Introduction

Research and innovation are key elements of the European research framework programmes to achieve European competitiveness in the world. Europe is promoting fundamental research to practical product innovation over number of years to stimulate the development of new products and services, which will lead to economic growth.

An important enabler of research and innovation in practical terms is the provision of European Future Internet Research Experiment (FIRE) facilities. The initiative started in Framework programme 6 (FP6) with funding number of testbeds development for different technologies and have evolved in the provision of multiple federated testbeds and experiment facilities in FP7 programme. This white paper will provide an overview of this evolution leading to the next level challenges to meet the users’ requirements and possible approaches.

There are other project deliverables from FIRE support projects FIRESTATION (D3.2, D3.7) and MyFIRE (D4.2) who have detailed the capabilities and resources of the FIRE projects in the timeframe of 2007-2012. Many of those early projects have been concluded and may not be available as experimental facilities for the open research community currently. Hence this paper will not include them while covering the research experimental facilities that are currently available.

There are parallel frameworks which have created additional infrastructures initiatives from different sectors (future Internet, Energy, security, critical infrastructure, etc...) under different schemes. These are covered under Research Infrastructure (ESFRI e.g. GEANT), Future Internet Public Private Partnership (FI-PPP), European Living Labs (LivingLabs), the European Institute of Innovation and Technology (EIT ICT Labs), CIP PSP-ICT, Future Emerging Technologies (FET) etc... In addition to all these infrastructure projects, national Governments have also created the infrastructure to promote the research and innovation in various sectors. The fragmentation in the provision of research infrastructure is one of the issues that comes under preview while preparing the review of European research facilities, which is briefly addressed in this paper. The details of all these are provided in the AmpliFIRE deliverable D2.1: FIRE portfolio capability Analysis.

The research experiment facilities should meet the user/researcher requirements with research and engineering experiment facilities, experimenter- and innovation-oriented methodologies, platforms to attract business interest and business model frameworks for collaboration and partnering. FIRE projects include 2 categories of projects: Integrated projects and STREPs. Only Integrated projects are considered to provide access to external user communities and hence are considered as the research experimental facilities. The STREP projects are funded as part of the strategy to test a specific technology or experiment from the closed research community, which can become part of research experiment facilities when integrated with open platforms.
FIRE Portfolio

Testbeds are an essential element for experiments since they provide the diversity and scale of resources necessary to deliver insight into the behaviour of ICT systems. The trend for increasingly interconnected applications, services and infrastructures means that individual research teams are not able to develop, operate and sustain the complexity of resources required to test their ideas. Global initiatives have emerged to provide resources and supporting management tools for Future Internet experimentation.

The current spectrum of experimental facilities include access to wired and wireless networking, Cloud environment for data processing, high-throughput and high-performance computing, data infrastructures, software/middleware, including authentication and authorisation infrastructures and virtual research environments that are to be used by international virtual research communities. The figure below shows currently active research facilities in the FIRE framework.

![FIRE Facilities Timeline](image)

Though TEFIS has ended in 2012, the research facilities are available for external community if the experiments are innovative and interesting. Fed4FIRE is the latest project with number of testbeds federated into this large scale experiment facility active since 2012. Two new facilities in SUNRISE and FLEX will be in place from 2013 to 2016 timeframe, which are being contracted in Call 10.

In the FP6 framework, FIRE facilities were very specific on technologies and some of those testbeds evolved and got integrated to federated testbeds in FP7 framework. Federation being considered as the key for large scale experiments to fulfill the demand of the future Internet researchers so that all facilities can be provided in the form virtual services such as Infrastructure as service (IaaS), Platform as a service (PaaS), Network as a service (NAAS) and software as a service (SaaS) leading to new paradigm of Experiment as a Service (EaaS).

Fed4FIRE facilities are in a position to supply most of the researcher demands will all kinds of technologies, tools and methodologies federated and providing a unique user access interface to the user community.

SUNRISE is expected to support underwater communication networks which combine undersea sensor networks, robotics and future Internet technology, which were not covered in other existing facilities.
FLEX facilities are expected to federate cellular and LTE networks to cover the gap in the mobile networks scenario.

