generation Communication Networks

FIRE remains strong in the majority of networking areas (wireless, content-based, fixed, etc.). Including newly funded facilities: **FLEX** (for LTE research), **WISHFUL** (for wireless networking research particularly in open software and hardware solutions), and **MONROE** (for measurement experiments in Mobile Broadband, particularly performance and user experience).

Software Defined Networks (SDN) has proved a driver of experimentation, with numerous projects surrounding OpenFlow. The picture remains unclear as to its future within FIRE as **OFELIA** came to a conclusion, i.e. whether SDN does remain a topic for research in itself, or whether SDN will simply become a technology resource integrated within other experimental facilities e.g. Data Centre management, or communication flows within federated testbeds.

The area of **5G technologies** is the next phase of mobile telecommunication technologies to deal with the rapid increase in number of mobile users and the exponential increase in data communications. There are many areas for research in this domain, particularly concentrating on the efficient use of resources e.g. spectrum sharing. New radio architectures, new hardware, new air interfaces are at the core of the research—and offer interesting future resources for FIRE testbeds to consider. There will also be increased research into a converged architecture where networks converge to deliver better and secure end-to-end services: virtualisation, QoS, QoE, SLA management are all important topics for experimentation within holistic 5G architectures. Research is also seeing the convergence of domains for 5G, e.g. the integrated placement of cloud resources in the 5G architecture (e.g. at a base station) to optimise delivery and efficiency. FIRE is particularly strong in networking with state of the art wireless and LTE technologies, and hence must continue to consider testbeds that complement the existing base and create the relevant resources for the 5G community.

We are also seeing trends to improve the efficiency of Future Internet resources through virtualisation technologies; here there aims to be more services available, at less cost and with fewer resource consumption. Services also seek to be easier to launch, distribute and manage remotely. Such technology developments will feed directly into Green ICT initiatives globally to reduce the digital footprint.

FIRE remains strong in communication networks technologies, with state of the art wireless and LTE technologies, and must pursue to complement the existing base and create relevant resources for the 5G community. FIRE must also pursue further efficiency of Future Internet resources, of importance for domains such as Green ICT, such as virtualisation technologies.

Internet of Things

In IoT there are well-developed niches or "silos" in which large numbers of inexpensive low-powered sensors, control devices, or simply unpowered echoing "radio bar codes" are already being put to effective use in applications such as logistics (barcodes), transport, manufacturing, smart cities, environmental monitoring, and aids to vehicle navigation. Some of the silos support viable businesses which have already given rise to de facto standards for collecting and distributing the information that flows within them. The challenge of bringing these already vital areas together through a "narrow waist" like that of the middle layer of the Internet seems even greater than the challenge faced by the designers of what became TCP/IP in integrating the proprietary networks of the 1960s and 1970s.

FIRE's recent portfolio additions contain a number of facilities that describe themselves as IoT or "IoT/cloud" projects. When looked at closely, **SUNRISE** (a late FP7 funded project on underwater acoustic communication among sensors) and **RAWFIE** (which networks unmanned surface and aerial vehicles) appear to be silos with significant existing technology content but little obvious connection outside their existing bases. **ORGANICITY** places the center of its focus on gathering richer end-user input and defining critical applications of the smart sensor data. But they must also conduct real experimentally driven research and will need controls, portal services and data standards to do this in a way that leaves a permanent mark. **FIESTA** proposes to ensure semantic interoperability between the data resources from multiple IoT testbeds including the established **SMARTSANTANDER** facility to address the challenges posed by IoT Silos.

The conjunction of bottom-up IoT projects such as those that FIRE is integrating and "clean sheet" attacks on IoT solutions to future manufacturing and other business problems all within DG-CONNECT is an opportunity for further progress. Such progress would mean getting behind a common platform for experiment control plane, for data curation and archiving, first within the various FIRE projects, since this work will be shortly competing with clean sheet elements resulting from initiatives from DG CONNECT units E1, A2 and others. Just as the FI-PPP ignored FIRE until some years of parallel development had been invested. A tactful recognition that the two projects had been working at different application layers has enabled a cooperative and complementary common approach to emerge, but these problems should have been forced into visibility two years earlier.

FIRE must align and federate its IoT facilities to provide useful and broad experimental resources; it must also align with other IoT research programmes to ensure complimentarity and a common approach towards the Future IoT Architectures.

Big Data.

The fastest growing application area for cloud computing is *Big Data*, whereby vast quantities of data is processed, mined and analysed. For example, Twitter produces 12 Tbytes of data every day that can be searched and analysed for social, marketing and political trends. Billions of energy meter readings can be analysed to predict and conserve consumption. The Sloan Digital Sky Survey of astronomy data produces 200 Gb of data every day. More and more open datasets are being made available on the web to support novel application usage[6][7] [8]: e.g. census data. Hence, there is a growing suite of facilities to build and demonstrate the potential of Big Data. The area of large-scale interactive content is another interesting area within the field of large data—again, there is need for experimentation into how such vast of amounts of data can be distributed, processed and managed. In particular, this asks new questions of the underlying communication networks—FIRE's expertise in this area means that it has an important role to play in future experimentation. The upcoming Big Data PPP will include research into new big data approaches, and FIRE has the potential to provide cutting edge networked facilities to support their experiments.

Big Data will bring together experimental research in data mining, predictive analysis tools, machine learning, natural language processing, computer networks, distributed systems, and many other computational data based research with the capabilities of distributed and cloud computing. Therefore significant innovation is required to make these facilities available such that they can be leveraged by the end users and scientists performing big data applications:

- *Integration of real time data streams* with cloud processing facilities and cloud software computation and storage stacks.
- Making data, modellers, analytic, visualisations, results, and indeed any big data services available to support future and repeated scientific experimentation. For example, EVOPilot[9]

[6] http://data.gov.uk/data
[7] https://explore.data.gov/
[8] http://aws.amazon.com/publicdatasets/
[9] http://www.evo-uk.org/

is a UK pilot project funded by the Natural Environment Research Council to create a universal observatory of scientific data and cloud based tools for performing environmental monitoring.

If we analyse the current situation we can quickly identify that FIRE so far has limited support for experiments involving large-scale data. The only facility directly relevant is Fed4FIRE's integration of BONFIRE's (a recently finished FIRE project) experimental resources**;** which concentrates more on computational resources than data resources and indeed will likely only be available as part of Fed4FIRE in the short term. Further there are no experimental services to better manage large data sources (open data sets). All current research trends indicate data at scale (e.g. IoT, Smart Cities and 5G) and FIRE must consider its service provision in this regard if it wishes to grow its user base beyond traditional networking and systems infrastructure and embrace interdisciplinary research.

FIRE must consider reusable facilities for Big Data research—this should support experiments in systems technology (e.g. the next Hadoop, MongoDB), in data mining and analytics algorithms, and in data curation.

The new LEIT Work Programme 2016-2017

The new LEIT Work Programme 2016-2017 (May 2015 available as draft) confirms the importance of emerging Future Internet areas of relevance for FIRE, such as 5G-PPP, Networking research beyond 5G, Smart Cyber-Physical systems, Cloud computing, Internet of Things research and platforms, Big Data PPP research & technology challenges and Innovation Hubs, as well as the trend towards large-scale smart systems e.g. represented by the Smart Anything Everywhere initiative. FIRE's positioning in this landscape is to establish a federated European-wide experimental infrastructure which is open for global collaboration. For FIRE during 2016-2017 is foreseen one or more large collaborative projects continuing the federation, as well as large collaborative projects in three areas:

- Management and control of cognitive radio;
- Service delivery networks, based on heterogeneous and cooperative networks integrated through SDN/NFV techniques and compatible with demanding high mobility environments, e.g. connected vehicles;
- Future multimedia Internet (FMI) services integrated with broadcasting, with a focus on high mobility scenarios and its impact on communication and storage infrastructures.

A new theme is high mobility environments, while at the same time FIRE does not explicitly seem to accelerate some of the key themes in its portfolio such as IoT and Smart Cities.

As regards non-FIRE ICT spearhead themes in the new Work Programme, FIRE is explicitly referred to for Cloud computing, IoT Large Scale Pilots, and Information-centric Networking.

Not visible in the Work Programme 2016-2017 (draft) is how FIRE will interact with other initiatives such as 5G-PPP and Big Data PPP and how these initiatives could efficiently make use of FIRE facilities. It remains a challenge for upcoming years to establish sharing of the various facilities and establishing collaboration among the involved DG CONNECT units.

