Towards a collaboration and high-level federation structure for the FIRE Facility

Working Group on modular federation of FIRE Facilities

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1. Introduction

The working group on modular federation of experimental test-bed facilities has been set up to derive an outline of common principles for a collaboration and high level federation architecture for the evolving facility prototypes. A federation of test-beds aims at creating a physical and logical interconnection of several independent experimental facilities or test-beds to provide a larger-scale, more diverse and higher performance platform for accomplishing tests and experiments. A collaboration/federation framework is not the same thing as having rigid control of all aspects. On the contrary, the aim is to have flexibility and individualism for the components/projects. In that sense, high level federation does not at all mean to agree on the same control plane, but only to allow resource sharing and collaboration towards establishing a sustainable customer-friendly facility. It is important to maintain the major goal of individual test-bed projects, which is to create innovative solutions for testing and to support their community of experimenters, but projects should also contribute to the common goal of collaboration and federation of experimental facilities.

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A simplified statement of the goal is to create an architectural structure that will allow the creation of a collaboration structure for new projects, and for existing ones. Indeed, experimental facilities research under FP7 has already been engaged, with several projects targeting various objectives. Due to the bottom-up approach, there is a need for further co-ordination. Another objective is to define an overview of the already evolving facilities and tools for future internet research and development and to highlight potential gaps.

The members of the working group have studied the main FIRE projects. In order to provide a framework that could fit the current project portfolio, evolve towards more collaboration in the future, allow independent work by the projects and make visible the gaps in the future experimental facilities for the future Internet research a map of FIRE facilities has been created to support future work.

The major goal of test-bed federation is to enable experiments on Future Internet research that are otherwise not possible, and this in a cost efficient and experimenter friendly way. The overall results for federated test-beds should also ensure interoperability, transparency and neutrality of the basic infrastructures. The federation/collaboration should also be considered at the dissemination level, having the requirements to exchange, compare and draw conclusions from research results. Effort should not be duplicated, and at the same time the complexity of the system shall be manageable. To achieve this, standards and transparency are essential. New participants should be encouraged to join the FIRE effort with new test-beds. Promoting the use of the FIRE federated test-bed facilities to existing and new research projects is also required. This report provides some suggestions and recommendations as to how FIRE could be oriented in order to progress towards such objectives.

2. FIRE basic collaboration structure

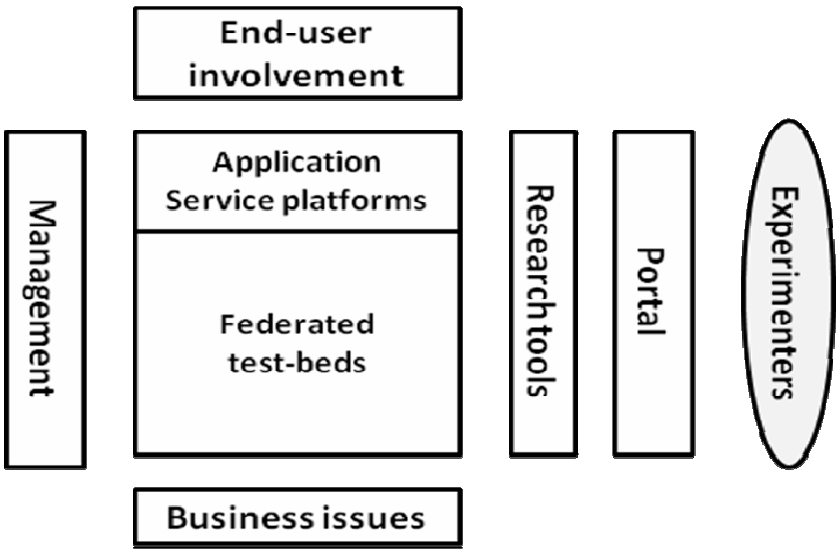

Figure 1 Fire basic structure towards federated test beds

Figure 1 provides a basic representation of FIRE towards a better coordination of test bed facilities (stated in the diagram as "federated test beds"). The following paragraphs define in more details each box represented in this diagram. The idea is to provide on the one hand a cartographic representation allowing to position existing and future FIRE test beds, and on the other hand to show what is additionally required to position FIRE facilities as a whole in a context which will allow for future federation.

2.1. Federated test-beds

The federated test-beds are the center of the work in FIRE. They include facilities from connectivity to networking test-beds, which are often today separate projects. The federated test-beds should include several types of networks (as home, access, distribution, core, both fixed and wireless) but also centralized and distributed computing/storage/information resources and edge devices. This could be implemented by a mix of commercial facilities, field deployed experimental facilities or emulated experimental facilities.

2.2. Management

Management tools and policies is the support for the facility providers (test-bed providers) to create standards for test-bed interfaces and federation mechanisms. Management contains the tools to supervise the usage and misusage of the federated facilities. Control of scarce facilities is also an important management issue to support efficient sharing.

