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FIRE: Future Internet Research and Experimentation

ANNEXES

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1. The relation between FIRE and the Capacities Programme (Unit F3)

1.1 The GÉANT and NREN organisation

The Research networking in Europe is organized on a three-tier federated architecture. At the base are the networks of the end users (LANs, MAN, Regional networks), The National Research and Education Networks (NRENs) aggregate the user traffic which is then distributed throughout Europe, and to research networks worldwide by GÉANT.
The NREN Compendium offers detailed information of NRENs (http://www.terena.org/activities/compendium/).

It is important to note that GÉANT offers connectivity to NRENs, not to the end users. End users should approach their local institution and the NRENs to obtain trans-European connectivity. The whole process is not automated and needs a certain amount of time. In addition, the costs of the connections could be considerable depending on the bandwidth/service requested.

1.2 Current service offers from GÉANT (www.geant2.net)

Today, GÉANT offers the following services (see also http://www.geant2.net/server/show/nav.744).

- The *GÉANT IP service* offers NRENs access to the shared European IP backbone. This allows transit for IP traffic between European NRENs, and between European NRENs and associated networks globally. This includes IPv4, IPv6, IPv4 multicast, VPN and Premium IP.
- The *GÉANT Plus service* allows user access to point-to-point circuits between 155 Mbps and 10 Gbps across an existing pre-provisioned network (typically 1 Gbps and 10 Gbps Ethernet are used today). It enables projects and researchers to link end-to-end across multiple domains and provides a flexible "private line" service. Local NRENs and GÉANT2 are responsible for creating these links on behalf of a specific user request.
- The *GÉANT Lambda service* provides private, transparent 10 Gbps wavelengths between any two GÉANT NRENs connected to the GÉANT dark fibre cloud. These services are used by Europe's most data intensive users. The provision of a fully transparent service puts the user in control at the network transport layer and offers ultimate flexibility regarding the use of that circuit.
- In addition there are some more experimental services developed (e.g. AutoBAHN for bandwidth-on-demand. See the GÉANT website for more details).

Not all the NRENs offer the same set of services. In particular the creation of a dedicated circuit between two users in two different countries may require manual provisioning or be quite expensive, depending upon the local situation.

1.3 Some generic requirements from FIRE towards GÉANT/NRENs

For the moment NRENs are involved minimally in FIRE projects. This results in the reluctance to utilise the network capacity offered by GÉANT due to heterogeneous pricing for connections. Incentives and encouragement to get more NRENs to participate, or to contribute to the FIRE facility is highly welcome. It is believed that co-operation between NRENs and FIRE could be of mutual benefit in the following ways:

- NRENs have the ability to set up pan-European connections between NREN PoPs (crossing the NREN stub networks and GÉANT), with high bandwidth (up to 10 Gbps, at the level of wavelength or routed IP).

- GÉANT and NRENs could benefit from the industry standard Resource Description Framework information model. This would help users and GÉANT/NRENs to achieve automated on-demand provisioning of resources.
- The use of a common control framework with published and accessible interfaces based on standards such as web services would also contribute towards the automated control and management of resources.
- A framework for facilitating the extension of the scope of NRENs would enable other initiatives (e.g. industry-based) to connect with GÉANT creating or maintaining their own PoPs.
- Allowing access to standard measurements of Internet traffic in the nodes of the production network (measurements done by GÉANT and NRENs) would be a useful source of (probably) non-commercially sensitive data.
- Providing the possibility to perform specific measurements required by FIRE projects on the GÉANT and NRENs network (possibly using measurement routines or equipment provided by the projects themselves) would be interesting for some FIRE projects. This, of course, within the legal boundaries.

1.4 Some specific interests from FIRE testbeds towards GÉANT/NRENs

OneLab2 expects that the virtualization capability that FEDERICA is developing will be useful for its work, if a facility is created to reserve e.g. tunnel bandwidth for direct interconnect between different wireless testbeds, both those with similar and very distinct (DTN-like) technologies.

It would be interesting to have FEDERICA capabilities integrated in the future as a standard service in the NREN/GÉANT environment. A second initiative is to integrate FEDERICA into the Private PlanetLab framework that OneLab2 supports in order to offer direct access to experiments on FEDERICA's virtualized network. Naturally this requires close collaboration with each NREN involved. An effort in this direction is underway between two OneLab2 partners (the ETOMIC team) and the Hungarian and Spanish NRENs

PII is building a testing resource and service broker, as well as the necessary service provisioning and orchestration engine. In order to fully automate the utilization of NREN/GÉANT resources, PII needs a resource description based on of the NREN/GÉANT resources that are made on-demand available to the customers. Furthermore PII needs access to published interface specifications to convey simple control messages to a NREN/GÉANT domain manager for example to add, delete, and modify resources.

FEDERICA is looking at solutions for allocating, controlling and managing virtualised network resources in a multi-domain infrastructure. Reduced timescale and costs for extension in GÉANT and possibility to extend in some other countries are important future requirements. Gigabit Ethernet is the preferred initial technology, possibility to include a dark fibre is also in scope.

Vital++ is building a testbed that will combine features of P2P and IMS. In particular, it will enhance P2P systems with AAA mechanisms and QoS. The latter objective can be greatly supported by GÉANT mechanisms that allow virtualisation of the communication resources available in GÉANT. To this end, separate P2P communities may be deployed by using their own GÉANT virtual network distributed across Europe, while the Vital++ QoS algorithms may optimize these virtual network resources. As the traffic exchanged among peers concern mainly content that may reach several Mbps, the requested communication resources for each virtual network should be of the same order.

2. On Federations... by OneLab2

Federated testbeds are the cornerstone of the FIRE effort, yet the word "Federation" is used in what appear to be different ways by the various present FIRE projects. Perhaps some discussion of what the word means and the activities that it entails in the creation of technologies underlying the Future Internet will be helpful in understanding present activities and in planning future FIRE projects.

The dictionary provides a definition of Federation that emphasizes the use of the word in its political or government context: "A federation is a union comprising a number of partially self-governing regions united by a central "federal" government under a common set of objectives."

This definition seems quite appropriate for the discussion of federating the resources available in networks, the networks themselves, and test environments for future styles of networking. Most importantly, we note that the presence of common objectives defines a federation. Without common objectives, a federation is meaningless. In addition, some objectives may constrain the type of resources involved or the techniques used to combine them, making other objectives unfeasible.

Some of the potential objectives in networking for which federation is natural include:

- Achieving scale
- 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 sharing resources, and creating a community
- Scientific gain through exchanging results
- Increasing geographic extent of the prototype

In addition to common objectives, there are a number of constraints that make the achievement of certain objectives difficult or even impossible. For example, many constraints arise through the usage context of a shared resource, e.g. the usage of particular sensor data in its acquisition context. Thus reproducibility is often hard to achieve in a testbed intended to provide real-world variability. A testbed which emphasizes access to a broad scale or spatial distribution of inputs or environments may not easily extract information about each locality covered. Also, the objective of achieving very large scale is difficult when the resources are extremely heterogeneous, as occurs in sensor networks and new types of wireless cells.

Achieving large scale in a shared resource is often accomplished by slicing, yet this will sacrifice reproducibility, the measurements are affected by interference from the unseen activities that take place in other slices sharing the resources. In addition, a central problem of high heterogeneity, combined with large scale is the existence of a bottleneck for the resources. For example, a wireless testbed allowing only for time slicing makes it almost impossible for long-term experiments to use it as part of a heterogeneous network topology. The existence of such bottleneck resources create scarcity, which is a problem that could be solved either through increasing the amount of resources (e.g. making more wireless testbeds available) and/or sophisticated resource allocation policies (providing access based on payments or resource contributions).

Probably the most obvious source of conflict in these objectives is between the customers who benefit from scientific openness, and those for whom commercial constraints require keeping test results and test details confidential. Local governance rules and policies introduce constraints on federation. Examples are IPR, rules for dealing with human subjects, the requirement of funding to defray the costs of the resources, and policies regarding the exposure of information. Privacy is a ubiquitous concern of this class, as is the confidentiality required when the research has immediate commercial impact. The complexity that arises when very diverse systems are integrated is always a restriction on

the extent to which federation can be applied. This conflict highlighted the difficulty of federating „commercial" and „non-commercial" facilities. It will be worth also exploring other possibilities where a „non-commercial" facility can spin-off commercial ones with a well-focussed target and application and the fulfilment of its user requirements (see for example the case of CoDeen or M-Lab in the PlanetLab constellation).

The existing FIRE projects have taken somewhat different approaches to federating the testbeds they presently involve. Their differences can be traced to the fact that each supports different customers, who have different objectives. We can analyze each of them to identify the constraints that result from their choices of objectives.

