e.Mobility Technology Platform

Working Group on Post-IP Next Generation Internet

White Paper on

Experimental Facilities with a focus on Wireless research and requirements

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Working Group on Post-IP Experimental Facilities

1. Abstract

This White Paper complements previous WP on Post-IP technical and non-technical challenges and the justifications for Next Generation Internet in Post-IP era. The emphasis of this WP is on identifications of experimentally based research topics in Post-IP and suitable experimental test-bed requirements. The identified research areas and approach are used to derive a reference model and general recommendations for development of test-beds that aim at supporting evolutionary or revolutionary "Post-IP" research approaches towards the future Internet.

2. Experimental Research Topics and Scope

One important driver of requirements is the type of research topics that experimental facilities and test-beds are required to support. The experimental research that one expects to carry out determines to a great extent the actual architecture and structure of the facilities. Since such experimental facilities need also to interact and communicate (and logically interoperate) with existing test beds and platforms, additional requirements for interoperability and compatibility are foreseen. An objective would be to deduce and specify these requirements to design, to orchestrate and to choreograph these experimental facilities to evaluate new concepts for both evolutionary and revolutionary approaches to the future Internet.

The experimental facilities should ease the emergence of completely new paradigms and minimise limitations of current test beds and platforms as well as interference of the current Internet in the analysis of the new protocols and solutions. The nature of the experimental research is integrated solutions for end-to-end performance and joint optimisation and interoperability of several related topics. The ultimate goal of the experimentally based research is full specifications of future Internet architecture(s) including service architecture(s) as well as its supporting protocols, such as identity and naming schemes, routing, mobility paradigms, resource management and operation management for quality of service together with solutions for security, resilience and reliability.

The European scientific community has identified a number of ongoing projects (some of which are funded by EU) addressing the above objectives but inventing the new Internet requires neutrality and innovation in environments that allow creativity and testing of various ideas and solutions. The experimental environment should in fact foster and facilitate the emergence of clean slate solutions and blue-sky research.

A non-exhaustive list of research topics that are expected to be the subject of investigation, testing and validation using the experimental facilities is provided here as a reference and used as a guideline in defining a reference model of the experimental facilities:

- Research and development on the integration of networked sensors and information elements as natural and innate components of the future internet;
- 3D Internet and support of 3D mobile communications
- Integration of wireless access in the network of the future with opportunistic and autonomic/symbiotic/cooperative management paradigms;
- Evolutionary and revolutionary paradigms on mobility management, identity, naming and addressing providing separation of identification and location
- New routing and networking paradigms: network coding, delay tolerant networks, end to end light path provisioning and emergent principles;
- New and flat protocol frameworks, collapsed stacks, minimum and adaptive protocols suitable for heterogeneous interfaces and transport/switching technologies;
- Integrated solutions for security/mobility/QoS-E paradigms including trade off between quality of security and privacy;
- Multidisciplinary research with cross fertilisation between disciplines exploring bio-inspired principles, learning paradigms and cognitive science to model and manage complex systems;
- Dynamic service/content blocks integration and composition;
- Virtualisation, virtual networks provisioning, management and programmability;
- Dynamic pricing policy, enterprise interworking and new business and economic principles.

3. Experimental Facilities Requirements and Expectations

Experimental facilities with a Europe-wide scale are expected to materialize gradually over time through cooperation, collaboration and interconnection of existing as well as future experimental testbeds and platforms.

The starting point consists of listing a number of technical requirements on the experimental facilities that will ease the establishment of self organized and managed (by all members/actors) platforms to lead to sustainable facilities from the operational standpoint leaving aside the needed initial investment as well as means to get return on such investments.

The focus is rather on identifying requirements for experimental facilities enabling future Internet research and development in Europe. Candidate clusters, platforms and experimental facilities

can use these requirements and recommendations to check how they meet the expectations in terms of flexibility and features provided to the users.