2.3. Business issues

Business issues include handling of business cases for test bed providers and test case users. It includes issues as sustainability in terms of capital and operational expenditure, cost of usage, IPR protection, and methods for sharing scarce resources. This is especially important when collaboration is created with companies providing test-cases that need protection. However,

policies for dissemination also for commercial users must be developed in order to share results that could be shared without revealing product ideas. In addition, the business relationship might or might not include service level agreements. The sustainability of the FIRE facility is in the interest of all stakeholders. It ensures that experiments can be repeated over long periods of time. Sustainability requires development of revenue, payment, business and governance principles for all FIRE facilities.

2.4. Portal

The purpose of portals is to simplify the choice and discovery of test-beds that are appropriate for the experimenter. The portal shall aid in combining different test-beds into the test-case environment needed. One overall aim is to allow one stop shop of test-bed facilities, and discovery and support of both novice and advanced users. The portal could support brokering of facilities and reservation of usage when facilities are scarce. It could also support a high level federation e.g. by creating a wrapper around test-beds to combine e.g. an application service platform with a networking test-bed. Since this is still a research topic, active support of experimenters will need human interaction (e.g. a "FIRE desk").

2.5. End User involvement

The group of "End users" is part of an experimental facility and in many cases the driving force for innovation in the future internet area. One view is to consider End user involvement, the federated test-beds and application service platforms as the total experimental facility platform. The end-users will also create critical mass and user feedback in experiments. End-users are both individuals with e.g. a mobile device and enterprises participating in an experiment.

2.6. Application-service-platforms

Application services platforms include platforms for e.g. content distribution and cloud computing. These are users of networking capabilities and they are present in order to try out the proposed future networking capabilities. The FIRE facility should allow for the evaluation of effects of changes to the networking layers to the application services layers and vice versa.

2.7. Research Tools

Research tools are the tools for obtaining results from tests and help creating complete tests. These tools include measurements and monitoring tools for scientific and technical analysis of tests and also tools for supporting socio-economic impact assessment. Support for creating tests are traffic generation tools, test result repositories, statistical packages for analysis, simulation tools, tools for user emulation, etc.

Research tools are together with the portal the main interfaces of the experimenter towards the experimental facilities.

2.8. Experimenters

The experimenter or the test-case owner or the customer is the partner bringing in test-cases that will use the experimental facilities. The experimenter will come both from inside and

outside the test-bed community and will have a valid test-case for the development of the future Internet. Creating and developing a large experimental facility needs real use. This can be driven by many actors, found in the networking research and application research communities. The network research community will develop security technology, routing and control protocols, etc. The application researchers will develop new software services, entertainment, gaming, e-health, enterprise systems and platforms, etc.

3. Map of existing facility prototypes on collaboration structure

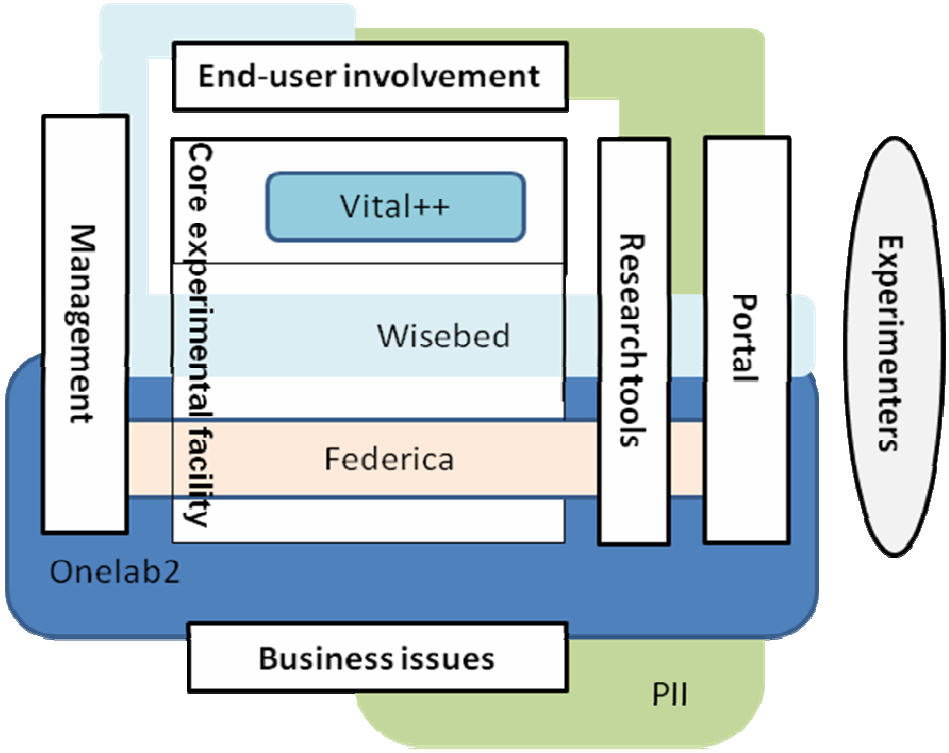

Figure 2: map of existing facility prototypes on collaboration structure.