3. Trends in the Future Internet Landscape

FIRE's roadmap is not only shaped by technology and portfolio developments but also by FIRE's evolving position within the wider Future Internet landscape. Deliverable D1.2 highlights FIRE's current position in the current Future Internet Landscape [2] (see Figure 3). We do not provide a detailed analysis here (see the prior deliverable), but the key initiatives from this set to increase FIRE's impact are: international linkages, FI-PPP (market-oriented users), Big Data-PPP and 5G-PPP. With the 5G-PPP just beginning within this roadmap phase frame and the FI-PPP coming to a conclusion, collaboration solutions should prioritise the alignment of FI-PPP with FIRE, i.e. *"To create an overall end to end Future Internet innovation ecosystem, which goes from the early experimentation phase (FIRE), to the large scale industry and commercial oriented service phase (FI-PPP)"* [2]. Progress on this has begun:

- Development of IoT applications using FIWARE software on the SmartSantander testbed; there was a dedicated developer event on this topic in Santander in October 2013[10]. The new FIRE project OrganiCity which started early 2015, working on Experimentation-as-a-Service facility in smart city co-creation contexts, continues and strengthens the collaboration with FIWARE in the domain of Smart Cities.
- Exploration of the above Innovation pathway within the XIFI project; here a QoS experiment from the OFERTIE project is transferred to use FIWARE software on the XIFI infrastructure[11].
- The deployment of FIWARE generic enablers during the third phase of the FI-PPP will also be possible on a typical FIRE testbed (iMinds), whose resources are available to both FI-PPP (via the XIFI cloud stack) and FIRE users (e.g. via the Fed4FIRE APIs). In this context, iMinds is also capable of optimizing the use of physical server resources used by XIFI[12], by dynamically installing the XIFI software on a changing number of servers, based on the actual demand; For this, tools that were co-developed as part of FIRE are used.

Furthermore, the Horizon 2020 LEIT work programme is looking towards collaborations between Japan and Brazil in the 2014-2015 work programme (EUJ-4 and EUB-3 calls for proposals on experimental platforms). The new LEIT Work Programme 2016-2017 focuses on collaboration on the Future Internet with China and Mexico.

As regards the US, GENI is the US equivalent to FIRE (and hence is a key collaborator to increase global usage) - they are technically closely aligned. Although the long term future of GENI is uncertain it is a priority to maintain momentum between the two communities to establish common standards and access policies. This initiative is led by Fed4FIRE, and has already led to one of the Fed4FIRE tools (jFed) being adopted by GENI (see e.g. http://groups.geni.net/geni/wiki/GENIExperimenter/Tools) and such common standardization efforts should continue through the 2016 phase. We will also see the first research projects of H2020 who may have need to leverage FIRE-like experimental resources; and hence there is a growing need to establish strategic alignments between EC units to ensure that experimental facilities are not repeatedly implemented (where ones already exist).

In the 2016-2018 timeframe the key initiative for FIRE to collaborate with is the 5G-PPP, and solutions within this phase should consider such collaboration opportunities. In the early stages, FIRE has significant value in that is has already available 5G relevant testbeds—reducing the need to fund new experimental facilities (where they are already available in Europe). FIRE may also be better aligned to the 5G-PPP in comparison to the FI-PPP. The FI-PPP is an operationally oriented ecosystem—with applications/sectors tightly couple to the vertically integrated solutions e.g. the FITMAN project using FIWARE software deployed on FI-Lab nodes. The 5G-PPP promises to be more research oriented with scope for FIRE resources to be

[10] http://www.fi-ware.org/2013/09/19/santander-smart-city-event/
[11] XIFI, "XIFI Showcases Design V1," Deliverable D6.1, 2014.
[12] When accessing resources via XIFI, there is however still a potential capacity problem due to the FIWARE Lab architecture requiring a large pool of scarce, public IPv4 addresses

directly leveraged, and for FIRE projects to build upon 5G-PPP results. This follows the more traditional open innovation path of networking technology research.

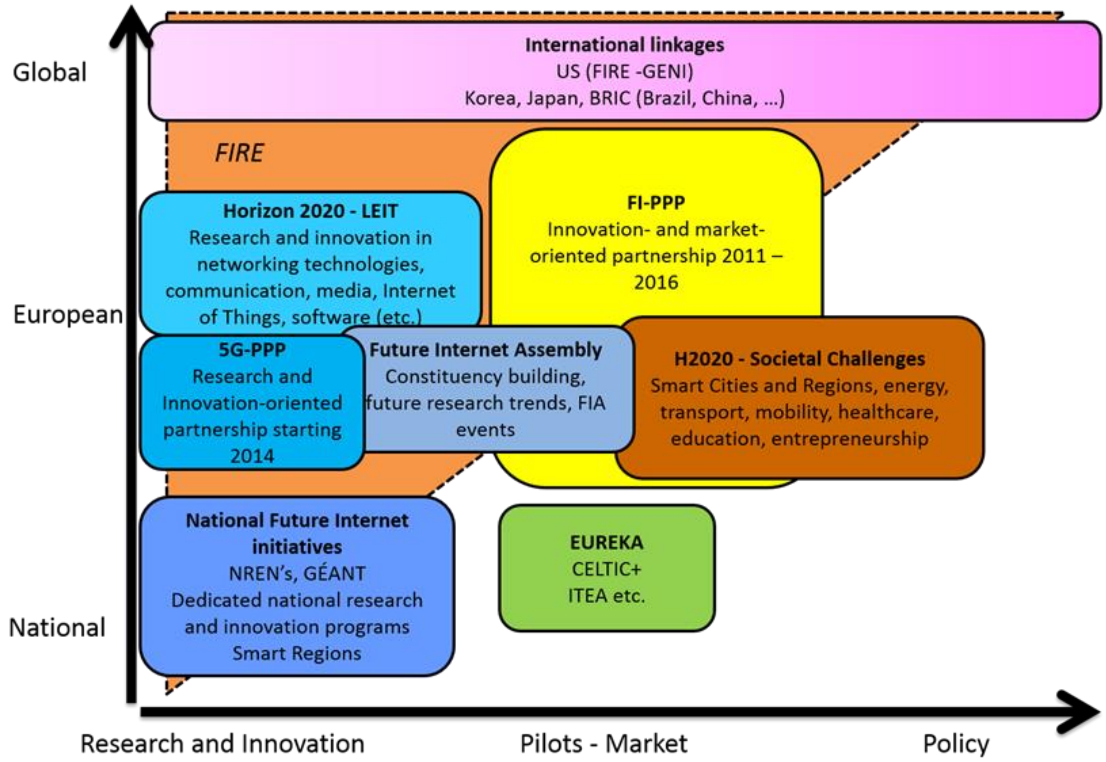


Figure 3 Positioning of FIRE in the Future Internet Landscape (AmpliFIRE D1.2, 2014)

4. Implications of the identified Trends for FIRE's Future

If FIRE is to increase its relevance within Future Internet research in capitalising on the clearly visible trends in Future Internet technologies and landscape, it should consider the need for larger scale facilities that cannot easily/cheaply be put together on a per experimenter basis. The growing needs of user focused research, technology convergence and interdisciplinary research can potentially meet a much wider user base than networking systems and experimenters. While clearly FIRE should continue to be seen as a flagship for networking research, it should ensure its value added role in new and important areas of networking research (5G) as well as establish its position in complementary areas, both at technology domain and application domain level. The following recommendations are based upon identified technology, portfolio and landscape trends:

- FIRE to fund testbeds directly relevant to 5G experimentation; and/or fund the continuation of networking testbeds [short term].
- FIRE to continue towards a converged federation supported by common central tools, particularly with the goal of supporting 5G and IoT research [short term].
- FIRE to consider more comprehensive IoT facilities that allow realistic experimentation with real-world impact [medium term].
- FIRE to address support for Big Data requirements through additional or improved FIRE testbeds that can add to the heterogeneity and scale of experiments [medium term]
- FIRE to consider what future testbeds will look like for large-scale, smart networked systems i.e. where the technologies from smart networks, big data, IoT converge to a new technology class [long term].

More detailed recommendations and conclusions are included in AmpliFIRE's D2.1 report "Conclusions and Recommendations for FIRE's Future" (February 2015).

5. Vision and Objectives for FIRE Towards 2020

The mentioned recommendations and their translation into a concrete roadmap and action plan (presented in section 6) are grounded in a future vision of FIRE. This future vision is elaborated in detail in AmpliFIRE D1.1 (2013, 2015) [1] and D1.2 (2014, 2015) [2] reports. In this FIRE Roadmap document we summarize the key elements of the FIRE vision in terms of objectives to be pursued towards 2020.