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<th>Key Technologies covered</th>
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<td>SUNRISE (2013-)</td>
<td>Underwater communication networks: infrastructure, sensor networks, robotics</td>
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<td>FLEX (2013-)</td>
<td>Federate mobile network testbed: cellular and LTE</td>
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<td>Fed4FIRE (2012-2016)</td>
<td>Large scale Federated testbed for wired, wireless and cloud networks: demand driven common network with standardised interfaces and a structured approach to making experiments.</td>
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<td>CONFINE (2011-2014)</td>
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<td>Facility providing control and experimental plane middleware by deploying software and tools to choose appropriate testbeds.</td>
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Table 1: FIRE Projects and Key Technologies addressed

European non-FIRE infrastructures and facilities

**FI-PPP**: Two key projects of FI-PPP are Fi-WARE for the provision of infrastructure in the form of ‘Generic Enablers’ and XIFI as capacity building project for promoting the federation of infrastructures identified across number of initiatives. The current FI-PPP programme is active until 2016. The first phase with development of Generic Enablers (GE) has been concluded and the second phase with the development of core platform and early trials have started with launching of call for proposals for specific use case scenario based projects.

**EIT ICTLABS**: European Institute of Innovation and Technology (EIT) has been launched to promote innovation and competitiveness in three knowledge and innovation communities (KIC): climate change, ICT and sustainable energy. EIT ICTLABS has six focus areas: Smart space, Smart energy, Health & Wellness, Digital cities, Future Media and content delivery and Intelligent Mobility and Transportation. The EIT ICT Labs' model, the so-called "catalyst-carrier model" adopted in which the facility providers, research institutes and the entrepreneurial ideas are brought together to change the mind-set towards the promotion of a more innovative and entrepreneurial culture. The carriers in the model represent the experimental facilities, such as FIRE. ICTLabs aims to integrate hardware and software platforms to experiment and validate technologies and applications.

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1. [www.fi-ppp.eu](http://www.fi-ppp.eu)
2. [www.eitictlabs.eu](http://www.eitictlabs.eu)
Living Labs\(^3\): A Living Lab is a real-life test and experimentation open platform where users and producers co-create innovations. Living Labs have been characterised by the European Commission as Public-Private-People Partnerships (PPP-P) for user-driven open innovation. The initiative started with different funding models started in 2006 with few projects has evolved into the community of 340 Living Labs projects in 2013 with communities worldwide, with 80% share of European communities. Living Labs research has proved that user involvement leads to innovative ideas and the user community generally assesses innovative ideas differently from the enterprise.

National Testbeds\(^3\): Most of the European member and associated states also promote innovation through the provision of research infrastructure in the form of Technology parks associated with the publicly funded research institutes and Universities. They also facilitate incubator facilities to the SMEs to test their innovation ideas and promote the marketing of their products and solutions. These infrastructures are made available in the vicinity of the SME communities with link to experts at the research institutes to assist the experimentation with the new ideas: these infrastructures have high potential for innovation due to the networking of the communities (technical experts, entrepreneurs and financial assistance). They should be integrated to larger experiment facilities to extend the horizon of experimentability and have higher impact on the European competitiveness.

**FIRE Portfolio Requirements and Gaps**

For any research experiment facility the sustainability is one of the major criteria. The sustainability depends on the usage of the offered research facility by the research community effectively with innovative experiments. In other words the Research experiment facilities should be primarily developed to supply the demands or needs of the user community. During the evolution of FIRE facilities from FP6 to FP7 time period many of these experimenter requirements are considered to improve the attractiveness of the facilities.

The major experimenter requirements are the services that are coherent, managed and above all integrated so that they can work on the experiments they want to run, to validate the specifications and functionalities supported. In the current FIRE portfolio the key performance indicators (KPIs) are not defined to measure the impact of experimental facilities in terms of number of external users, experiments run and innovation levels of those activities. Of late, it has been recognized and the model of ‘Open call’ has been introduced to attract the innovative experiments by the SMEs and research community with public funding to the user community. Enhancing the role of user involvement in relation to future Internet experimental research is one challenge for the years to come. Some new projects such as Smart Santander, Experimedia have reached partial success in the smart city and networked media environment, involving Living Labs and the users. Meeting the user requirements needs a demand driven evolution of the testbeds, as well as dynamic models to facilitate the sustainability of the features offered by the set of test beds considered as one global federated facility.