The current set of projects covers already much of the basic structure. New projects can fill some gaps, and moreover are encouraged to support creating an active collaboration framework. Many aspects are today only partially handled like standardization, business cases for the addition of commercial test-beds and coordinated management of test-beds.

Besides providing access to testing resources, the ongoing IP-projects Onelab2 and PII have different focus in the structure:

- OneLab2 performs most of its work in the "research tool" area, with monitoring and measurements and support as main contributions.
- PII performs most of its work in the area of "tools and portals", and addresses "business issues" for test-bed providers and experimenters. In the area of end-user involvement, PII collaborates with Living Labs projects.

Another difference in approaches between the two projects is that Onelab2 mainly focuses on longer term and clean slate research, while PII focuses on industrial aspects like close-to-market vertical and horizontal interoperability and transition paths from clean slate to reality.

Wisebed is a sensor test-bed, with aims to create strategies for federation of several sensor test-beds. Wisebed plans to standardize sensor test-bed federation, which will allow easier integration of other sensor test-beds. Further such work is needed in other test-bed areas.

Wisebed as most other test-bed project implements a portal and creates management functions. Such overlap is necessary, but the goal of FIRE is to create federation in addition to single test-bed or single technology availability.

Vital++ is a project combining P2P and IMS based systems and is an application service platform project. Vital++ collaborates with PII.

Federica supports core network experiments also on lower levels in the protocol stack within the GEANT framework. Federica is collaborating with OneLab2 and plans to collaborate with PII.

4. Principles for a high-level FIRE federation architecture

To run large individual projects, it is necessary to accept some overlap both in work and approaches, especially when the focus on coordination has not been explicitly stated. The evolution towards a federation architecture will be progressive, and will require extra work and changes in individual projects' approaches.

In order to ensure that new projects from the beginning can be embedded in a federation, they should take into account existing work, and find a way to collaborate with existing projects. The aim of the suggested structure is also to show where gaps are and where it is profitable to place new projects.

The key issues behind a future high-level FIRE federation architecture are described in this section. First, the main issues behind the concept of federation are defined. Then, an extended view of the basic FIRE structure is presented, showing more details on what is required to achieve federation. Finally, some future priority issues for the success of a high-level federation are highlighted. They could for example be addressed by proposals in the next Call.

4.1 Federation issues

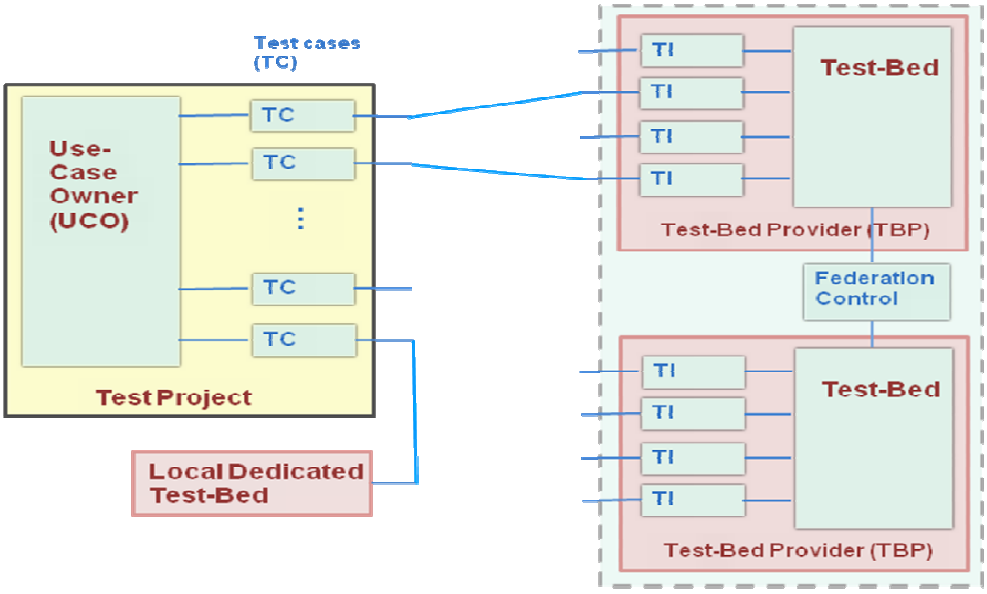

Figure 5: federation issues

The federation of experimental facilities is needed for integrating and validating next-generation network technologies, but also system level and interdisciplinary research. The federation helps to reduce the risks and costs of large-scale network infrastructure testing and enables end-to-end interoperability testing of platforms, networks, and services. Given a Test Project (TP) of a Use Case Owner (UCO or Experimenter), the TP is normally broken down into a number of Test Cases (TC). Each in turn, needs to be tested on a particular test-bed for a given purpose, e.g. functional testing or estimation of scalability. Prior to start investigating the use of a test-bed or an experimental facility, it should be clear why and if this Test Project requires federation and even more specifically, which Test Cases (TC) within this TP requires

federation. Indeed, federation shall not be seen as a purpose in itself, but as a method of achieving a particular goal.