The longer term FIRE strategic objective for 2020 is that **FIRE becomes Europe's open lab for Future Internet research, development and innovation. FIRE is to be an accelerator within Europe's Future Internet innovation ecosystem. FIRE is also sustainable, part of a thriving platform ecosystem, and creates substantial business and societal impact through addressing societal challenges.** We shortly elaborate on some of the key elements.

By 2016 FIRE will increase its relevance and impact primarily for European wide technology research, but will also increase its global relevance.

To become an R&D&I environment for Future Internet technologies [2], on the short and medium term FIRE must concentrate on increasing its relevance and impact, i.e. ensuring FIRE is seen as the preeminent worldwide experimentation facility. Activities along this pathway include: reducing the barriers to experimentation, ensuring open access, continuously integrating cutting edge facilities, and opening up for wider collaboration also globally. The roadmap in section 6 describes solutions and milestones to meet this objective. Note, project funding remains a key instrument in shaping the FIRE resource portfolio and hence many of the solutions are built upon this instrument.

By 2018, FIRE creates substantial business and societal impact through addressing societal challenges.

FIRE originating from networking technology should continue this focus and extend experimentation to newly emerging technology areas in this domain such as 5G, however it should also continue to widen its range of technologies and stakeholder groups and widen its scope from facilities and experimentally driven research towards innovation. FIRE will not be able to pursue this objective on its own so it should engage in collaborationships both bottom-up (initiatives stimulated within and among the projects) and top down (alignment and coordination among DG CONNECT units). An important step is to select application domains for experimentation and innovation activities within FIRE projects, such as Big Data, Smart Cities. Increasing the interaction with Internet of Things stakeholders is recommended, as Internet of Things is a dominant trend strongly interlinked with Big Data and Smart Cities.

By 2018 FIRE will become a sustained and open federation that allows experimentation on highly integrated Future Internet technologies; supporting networking and cloud pillars of the Net Futures community.

"The FIRE Sustainability Model should consider how to create, deliver and capture financial, economic, social, and technological value. Results oriented or pay-per-use models should be considered with clear distinction between facilities (to be) offered and experimenters usage, with the major contribution going to the experiments and innovative ideas towards market including the incubation. An independent stakeholder alliance with public private funding mechanism to manage the European common platform should be considered." [1]

Hence, this phase of the roadmap should continue the prior phase objectives towards a Future Internet R&D Lab; however, importantly this phase should concentrate on operating sustained FIRE facilities that users can depend upon. Here we examine solutions to meet such objectives.

By 2020 FIRE will become the Research, Development and Innovation (RDI) environment space that is attractive to both academic researchers, SME technology developers, and industrial R&D companies with emphasis on key European initiatives such as 5G, Big Data and Cyber Physical Systems domains.

This objective highlights the importance of expanding the FIRE offer and aligning this offer to support industrial collaboration (including SMEs and startups) by focusing on solutions in the following areas. Actions to be pursued in this context include:

- *Increased engagement of SME and industry stakeholders; incubator role*. FIRE should develop a pathway for transforming into a sustainable platform ecosystem which attracts technology researchers, developers, and users, and offers accelerator support to SMEs and startups. This will require international collaboration with parties active in SME business support.
- *Professional support services and service orientation.* Traditional thinking is in terms of offering access to facilities mostly to specialized researchers. It is of high importance to strengthen the service thinking in FIRE's context and lowering the barrier to make use the facilities. Realizing the Experimentation-as-a-Service perspective is crucial, by setting clear goals in terms of user friendliness and ease of use, and by offering the right support services in addition to the technical work.
- *Trustworthy and secure access to resources.* Industrial users require that their use of facilities is secure and their data and results are private from all. Furthermore, they must be able to trust that resources will be available long-term.
- *Develop a marketing model to attract external users*. "Currently the user community is not aware of publicly available experimental facilities due to lack of visibility of such facilities. So it is important to develop the 'marketing model' of the facilities towards the user community (particularly to SMEs) to be intensified through appropriate channels: Liaison with regional/national business promotion organisations (e.g. chamber of commerce), Booths in the commercial events, media promotion in the commercial sector magazines, etc."[13]

6. FIRE Roadmap Towards 2020

6.1 FIRE Roadmap Phase I (2014 to 2016)

The following describes each proposed solution that we recommend to meet the prior objectives over the given timeframe. Each solution has: a numeric reference (to link to Figure 1) a description and motivation for the solution; a set of action points to be carried out to apply the solutions; indication of external support for the recommendation; and finally the targeted outcomes that lead to the roadmap milestones in Figure 4.

Resource Solutions 2014-2016

I.1.1	***Fund facilities that increase impact and relevance by balancing FI pillars***

[13] S. Bouckaert, J. V. Ooteghem and P. Demeester, "Experimenter Requirements for FIRE Testbeds," AmpliFIRE White paper, 2014

Description	In order to achieve increased impact, and reduce the gap in the FIRE offering towards the pillars of Future Internet technologies (as identified in the above technology trend analysis) it is highly recommend that testbeds in the domain of software services are prioritised. This is also suggested based upon the future phases of the roadmap (see Technology trends 2016-2018); in phase II, 5G and converged networks will see increasing prominence in research and hence such technologies will lay the building blocks for a balanced offering.
Actions	1) Prioritise funding of testbed facilities that balance the Future Internet resource offering, i.e. software and services resources that match the current experimenter demands. 2) Keep funding testbed facilities that have a proven userbase, as sustainability without an EU funding component is currently problematic. 3) Add new FIRE testbeds to the work programme 2016-2018 in areas such as 5G, IoT, Big Data, CPS
External Support	- AmpliFIRE gap analysis indicates technology needs and gaps in the offering to cover IoT, Big Data and 5G[14] - FIRE+ Call 1 funded both software facilities (e.g. FIESTA, RAWFIE, ORGANICITY) and networking (WISHFUL and MONROE). New LEIT Work Programme 2016-2017 again has a balanced call for core networking and media facilities.
Outcome	*FIRE contains cutting-edge FIRE testbeds in key areas (5G, IoT, Big Data, Cloud) Targeting demanding application areas: CPS, Media, Smart Cities*

I.1.2	***Ensure a loosely-coupled FIRE federation***
Description	The benefits of federation have shown to meet future Internet researcher needs e.g. Fed4FIRE: efficiency of tools, single access points, lowering the barrier to experimentation by only needing to learn a single toolset, supporting cross domain experiments. However, multiple federations are emerging within FIRE e.g. Fed4FIRE, FIESTA, OpenLab—and while these do not need to be centrally managed they should be aligned to easily support cross usage.
Actions	1) Creation and operation of a technical WG led by members composed of current FIRE federation projects to ensure aligned usage of facilities. Particularly to align current disparity in IoT projects. 2) Federation to become more lightweight i.e. quick for testbeds to join, and experimenters to use. 3) Call for proposal texts to indicate that new projects must carefully integrate with FIRE federations, and utilize existing software and tools.
External Support	- Technology trends (Section 2) indicate research domains of highly heterogeneous and converged technologies, i.e. move to smart systems of network applications. - The AmpliFIRE white paper on experiment methodology proposes the need for tools and federation services that support innovation[15].
Outcome	*Openly accessible, looseley coupled FIRE federation to simplify cross domain experimentation.*

[14] AmpliFIRE consortium, "The Potential of FIRE as Accelerator for New Areas of Technological Innovation", AmpliFIRE white paper, June 2015.
[15] AmpliFIRE consortium, "FIRE Experimental Methodology Challenges", AmpliFIRE white paper, June 2015.