OneLab2, which has a research focus and uses open source software and toolkits, is primarily non-commercial. Because the results of its testbeds are archived and shared, governance issues arise only in allocating access to scarce resources. The major tool of OneLab2, an extended public and private collection of European Planetlab slices, has little usage context dependence due to the nature of currently shared resources. As wireless testbeds are added to its mix, this will change. Also, the sharing of controlled access to network bandwidth, in proposed collaborations with FEDERICA, will impose additional constraints due to the limited network facilities and portals involved.

FEDERICA, initially, is free to the academic users whom it supports, but the finiteness of their resources has caused them to impose an access control governance structure. Potential users make proposals, which are judged and prioritized. Access is limited in duration as well as in bandwidth. There is a strong possibility that FEDERICA users will eventually have to pay for dedicated resources that they consume, at least for the access links.

PanLabII (PII) supports a different set of customers, mostly industrial developers and researchers dealing with ideas which are closer to product or service realization. Governance issues are vital here, and have been a primary focus of the project, which has developed contractual terms and conditions for shared use of a wide range of specialized testbeds. In contrast to OneLab's customers, Panlab's customers have proprietary information and Intellectual Property Rights to protect, and do not expect to share the results of their experiments, which may be interoperability tests or customer focus group feedback. Because of the disparate nature of the different testbeds they represent, scaling to a larger number of individual computing or networking units will be complex and difficult, but it may not be as important to that set of customers. PII could be viewed as an infrastructure provider (conceptually similar to FEDERICA) which, in the best scenario, could provide access to its aggregated "commercial" testbeds to non-commercial users as well, if they wish to "pay the price". In that sense, federation with PII is a customer-broker relationship. However, it will be difficult for PII to play the role of the broker for OneLab2 resources, as PII and OneLab2 do not share the same objectives as each other, and also because its allocation policy (market-based) is incompatible with the one currently used in OneLab2 (best-effort).

The above remarks motivate the need to discuss in more depth the various types and levels of federation that might exist together with their resource management policies. For that, let us consider the case of two independent testbeds federated into a larger one. The question is whether the users of the two federating authorities will have the same access rights to the aggregated federation resources or these will depend on the "value" of their authority's contribution to the federation.

An important parameter is whether an authority is associated with a specific set of users or not. For example, federating FEDERICA with OneLab2 (or PlanetLab_Europe [PLE]) is different conceptually than federating PLE with Planetlab_Central (PLC). In the first case, OneLab2/PLE users are by default potential FEDERICA users (they are a subset of them). Also, the federation would mean for them the ability to run their experiment across both platforms at the same time. Therefore, the most important challenges are technical (resource specifications, APIs, etc.). When OneLab2/PLE alone (or with

FEDERICA included) federates with Planetlab (with other testbeds included) then "remote" users might need to have different access rights from the "local" ones. If a remote user wants to have access to FEDERICA resources, through the federation of PLE with PLC, there exists a resource management problem that is very much like that of the Internet but in a more general sense (since the set of resources is larger than mere routing resources that are shared in today's Internet). Hence, what is required for these cases of federation are "peering agreements", i.e. agreements on how to share particular resources across federations. In addition, similar to the transit and peering relations in the Internet, a tiered model of peering relations seems to be worthwhile considering.

This situation is currently being considered in the PlanetLab constellation, with federation at level 1 (highest level) between PLE, PLC and PLJ (Japan), while a federation at level 2 is considered for integrating highly heterogeneous testbeds and highly specialized resources, to which access is more tightly controlled (for example, PLE with a small wireless testbed that has possibly a small number of associated users with it). Such small testbeds will be considered as "special" PLE sites that will be integrated into PLE's aggregated resources and will be subject to the local PLE's policies. Similarly, discussion with G-Lab concluded that, due to the restricted and controlled access to G-Lab resources, this testbed should better be federated at layer 2, with PLE delegating access to G-Lab for managing their own resources.

Summary

Federation has been introduced a few years ago as a way to benefit from various existing or future testbeds, increasing the benefit for the end user and the sustainability of the diverse facilities. Nevertheless, it is important to note that the presence of common objectives defines a federation. 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. Considering federation in a general case is certainly neither feasible nor meaningful for the problems to be solved within the FIRE framework.

3. Official text of Objective 1.6 in 2009-2010 ICT Workprogramme

Objective 1.6: Future Internet experimental facility and experimentally-driven research

Target outcomes:

a) **Building the Experimental Facility and stimulating its use**: Building the prototype of the Future Internet Research and Experimentation (FIRE) experimental facility to support research for the Future Internet at different stages of the R&D cycle based on the design principle of 'open coordinated federation of testbeds'. The facility shall allow for: large scale experimentation with and comparison of visionary approaches for network architectures and technologies, service architectures and platforms, networked media and trustworthy infrastructures for the Future Internet; experimentation with systems based on cross-layer or non-layered approaches; direct involvement of user communities; assessment of the socio-economic and environmental impact of changes to the Internet. The facility should be dynamic, sustainable, open at all levels and based on open standards. Participation from INCO countries in particular at use level is encouraged.

   a1) **FIRE Components**: an operational prototype facility should be provided at an early stage in the project. Normally, at least 20% of the resources should be earmarked for

gradually expanding the functionality of the prototype in a demand-driven and open way by federating testbeds providing additional functionality within the facility.

a2) **FIRE Users**: using the mechanism of open calls, it is expected that another 20% of the resources are used for extending the use of the experimental facility for research groups that propose innovative usage scenarios exploiting the multiple dimensions and scale of the facility. These activities should exhibit a high degree of innovation in the use of the facility, including system level experiments making a comprehensive use of several components of the facility, large scale experimentation, broad involvement of user communities, and assessment of socio-economic and other non-technological aspects. The results, lessons learnt and recommendations drawn must be of mutual interest, serving the needs of the users as well as helping the facility operators to refine the concept of 'open coordinated federation of testbeds' and the services provided by the facility. Support of individual experiments should be focused on the setting up and running of the experiment and should typically not exceed EUR 200000 per experiment.

b) **Experimentally-driven Research**: Visionary multidisciplinary research, defining the challenges for and taking advantage of the Experimental Facility above, consisting of iterative cycles of research, design and large-scale experimentation of new and innovative network and service architectures and paradigms for the Future Internet from an overall system perspective. The refinement of the research directions should be strongly influenced by the data and observations gathered from experimentation in previous iterations. Research should consider the Future Internet as a complex system and therefore address all the associated aspects in a holistic vision and at all relevant levels and layers. This includes the definition of relevant metrics as well as taking into account energy, low cost, environmental or socio-economic aspects. This research will be an important driving element of the Experimental Facility.

c) **Coordination and support actions**: Coordination of related EU-level and Member States / Associated Countries activities, international co-operation with other initiatives in industrial and emerging countries, and collaboration on standardisation in order to exploit synergies; multidisciplinary networking of research communities addressing both technological and socio-economic and environmental aspects of the Future Internet; coordination of experience research and user-driven open innovation activities establishing common concepts, roadmaps, methodologies and tools, including the sharing of best practices across pilots and sectors.

Expected impact:

- Improved European competitiveness in Future Internet research and development by providing European researchers, in industry and academia, with a unique operational, sustainable, dynamic, and integrated large scale Experimental Facility, which is used by a significant number of Future Internet research projects in European and national programmes and beyond.
- Establishing the methodology of experimentally-driven research for the investigation of innovative concepts for the Future Internet taking a multidisciplinary and holistic approach.
- Assessment at an early stage of the technological, societal, economic and environmental implications of changes to the Internet.

- Strengthened European competitive position on experimentation environments through targeted international co-operation.
- Increased acceptance and use of the concept of user-driven open innovation through demonstrated benefits from complementary approaches of open testbeds, pilots, experience research, etc.

Funding schemes:
a): IP; b): STREP; c): CSA

Call:
ICT call 5

4. Summaries of projects

4.1 FIRE Project Summaries

ECODE combines networking and machine-learning techniques, and (based on these) develops, implements and validates new cognitive routing systems. The new system will improve Internet manageability and security, the availability of Internet paths, and the scalability and quality of the Internet routing system. The new cognitive routing system allows to sample traffic on core links adaptively, monitor the path performance by combining passive and active measurements, detect traffic anomalies leading to performance or QoS degradation, and detect intrusions and attacks. Finally, the routing system proposed by ECODE bases its routing decisions and actions on the metrics derived from these, i.e. the correlation of traffic flows to diagnose and predict deviation over time, efficient path ranking based on QoS and availability metrics, and rerouting to other links in case of failure.