3.1. General Requirements and Expected Features

The following requirements and features are general and expected as minimum features from test beds and platforms in order to be qualified as suitable candidates for future internet research. These set of requirements is to enable both clean slate research as well as evolutionary approaches which rely on current technologies and paradigms:

- Offer a canonical base, in terms of technologies to cover and provide a heterogeneous networks environment, that includes access and backbone infrastructures and that is sufficiently broad to achieve scale and reflect as closely as possible the steady state behaviour of traditional networks as well as networks that introduce emerging concepts such as symbiotics and/or bio-inspired networks, autonomic and cooperative communications/organization/management and virtual networks;
- Set experimental facilities that achieve proper scale and embed all forms of devices (including sensors and actuators), all kinds of networks and information elements (related to content, applications and service components) – i.e. aiming at the Internet of things;
- Provide tools and a framework to allow developers to embed easily their own components and architectural building blocks into the experimental facility;
- Allow run time dynamic configuration and deployment in the experimental facilities of protocols, protocol stacks and architectures;
- Ensure secure access for members and users and provide the possibility to set up, configure and control experiments as well as some of the experimental facilities physical resources and substrates;
- Offer the capacity to store experiments settings and associated results to ensure repeatability of the tests and conditions as well as benchmarking for performance comparison, tests and validation purposes;
- Embed monitoring capabilities and failure recovery mechanisms to respectively enable system observation and performance measurements and ensure high levels of reliability and stability of the experimental facilities;
- Provide tools for data analysis and analytical/practical models extractions from tests;
- Include local management frameworks compatible with resource provisioning and management of the overall federated experimental facilities;
- Provide isolation of users, software, hardware and operating systems to ensure protection of users and business interests over the experimental facilities. In other words, facilitate protection of IPR to encourage full involvement of all stake holders;

- Offer sufficient flexibility to accommodate a variety of different business models and interfaces.

Existing and new testbeds, whether stand alone or interconnected and forming federation of experimental facilities, are expected to meet most of these requirements at some stage in their development and evolution. A phased approach is also envisaged for the developments of experimental facilities in Europe over the 2008-2013 time frame (see section 5), experimental facilities have to strive for reaching the level of openness, programmability, control and management reflected in the requirements to foster the emergence of the network of the future by addressing related architecture, manageability and governance aspects.

4. Reference Model for Test Platform

4.1. Model requirement

A reference architecture is an abstract representation of the entities and relationships involved in a problem space. This forms the conceptual basis for the development of more concrete models of the space and ultimately implementations. The reference architecture provides a validated template solution and a common vocabulary and taxonomy for a particular domain. Usually the reference architecture consists of a list of functions and some indication of their interfaces and interactions with each other and with functions located outside of the scope of the reference architecture. In the context of the network of the future, the reference architecture can be defined as a consistent set of best practices for Next Generation Internet (NGI) test platform design and development.