Services and Access Solutions 2014-2016

I.2.1	***Require FIRE funded facilities to offer open access***
Description	FIRE is often seen as a closed shop, with access to facilities restricted to consortium members or by winning an experiment through an open call mechanism. This means that the number of experiments is pre-determined by the project's budget. To increase the number of experimenters, and indeed attract them to FIRE in the first place – the facilities themselves must be available for use. Open access does not necessarily mean open to all and does not mean open for free; the project can limit the experiments based upon submitted proposals to use facilities.
Actions	1) Require that a facility project funded within the FIRE+ programme has 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). Also make sure that the financial means are available for testbed owners to provide crucial support.
External support	- *FIRE Poll 3 (see appendix A):* "Overall Result: Strong indication for making open access a key feature of all FIRE facilities". There doesn't need to be a common mechanism for open access across facilities, but each must consider how to allow wider use of publically funded resources.
Outcome	*Openly accessible FIRE federations that simplify cross domain experimentation.*

I.2.2	***Improve ease of use, and repeatability and reproducibility of experiments***
Description	Work should be co-ordinated across FIRE to manage FIRE specific tools. FIRE+ in the 2014/2015 programme called for projects promoting Experimentation as a Service (EaaS); no doubt this will help users lower the barrier to experimentation. However, this does not go far enough—there remains a danger that history will repeat itself within FIRE, where individual projects created tools and there was then a need to fund convergence activities. An ecosystem needs to monitor and manage its effectiveness and make timely corrections. This means that a visible form of customer satisfaction reporting should be a requirement on FIRE infrastructure projects that support external users in future years. Start by making this a question addressed in reviews and perhaps put out a poll to existing open call/access winners. Then in future calls, specify this as one expected part of a successful proposal.
Actions	1) Implement (or choose) a separate FIRE portal which all FIRE projects (operating in open access mode) must be usable from. 2) Fund EaaS activities with preference given to services supporting reporting and reproducibility (where there remains a gap in the current service offering). 3) Funded projects required to perform customer satisfaction testing and reporting.
External support	- *FIRE roadmapping workshop, March 2014 (http://wiki.ict-fire.eu/FIA_2014_-_1st_FIRE_Roadmap_Workshop): numerous suggestions for better reporting services, and easier to use experimental portals.* - *FIRE roadmap workshop, September 2014[16]: Identification of the need to consider how FIRE can do repeatability better.* - *FIRE Poll 1 (See [3] Appendix B): 87% replied "Ease of Use" very important, 100% important.* - *FIRE Poll 1 (See [3] Appendix B): 61% replied "repeatability" very important, 89% important.*

[16] *FIRE Roadmap Workshop: Technology Trends in Future Internet Testbeds. Munich, September 2014.*

Outcome	*Openly accessible FIRE federations that simplify cross domain experimentation.*

User (Experimenter community) Solutions 2014-2016

I.3.1	***Increase broader Future Internet user base***
Description	Make FIRE accessible to the larger Future Internet community; within the Future Internet landscape: FI-PPP and GENI are prominent initiatives in this time period (as discussed in the landscape above). One instrument to implement this activity is to offer APIs that match community practices, i.e. user friendly tools and APIs. Bonfire and Experimedia are examples of FIRE resources with community APIs (with Bonfire also integrated into the Fed4FIRE federation) and highlight what is possible.
Actions	1) Require common experimentation standards across initiatives e.g. for cloud resources promote cloud APIs, for IoT resources promote IoT APIs. 2) Implement interoperability solutions between FIRE and GENI 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. 3) Implement interoperability solutions between FIRE and FI-PPP resources; consider a small action to investigate the issue in greater depth.
External support	- *FIRE Poll 2 (See [3] Appendix B) shows community agreement to align EC and global initiatives in the Future Internet to create a seamless interconnection of resources.*
Outcome	• *Increase the number of experiments operating across all FIRE facilities. A 10% increase was targeted by 2014; 10% yearly growth to 2016 would represent a significant increase in impact.* • *Growth in the percentage of SME and industrial users. The FIRE community did not see pressing need to significantly increase this user base.* • *Growth in the percentage of users from outside EC funded projects and international users.*

Framing Solutions 2014-2016

I.4.1	***Align EC Units***
Description	Strengthen the strategic alignment between FIRE and other EC programmes of research (DG CONNECT and wider); the pool of research projects offer another growing user base, and may also significantly reduce repetition of capacity building. There have been identified several opportunities for collaboration between FIRE facilities and other initiatives such as Internet of Things, Big Data, Smart Cities, FI-PPP and recently 5G PPP. FIRE should continue to promote such collaboration opportunities and continue discussions with other initiatives and related Units, based on clear value propositions that are attractive for all stakeholders.
Actions	1) Prepare for joint / shared calls for proposals, stimulating interactions among the unit priority areas. 2) Establish collaboration among EC Units to stimulate exchanges among projects involved in research and experimentation on the Future Internet.
Outcome	*Greater usage of FIRE facilities by research and experimentation initiatives within other units. Identify opportunities to share resources among Future Internet initiatives. Cross-initiative collaboration enabling seamless interconnection*

I.4.2	***Professionalisation of FIRE organisation***

Description	The FIRE initiative currently is not much more than a loose collection of EC-funded projects. In order to more easily and credible establish collaborative relations and coordinate external activities (marketing, PR), FIRE should establish an organisational infrastructure aiming for sustainability and professional service offering on the longer term.
Actions	1) Professionalisation of FIRE as a community organization (community board, priority areas, working groups, common vision development, community support). 2) Provide support for individual testbeds to professionalise their offering.
Outcome	*FIRE as a visible community to more easily to establish collaborative relations and plan towards sustainability. FIRE is more business oriented.*

6.2 FIRE Roadmap Phase II (2016 to 2018)

Resources solutions 2016-2018

II.1.1	***Fund Big Data Testbed Resources***
Description	Based on the state of the art analysis and trend identification there is a specific need to consider testbeds that will support both academic and industrial stakeholders in performing research and development in large-scale data oriented solutions: - Research into new big data software platforms, e.g. the data processing engines, data query and storage platforms, data analysis algorithms that will simplify the task of data scientists to programme and execute their solutions. Essentially this will support researchers and companies in creating the next Hadoop (or PaaS solutions). - Research into data management and resource configurations e.g. the placement and connection of data processing solutions. I.e. testing the effect of changing underlying networking technologies (SDN), or storage types (SSD versus tape). - Initial testing of new big data ideas i.e. solving a big data problem using the different platforms and resources available.
Motivation	- Need for industry-oriented testbed resources for data analysis. Access to resources to quickly prototype big data solutions to problems. Reduce the effort to learn and deploy new techniques i.e. time to create and configure a big data solution, time to learn new technologies, time to programme and deploy the algorithm. - Provide access to resources instead of costly reproduction of big data facilities across research and industry institutes. - FIRE has a growing number of data-oriented facilities, e.g. FIESTA (http://fiesta-iot.org) with limited facilities for processing of data. Hence, a FIRE federation will need to contentrate on data experimentation.
Actions	1) Add to call for proposals in the 2016/2017 work programme and beyond- new FIRE testbeds in the following areas: "Testbeds to support big data experimentation, particularly for new data processing technologies (e.g. Big data PaaS platforms), and the provision of configurable platforms to support data scientists solving big data problems."

External Support	1) "Obvious need for data resources. Big Data. Support the growing community of data scientists. Amazon Web Services only provides certain services, researchers need more"[17] 2) The MIT Big Data Initiative illustrates the growing research needs in this area, with an experimental testbed in place for support[18]. *3)* The FIWARE Mundus roadmap identifies Big Data and Cloud computing as two of five key Future Internet challenge areas[19]
Outcome	*FIRE contains cutting-edge data facilities relevant to research and technology demands to support industry and support the solving of societal grand challenges.*

Service and Access Solutions 2016-2018

II.2.1	***Fund Support action to implement cross facility experimentation***
Description	In the prior objectives 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, during this phase Fed4FIRE will no longer be a funded project, and hence particular consideration must be taken into account as to how such activities can be carried on.
Actions	1) 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. 2) Require integration of new facilities under this support action umbrella. Project budgets to reflect man power required for integration. 3) Co-ordinated open calls for FIRE experiments. Funding both single and multiple facility experiments.
Outcome	*Continued operation and management of a central FIRE federation, and also manage a central budget for cross domain experimentation by 2018.*

II.2.2	***Fund a FIRE Broker project***
Description	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 and where moving forward is 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 will similar knowledge about FIRE will be better supported, as identified as recommendation from[20] "*One of the key challenges for especially 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)".*
Actions	1) Fund action (potentially as part of a wider FIRE support action or federation project) to provide broker services across the FIRE portfolio.

[17] *BonFIRE 2020: Building Service Testbeds on FIRE.Kostas Kavoussanakis (EPCC). FIRE Roadmap Workshop: Technology Trends in Future Internet Testbeds. Munich, September 2014.*
[18] *http://bigdata.csail.mit.edu/*
[19] *Jose Gonalez (UPM). FIWARE Mundus Roadmap. FIRE Roadmap workshop Session. FIRE concertation meeting, Brussels, March 2015. (http://www.ict-fire.eu/fileadmin/events/2015-03-NetFutures/Concertation_Meeting/FIWARE_Mundus_Roadmap.pdf)*
[20] AmpliFIRE, "FIRE COLLABORATION MODELS," Deliverable D3.1, 2014.