NANODATACENTERS turns the thinking of resource offering and data storage upside down by proposing to take the data storage into the edge of the network. Instead of increasing the capacity of centralised data centres, so-called nano datacenters are introduced, i.e. ISPs would manage the resources in customers´ end-devices (e.g. home gateways and set-top boxes) in a peer-to-peer way. NANODATACENTERS will design and develop the (potentially) cheap and scalable nano datacenter communication architecture (data hosting and delivery), including also security and incentive mechanisms. The full architecture will be implemented, i.e. a NANODATACENTERS box will be fully specified and developed within the project.

N4C is developing networking methodologies to reach the most remote areas, such as scarcely inhabited (camp-based) mountains and forests. Implementation of DTN (Delay and distribution Tolerant Networking) techniques in both Swedish Lapland and Slovenian mountain are studied for different connectivity purposes: reindeer herders in Lapland, radioactivity measurement data in Slovenia. The trade-off between connectivity time and cost is studied, and feasibility and business models verified with several SMEs piloting the ONA (Opportunistic Networking Architecture) solutions. The current scale of the delay in connectivity in the pilot areas is in the range of days and weeks; new technology developed in the project, utilising the existing SNC (Sami Network Connectivity) architecture) is anticipated to reduce the delay by approximately two-thirds, or enabling connectivity in regions where none exists yet.

OneLab2 continues building a large-scale federated experimental facility based on PlanetLab, which is a global testbed enabling research on networking by connecting resources worldwide as slices from distributed servers (nodes). It extends and expands the existing PlanetLab Europe (PLE) by widening the offering with added nodes, features (e.g. wireless), tools (e.g.

monitoring) and federation mechanisms. The PlanetLab framework also grows in Asia, as PlanetLab Japan is to be federated with PLE and PLC (Central). The OneLab2 project directly involves pilot projects that are potential customers of the testbed, trying out novel ideas in both real-world and synthetic environments. The PlanetLab federation concept will be further developed in terms of various incentives, and also heterogeneous testbeds will be interconnected and included in the federation.

OPNEX delivers a new integrated system design framework for wireless multi-hop networks from the physical layer up to the network and transport layers. The new paradigm is based on systems and optimisation theory, yielding the full transportation capacity of the network. This is due to the fact that wireless networks predominantly operate on principles and protocols inherited from the wire-line world, or rely on purely empirical, ad-hoc resource allocation and parameter adaptation rules. The developed system within the OPNEX design framework optimises its performance through validation and comparison with the theoretically optimal performance in terms of throughput, spectrum and energy utilisation. The adopted approach, featuring decentralisation, communication and computational complexity reduction as well as autonomous operation, will lead to implementable algorithms and architectures to be validated eventually in testbeds.

PERIMETER establishes a new paradigm of user-centricity for advanced networking by developing and implementing protocols based on Quality of Experience (QoE). An innovative implementation will be made of "Distributed A3M" protocols for Fast Authentication, Authorisation and Accounting based on privacy-preserving digital identity models. All these mechanisms will be designed to be independent from the underlying networking technology and service provider, so that fast, inter-technology handovers will be possible. PERIMETER will develop and implement middleware that supports generic QoE models, signalling and content adaptation, as well as exemplary extension applications and services for user-centric seamless mobility. The new paradigm and its middleware will be tested in two large-scale interconnected testbeds with real users, in three cycles of increasingly complex scenarios.

PII implements the Panlab (Pan-European laboratory for networks and services) framework, by building a prototype testbed federation based on: a) the interconnection of testbed clusters in four countries: Berlin (Germany), Patras (Greece), Oulu (Finland) and Brittany (France); and b) IMS as a common denominator in the testbeds, that is utilised for the resource management. PII develops an automated resource composition tool, Teagle, to identify and combine the needed elements from various (distributed) sources which are part of the federation, according to the request defined by the testing customer. PII studies also the socio-economic aspects of the federation and implements UDI (User-Driven Innovation) concepts in both the design and offering of the experimental facility.

ResumeNet increases the resilience of the network, by introducing a new architectural approach to Internet resilience that is multilevel, systemic, and systematic, but yet maximising interoperability with legacy network components. The resilience is defined by the project as the ability of the network to provide and maintain an acceptable level of service in the face of various faults and challenges to normal operation. The architectural approach builds on identified principles (self-protection, redundancy, diversity, and resource tradeoffs), their relationships, challenges to the network operation, i.e. threats, and required building blocks (monitoring, learning processes, decision engines). Finally, ResumNet selects particular network-level and service provision scenarios for deepening the mechanism-level analysis and carrying out experimental evaluation.

Self-NET develops a framework that is based on the operation of self-managed Future Internet elements around a novel feedback-control cycle. Self-NET embeds new management

capabilities into network elements in order to take advantage of the developed knowledge among the various autonomic elements and develops cross-layer design optimisation approaches that alleviate the shortcomings and duplication of functionalities in different protocol layers of the present IP stack. Self-NET provides a peer-to-peer style distribution of responsibilities among self-governing elements of the Future Internet and, based on hierarchical distributed cognitive cycles, orchestrates and optimizes the configuration of mobility management, flow control, and QoS mechanisms. Applicability, robustness, and stability of the Self-NET solutions are verified in a prototyping environment. In parallel, scalability and performance sustainability of the Self-NET outcome are also simulated.

SMART-Net proposes a novel system architecture and associated networking protocols enabling the next generation of Broadband Wireless Access (BWA) based on a decentralised vision in which access infrastructure and functions are partly distributed across the network and smart antennas. This yields a reduction of service cost and a significant increase of performance by allowing the system to support a high number of simultaneous transmissions, re-configurability, scalability and security. The approach is strengthened with advanced routing and scheduling protocols specifically designed for heterogeneous wireless mesh networks. SMART-Net verifies the developed architecture in large-scale experimental facilities by interconnecting the real and virtual testbeds, thereby merging both real and simulated worlds.

VITAL++ combines peer-to-peer technology with IMS-type Control Plane functionality, hence studying a novel paradigm combining the two popular worlds. Peer-to-peer fosters self-deployment and self-organisation, reducing operational costs, while achieving optimised resource utilisation. On the other hand, IMS as a Control Plane technology addresses issues of heterogeneity of access technologies, addressing schemes, AAA, security and mobility management. This led to the idea of developing the complementary technologies for satisfying the needs of both the user-created voluminous content distribution and increasingly fragmenting legacy/transition networks. The project sets-up an IMS client for peer-to-peer content transmission and connects several IMS testbeds around Europe to create a realistic experimentation and verification platform for the new paradigm, which will be open for others requiring comparable resources (e.g. experiments on scheduling in content distribution and Control Plane issues for the Future Internet architecture as addressed also in GENI).

WISEBED provides a multi-level infrastructure of interconnected large-scale wireless sensor network testbeds. The WISEBED approach integrates the aspects of hardware, software, algorithms, and data. This will demonstrate how heterogeneous small-scale devices and testbeds can be brought together to form a well-organized, large-scale structure that enables research despite the scale, also in different quality, due to its heterogeneous and dynamic structure. WISEBED implements recent theoretical results on algorithms, mechanisms and protocols and transforms them into the software library WISELIB. The developed interconnection of wireless sensor network testbeds will be made available to all European researchers.

FIREWorks

Paradiso

4.2 FET-SAC projects

ANA (Autonomic Network Architectures) is developing a novel network architecture (beyond IP) that can enable a flexible and autonomic formation of network nodes according to working, economic and social needs. Its objectives are mainly focused on studying the adaptation and

reorganisation of the network. In particular, the project aims at analyzing fundamental principles around functional scalability, both horizontally (adding more functionality) and vertically (integrating the functionality).

BIONETS (BIOlogically-inspired autonomic NETworks and Services) investigated nature and society for the introduction of novel networking/service provisioning paradigms tailored to pervasive computing environments. BIONETS exploits opportunistic communications as a mean to provide a localised peer-to-peer support to autonomic services, which embody evolutionary capabilities in order to be able to adapt and self-organise without requiring any explicit human intervention.

CASCADAS (Componentware for Autonomic, Situation-aware Communications And Dynamically Adaptable Services) has defined a new generation of highly distributed, pervasive, situation-aware, semantically self-organising communication-intensive services, by developing a common abstraction level for autonomic communication services. The focus is on situation awareness, semantic self organisation, self-similarity, and autonomic component-ware.