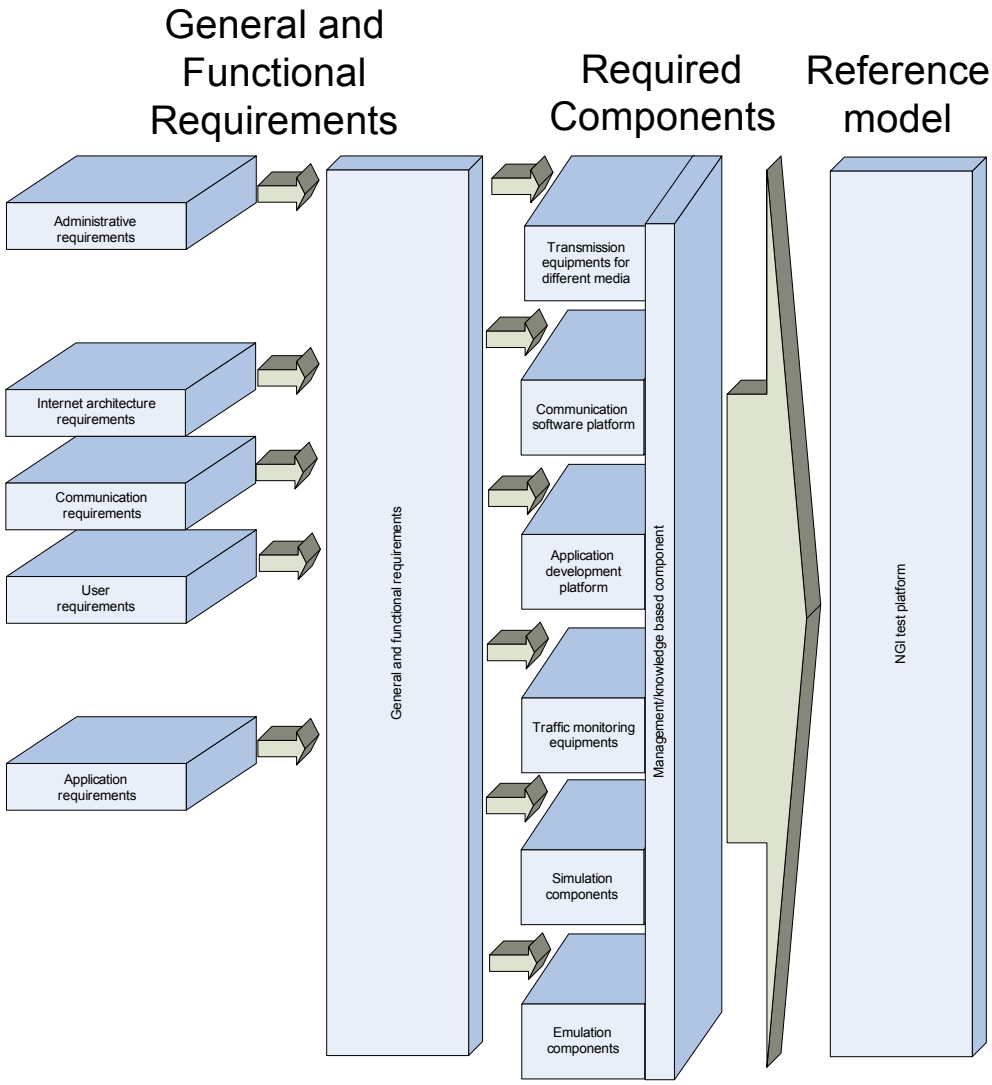

Figure 1. Reference Architecture to derive a reference model for setting up NGI experimental facilities

The reference model or architecture is usually defined with different levels of abstraction, or "views," to provide flexibility in use. A highly abstract reference architecture may show, e.g., different pieces of equipment providing different functions on a communications network, and a fine-grained lower level model may demonstrate, for example, the interactions of procedures within a computer program defined to perform a very specific task. The reference model for the NGI test and experimentation platform uses a higher abstraction level without going into very specific functional descriptions. This ensures sufficient freedom for developers to build up the NGI experimentation platform and to define and execute tests for evolutionary research on future Internet and Post-IP solutions.

The reference model for experimental facilities should reflect and take into account the requirements identified in section 3 and the research topics presented in Section 1 and serve as a means to present and validate any proposed experimental platform model for future Internet research. This means that with the aid of a reference model, it should be possible to define a test

platform for communications protocols and service architectures research and to design for the future Internet. Figure 1 depicts a reference architecture that should be used to set up next generation Internet test platforms and to verify compliance with the reference model.

The proposed reference model, derived from the Future Internet requirements analysis and the identified challenges and problems as published in the eMobility Post-IP White Paper, consists of seven basic building blocks: *transmission equipments for different media (from multiple technologies), communication software platforms and environments, application development platforms, traffic monitoring equipments and simulation, emulation and management/knowledge components*.