External Support	- *FIRE Poll 2: 65% agree that setting up a broker would benefit FIRE* - *LEIT ICT 2016/2017 work programme references need for federation along with broker services.*
Outcome	*Continued operation and management of a central FIRE federation and broker – with increased FIRE usage via the broker.*

User (Experimenter community) Solutions 2016-2018

II.3.1	***Align FIRE with 5G research community and 5G industry***
Description	In this phase, the 5G-PPP will represent a large community of technology developers and researchers from across both industry and academia. With little information available about the expected composition of the 5G-PPP little can be said beyond prioritising the investigation of the relationship once the activities are in place. Further, FIRE projects may be able to participate directly through the use of their resources in 5G-PPP projects; therefore, it is important that FIRE market its potential throughout this time period. The loosely coupled federation may further evolve into the convergence of research facilities into a single federation. FIRE has progressed into this direction through the FED4FIRE project which has significant potential to support cutting edge research e.g. end-to-end research in holistic 5G architectures. A similar initiative should be considered in the 2016-2018 timeframe.
Actions	1) Implement a FIRE task force (at the FIRE board level) to investigate and manage the alignment activities. Interested projects (from both FIRE and the 5G-PPP naturally to be included in the execution of this task force. 2) Market FIRE testbeds to 5G experimenters, and indeed to the 5G-PPP as a whole to be included in 5G-PPP proposals. 3) Initiate next-phase federation initiative aligned with 5G.
External support	- *EUCNC 2015 workshop[21]: 5G Testbeds and Hands-On Experimental Research Workshop @EuCNC 2015 will discuss how the two communities can converge* - *Session 2: Accelerating 5G – How to cooperate for mutual benefits @ FIRE Forum 2015[22] identified numerous mutual benefits particularly in reducing the need to reimplement testbeds*
Outcome	*Openly accessible FIRE federations aligned with 5G architectures that simplify cross domain experimentation.*

II.3.2	***Establish FIRE technology accelerator functionality***
Description	Open Calls and Open Access have been important steps to facilitate increased use of FIRE facilities and services by researchers. The issue remains how FIRE could contribute to boosting product and service innovation of SMEs. FIRE could work together at EU level with specialized parties such as universities and research centers, science parks and business innovation networks to initiate a FIRE Accelerator initiative aimed at technology driven business creation in the Future Internet. A Support Action could initiate this activity.

[21] http://www.ict-fire.eu/events/5g-testbeds-and-hands-on-experimental-research-workshop-eucnc-2015.html

[22] FIRE Forum, Brussels, October 2014 http://www.ict-fire.eu/events/past-events/fire-forum-2014.html

Actions	1) Initiate FIRE Accelerator Lab by 2017 2) Establish EU-wide collaboration supporting the initiative.
Outcome	*Creation of a FIRE Accelerator Lab initiative.*

Framing Solutions 2016-2018

II.4.1	***Create a FIRE legal entity***
Description	To realize the vision and resolve the challenges, a Network of Future Internet initiatives (NFI) should be established as a legal entity. This would enable pay-per-use services including resource use and consultancy services; industrial and private users can have contracts in place with FIRE itself. The form of legal entity cannot be recommended at this stage, it must be decided by the participating stakeholders. Options are: - Participating companies, if they can agree on the proportions and shareholder's agreement on picking up the running costs. There is little chance for a financial upside in practice, thus fights over ownership are not necessarily going to be an issue in that respect. - Foundation: no owners — makes it neutral but: needs a starting capital which should be preserved, and needs external actors to keep up the development; these could be NewCo's or old actors with specialised missions (secretariat etc.) contracted out to them - Association: no capital needed for the legal entity. Activity depends on the interest of its members; can receive endowments by member companies, act as a beneficiary in EC funding structures etc. For example, the European Network of Living Labs (ENoLL) is organised as such under the Belgian law.
Actions	1) FIRE stakeholders to investigate and initiate a FIRE action to create and operate a legal entity; consider the options and select a legal model best suited to the co-operation (if required).
External support	- *FIRE Poll 2: 60% support the operation of a FIRE legal entity to support pay-per-use.*
Outcome	*Established FIRE legal entity supporting pay-per-use usage.*

6.3 FIRE Roadmap Phase III (2018 to 2020)

Resources solutions 2018-2020

III.1.1	***Resources to meet demands of smart systems of networked applications***
Description	FIRE should continue to add new resources that match advanced experimenter demands. There is a need to consider 5G testbeds, large-scale data-oriented testbeds and testbeds relevant to large-scale IoT and CPS. Eventually FIRE will create resources and offer services based on Experimentation-as-a-Service. The new application areas emerging e.g. Augmented reality, virtual presence, rich media, smart manufacturing, etc. that may be the application areas of research in this period will need to be supported. More specifically, we see smart systems of networked applications across IoT, Data, and 5G resources as the basis of resources.
Actions	1) Add new FIRE testbeds to the work programme 2018-2020 in areas relevant to new research areas. 2) Integrate FIRE experimental facilities with experimental facilities of other initiatives

External Support	- AmpliFIRE gap analysis indicates technology needs and gaps in the offering to cover IoT, Big Data and 5G[23]
Outcome	*FIRE contains cutting-edge facilities relevant to research and technology demands of smart systems of networked applications*

FIRE Service and Access Solutions 2018-2020

III.2.1	***Implement Secure and Trustworthy Resources***
Description	To attract industry it is necessary to create secure and trustworthy facilities e.g. a trusted cloud facility, or a commercially relevant 5G infrastructure. Therefore, to implement such capabilities it is required that relevant projects move forward and mature their services. Future projects willing to be industry facing must then follow similar methods.
Actions	1) Ask for percentage of project budget available for secure service development and collaboration with industrial partners to meet requirements. 2) Projects to have industrial partners to lead such activities.
External Support	- *FIRE Poll 1: 86% of responders agreed for the need for secure and trustworthy resources*
Outcome	*Industrial users attracted to FIRE based on their trust in the services.*

User (Experimenter community) Solutions 2018-2020

III.3.1	***FIRE implements responsive SME open calls***
Description	Experimedia successfully demonstrated the benefits such a mechanism provides given the short planning involved in the operation of an SME. This process was similarly followed by Fed4FIRE after the initial open call showed that the "general" open call mechanism which is open to academia and SME/industry at the same time makes it very difficult for SMEs to compete with academia and research institutes, as academia and research institutes are (i) more used to writing proposals and (ii) typically have a different way of interpreting innovation; For SMEs, innovation may be less ground-breaking than for academic researchers.
Actions	1) All projects required to tailor their open calls to SMEs in a responsive mode. 2) Central open calls implemented by FIRE support to target SMEs.
External support	- *FIRE Poll 1 (See [3] Appendix B) indicates the need for SME usage to grow, if not to the primary usage.*
Outcome	*Lower barrier for SMEs leads to increased SME usage.*

III.3.2	***Provide Start-up Accelerator Funding***
Description	A well-known example of a Future Internet Accelerator initiative is the DAIR initiative which is part of CANARIE. Possibly FIRE could work with regional stakeholders such as universities to develop regional Internet Accelerator Hubs, integrated cooperation-based initiatives where FIRE collaborates with NRENs, FI-PPP, academic and research institutes with regional presence and already working

23 AmpliFIRE consortium, "The Potential of FIRE as Accelerator for New Areas of Technological Innovation", AmpliFIRE white paper, June 2015.

	in FIRE. Complementary, FIRE could establish cross-linkages with the ESIF (Structural Funds) and initiatives developed by the Committee of the Regions.
Actions	1) Concretely an initiative could be part of the next Work Programmes focusing on (collaboratively) creating a regionally-based accelerator initiative, co-funded by regional resources, by ESIF and by Horizon project calls.
Outcome	*Start-up funding for full service accelerator*