HAGGLE (An innovative paradigm for autonomic opportunistic communication) is developing a new (cross-layer) network architecture exploiting intermittent connectivity. In this new architecture, message forwarding is driven by the application rather than by the control information of the network layer. This way, the architecture is able to support an opportunistic networking paradigm in which the delivery of messages is based on storing and forwarding, exploiting situated information.

EVERGROW (EVER-GROWing global scale-free networks, their provisioning, repair and unique functions) studied Internet measurement technologies and their effects on distributed applications. It invented methods and systems, and built infrastructure and peer to peer overlay networks and algorithms, for the measurement, mock-up and analysis of network traffic, topology and logical structure, so as to start addressing now the opportunities presented by the Future Internet, also by exploiting complex systems research principles and physics-based approaches.

CATNETS (Evaluation of the CATallaxy paradigm for decentralised operation of dynamic application NETworkS) proposes an alternative approach for realising resource allocation in dynamic application layer networks, by applying a decentralised economic self-organisation mechanism called "Catallaxy". The project is studying the applicability and implementation possibilities in P2P middleware, eventually providing a prototype, to obtain performance results both from a technical and economic point of view.

COOPCOM (COoperative and OPportunistic COMmunications in wireless networks) studies the combined use of cooperation and opportunism, two concepts that have recently revolutionised the way engineers think about wireless system design and which target the maximisation of the spectral and power efficiency at the system level. It will explore performance limits of cooperative and opportunistic schemes and develop efficient strategies also for efficient resource allocation with limited feedback, including decentralised resource allocation, eventually implementing selected schemes on a test-bed.

NET-REFOUND (NETwork REsearch FOUNDations and trends) aims to develop the theory, methods and algorithms suitable for the modelling, analysis and design of future

telecommunication networks. The long-term goal is the theoretical understanding of the collective interaction of a multiplicity of communicating nodes beyond the boundaries posed by specific telecommunication standards. This will lead to a quantitative characterisation of the fundamental performance limits of these systems and eventually to algorithms for achieving them.

4.3 Research Networking Testbeds

Under the Strategic Objective on Research Networking Testbeds (~€30m funding), several testbed projects were started to pave the ground for a future generation of e-infrastructures for research. The goals of these projects are integrating, testing, validating and demonstrating new fixed and wireless networking technologies and services in both real-world settings and production environments.

Two of the projects, started in 2006, experimented with the *concept of federating or interconnecting testbeds on networking and services*:

ONELAB (An Open NEtworking LABoratory supporting communication network research across heterogeneous environments) addressed proof-of-concept testbeds for researchers, by extending and deepening the current PlanetLab approach to Europe (PlanetLab is a worldwide interconnection of testbeds for networking technologies managed by Princeton University).

PANLAB (The Pan-European Laboratory for Next Generation Networks and Services) derived a framework for the federation of testbeds on a broad scale.

Three of the projects dealt with *Quality of Service*:

OPENNET (OPEN interconnect for the interNET community) identified solutions to the main barrier for a fuller-scale IP deployment: the lack of predictable support for QoS, when packets have to cross many domains. The project brought together the major Internet router manufacturers worldwide and identified QoS parameter values for Premium IP services.

NETQoS (Policy based management of heterogeneous NETworks for guaranteed QoS) addressed the issue of management of QoS in heterogenous environments, with the objective of adapting the QoS system according to the changing physical networks taking into account QoS management policies.

EuQoS (End-to-End Quality of Service support over heterogeneous networks) resolved the design issues associated with the delivery of end-to-end QoS service across heterogeneous networks. The key objective of EuQoS was to research, integrate, test, validate and demonstrate and-to-end QoS technologies to support the infrastructure upgrade for advanced QoS-aware applications.

Two of the projects dealt with the development and implementation of the *IPv6 protocol*:

IPv6 TF-SC (IPv6 Task Force Steering Committee) The aim of the project was to assure the success of IPv6 deployment. The IPv6 TF-SC project, in its role as the facilitator of the Task Force, monitored the academic, market and industrial activities, and provided guidance to avoid duplication of work.

RING (Routing In Next Generation) investigated the routing protocols and infrastructure, and their ability to support new services in a scalable manner. Multihoming situations, inter-domain traffic engineering, the security of the routing infrastructure and utilisation of IP in airplanes, cars, trains, ships and other forms of transport were considered.

Two projects took an *application-oriented view*:

ANEMONE (Advanced NExt generation Mobile Open NEtwork) realised a large scale testbed, providing support of mobile users and devices and enhanced services by integrating cutting edge IPv6 mobility and multihoming initiatives together with the majority of current and future wireless access technologies.

VITAL (Enabling convergence of IP multimedia services over next generation network technology). Building on the results of past and ongoing IST projects related to the research on IMS technology, VITAL consolidated the technological framework to enable the smooth transition of multimedia communications, including voice, from circuit- to packet- switched domain of the communication. The project set up an experimental IMS distributed platform, elaborated solutions to the aforementioned problems and tested, validated and assessed the resultant integrated IMS functionality in the context of advanced traffic experiments and theoretical simulations.

4.4 Selected Future Networks Project Summaries

UNITE – A (simulation) testbed for experimenting with several different radio technologies – up to Layer 3.

RESERVOIR -

IRMOS (www.irmosproject.eu) works on virtualisation approaches that go beyond storage and Cloud computing by delivering real-time, end-to-end QoS guarantees

Trilogy – incremental evolutionary approach, but is moving fast, and closing the gap with revolutionary work.

4ward -

5. Use cases from the Services research community

Project	Main topics	Facility need/output
SOA4ALL	In a world full of services it is the service that counts, not the software or hardware components that carry it out. SOA4All integrates four technological advances into a domain-independent service delivery platform: Web principles for the underlying infrastructure; Web 2.0 to structure machine-human cooperation; Semantic web to enable meaningful service discovery; and context management to process user needs for human-machine interaction.	A main contribution of SOA4All will be to provide mechanisms for the adaption of services to local context. Providing diverse instances of local context is one way a testbed could be of service to SOA4All.
RESERVOIR	Reservoir will provide an infrastructure for the reliable and effective delivery of services as utilities. The infrastructure will support the set-up and deployment of services on demand across disparate administrative domains. Through harnessing the power of virtualisation and grid technology, Reservoir uses each service in a cloud-like way to maintain QoS through tight SLA control.	Through modelling the multiple administrative domains in the services layer, a future FIRE facility could test Reservoir hypotheses relating to service and

Project	Main topics	Facility need/output
		infrastructure management in specific administrative domains.
IRMOS	Differentiated from Service-Oriented Infrastructure in general, IRMOS provides a single infrastructure that manages human-machine interaction based on real-time attributes at all levels (network, processing, storage, application, workflow and business) whilst guaranteeing quality of service, It does this within a virtual organisation uniting individual participants in an inter-organisational value chain. It provides a quick and efficient assembly of these value chains without the need for protracted manual negotiations.	A testbed with resources whose attributes vary in real time and with competing participants for the value chain position would allow IRMOS to optimise the automatic breaking and making of business agreements within the value chain (ie the reconfiguration of the process in question).
Smart LM	Smart LM aims to provide a new generic framework for licensing software in a virtualised framework – highly pertinent to the Internet of the Future where software cannot be considered tied to any one piece of hardware and, as discussed above, we see a paradigm shift from using specific pieces of software and hardware to perform a certain function to calling on a service to perform that same function, but where we no longer worry – or even know - which software or hardware was used by that service.	A testbed of virtualised resources will provide software vendors and researchers with the ability to test the compliancy of their software to the Smart LM framework.
COIN	By developing an adaptive service platform to host interoperability and collaborative services for SMEs to run their businesses in a secure, reliable and efficient way, COIN will provide the "glue" to fully exploit pre-existing and innovative services. Based on a Software as a Service Utility (SaaS-U) approach, to be successful the platform must be robust enough to withstand the demands made of it by SMEs with a strong guarantee of service. Once launched for use by the SMEs, improvements and developments made to the platform must not interfere or risk the service received by the SMEs, who rely on it for business.	A suitable testbed would allow the platform to be isolated from the end users for second-generation experiments to be carried out in a controlled manner, with no risk to the existing customers.
ASPIRE	ASPIRE is developing a middleware designed to incorporate privacy protection and 'privacy friendliness'. This is done through removing unnecessary data tags, separating personal and object data, establishing certification programs and drafting guidelines for adopters, among others. A series of pilots are being carried out that will verify that the developed middleware is programmable by SME developers, that it can be deployed in a cost efficient manner, that it is scalable and that it is user friendly.	Moving from preplanned pilot scenarios to the sheer scale and complexity offered by federated testbeds would increase the observable and controllable conditions available to the project and enhance the validity of these tests several fold.