Every research project consists of some test projects whose tests are performed either within a local test-bed at one site, within a local experimental facility, in an emulation facility or within a federated test-bed.

When asking whether federation is required, the support towards experimenters within FIRE should include answering questions like i) Can I do the test without federation, and ii) Which methods should be used when the scalability test cannot be done in an experimental platform, e.g. the use of simulation or analytical modeling.

As an example, a reason for a federating test for this TC could be scalability. Then the question is what type of federated facility is needed. If scalability is the reason for federation, it should be clear how many nodes or how large the federated resulting test-bed is needed to make the TC sensible. If diversity (many regions of the network and diversity of background end-users) is the main reason for federation, how does the architecture of the test-bed look like? If system level experimentation is the main reason for federation, how does vertical integration of test-beds of different kind work? In the FIRE context support should be provided to potential experimenters to answer these questions. More concretely, the tasks of supporting potential experimenters could be to help find responses to: i) For which purpose does an experimenter want a federated test for a particular TC, ii) With which test-beds can this TC perform a federated test, and iii) How is the work flow, who has to provide the adaptation, who has to write the Test Interface (TI).

Examples of when federation of test-beds is required include:

- Combining different test-bed functionalities
- Testing under more realistic conditions (real traffic)
- Achieving more realism in the prototype's operating environment
- Access to specialized or diverse resources
- Savings through sharing unused resources (or revenue from making them available) Scientific gain through exchanging results and creating a community
- Increasing geographic extent of the prototype (e.g. longer distance)
- Accommodating different policies for use and access (e.g. agreeing on a common subset)
- Testing not only within one tier but across tiers up to complete system level
- Achieving scale in size and management
- Testing of algorithms in a heterogeneous environment

There are different angles with which to approach the concept of federation. One of them is defined as horizontal and vertical.

- **Horizontal federation** has as primary objective to achieve greater scale, and to a lesser extent diversity. It supports experimentation on a small number of closely related layers of the telecom stack. It is also an inexpensive and simple way to dynamically pool and use resources for experimentation of new network paradigms. The characteristics in terms of control and data plane, business model and customers are similar.

Examples include: The federation between PlanetLab Europe (operated by Onelab2), PlanetLab Central (Princeton, US), PlanetLab Japan allows greater scale. The OneLab federation of resources is based on virtualization, slicing and a straightforward business model based on contributing resources in order to get the right to use the facility on a best-effort model. Panlab/PII federation between different testing labs where software integration is a more dominant aspect and many of protocols comes from the telecom world. PII is more oriented towards industry and addresses many industry requirements. Wisebed is federating between multiple wireless sensor networks that may have some distinct features.

- **Vertical federation** supports system-level testing of new internet networking and services paradigms across layers or in a layer-less model.

  Examples: The federation of OneLab2 and Federica would mean for them the ability to run their experiment across both platforms at the same time. Federica brings to OneLab2 the capability to access the lower network layers.This will allow experiments allowing the possibility to compare PlanetLab with a controllable infrastructure. OneLab2 and Grid'5000 can support research activities in the area of Cloud computing and the underlying networking infrastructure, allowing for experiments of Cloud systems without imposing any particular technologies.

  A FIRE scenario in the services area can be collaboration between network researchers, service technology developers and service-based application developers to explore how next generation networks can support technology developments. A series of large-scale test-cases from the business and scientific sectors could be selected and used to explore next generation network research ideas. Example applications may include: (1) large scale data access and integration for a multinational business wishing to join disparate and widely distributed data sets together for business advantage or (2) the processing of scientific datasets requiring data and information from widely distributed data services, as is common in the bioinformatics sector or (3) the support of distributed media production facilities combining broadcasters and production houses. This will only succeed if all three communities work hand-in-hand. It is certainly the case that those working on SOA technologies will not know all questions to ask the networking researchers and vice versa. However, by bringing these communities together, Europe can harness our disparate skills to drive the Internet forward to mutual benefit. This type of collaboration will make possible cross-layer testing to propagate service-level requirements down to the connectivity levels and experiences back and the other way round, i.e. changes to the connectivity architecture and its repercussions on the services level.

In addition to the more core-based federation of test-beds, the following approaches may also be considered:

- **Software federation** supports exchange of test-bed-related software as e g measurement tools.
- **Human federation** offers the possibility of student internships and post-doc exchange. Here should also the organization of events like FIRE workshops to give technicians and researchers the possibility to exchange ideas be considered.