Framing Solutions 2018-2020

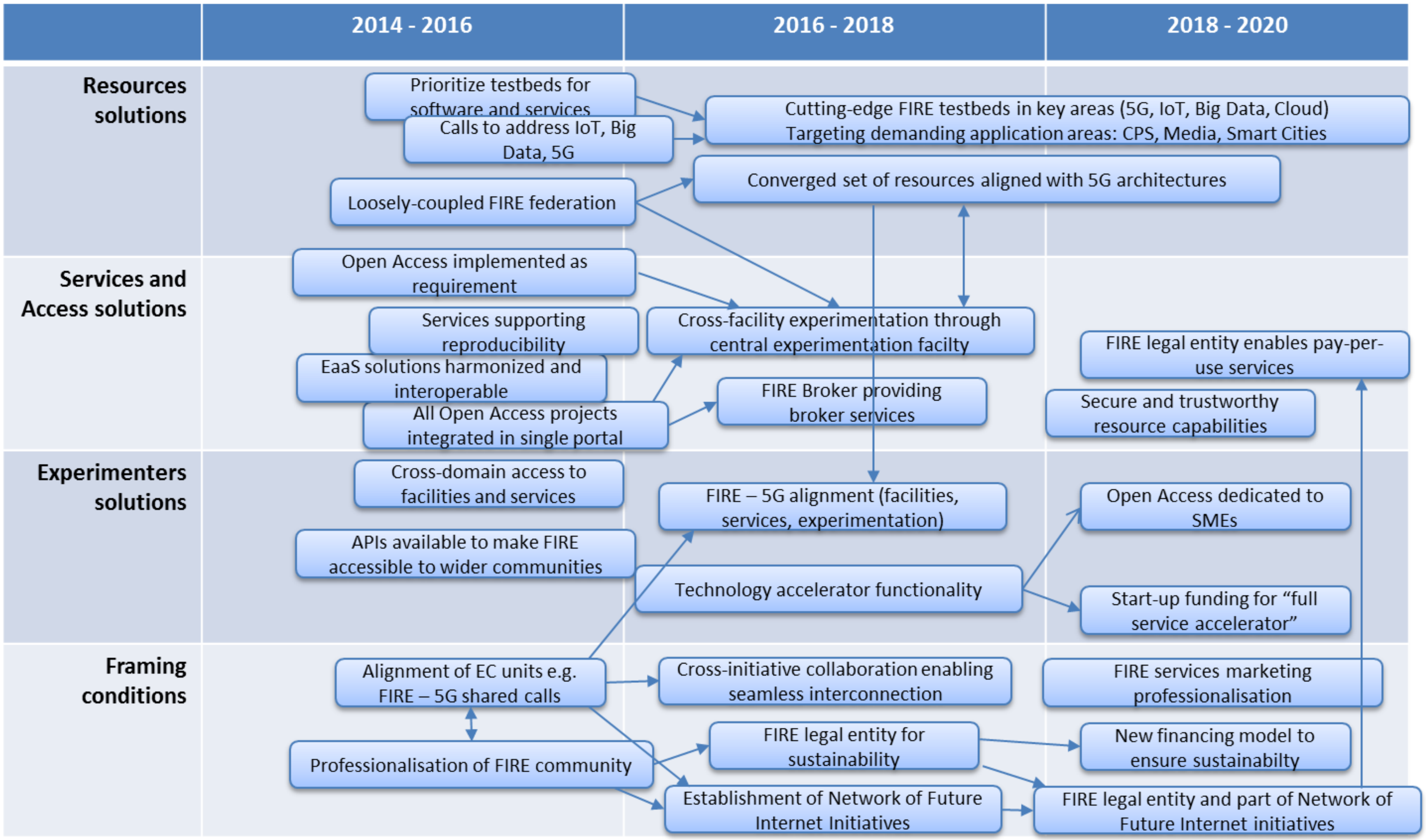
III.4.1	***New Funding models for continued operation of testbeds***
Description	FIRE supports sustainable facilities with continued minimum funding (small % of funding for experiments carried out). Hence, there is some guarantee of sustainability of industry important facilities beyond a project lifetime. On a usage basis; facility projects have access to central funds—supporting a lightweight, demand driven model. For example, project X needs to have access to a testbed; they ask the testbed for a quotation; the testbed makes an offer for this and can indicate to project X that the testbed access they require can partly be funded through a “central mechanism”. The central mechanism should be very lightweight in this. This will create a new finance model that encourages projects to be successful (rather than simply support their own experiments); with increased demand they have access to further funding.
Actions	1) Require project budgets to make room for operating in sustainable mode e.g. 1 year after project finishes. 2) Define funding method for operation costs of testbeds and facilities. All continuation proposals to be fully costed with a sustainability plan and business model. 3) Define KPIs for impact and relevance; offer first point of cut off for projects. 4) Rethink 50% budget for open calls in projects. Restricts development work to advance existing facilities to state of the art.
Outcome	*Continued operation of facilities beyond project lifetime.*

III.4.2	***Integrate FIRE legal entity into a Network of Future Internet Initiatives***
Description	To realize the vision and resolve the challenges, a Network of Future Internet initiatives (NFI) should be established as a legal entity. This would enable pay-per-use services including resource use and consultancy services; industrial and private users can have contracts in place with FIRE itself.
Actions	1) EC to initiate a FIRE action to create and operate a legal entity; either through public funding or a partnership with an organisation willing to take on the role/costs.
Outcome	*Established Network of Future Internet Initiatives.*

7. Key Roadmap Milestones

The roadmap solutions lead to a set of key milestones indicated in Figure 2; these highlight FIRE’s achievements by specific dates towards 2020. That is they take the separate solutions and plan a sequence of milestones that move towards the objectives over time.

Figure 4. FIRE Roadmap Milestones



8. Alternative Pathways

This roadmap has so far illustrated a series of trends and, based on the FIRE future vision and a set of objectives, identified the related solutions that can achieve these specific FIRE strategic objectives (as first provided in Deliverable D1.2). We have made specific recommendations to achieve the objectives. However, there are uncertainties, in particular in terms of budget and alignment of EC Units that mean that the proposed paths cannot be followed. Here we consider the alternative paths to react / anticipate to uncertain events.

1. *There is limited budget available to advance FIRE in new directions, and there is limited support for the proposed changes—hence FIRE continues as "normal"*. In this situation, FIRE funds experimental testbeds and experiments based on the work programme call text. It follows current research trends and leads to a range of increasing federated cutting edge facilities that are available in the medium to long term (5 to 10 years). FIRE further advances Experiment-as-a-Service tools and the experiment lifecycle for Future Internet technologies. Stakeholders remain largely academic researchers and testbed operators. FIRE specializing on a core methodology may still establish its relevance towards large-scale networking initiatives in particular 5G and IoT.
2. *Changes to increase SME and industrial usage do not bring about the expected impact, budgets are decreasing and FIRE concentrates on becoming a social innovation eco-system.* FIRE funds experimental testbeds and experiments based on the work programme call text—it follows current research trends and leads to a range of cutting edge facilities that are available in the medium to long term (5 to 10 years). However, the focus shifts to facilities where end-users and societal challenges play an important role. For example, through co-creation of content and services, through data collection and curation, and through crowd-sourcing activities. FIRE's stakeholders are societal stakeholders, academics and communities wishing to solve open socially important problems through experimenting and applying advanced Internet technologies. For example, sustainable smart cities or climate/environmental monitoring.
3. *FIRE budget changes meaning less support for new facilities, but there is a growing industrial base willing to pay for use; hence FIRE moves forward as an industrial co-operative*. FIRE facilities are selected over time to meet current industry and SME needs. FIRE becomes a secure and trusted federation of experimental facilities that can be used early in the innovation lifecycle e.g. initial proof of concept of ideas, early experimental testing, and gaining confidence for initial market trials. FIRE stakeholders are largely SME users without the financial means for larger scale test, and who can gain significant value from the facilities at low cost.

9. Implications for next Work Programmes

A concrete step towards implementing the FIRE Roadmap is to include elements into the Horizon 2020 LEIT Work Programme. For 2016 – 2017 this Work Programme is already available in draft (version February 2015), and AmpliFIRE has provided inputs to this Work Programme end 2014 and early 2015. Therefore as a conclusion we focus on formulating some recommendations as regards the next Work Programme(s) covering 2018 – 2020. The roadmap as presented in section 6 for the period 2018 - 2020 provides a detailed overview of suggested elements of which the following are highlighted.

1) **Make FIRE facilities more easily available for SME innovation**. Open calls and open access are effective instruments to some extent, within the context of a project. FIRE must ensure technical support services are available to quickly bootsrap the use of technical facilities by SMEs. Further, sustainable support for product and service innovation by SMEs

and startups requires international, European-wide collaboration or partnership with existing players specialised in business support. It also requires to concentrate more thoroughly on service provision and service management (easy access, customisation and use of experimental facilities, tools, and methods).