6. FIRE Relation to Member State initiatives

Not only has FIRE to continuously position itself with the State-Of-the-Art internationally, but it needs to also find the right interaction with EU national initiatives to leverage the global effort, and for the large-scale testing of service-oriented applications. This was clearly emphasized during the FIRE launch event held in Paris (September 2008) with a specific focus on the French and German initiatives.

Mechanisms need to be found to include national resources in that federation, and discussions are on-going with the most-advanced and relevant national initiatives in order to better explore synergies and potential for cooperation at different levels.

However, it must be recognized that the above outlined objectives of a federation of national resources are unlikely to be realized in a single form of federation since they can or are contradicting and are therefore hard to align (common objectives are a cornerstone of ANY federation). Hence, the establishment of different federations must be considered, e.g. one that targets early stage (open) research exchange to stimulate new and innovative ideas, another one targeting pre-commercial exploitation (including the generation of patent and the alignment with upcoming standards) and yet another possible one that targets integration of end user involvement (requiring alignment with local usage policies, governance policies and alike).

Following, are presented some meaningful national initiatives within the FIRE area.

6.1 French National Initiatives in the area of Testbeds

Several technological networking testbeds exists in France, mainly funded by ANR or other Agencies such as INRIA. Most of the ANR testbeds are related to low layers and physical technologies. However, a few are within close interest to FIRE.

6.1.1 IDROMEL: Impact of reconfigurable equipments for the next generation of wireless systems

The main objectives of IDROMel are:

- An impact assessment of reconfigurable equipment in the next generation of wireless systems
- To propose to the French and international R&D community an open architecture reconfigurable equipment

The Hardware and Software elements developed in IDROMel will be integrated into a demonstrator that will have the main features of a reconfigurable radio access network. The resulting testbed will be validated through realistic experimentation in Sophia Antipolis, France. This testbed will be open at several levels:

- As far as possible, the Software will be under a General Public License, an a broad access to this Software will be given to the R&D community
- The hardware parts of the testbed will be duplicated for external partners or projects, in order to give to the R&D community a tool for the validation of Software Designed Radio related studies.

6.1.2 SenseLab: ANR RNRT “Very large open wireless sensor networks” (2008-2010)

The purpose of the SenseLab project is to deploy a very large scale open wireless sensor network platform. SenseLab's main and most important goal is to offer **an accurate and efficient scientific tool** to help in the design, development, tuning, and experimentation of real large-scale sensor network

applications. Ambient and sensor networks have recently emerged as a premier research topic. Sensor networks are a promising approach and a multi-disciplinary venture that combines computer networks, signal processing, software engineering, embedded systems, and statistics on the technology side. On the scientific applications side, it covers a large spectrum: safety and security of buildings or spaces, measuring traffic flows, environmental engineering, and ecology, to cite a few. Sensor networks will also play an essential role in the upcoming age of pervasive computing as our personal mobile devices will interact with sensor networks dispatched in the environment.

The SenseLab platform will be distributed among 4 sites and will be composed of 1,024 nodes. Each location will host 256 sensor nodes with specific characteristics in order to offer a wide spectrum of possibilities and heterogeneity. The four testbeds will however be part of a **common global testbed** as several nodes will have global connectivity such that it will be possible to experiment a given application on all 1K sensors at the same time.

When deployed, SenseLab will be a unique scientific tool for the research on wireless sensor networks.

The participants are INRIA-ARES (E. Fleury), INRIA-ASAP (M. Bertier), INRIA-PoPS (D. Simplot-Ryl), Thales Communication S.A. (V. Conan), UPMC-LIP6 (M. Dias di Amorim), ULP-LSIIT (T. Noel).

6.1.2 PERSYST II

PERSYST II (Platform for tEst and Research on optical telecommunication SYSTems) is a physical layer testbed and therefore only partially related to the FIRE topics. The platform will increase the bit rate of an earlier long haul wavelength division multiplexed (WDM) transmission system from 40 Gbps up to 170 Gbps, which corresponds to the next generation of WDM systems

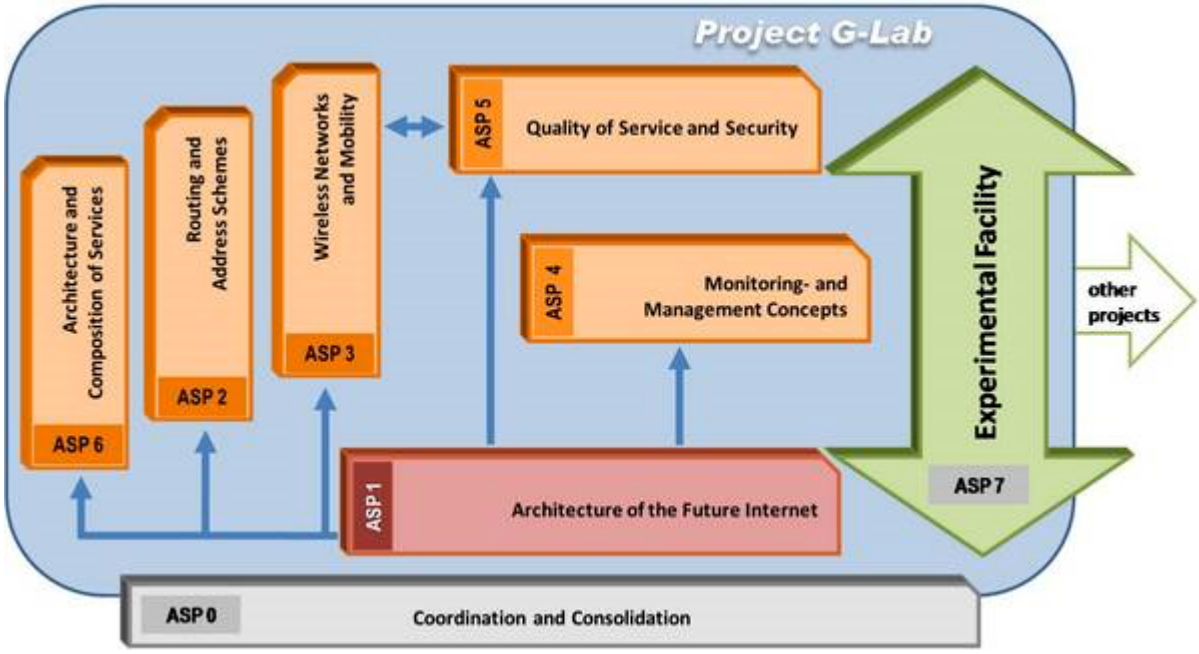
6.2 German National Initiatives in the area of Testbeds

6.2.1 G-Lab “National Platform for Future Internet Studies”

G-Lab (www.german-lab.de) is a Germany-wide research project funded by the German Federal Ministry of Education and Research. It consists of a research and experimental facility used to investigate the interplay between new technologies and the requirements of emerging applications. The first phase of the project consists of six partners from Universities, started in October 2008 and runs for three years. The initial G-Lab testing facilities consist of wired and wireless hardware with over 170 nodes which are fully controllable by the G-Lab partners. The second phase will start at the end of 2009 and will integrate industry partners as well as research centers into the consortium.

The project partners develop a secure and reliable platform for applications and services. Most important is the development of new mechanisms for routing, addressing, etc., and their investigation with regard to practical feasibility, scalability, and performance in realistic environments. The current problem is that new Internet services and applications make increasing demands on security, reliability, and quality of the networks. It is more than just music and video downloads: services in medicine and healthcare. Business processes or advanced training over video conferences are examples for fields of applications for which the Internet becomes indispensable. To cope with the growing demands, new architectures and protocols need to be developed on the conceptual level and tested in an experimental facility.

To cope with these problems, 8 workpackages have been set up within the G-Lab project as shown in the figure below. One work package (ASP7) is responsible for the testbed setup and maintenance. The other work packages (ASP1 to ASP6) are research projects whose research can be seen as experimental-driven research.



Every research project consists of some test projects whose tests are performed either within a local testbed at one site, within the G-Lab experimental facility, or within a federated testbed. A federation of G-Lab with other testbeds might be required to:

- Perform scalability tests (G-Lab consists "only" of 170 nodes)
- Testing algorithms in a heterogeneous environment
- Testing not only within one Tier (All G-Lab nodes are connected to the DFN)
- Testing under more realistic conditions
- Extend the geographic distance between the sites to get e.g. longer delays

As the initial G-Lab platform is based on the PlanetLab Software, a slice-based federation between e.g. OneLab and G-Lab may be realized. Besides the hardware-based federation of testbeds, the following federation approaches should also considered:

- Software federation: Exchange of testbed-related software
- "Human" federation: Offer the possibility of student internships
- Knowledge exchange: Organize events like the FIRE Workshops to give technicians and researchers the chance to exchange ideas

6.3 Belgium National Initiatives in the area of Testbeds

6.3.1 iLab.t Testbeds

IBBT (www.ibbt.be) is an internationally recognized multidisciplinary ICT research institute, stimulating ICT innovation (looking at technological, legal, business and sociological aspects). IBBT enables accelerated development and exploitation of new ICT products and services in strategic sectors in Flanders. IBBT unites more than 600 researchers from numerous Flemish universities and knowledge centers.