FIRE facilities represent multi-disciplinary and user driven approach in defining the experiments execution in federated testbed environment. Hence FIRE can provide an appropriate platform for creating innovative start-ups, through the provision of incubation facilities by providing research

\(^3\) www.openlivinglabs.eu

\(^3\) CEFIMS project deliverable D3.2 – Report on existing Member State Future Internet activities
support and go-to-market assistance. SMEs being the backbone for the economic growth of any regions, their needs have to be met along with the necessary technical support for experimentation. The open call experiment has addressed part of their requirements, but still the participation of SMEs is limited due to various reasons. One of the reasons being lack of awareness of available facilities and usability of the testbeds. There is a need to promote marketing segment by Facility providers participation in the national ‘chamber of commerce’ and ‘Technopark’ events with SMEs participation so that they can reach the SMEs directly. It is conceivable to build an alliance of all stakeholders (public, industry, research institutes and user communities) to deploy sustainable testing platforms and to manage them to meet demand and supply model to certify the compliance to the standards and specifications, to promote the Go-to-Market initiative by provision of incubation models.

The large industries have their own experimental facility infrastructure to protect their IPR and hence are not major users of the FIRE facilities. However, FIRE provisioning the federated large scale experimental facility, the model should be developed so that they connect their facilities with the FIRE to extend the scalability and multi-functional testing possibilities. Such scenario should also foresee the possible provision of making ‘open experimental platform’ for research community usage of investments.

Innovations are not limited to the engineers only in the new WEB culture environment. High school and College students are real potential entrepreneurs and innovators. Hence, an open platform to assist such young entrepreneurial community will have a big impact on the innovation promotion.

**Technology Evolution and Promotion**

Future Internet landscape goes beyond the traditional methods of experiments and testing. DATA centric (big data, linked data, data storage, Software defined networks and Services,.. ) communication networks needs different perspective of experimental methodologies. The new model should be ready to address non-linear behavior systems derived from open world events with an increasing periodicity of change, approaching real-time in applications. Researchers need assistance with the provision of testbed resources supported by a systematic experimentally driven methodology that considers how socio-economic and technical factors within the environment influence specific ICT innovations. FIRE must support an experiment lifecycle that considers data (i.e. observations and measurements) at its core as the basis for reproducibility and the assessment of value propositions resulting from hypothesis testing. There is a need to combine FIRE and Living Labs Models to find the best way to meet the real time changes expected in users’ behavior to capture user friendly solutions as part of innovation life cycle. Simulation technique (for larger experiments) should become part of technology evolution so that experimental results can be properly validated with the limited users’ participation.

The future experimental facilities should consider user needs in terms of Technical and usage requirements, experiment methodology, functional features to support the specifications compliance testing with a user friendly interface to configure the testbed to meet the experiment needs.

The need of infrastructure is fundamental to support various use case scenario testing. In Europe, though infrastructure for the scientific community is well developed, they are fragmented under different frameworks. FIRE federated experimental facilities and Living Labs, interconnected through regional NRENs as part of GEANT network and the FI-WARE generic platform being deployed by FI-PPP initiative provide an existing base to further develop smarter infrastructure in Horizon 2020.
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FIRE facilities should be able to reach SMEs and researchers at the remote places of Europe. In such scenario, Infrastructure as a service (IaaS) can be foreseen which will effectively support all research community users across Europe.

Technology is evolving as part of service offering to meet the user needs. In the current scenario services offerings from the facility providers are not well defined. The future FIRE facility will depend on the provision of infrastructure, platform, network, software as services (IaaS, PaaS, NaaS, SaaS etc.) in Cloud Computing and software defined networks (SDN) scenarios.

Software applications for monitoring, business processes, test environment and communication across modules and systems in the testbeds provided as tools in the current scenarios are not easy to use, since the user community is not familiar with different tools used in the testbed facilities. Those tools and methods should become transparent in the form of Software as a Service (SaaS) in the future. Such offer will improve the maintenance and support needs of the user community. The SaaS should also include security and privacy issues to guarantee the IPR issues of the users.

The issue of standardization as an approach to innovation is not considered in any of the research testbed activities. Since standardization provides a wider market place, it is necessary that the European researchers participate in standardization process and create standards from their research results, which provides them a leading position to market place. Standards are good for benchmarking different competing solutions. As a part of innovation promotion the research facilities should consider Incubation facilities for the new products to strengthen the innovative experiments and to attract the creative ideas and entrepreneurs, with Go-to-Market assistance to make the future FIRE facilities as a platform for innovation to achieve European Competitiveness success in the international market. Innovation prizes are to be introduced as part of innovation promotion in the FIRE framework.