2) **Increase FIRE's relevance in focusing on Internet of Things and related application domains**. IoT is a key development in the Future Internet. FIRE is well-placed to further expand into this area. FIRE should consider more comprehensive IoT facilities that allow realistic experimentation with real-world impact e.g. in Cyber-Physical Systems. This way FIRE will also more easily connect with related activities e.g. Big Data and Smart Cities.

3) **Support Big Data requirements**. Through additional or improved FIRE testbeds that can add to the heterogeneity and scale of experiments.

4) **Address convergence to large-scale smart systems**. FIRE should consider what future testbeds will look like for large-scale, smart networked systems i.e. where the technologies from smart networks, Big Data, IoT converge to a new technology class. FIRE should anticipate to such development in bringing closely together "experimentation" and "innovation", and accordingly further develop its methods and tools.

5) **Develop FIRE into a self-organised professional community.** The FIRE community and the Experimental facilities unit should work together to establish a visible, active community. This implies creating a form of self-organisation entity which establishes a board and working groups, which plans aligned dissemination and communication activities, develops common views about FIRE's future, and which is also capable to engage in contracting activities.

References

[1] AmpliFIRE D1.1: FIRE Vision and Scenarios 2020. Report 2, May 2015.

[2] AmpliFIRE D1.2: FIRE Future Structure and Evolution. Report 2, March 2015.

[3] AmpliFIRE D1.3: FIRE Ecosystem Progress Report. Report 1, September 2014.

Appendix A: FIRE Roadmap Poll 3 Results: Open Access

Open access to experimental facilities provides anyone with the opportunity to use FIRE. Open access does not necessarily mean open to all, or available for free.

There are two important dimension to open access:

1) Who can access a testbed? Anyone can access, or an experimenter can make a proposal and have it vetted (evaluated by the testbed), if accepted they will have access.

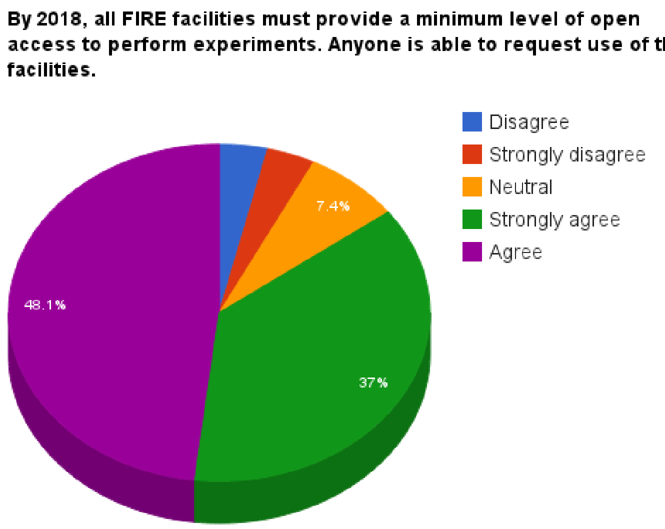
2) What can experimenters access? The access they receive is limited in extent or amount, perhaps with charges for additional privileges (such as more resources or technical support). Or access and support is completely unlimited.

In this poll we sought opinions regarding the extent to which FIRE facilities should provide open access to experimenters wishing to leverage their facilities for their research. We now present and analyse the results of the poll in question by question fashion.

Q1 - Open Access in FIRE

Overall Result: Strong indication for making open access a key feature of all FIRE facilities

The first question focused on the importance of providing access to FIRE facilities. The current responses shown in the chart below indicate overwhelming support for open access in one form or another, although comments indicate that significant thought must go into the operational and management details of such access.



The responders to the poll provided further detail with opinions regarding what this would mean, particularly for how use of the facilities would be funding; and how resources would be accessed. We provide these comments directly:

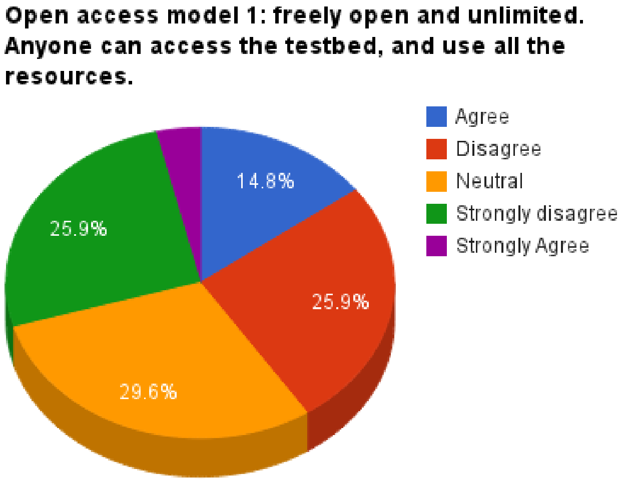
Funding	• *The basic thing to note here, is the funding model of the testbed: if the testbed is funded by local money, it cannot be pushed from FIRE that there should be open access for that testbed. (just as the testbed can disappear suddenly if the institute decides to stop funding)* • *Since testbed are built with public money they should be accessible to the public, at least at some minimum level. Researchers should be able to get preferred access based on transparent criteria.*

Resources	• *Everyone can *request* access, but resources are not infinite and testbeds are not well understood production services. We need a general guidance policy on how to prioritize programs and service levels.* • *In general, we want to reduce obstacles to access. So we should only limit where testbed resources themselves are limited, and then only to insure fair sharing (or prioritized sharing as we deem appropriate) , to insure the continued availability of the facility, and to insure the facility is not deliberately or inadvertently turned to the dark side.* • *In general, we do not want to pass judgement on the veracity of the research - that is for other review panels to decide. But we should be able to vet projects on their timeline, funding level from other (or this) program, etc. There must be a clear service description if real money changes hands (that are not FIRE funds).*

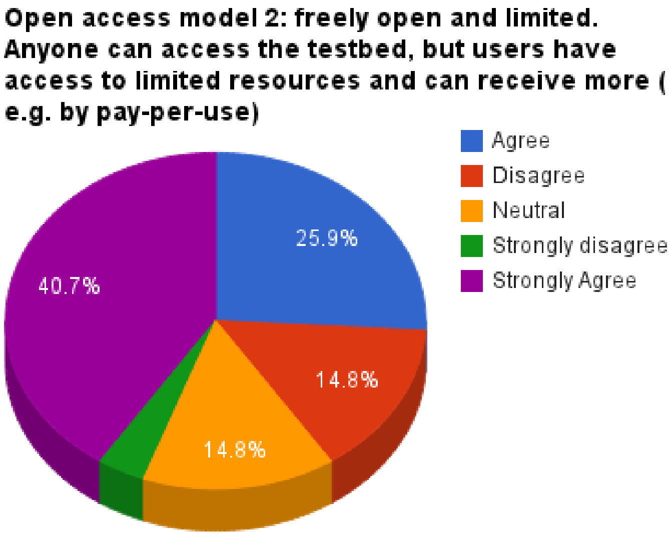
Q2 - The Preferred Open Access Model

In the second question we looked at the different models of open access to determine which were best suited to FIRE resources. Clearly opinion about these models will be driven by the facilities they are attached to. Responders were asked to choose a facility and hence we perform deeper analysis later to see whether different models are better suited to different testbeds or federations.

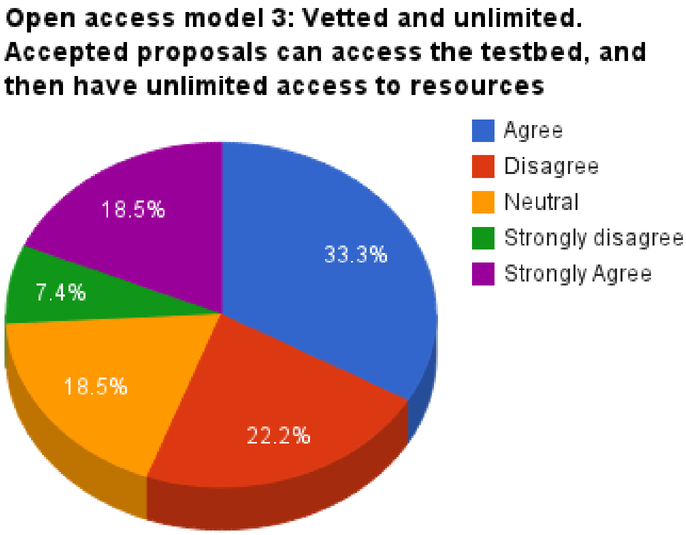
Model 1: Strong trend to disagreement for reasons of misuse, resource availability and cost:



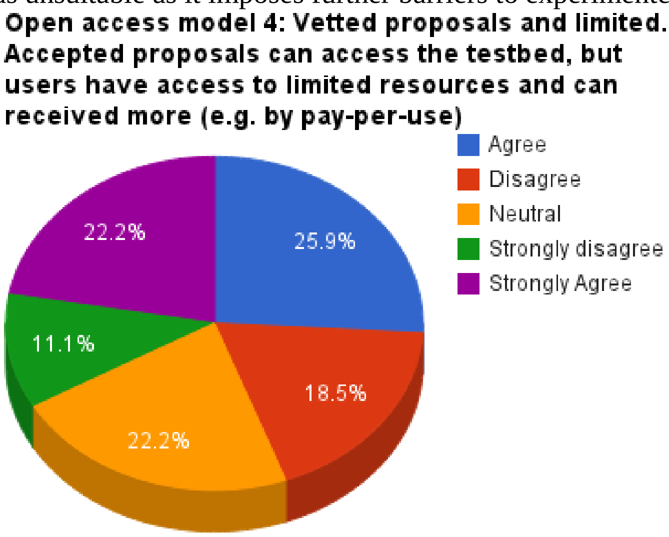
Model 2: Preferred option and aligned with Fed4FIRE:



Model 3: Tends towards a suitable model for some if not all FIRE facilities:



Model 4: Tends towards unsuitable as it imposes further barriers to experimenters:



Analysis of Models

Clearly Models 2 and 3 are favoured in providing the right level of incentives to attract experimenters, but there needs to be case-by-case thought on the level of resources that an experimenter receives when they wish to scale up. We now look at whether the facility affects the choice of model, and what this means for implementing open access across different types of testbeds. The table below captures this data - the responses for each testbed are collated and based upon the weight of answers a Yes or No indicates whether the model is preferred or not.

Facility	**Model 1**	**Model 2**	**Model 3**	**Model 4**
All FIRE	N	Y	N	Y
Fed4FIRE	N	Y	N	Y
CREW	N	Y	N	N
Flex	N	N	N	Y
CONFINE	N	Y	N	N
SmartSantander	N	Y	Y	N
Non-FIRE testbed	N	Y	N	Y

These results indicate some important lessons:

- ***For federations and cross FIRE models; having a fully open model means that resources must be limited but allows testbeds to sell their offer; and then getting more resources means vetting proposals.***
- ***Individual testbeds may need to set their own models beyond the cross FIRE ones.***

Analysis: The Fed4FIRE open access model

As input to the poll, Fed4FIRE described their open access policy:
"In Fed4FIRE we will do it as follows, which makes a lot of sense we think: if you get an account in the federation, this allows you to execute a basic tutorial on every testbed. This tutorial is set up by the testbed itself (so the testbed can put things in focus they want and give resources as they want). This gives the experimenter access to all testbeds to learn what it can do, while using only very limited resources.

After that, he can submit a short request to particular testbeds (available in all tools of the federation!), to ask for more resources and a description. Each testbed can then grant as they want. (Policies are decided by the testbeds, NOT by the federation). So testbeds can decide individually on pay-per-use

This aligns with model 2 and gives further indication of the types of access that can and will be provided across FIRE testbeds

Additional Comments

Respondents also discussed the issue of vetting proposals i.e. in terms of implementing an open access procedure. The following comments are presented but they indicate that this shouldn't scare people away and should do its best to be inclusive of valid research:

Vetting	• *Vetted access should be generous - i.e. we want "good" research or a compelling development testing scenario so that the testbeds operations are not weighed down by busy work. That said, we do want to encourage even small users/companies to innovate. I would gauge access to the facility since resources are not unlimited.*

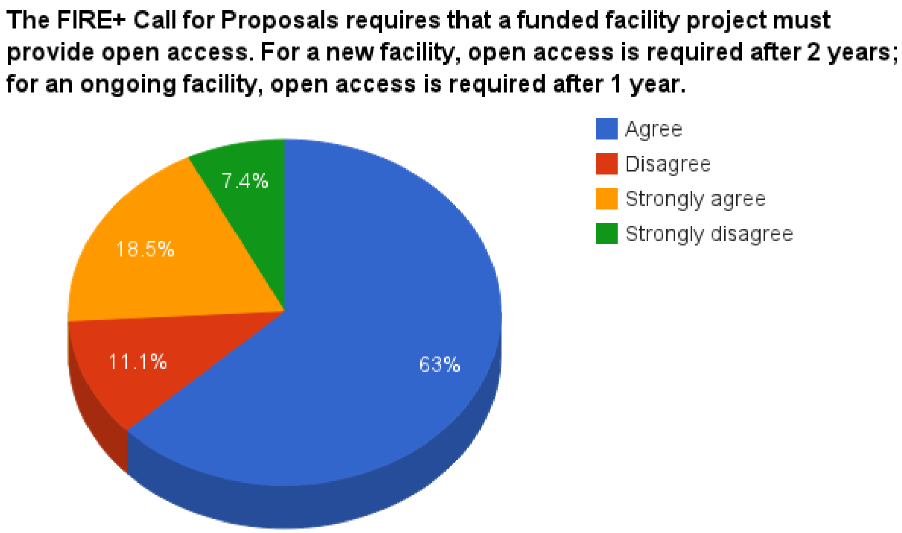
	• *Access should be "generous" - maybe a novice mode that allows one to kick the tires but no large scale resources, a normal mode of vetted research that has mostly unfettered access, and super users who have a very compelling need to monopolize all or a major part of the facilities for periods of time and who may be evolving the facility itself.* • *Case by case. There are always exceptions - constraints of providers (legal, technical, economic), the business model maturity of the testbed (are they ready to charge) and the demands of the experimenter (will they hog the resources and squeeze out others?).*

Q3 - Implementing Open Access across FIRE

We proposed that the work programme offers the capability to make open access a requirement i.e. the DoW of proposals must describe a procedure. We then asked if the following call text would be appropriate:

"The FIRE+ Call for Proposals requires that a funded facility project must provide open access. For a new facility, open access is required after 2 years; for an ongoing facility, open access is required after 1 year."

The results indicate that the **community strongly agrees with this requirement to make successful proposal consider some form of Open Access**.



Further comments from responders

Time	• *I believe that open access has to remain in place for at least 4 more years*
Call text	• *If the testbed is funded by the EC, then it seems logical that the EC can set the policy, e.g. for open access.*
Risk	• *Additionally one of the big issues in project work is a project must fulfil its contract with the EC. Creating a dependence (and therefore risk of contract breach) on a 3rd part testbed is a tough sell - lessened with a guaranteed availability over a defined time window. The shorter that window, the higher the risk, the less attractive the facility.*

Q4 - Drawbacks of open access

Finally, we optionally asked for comments about the drawbacks to open access. We list some of the contributors comments here:

1. *The rule just above (Q3) may make it impossible to bring in really innovative testbeds, but this will have to be dealt with through either longer time frames or research contracts before a facility contract is appropriate.*
2. *Management overhead for the project, Risk for the providers. Both manageable.*
3. *If security and isolation of testbeds and the outside is correctly enforced, there is no major drawback. Otherwise, it may be a huge drawback even though users are known and can be traced.*
4. *Do we support projects not based in Europe? I presume open access includes commercial enterprise. I think this is good, but we need to address the aspects of public funding and intellectual property. Are results of open access research then to be open as well?*
5. *IMO, "testbeds" are different from a production facility that provides a service (even if that service addresses research needs). A service tends to have a broad based model that can serve a broad constituency - some generalized notion of the "service" it provides to a large customer base. Where as a "testbed" is specialized to address a particular R&D topic (e.g. openflow, photonics transmission, mobile or wireless, or even higher layer topics - security, privacy...) testbeds may be less malleable, or may need specialized resources - and may not have a large prospective customer base to uses a particular piece of technology.*
6. *"Federation" is still poorly understood and not always feasible (for good reason IMO) There are still many issues with even similar testbeds interoperating. A) is there a need for a common authorization service even if the testbeds themselves do not or cannot interoperate? B) under what scenarios do we expect testbeds to interconnect or to interoperate?*
7. *Overloading may be a problem - but this usually happens only before large conference deadline.*
8. *Open Access means testbeds are serving users with requirements for availability in timeframes that might interfere with project timeframe.*
9. *Financial sustainability for the testbeds' NOC.*
10. *We need to be clear that open access does not mean sustainable, which is the real challenge along with building up a user base, preferably one that pays.*
11. *Misuse*