The transmission equipment block includes all the transmission devices needed to fulfil the transmission requirements. The communication software block is responsible for flexible and extendible communication software development whereas the application development platform enables application development. The monitoring block facilitates network traffic supervision and recording. The simulation and emulation blocks enable connection of simulation and emulation models to the test platform in a seamless way. The Management and knowledge frameworks link all other blocks to achieve the required control functions with a minimum amount of control information.

4.2. Reference model framework

Figure 2 illustrates the reference model and envisioned NGI test platform components. The reference model components are divided into three main categories:

- support infrastructures,
- facility components and
- management and control interfaces.

The reference model should include the common rules and interfaces for user interactions and governance of the whole system. Based on the requirements presented in the earlier sections, the platform governance and management functionalities should be arranged to provide flexible integration and system expandability. Since the purpose of the experimental facilities for Future Internet research is to provide as open an experimental platform as possible for different actors, the governance of the facility should be sufficiently simple and clear to understand and adopt but needs be robust. The facility has to provide also generic guidelines for its administration and management, edict common rules for using the research results and the facility itself and specify the associated IPR guidelines. In addition, system control and management must allow platform

users to slice and isolate their system and experiments for specific testing and development activities and guarantee adequate security and protection of gathered data and solutions under test.

The experimental facility management and control need to be arranged at the node, cluster and facility levels. Each node in the cluster should support the common control and management interfaces, through which the resources and access to the system can be managed. Based on the requirement of the NGI test platform, the platform should include also specific support infrastructures. These include the facility interconnection components, different kinds of repository components and interfaces for future expansions as well as integration of legacy testbeds.

The target for NGI test and experimentation facilities is to provide a platform for large scale testing where Future Internet and Post-IP research can use different types of components (custom off the self but open and programmable as well as those that are user designed/customized) that would easily plug and play into the platform. Such facility components should also provide a possibility to include different kind of analysing and modelling tools in experimentation as well as monitoring and measurements tools.