**Future Requirements**

FIRE will continue to evolve in Horizon 2020 framework to support the European research community. It is expected to develop the synergy across multiple experimental facilities to offer cohesive experimental facilities across FIRE, FI-PPP, EIT ICT Labs and Living Labs to support ICT related priorities of Excellent Science, Industrial leadership and Social challenges. With this approach, the experimenter requirements of FIRE includes heterogeneity of resources and devices; software-defined data centers and cloud networking; security; and rising demands for better quality of user experience.

GEANT, the federated NREN network of Europe is one of the important milestones in operation as a scientific infrastructure in Europe. The key measure of the success of GEANT is that 3500+ universities or research institutions are reachable through a coherent network organisation. The size of this scientific community, which corresponds to the European Research Area is unique in the world.

The FIRE facilities should address the capabilities, collaboration models and service offering portfolios to support future research and innovation ecosystem, through GEANT type of operational network involving all NREN networks and facilities to facilitate matured experiments across the EU in a virtualised mode by using one or multiple resources in integrated and federated infrastructure
environment, which would have potential for international dimension. It is important to coordinate
the experimental facilities federation with virtualised service provision to include all available
experimental facilities and market with good dissemination tools for different business sectors, to
achieve the major impact.

The experimentation processes are still inefficient due to lack of adequate and comprehensive
measurement and evaluation frameworks (including the definition of adequate measures and Key
Performance Indicators (KPIs)), which are the main barriers to the systematic improvements in the
different areas of activities of an organisation or entity involved into experimentations. Little effort
has been allocated to the “reporting”, “analysis & evaluation” and “decision taking” processes, which
should be addressed in the future.

**Experimentation as a Service (EaaS):** Future FIRE facilities are expected to support new paradigms
which are more oriented towards software defined networks and services which corresponds to
virtualisation of all kinds of services such as IaaS, PaaS, SaaS etc.. Such virtualisation requires access
to the testbed at any location to the user as a service offering for the experimentation leading to the
new paradigm of 'Experimentation as a Service (EaaS)' with virtualised operational networks and
services. EaaS is expected to provide on demand federation and reconfiguration of facilities and
platforms, in order to serve the researcher's requirements and provide tools for reporting, benchmarking and monitoring.

**Usage models:** Key performance indicator (KPI) of any research facility reflects its usability factor.
The most critical parameter of the maturity of offered services is reflected in number of experiments
carried out by external users. The usage in the current facilities is relatively low either due to lack of
awareness or the lack of maturity of research facilities. The open call model adopted in Integrated
Projects of FIRE provided some feedback on this aspect. Awareness is poor among the SMEs and
business communities as there were not many new entrants according to the statistics. Hence
marketing of research facilities across local bodies is important to get any important and relevant KPI
before assessing the maturity of any research facility. The new models should be introduced to
attractive innovative SMEs and entrepreneurs.

**International dimension:** Internet has made the business 'Local to Global' and 'Global to Local'
adapting the innovative products and solutions towards market needs. There are very few
international partners in the testbeds currently. To be more effective, it would be advisable to
include the international testbeds accessible to European partners through bilateral or multi-lateral
collaboration models, so that new future Internet paradigm (SDN, virtualised experimentation) based
experimental facilities can be provisioned for mutual benefits.

**Collaboration and cooperation:** FIRE experimental facilities should become platform for a
collaborative, community- and market-driven environment where new technologies are rapidly
tested, entrepreneurial activities are fostered and innovative SMEs are initiating and participating in
research, experimentation and product and process innovation in secure and trusted environments.

FIRE facilities should be upgraded to support e-Science experiments in the H2020 framework, to
make a significant impact of ICT in e-Science community. Big Data, open data and Linked Data
research are gaining moment in the e-science field globally as research domains are experiencing
exponential growth of data produced with doubling rates, sometimes referred to as a “data tsunami”
and presents major challenges in terms of storage, computation and long term preservation and experimentation. Virtual Research Environments (VREs) in the framework of ESFRI can be collaborative platforms for researchers from across the sciences and humanities that support users in a variety of ways.