Future Internet research is one of the main research themes in the programs of IBBT. This is reflected in the long-term research projects, in which Future Internet research is an important research area. On the other hand there are the research programs with industry, which have shorter-term goals, looking at

the shorter-term impact of the Future Internet developments. In order to support the research for the Future Internet, IBBT has invested heavily in the development of a technological Future Internet research infrastructure, the iLab.t Technology Centre (ilabt.ibbt.be).

iLab.t is a technology and knowledge center at IBBT to support experimental multi-disciplinary research for Future Internet technology and innovative ICT services and applications. It is connected locally to industry and research groups, and connected globally for worldwide collaboration. iLab.t is flexible and adaptable to support a wide range of research projects. iLab.t contains an extensive set of user devices, network technologies, and advanced testing and measurement equipment, and has adequate network connectivity. The floor space covers around 500m^2, with 80+ racks, 550+ server nodes, and various technologies like IP, Ethernet, xDSL and coax access. In addition to a wired testbed, iLab.t includes a significant wireless testbed, Virtual Wall emulation facilities, an operational GRID network, file-based production, video testing and physical layer facilities. The iLab.t Technology Center can be accessed externally for collaborative research through remote login facilities, under policy conditions.

The **iLab.t Wireless Lab** is an extensive wireless mesh and sensor network infrastructure deployed in IBBT office spaces, meeting rooms, student lab rooms, corridors, iLab.t, … It consists of 200 heterogeneous sensor nodes and 400 802.11 WLAN access points. It has a limited set of mobile sensors (on moving robots). The Wireless Lab is connected to iLab.t Virtual Wall, high bitrate wired network, generic test equipment … It features automatic control, software configuration, and remote access. Its unique features include power monitoring, control (no batteries, PoE), and measurement, as well as emulation (e.g. replay) of sensor measurements. The iLab.t Wireless Lab allows for easy and flexible testing of functionality and performance, of stress, interference and scalability, and log of the sensor and WLAN nodes' events.

The **iLab.t Virtual Wall** is a generic test and emulation environment for advanced network, distributed software and service evaluation, and supports scalability research. It has 100 nodes (dual CPU, dual core, over 500x 1 Gbps Ethernet network interfaces), interconnected via a non-blocking central switch (Force 10 networks: 576x 1 Gbps port; 8x 10 Gbps port; 1.6Tbps backplanes), and a display wall of 20 monitors for experiment visualization. Virtual Wall nodes can assume different functionalities: terminal, server, network, impairment node. They can be connected to test boxes for wireless terminals, generic test equipment, simulation nodes (for combined emulation and simulation), etc. Full Automatic Install is available for fast context switching (e.g. 1 week experiments). The iLab.t Virtual Wall emulation facilities are remotely accessible.

IBBT's current projects related to Future Internet research are:

- European projects: DICONET, MOBITHIN, SOCRATES, ECODE
- Projects with local industry: DEUS (Deployment and Easy Use of wireless Services), PecMan (Personal Content Management Platform), GEISHA (Grid Enabled Infrastructure for Service Oriented High Definition Media Applications), TIGER (Together IP, GMPLS and Ethernet Reconsidered)

6.4 The Netherland National Initiatives in the area of Testbeds

The following testbeds are not necessarily located in The Netherlands but The Netherlands participates heavily in them and they are very important for the development of the Research Networks and the Internet.

6.4.1 DAS-3 (The Distributed ASCI Supercomputer 3)

The Computer Science institutes at a number of Universities have an experimental testbed named DAS-3 <http://www.cs.vu.nl/das3/>. DAS-3 is a five-cluster wide-area distributed system designed by the Advanced School for Computing and Imaging (ASCI). DAS-3 is funded by The Netherlands Organisation for Scientific Research, the VL-e project, and the participating universities and organisations (see below). As one of its distinguishing features, DAS-3 employs a novel internal wide-area interconnect based on lightpaths.
The goal of DAS-3 is to provide a common computational infrastructure for researchers within ASCI, who work on various aspects of parallel, distributed, and grid computing, and large-scale multimedia content analysis.

The following institutes and organisations are directly involved in the realization and running of DAS-3:

- Vrije Universiteit, Amsterdam (VU)
- Leiden University (LU)
- University of Amsterdam (UvA)
- Delft University of Technology (TUD)
- The MultimediaN Consortium (UvA-MN)

DAS-3 has connections with the French G5K testbed.

6.4.2 The SURFnet7 Testbed

SURFnet runs a test network to test new developments. Part of it is StarPlane <www.starplane.org>. The test network is connected to NetherLight and to SURFnet7. For more details, see <www.surfnet.nl>

6.4.3 GLIF, Global Lambda Integrated Facility

GLIF, the Global Lambda Integrated Facility, is an international virtual organisation that promotes the paradigm of lambda networking. GLIF provides lambdas internationally as an integrated facility to support data-intensive scientific research, and supports middleware development for lambda networking. It brings together some of the world's premier networking engineers who are working together to develop an international infrastructure by identifying equipment, connection requirements, and necessary engineering functions and services.

The GLIF participants are National Research and Education Networks (NRENs), consortia and institutions working with lambdas. Administrative support is provided by TERENA with financial support from sponsoring organisations.

6.4.4 CineGrid: Digital Cinema and HQ media on Optical Networks

CineGrid <www.cinegrid.org> is an interdisciplinary community that is focused on the research, development, and demonstration of networked collaborative tools to enable the production, use and exchange of very-high-quality digital media over photonic networks. The University of Amsterdam is one of the founding members.

6.5 Swedish National Initiatives in the area of Testbeds

The national programme “Branschprogrammet” is managed by the the Swedish Governmental Agency for Innovation Systems, VINNOVA (www.vinnova.se). This is a Research & Development programme for the IT and Telecom industry in Sweden within mobility, mobile communication and broadband, in collaboration with the public sector. The programme started in 2006 and ends in 2010. It

has initiated more than 50 R&D and demonstration projects with a total budget of approx 24 MEUR. More than 40 research groups and more than 40 companies participate. The overall goal is to support Swedish industry and research in this IT and Telecom sector to keep a world class position. The objective is to create technical solutions which create growth in network-based and mobile services. The main actors are Swedish Universities and telecom operators (e.g. TeliaSonera) and industry (e.g. Ericsson).

Research is ongoing at several Swedish Universities and R&D institutes, both national and international e.g. EU funded projects. Some are R&D programmes, some are small individual projects, some are public and others are private (company related). Some examples are given below.

6.5.1 The SICS Center for Networked Systems

The SICS Center for Networked Systems (CNS) is a joint industry - academia research center. The center is funded by VINNOVA, SSF, and KK-Stiftelsen through the programme Institute Excellence Centres. Researchers at the center perform leading edge research on networked systems in close collaboration with industry and the public sector. Results are commercially exploited by the partners and also communicated to the public. Their research vision is of a secure and reliable Internet infrastructure which provides a predictable service and enables robust applications on heterogeneous networks that are easier to manage.

Like FIRE, they believe that the current Internet technology has fundamental deficiencies making reliable operation of critical applications difficult. To address these deficiencies, the whole networked system, comprising the systems view from user expectations to the underlying network technology, needs to be considered. Examples of networked systems are mobile telecommunication systems, factory automation systems and banking systems.

The industry partners are ABB, Ericsson, Saab Systems, TeliaSonera and T2 Data. The academic partners are KTH, Mälardalen University and Uppsala University.

Contact : Bengt Ahlgren, bengta@sics.se, www.sics.se/cns

6.5.2 Fiber Optic Valley

The core business of Fiber Optic Valley (www.fiberopticvalley.com) is to assist the growth of global and local companies. This is achieved through their specific support for research, training, financing, contacts and business development, combined with a modern test environment for technical tests and behavioural science studies. It is a unique meeting place for system suppliers, operators, service developers, innovators, researchers, users and intended customers. The end users, or test pilots, can be private citizens, companies or public bodies.