Federation of test-beds is required for the development of a heterogeneous collection of test-beds. The need for standardized techniques for interoperability and standard interfaces is part of this effort that should be developed within FIRE. Nevertheless, it is important to note that a federation is defined by the presence of common objectives. Without common objectives, a federation is meaningless. Moreover, different levels of federation should co-exist to take into account issues related to cost, complexity and context. We want on one hand foster a rich and diverse 'eco-system' of test-beds and their respective resources while on the other hand leverage tools, methodologies and processes. Therefore, successful federation will require the right balance of sound architectural principles and specific manifestations of these principles which simplifies the introduction of new technologies or the building of new test-beds.

4.2 FIRE extended structure

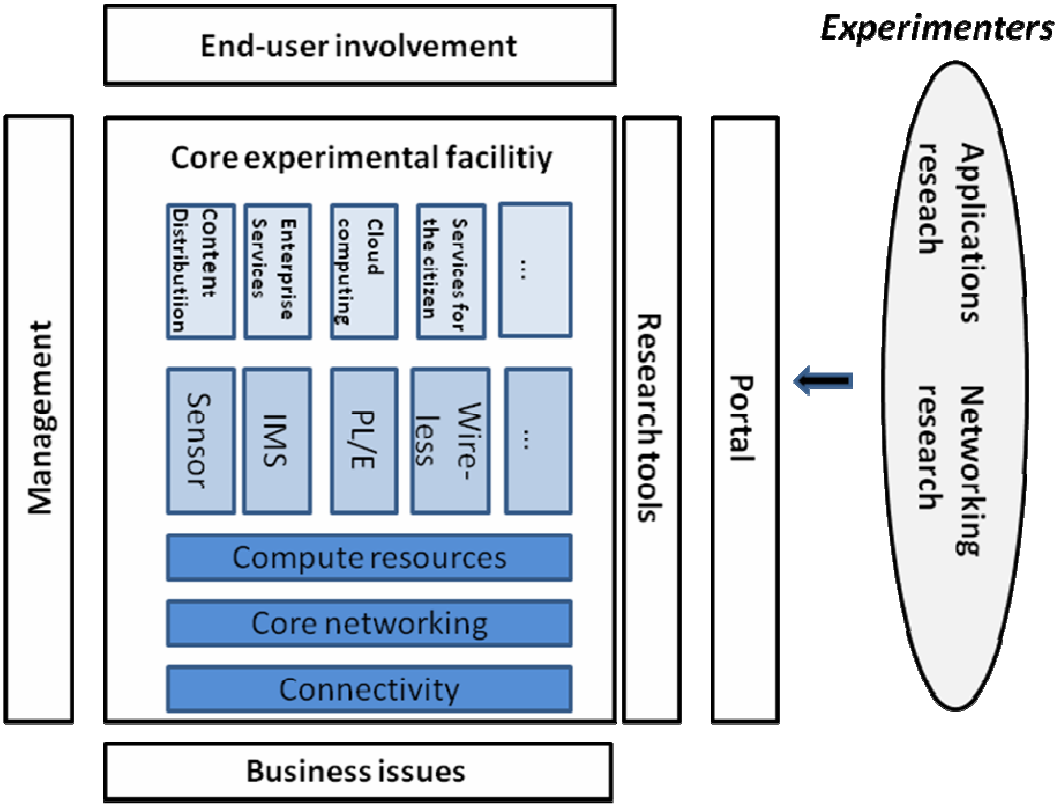

Figure 3 more detailed view of the “core experimental facility”

The core experimental facility may be divided into the following areas:

- Basic connectivity (as e.g. GEANT),
- Core connectivity (as e.g. Federica),
- Compute resources (as e.g. the nodes of PlanetLab, Grid5000).
- Various specific test-beds with focus on topics such as sensors, wireless, IMS (as e.g. Wisebed, FOKUS IMS-playground).
- Application service platforms as content distribution, enterprise services, etc.

A simple-minded view of the relationship between experimental facilities can be partially derived from the relationship between ISPs and ASs (autonomous systems) in the Internet. In such a world future test-beds may be

- Peers
- Customers/Providers

A more subtle facet is that they may also be in a layered relationship, hence:

- Underlay
- Overlay

This can be extended not just to performance guarantees (e.g. for repeatable experiments, or provision of tracing during an experiment) but also to security (e.g. obligations, versus affordances) and audit trails (in the event of abuse).

A more technical approach is shown in the following diagram.