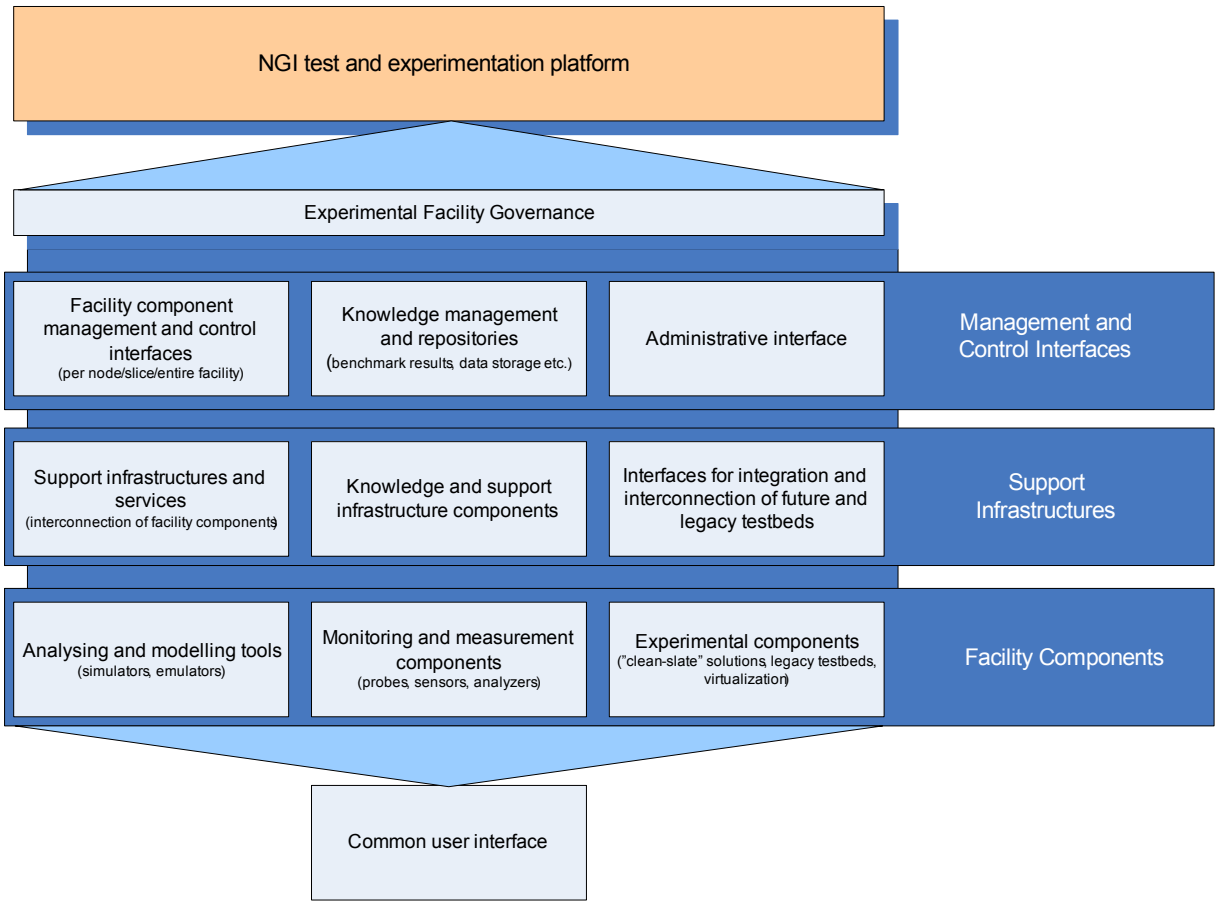

Figure 2. Reference Model for NGI experimental facilities

The interfaces for generic emulators, simulators, analyzers, probes etc. should be taken into consideration when setting up the experimentation facility. In order to provide a good platform enabling a rich set of studies, the platform should provide also the possibility to use “clean-slate” components. The facility would thus span from Internet architecture studies to legacy IP based testbeds and virtualized networks for more service-oriented validation. In order to improve the usability of such large scale test and experimentation environments it is also necessary to introduce a common user interface for managing the set-up and execution of the experimentations and tests.

5. Experimental Facilities Roadmap and Recommendations

5.1. Phases of experimental framework establishment

A sensible and realistic way to set up the facilities, while building on existing test beds, platforms and on going EU and worldwide projects is to establish the framework in phases. Starting from stand-alone testbeds, moving to interconnected testbeds to set up larger scale environments the research and development community would combine these testbeds into a cohesive framework that enables the involvement of a wider range of users. This can be achieved through the potential phases listed below:

- Phase-I: stand-alone testbeds (focused on specific technologies such as wireless sensor networks, cellular, fiber, cable, broadcast, etc..)
- Phase-II: Inter-linked testbeds (between different technologies but also interconnected revolutionary clusters to avoid precluding or preventing new approaches/paradigms from emerging)
- Phase-III: involvement of large range of users while achieving right scale in the experimental facilities

Development of testbeds in the phase-1 must consider extensibility to larger testbeds by including appropriate interfaces to facilitate easy interconnections with other technology testbeds to make up a federated and large scale European experimental framework. For Post-IP era testbeds, mechanisms must be found to isolate the influence and interference of current internet architecture and protocols on the results. Note that phase II may very well be the staring point for operational facilities that already have built in interconnection capabilities.