Contact: info@fiberopticvalley.com

6.5.3 The Institute for Humane Technology

The Institute for Humane Technology (IHT: www.iht.se) works with the objective "Design For All". This means, "to take measures in environments, products and services with the purpose to ensure that everyone, regardless of age, sex, ability, or cultural/ethnical background, can take part in building society".

The IHT is a national knowledge centre founded by NITA, national user centre of IT at the University of Uppsala, the World Internet Institute (www.wii.se) and the municipality of Bollnas.

The IHT contributes to the creation of solutions to benefit large user groups through the use of knowledge about the needs and conditions of vulnerable groups in the community. The IHT is generally commissioned to analyse how an existing service or product is perceived and how best to design new products/services (or modify existing ones). Such commissions can relate to information

material, instructional texts on product packaging, web pages or Internet based services. The IHT works on Research & Development topics in collaboration with KTH and the University if Linkoping.

Contact: info@iht.se

6.5.4 The Interactive TV Arena

The Interactive TV (ITV) Arena (www.itvarena.com) is a development institution, where the knowledge of interactive television started being assembled in the early 2000s. Knowledge on the interactive TV service is currently scattered among a large number of operators in several countries. The formation of a cluster of related partners was considered to be the natural way to link research and innovation, as well as technology, service and business development to create a powerful center for this subject.

The mission of the ITV Arena, in cooperation with the cluster partners, is to develop and test interactive television and technology services, as well as initiate and pursue research projects. The ITV Arena supports market development for a broad launch of interactive services. This market consists primarily of public and private service providers, broadband network owners, as well as TV and production companies.

To achieve top industry standing in Europe, the ITV Arena works through five development projects.

1. *Infrastructure and test population*
   The design of technology solutions for production, integration and deployment of interactive TV services to a well-defined population.
2. *Design and functionality*
   The development and adaptation of the TV-medium's interface and functions for the optimal ease-of-use. The way in which services will be designed to reach different users, as well as how this new medium affects user behaviour are being compiled in a design manual.
3. *Service Development*
   The development of interactive services, for areas such as education, public transportation, employment and public services in fields such as nursing and care, but also for interaction with live television programs or television advertising.
4. *Service Technology*
   The development and adaptaion of software integration and distribution of interactive services.
5. *Positioning*
   This project works for the continued development of the cluster and the upholding of its values. It disseminates information through seminars, workshops, conferences and the media, and analyses the markets and potential investors to tap the interactive TV service's potential for business and social benefits.

Contact: info@itvarena.com

6.5.5 Future Position X

Future Position X (FPX: www.fpx.se) is the meeting-place for companies and organisations that promote growth and development within the GIS-field. FPX works towards the development of the Gavle region into an international GIS-centre.

FPX is an independent society that supports and develops the member companies' competitive abilities and presence in the market within the GIS-field. By being a development partner with an innovative and user-friendly perspective, FPX contributes to the forming of new companies and to the growth of

these companies. One of the targets of the society is to have participated in the creation of 150 new jobs by 2009.

Several new companies have been formed and more than 15 million SEK in seed financing/venture capital has been raised. Three foreign companies working in the GIS field are currently moving into the Gavle area. FPX has also established businesses in Norway, Estonia and Finland as well as formed a good and close co-operation with the Fiber Optic Valley. Much of the work during the first years has been directed towards creating a platform to build the activities upon. The next phase is to extend the activities and get more participants into the operative work; regionally, nationally and internationally. FPX has constructed a GIS development lab situated in Teknikparken on Nobelvagen in Gavle. The FPX-lab offers opportunities to test, develop and evaluate systems/services in a realistic multi-user environment, a closeness to GIS-competence as well as access to a community in which companies can try out their products on the market

Contact: info@fpx.se

6.5.6 Acreo National Testbed (ANT)

The Acreo National Testbed is a real access network delivering IPTV and Internet to approximately 60 households in the City of Hudiksvall. The ANT is also a meeting place for a wide spectrum of regional, national and international institutions and companies working with research and commercialization of products and services for broadband networks. The ANT includes different kinds of testbed work that can be roughly divided into the following areas:

6.5.6.1 ANT: Fixed access

The broadband access part of ANT contains a test pilot population of around 60 people living in Hudiksvall who are connected to Acreo equipment located in the network of the local municipal network. The test pilots have a high speed broadband connection (10 or 100 Mbit/s symmetrical) and get Internet and TV and in some cases telephony over this connection. The test pilots are subject to test of equipment (either in their own homes or in the access network) and services (primarily over the TV but also internet based). Acreo has designed and built an open IPTV platform which supplies TV but also many other services such as video on demand, games, guitar playing lessons etc.

6.5.6.2 ANT: Mobile access

A 3G testbed has recently been established which fully built out will contain 20 test pilots in scarcely populated areas outside of Hudiksvall. Some test pilots have never had broadband access before, and through traffic measurements and interviews we hope to get an indication of how such a fixed-wireless connection impacts people's lives and behaviour. The services that will tested are compressed IPTV and IP-based telephony.

6.5.6.3 ANT: Behaviour

The behaviour testbed includes traffic measurements of almost 2000 households in Hudiksvall and in a municipality network in southern Sweden. These measurements allow us to investigate people's internet traffic patterns in terms of popular applications, peak traffic hours etc. Other ways of monitoring test pilot behaviour are through personal interviews and through interactive, TV-based questionnaires.

6.5.6.4 ANT: Connectivity

Acreo has many partners - primarily around Stockholm and Kista, in Hudiksvall and at Mid Sweden University in Sundsvall - with whom we exchange contents. Typically Acreo partners get access to their IPTV platform. This requires operating a geographically wide network including switches, routers and optical transmission equipment.

The ANT is funded by a combination of EUs regional funds and national Swedish funds.

6.5.7 Acreo GMPLS Testbed

The Acreo GMPLS Testbed is a laboratory network that consists in a combination of real and emulated network elements using three data plane switching technologies:

- IP/MPLS
- Ethernet 802.1Q
- Optical cross-connects and ROADMs

An important benefit of the Acreo GMPLS testbed is the possibility of interoperability tests between vendors that had products in this area. Today, Acreo has full control and in-house development of their GMPLS software stack (routing, signalling, data plane control and emulation). Apart from interoperability testing, Acreo's in-house developed code base enables the implementation and testing of novel solutions, standard solutions, and to support work being done in standardisation bodies, as well as creating network demonstrators in various projects. Current development includes functions specific for MPLS Transport Profile.

The Acreo GMPLS Testbed receives funding via projects from several different sources, EU projects, Industrial projects and National Swedish research projects.

6.5.8 Testbed Future Internet

The Testbed Future Internet is a project funded by Vinnova (The Swedish Governmental Agency for Innovation Systems). The project aims at complementing the existing Testbed activities to create an attractive meeting point for developers of digital services. The project is carried out by Acreo and SICS jointly.

6.5.8.1Service platforms

The project is working towards developing a standardized API for open IPTV and to implement this in the IPTV platform of ANT. The project will also investigate possibilities to include an IMS platform in the ANT.

6.5.8.2 Panel of viewers

The project will use a panel of viewers and collect their opinion about the video quality in different situations. This is done within the frame of VQEG (video quality experts group) as a part of a large effort of developing objective video quality measures.

6.5.8.3 Information services

Network operators have information of the user behaviour, e.g. the amount of traffic they generate, the type of applications that are used, and in mobile networks also the position of the user. The project will investigate how to collect and make use of this type of information while maintaining user privacy.

6.6 Israeli National Initiatives in the area of Testbeds

IGT, originally a Grid consortium, which now also coordinates access to various cloud computing options in addition to GRIDs. They have national and industrial funding.

RESERVOIR, EC-supported and run out of IBM's Haifa Research Lab, is an open-source initiative in middleware for cloud computing.

Cisco's Labs in Herzlia run an annual set of workshops and sponsor small-medium sized research grants at many universities in Israel. (Yuval Shavitt, for example.) I don't know if they actually offer an externally accessible testbed.

6.7 Hungarian National Initiatives in the area of Testbeds

6.8 Polish National Initiatives in the area of Testbeds

6.9 Finnish National Initiatives in the area of Testbeds

6.10 British National Initiatives in the area of Testbeds

6.11 Italian National Initiatives in the area of Testbeds

6.12 Spanish National Initiatives in the area of Testbeds

RedIRIS is the Spanish academic and research network that provides advanced communication services to the scientific community and national universities. It is funded by the Spanish Ministry of Science and Innovation and included in the Ministry's map of Special Scientific and Technological Facilities.