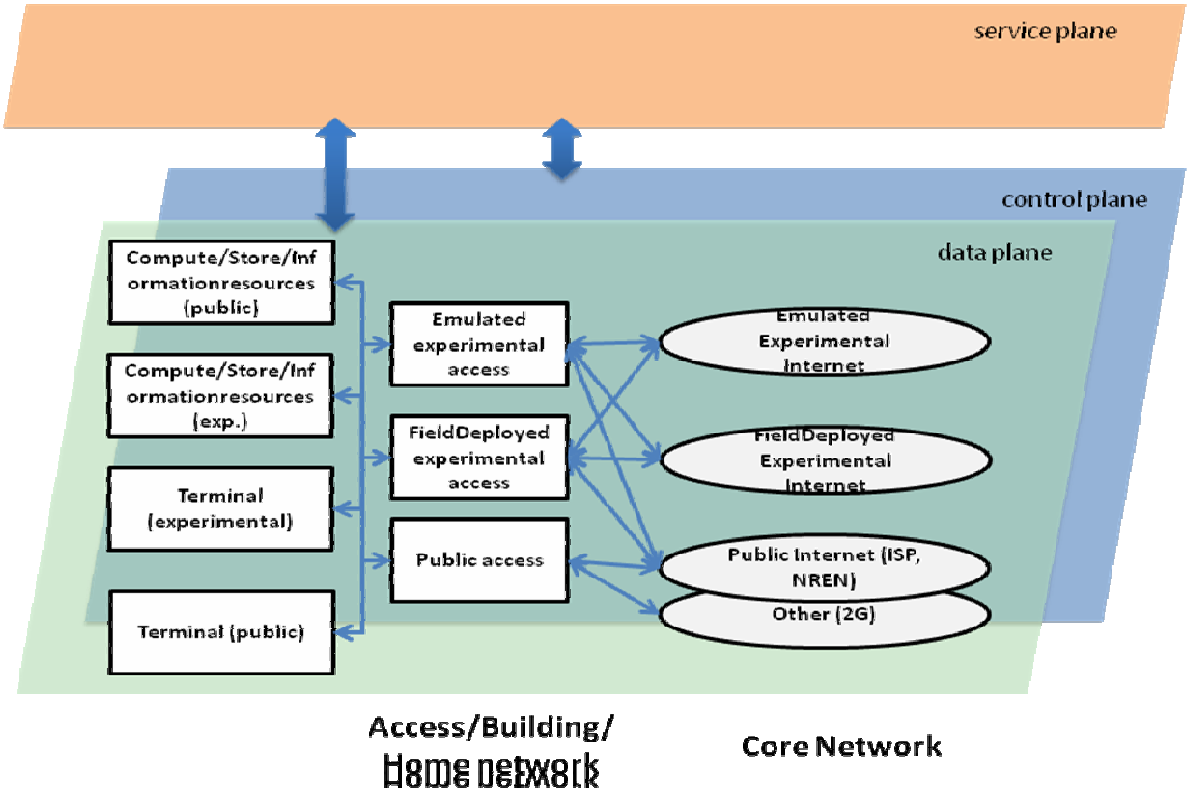

Figure 4: technical view of core experimental facility

1. Core network: this could be an existing public network (e.g. public internet : commercial ISP's or NREN's), a field deployed experimental Internet (e.g. as provided by Federica) or an emulated experimental internet (e.g. as provided by Emulab or iLab facilities)
2. Access/building/home network: here we could also make a distinction between public access (e.g. public hot spots), field deployed experimental access (e.g. an experimental

wireless sensor network in an office environment) and emulated experimental access (e.g. emulated wireless links).

3. Compute/store/information resources: they could be public (e.g. Amazon or Google resources) or experimental (e.g. Emulab or Grid5000 facilities)
4. Terminal: this could be public terminals (e.g. standard 3G terminals or a thin client) or experimental terminals (e.g. experimental terminal with display integrated in textiles and voice activation or standard terminal with experimental software).

Different experimental facility projects could have different interconnection schemes for these different parts. For example one could have experimental server nodes connected by an NREN access network to a public internet (NREN, GEANT).

A further split could be data plane related experiments, control plane related experiments, or both combined. Also management plane experiments could be conducted on this core experimental facility (not shown on the figure). On top of this, one may deploy a service plane that could run on this infrastructure (e.g. distributed on servers and terminals, integrated in networking devices).

The FIRE projects may also be described in relation to the view in Figure 4:

- FEDERICA: experimental internet (core network)
- ONELAB2: public internet (NREN/GEANT), public access (NREN), experimental compute resources (the servers); but also experimental internet in future (federation with Federica), experimental access (wireless networks e.g. Orbit) and emulated access (wireless links)
- PII: public internet for test-bed interconnection, field deployed experimental access, experimental and public terminals
- Wisebed: public internet for test-bed interconnection, public access (NREN), experimental access (wireless sensor networks)
- Vital++: public internet for test-bed interconnection, public or experimental access controlled by IMS, experimental terminals (running P2P software).

It is important to observe that different alternatives could be used to perform certain experiments (in some cases it is much more economical to use an emulated experimental internet instead of a field deployed experimental internet).