**Collaboration Models:** Europe has number of infrastructures under different schemes to promote innovation. To achieve collaboration models across different frameworks, a new initiative from user driven perspective should be considered. One such model that can be envisaged is with the creation of 'Technology Innovation Cluster (TIC)' with Go-to-Market (open innovation) initiative consisting of the provision of start-up accelerator (access to investments) and incubation facilities for the creative and market potential (with identified pool of early adopters) ideas and experiments. Such TIC initiative should coordinate the experimental facility offerings across all identified infrastructures and service offering to best suit the experimenter needs.

**Service offering:** Experimental service offerings have to fulfill the requirements of experiments, applications and user experience. It would involve broad spectrum of technical requirements such as proper infrastructure both physical and virtual, user friendly access to infrastructure, visualisation of topology of infrastructure, reconfiguration and resource control of interconnected and interoperable networks with needed bandwidth and service level requirements (QOS) associated with security and privacy for IPR protection. Usability requirements should be also met as service offering to include training and technical support needed by the experimenter. The services should guarantee reproducibility of experiments, through dedicated resources (or well-defined slices of resources), avoiding external compounding variables such as interference; and monitoring and control of experiments, in ways which are unlikely to be possible on existing commercial infrastructures.

**Sustainability Models**
The Objective of experimental facility is to develop innovative solutions with high potential for economic benefits in the future through competitive products, and hence should consider a sustainability model on how to create, deliver and capture financial, economic, social, and technological value. Experimental facility services should become part of the “virtual” world of testbed services (IaaS, PaaS, SaaS, EaaS etc...) for Horizon 2020 framework and vision. Procedures, and regulations designed for the usage of experimental facilities are to be governed to suit the requirements of user community at large. Organisational models, business models, governance structures, funding models, and standards compliance testing and certification models have to be revised for the sustainability of the FIRE experimental facilities. The issues in sustainability to be considered are: Visibility (awareness), Maturity of facilities (service offering), Public-private funding model (Business model) and Innovation promotion concepts (Incubation, Go-to-Market assistance, venture capital etc....)

**Visibility:** Project web site is not the only tool for dissemination of service offerings. It is not considered as pro-active model. Other channel used for dissemination is the open workshop among the research community, where only closed group participants and hence no impact on the user group is expected. INFINITY has created database of all known infrastructure, hardly visited by any SME or research groups. Open calls are partly successful in reaching SMEs, but not at large. Hence it should be envisaged to have local SMEs and industries collaboration in evolving the testbed with the
local innovation and industrial initiatives to promote the visibility of testbed to promote the innovative ideas to the marketable solution.

**Business Models:** Business models applied to testbeds for open innovation correspond to the sustainability of the facilities with continued support for infrastructure maintenance and expertise to support the execution of experiments. In general the sustainability is based on supply and demand equations. Since there are multiple research facilities have the capability to support the particular experiment, the competition across testbed providers can be used as a business model in attracting the user community as one of the scenario in Horizon 2020.

The other possible model would be based on results or key performance indicators of the research facility. This model will support the research facility provider to maintain and upgrade the facilities to the state of the art technologies and the user community will pay the experimentation costs following standard methods to the facility provider, which would be refunded by the Innovation grant to the user community. Such business model can be also envisaged as an Industry-user community alliance with public share-holding, managed by an alliance, like a legal entity (NGO).

The third model can be Pay-for-Use, which is well known in the cloud computing scenario. Since experimentation can be foreseen as a service, this model can be more effective in certain environment. This model can be also seen as a derivative of the second model above.

**Recommendations**

The following four recommendations are identified from the analysis of present FIRE portfolio towards the future portfolio in the Horizon 2020 framework.

1. Develop a Marketing model to attract external users
   a. 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...
2. Continue with Open Calls with simplified proposal templates
   a. Service offerings and Technical support should made clearly visible
   b. Possible incubation and start-up accelerator initiative to be included for the success full experiments, towards exploitation opportunities
3. Develop cohesive European platform for experimentation across different frameworks
   a. Service offerings as a virtual service (IaaS, PaaS, SaaS, EaaS,..) to be provided across a unique web interface
4. Develop appropriate sustainability model
   a. Consider different sustainability models
   b. balance between the technology improvement vs. user community benefit
   c. Consider an independent stakeholder alliance with public private funding mechanism to manage the European common platform.