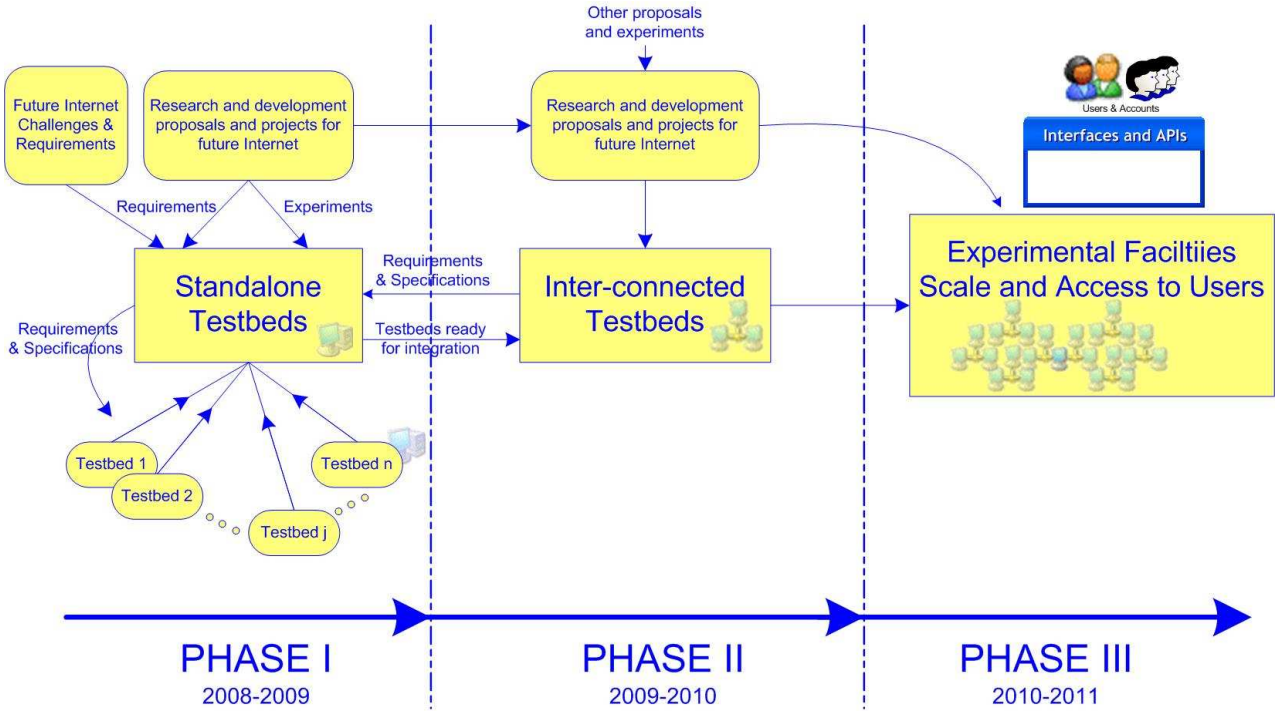

Figure 3 – Phased approach to the Experimental Framework

6. Recommendations

Summarizing the analysis conducted in this white paper leads to a set of key high level recommendations to EU-FP7 and National programmes to be considered in the initiatives for future funding of research on Next Generation Internet with the emphasis on mobilisation of resources towards common a goal thereby enforcing and consolidating Europe position in Next Generation of Internet.

R1. Encourage research community to adopt both experimental based end-to-end and integrated research (research methodology) as well as computer simulation and quantitative analysis of innovative technologies.

R2. Foster investigation and experimental validation of innovative, revolutionary as well as disruptive ideas, Post-IP, and concepts for the Future Internet

R3. Include in the future programmes investigation on transition between current internet to future Post-IP internet covering technical issues such as; network architecture, protocols, services and non-technical matters covering required new regulatory and standardisation issues

R4. Encourage adoption of the reference model for development of new as well as enhancement of existing test-beds to ease their federation into an open, reliable and large scale cooperative experimental facility

R5. Provide unconstrained connectivity to experimental facility to academic research community that may not involved in any EU or national funded programmes but address the problems and challenges of the Future Internet in terms of overall architecture, manageability and governance;

R6. Provide dependable Post-IP research and technology development facilities that enable the set up of experiments at the right scale under realistic operational conditions.