4.3 Some Priority Issues for future projects

FIRE portal & methodology

The experimenter that will use the federated test-bed will need support to have easy access. A portal supporting one-stop-shop of experimental facilities is a basic FIRE requirement. One stop shop means that a portal should support the non expert to find and reserve capacity of a test-bed or a combination of such. In addition support of interoperability, downloading of application software and the measurement/monitoring tools are required. The portal should help identifying what facilities could be used and aid in creating a federated test-bed for the test-case in mind. A foundation for experimental validation in a heterogeneous environment is the ability to clearly describe resources and their dependencies and relationships. E.g. the need to capture, that two radios on two different machines can interfere with each other if they

are within certain range and using similar parts of the spectrum. We also need to be able to tie experiment results to hardware, OS version, driver version, application settings, time of day, weather, etc. The portal must be able to capture such properties to be valuable. A portal should help identifying what facilities could be used for a given test case. It should operate as an additional offer to experimenters vs. existing offers from each single facility. It could trigger new test bed offering facilities that are not yet available. If a user knows which test facility he wants to use, he should be able to go there without overhead introduced through higher-level federation or even special tools. If an experimenter could use several facilities, he should get advise which one to use (based on suitability, business model, convenience, etc.).

Development of methodology, technology and interaction between different approaches like those of local dedicated test-beds, large scale emulation systems, simulation and modeling is also part of FIRE activities. The portal has the role to help experimenters to choose appropriate and cost-effective methods for tests. E.g. Federica (core networking facilities) with expensive resources (fiber and other equipment) which only should be used when required; otherwise PlanetLab slicing or emulation based on standard Internet connectivity may be more adequate.

Cooperation with other projects

A common set of federated test-beds will not stand alone and will need support and/or use by other projects in the research community. It will be a key requirement that a future Geant3 project elaborates and plans for FIRE needs in order to support networking research. Also support of FIRE initiatives to explicitly, strengthen the communication between NRENs and FIRE should be encouraged.

Projects using experimental facilities under FIRE are not intended to become applications research projects, but target innovative Future Internet developments. This would require collaboration with a networking research project or partner.

Efforts to collaborate both with FP, International and with national projects should be exploited. Examples of this are the collaboration between PII and Vital++ and Onelab2 collaboration with the national German G-lab project. In order make that at all possible there is a need to agree on a cost model for resource use.

New areas of work

New areas of research that fills the gaps are expected. Applications areas as entertainment, enterprise services, e-health should bring in test cases that could drive networking research forward etc. Networking and services technologies currently not present in FIRE should be included in new test-bed activities some examples could be optical, cognitive radio and service platforms.

Fire Office

Crucial for the successful implementation of the proposed high-level federation and collaboration framework is a powerful FIRE office, which takes the lead in implementing the collaboration and high-level federation framework. The office should be the balancing factor between the goals of the individual projects and the common goal of federation. This office should have following responsibilities and characteristics:

- Have a lead technical person/architect or an architectural board. The architect or the members of the board should be neutral and independent from the FIRE facility projects. They should have the profile of being able to discuss and mediate between strong project leaders at eye level. He/she/it shall take the lead in the collaboration structure and have some influence on those resources of participating projects clearly earmarked for collaboration and high level federation.
- Chair the collaboration between projects under each component of the framework.
- Have all FIRE facility projects be formally represented in a FIRE Office project.
- Co-ordinate linking to other test-beds and facilities at national and international level, including Geant. Only test-beds which can prove a demand and high quality should be linked.
- Operate the portal and advice experimenters and test-bed providers when the portal is not sufficient.
- Advertise and promote the FIRE facilities in collaboration with the projects.
- Coordinate cross-cutting work from ongoing projects, as e.g. methods for creating interoperability between test-beds. One example could be open-source software defining interfaces (resource point interface), to be used for integration of test-beds. This includes standardization.
- Organizing technical workshops to exchange idea of using the existing platforms to work towards Next Generation Networks and expand towards other types of system level and interdisciplinary research experimentation. This should give researcher spaces to discuss new ideas across different projects. This includes representing FIRE in initiatives like Joint Technology Platform or Public Private Partnership on the Future Internet.

FIRE in the broader scope of Future Internet research

The EC and the Future Internet research and industrial community are currently looking at the priority topics to be implemented in the next few years in order to constitute the basis and the environment for a Future Internet that will support the development of innovative “smart” applications, in such areas as energy, health, transportation, and others. Beyond the current mostly “vertical” research approach developed by the FP7 ICT Work Programme, a more “horizontal” approach, tackling both “fundamental enablers” for the Future Internet and interdisciplinary research, is being investigated as a complementary approach. Although this is not yet final at this stage, it is important to take it into account in the development of the next generation of FIRE facilities.