RedIRIS participates in the FEDERICA project, contributing in the following aspects of the project:

- Identification of user groups and their specific needs and requirements.
- Collaborating in the dissemination of the project and organizing training courses. Collaborating in network infrastructure design and in the development of management and monitoring procedures in a multi-domain environment.
- Integrating authentication and authorisation infrastructures for accessing project services and participating in the development of tools for creating and controlling virtual infrastructures.
- Participating in research work on new resource management models.

PASITO (Telecommunications Service Analysis Platform) is a project funded by the State Secretariat for Telecommunications and the Information Society (SETSI) of the Spanish Ministry of Industry, Tourism and Trade (MITYC) and coordinated by RedIris. Its aim is to provide experimental activities in services and Internet protocols. It encompasses the design virtual network infrastructure for experimentation and the definition of priority lines of research such as: service quality transport technologies, virtualisation and self-configuration of networks and services, network and service monitoring technologies and tools, optical services for data-intensive projects, network security improvement technologies, etc. The main objectives of the project are the Deployment of an experimentation platform for new Internet services and protocols as well as to provide an Open platform in which other academic and research centre research groups and, occasionally, operators and manufacturers, collaborate.
Activities in the project enclose:

- Massive information transfer in IP networks
- Network virtualisation

- IPv6 © services
- Multi-service NGN networks - includes IP network service quality management techniques , intermingling of multimedia flows , high-performance multi-service provision for IMS/NGN networks , multi-protocol collaboration experiences and service provision in a multi-supplier environment
- Measuring, monitoring and management tools
- Next-generation optical networks – includes very high-capacity services over optical networks , service rendering over optical networks and multi-domain protection in IP/G/MPLS networks
- Authentication and authorisation services

7. FIRE Relation to International initiatives

In the international context, the main interaction is with the US NSF/GENI initiative as testified by the FIRE/NSF meeting held in Madrid on December 2008 and a subsequent meeting in Washington? in April 2009. In addition, several workshops have been held between the European Commission and Japan on the one hand and Korea on the other hand. This has already led to concrete co-operations such as the inclusion of Aki Nakao (NICT Japan) as an OneLab2 partner and the future federation of PlanetLab Japan with PLE (PlanetLab Europe) and PLC (PlanetLab Central). In addition, the 4th International Conference on Future Internet technologies CFI'09 is jointly chaired by Dougman Lee (ICU, Korea), Craig Partridge (BBN) and Serge Fdida (UPMC) with a strong emphasis on the FIRE framework.

7.1 United States

In the US, several NSF (National Science Foundation) programmes merged into NetSE (Network Science and Engineering), which started on September 5 2008.

Part of the NetSE is GENI (Global Environment for Network Innovations) Initiative, which is a national-scale suite of facilities to explore radical designs for a future global networking infrastructure. GENI. GENI is run by a GENI Project Office which arranges Calls for projects to apply for funding. In the latest Call most of the interest was on control, workflow, management and measurement; there was less interest on security. The GENI vision in detail is still open, but at least it will be programmable, virtualized and federated. GENI implements a spiral form of prototype development (Strawman): Plan - Design - Build - Integrate - Use.

The first FIRE/GENI meeting was held in Madrid on December 8, 2008. Representatives from NSF, BBN and EU were involved, as well as researchers from various projects conducted within NSF and FIRE. The focus of the meeting was on a general presentation of the testbed activities as well as a discussion on the possibility to interconnect some testbeds and develop federation links across the Atlantic.

The presentations from the US side were mainly covering the Control Plane framework:

1. Cluster A -Ted Faber: DETER, security
2. Cluster B - Marc Fiuczinski - PlanetLab (GENI Wrapper)
3. Cluster C - Steve Corbato : Emulab - ProtoGENI the Control Framework for "Cluster C" of Spiral One of the GENI effort www.protogeni.net

4. Cluster D - Cloud Computing, Sensors (Jim Kurose), DieselNet (Mobility, B Levine), ORCA service-oriented resource Control Plane for an Internet operating system : Jeffrey Chase
5. Cluster E - Max Ott, Wireless, ORBIT Management Framework (OMF), http://omf.mytestbed.net

The presentations from the EU side were:

1. PII: SOA-NGOSS based, driven by the telecommunications industry
2. OneLab2: PlanetLab (Europe)-based, targeted at networking community, special focus on longer term wireless and autonomic communications research
3. FEDERICA: GEANT/NREN-based, networking research in a network technology agnostic environment
4. G-Lab: German initiative, addressing the service-aware networking community.

The meeting demonstrated that we share common problems and similar interest. Although the approaches taken on both side are different, the level of achievement is similar. There was a consensus that the physical interconnection between US and EU will be easy now but that more Use Cases are needed to justify an immediate action.

A long discussion on federation shows that a better semantic of this concept is needed. Potential partners on both sides were identified for progressing with concrete federation plans such as:

- PlanetLab (OneLab / FEDERICA / Cluster D)
- PII and ORCA

It was also stressed by Chip Elliot (BBN) that there is a possibility for EU partners to participate to the GENI calls (http://www.geni.net/GS02/GS02.html)

The next FIRE/GENI workshop will be co-located with the GENI Engineering Conference in Seattle (July 2009).

7.2 Japan

The Japanese Future Internet research landscape is based on two concepts: Next Generation Network (NXGN) and New Generation Network (NWGN), the latter using new paradigms and architectures, with a view to replacing the current IP. For the moment, the AKARI Architecture project works on the design of the future network, which is to be implemented by 2015 in the AKARI 2nd phase. The experimental network project JGN2 (Japan Gigabit Network 2) is nearly completed and JGN2plus is about to start (April 2009).

The Network Virtualization Lab studies how to achieve more robust and efficient networks. The focus is on infrastructure, including the enhancement and federation of testbeds (collaboration is taking place with PlanetLab/OneLab2/CORE/PII), overlay infrastructure service and network virtualization as the "Network Architecture". Another research interest is in the application of overlays and network virtualization. This includes topics such as robust networks, DDoS mitigation, multipath routing, self-organisation, efficient network, content distribution, P2P traffic mitigation, and business and economic incentives.

Two collaboration events took place in 2008:

1. Tokyo, 4th - 5th March: At the EU-Japan Co-operation Forum on ICT research, in a session dedicated to the theme of "New Generation Network (NWGN)" and "Future Internet (FI)", a first exchange between leaders of some important research projects took place. Two of the four speakers emphasised experimentally-driven research and presented the respective approaches towards an experimental facility.
2. Brussels, 9th - 10th June: At a special session on Experimentation at the 1st EU-Japan symposium on "New Generation Network (NWGN)" and "Future Internet (FI)" research, prospects for a deeper exchange and collaboration between Japanese and European research communities in these areas were explored.

It was concluded that on both sides there are similar long term goals in redesigning the Internet. Related to experimentation, EU-Japan contacts related to the "federation of testbeds" and "decentralisation of PlanetLab" were reinforced. It was felt that deeper collaboration between the research communities would be of mutual benefit, in particular as there are certain possibilities for cross participation in the respective research programmes.

The dialogue will be continued at the next (2nd) EU-Japan symposium on research into the "New Generation Network (NWGN)" in Japan and the "Future Internet (FI)" in Europe, which is currently under consideration to be held in Japan in July, 2009.

7.3 Korea

Two significant events during 2008 have fostered collaboration between Korea and EU. A number of Fire related contacts and potential relations with researchers in Korea were taken during the OECD Conference and the Korean-EU bilateral meeting in Seoul 14-20 June 2008. In this Korea-EU event around 100 Korean Researchers participated during two days. Parallel workshops were arranged with speakers and chair persons from both sides on different aspects. Professor Choi was the co-chair in the Fire related session.

A more detailed discussion in order to open up collaboration took place between Onelab and three prominent researchers, Prof. Yanghee Choi, Seoul National University, Prof. Dae Young Kim, Chungnam National University and Prof. Chong-Kwon Kim, Seoul National University. Contacts was also established with Prof. Emeritus Kilnam Chon, Kaist, founder of Asia FI, grouping China, Japan, Korea future internet people, along with others in Asia.

In November 2008 a bilateral event between Korea and EU was arranged in Brussels with parallel workshops. One session was devoted to Fire and a number of Fire projects where presented and present. Prof. Mrs. Sue Moon was one of the more prominent delegates from Korea.

7.4 China

Preliminary discussions have started in June 2008 with Professor Li Xing from the University of Tsinghua followed by presentations and discussion in April 2009 at Beijing University of Communication (Professor Yan Jinyao), Beijing Jiaotong University (professor Zhang Hongke) and Beijing University of Post and Telecommunication (BUPT, Professor Shiduan Cheng).
In depth cooperation is plan during 2009.