One concept which is being discussed for future EC support is the development of very generic platforms, which would constitute the basis for the development of Future Internet enablers and environment at individual technology or system level, also focusing on interdisciplinary research. Such platforms would comprise infrastructure elements of the Future Internet e.g. network-, storage-, computing-, service-, or content-related, along with middleware, tools and core services, so that applications and services could be built and provided to individuals, communities and businesses.

These platforms would be able to interconnect and interoperate. They would be open to any organization, individual or community to use them or to develop new applications, content and services. And they need to be trusted, in order to inspire confidence when using them.

Large-scale Internet-based systems and platforms will not only be developed through standard research projects such as IPs and STREPs. They would also need projects allowing for large-scale experimentation and trials.

Therefore, future FIRE facilities or/and a targeted evolution and expansion of the existing ones will be needed to support not only pilot experimentation for research projects and customers as it does today, but also for larger projects and trials related to the above-mentioned platforms. At this stage, although discussions are still under way and no decision has been made yet, it is likely that such projects could be included in EC ICT programmes as soon as 2010 or 2011. This development should be carefully watched and be taken into account gradually.

Currently, Future Internet Research and Experimentation, or FIRE, is covering two main areas:

- Experimentally-driven research on new paradigms and advanced networking approaches for the Future Internet;

- Interconnected test beds on networks and services.

The first topic is primarily used as means to test innovative and potentially disruptive ideas in large scale environments, which is critical to assess the feasibility of new concepts. In particular, the methodology of experimentally-driven research is trialed and evaluated here.

As explained in this report, the second topic is now aiming at building up on the various existing projects to reach a higher level of interconnectivity, interoperability and interworking between test beds, that is being called “federation”.

This is particularly important in the context of the development of Future Internet platforms and systems. Indeed, FIRE facilities that are required in this case represent the evolution of today's test beds towards test beds serving both research and large-scale trials projects. It would allow testing for example innovative networks, new service and content discovery and media distribution solutions, security and trust developments, new business models, etc.

Experimentation in Future Internet platforms and systems will need to be stimulated both at individual technology levels and at system level. The main ideas supported and promoted by FIRE would still stand, and would need to be expanded as already highlighted above, to cover areas that do not only tackle connectivity as it mainly does today, but also interoperability and

interworking. This would allow system level and interdisciplinary research experimentation. It could also be the "glue" between disciplines and research communities.

These facilities and test beds should themselves act as model implementations and proofs of concept of the suggested innovative mechanisms and technologies of the Future Internet. In this context, a responsible "one-stop-shop" organization that would offer configurable test beds "as a service" will likely be a "must-have".

All this is in fact very much in line with the idea of a modular federation of experimental test-beds facilities, and with the recommendations from the current report. It indeed states that FIRE facilities should evolve and promote system level experimentation in addition to component level and interworking, and become more user-friendly, e.g. through an intelligent portal, brokering support, one-stop shopping across facilities, or provisioning of measurement tools, and would allow for experimentation in a socio-economic context with broad end-user involvement. In particular:

- The "FIRE portal" and "FIRE office" concepts should prove to be particularly relevant to make this evolution possible;

- The cooperation with other projects and especially GEANT and NRENs would also help supporting system level and interdisciplinary research experimentation in the near future.

The new areas of work should also take into account support for system level and interdisciplinary research experimentation.

5. Final Conclusions and recommendations

The working group on modular federation of experimental test-bed facilities expresses the following recommendations:

- Future projects shall be able to demonstrate their facilities within a short time of work. This means that new test-bed providers should identify from the outset experimenters owning test-cases and willing to run them. The issues of test case definition and customer acquisition and integration must be integral parts of the facility.
- In order to avoid idle test-beds, all facility projects should search for and bring in experimenters with test cases also from an area outside the actual test-bed itself. Promotion and support of both experimenters and test-bed providers is necessary in the FIRE environment. New test-bed providers should identify from the outset experimenters owning test-cases willing to run them. Issues of test case definition and experimenter acquisition should be integral parts of the project.
- New facilities should either extend existing facilities and/or create a clear and measurable added value expanding the capabilities of the FIRE facilities as a whole.
- It is suggested that experimentation infrastructures should be (partly) supported by public funds (of course depending on the business models developed with a clear difference between short and long term research goals). Indeed, an experimental facility provides a basic infrastructure for research and it needs long term support in order to be sustained. There is little difference between the need for network connectivity for researchers (typically supported by the NRENs and GEANT) and

shared experimental resources for network and Internet research. Test-bed use has to be planned and sufficient funds must be allocated to support the operations of the shared experimental facilities.

- One of the first steps towards federating a test-bed is opening it to others, and in more practical terms making it more robust. All test-beds must be built to remain operationally reliable over an extended period.
- FIRE facilities should open up beyond interconnectivity towards more interoperability and interworking experimentation, for individual technologies but also at system level, and allow for interdisciplinary research testing. FIRE should provide experimentation facilities both for research projects but also for large-scale trials.