eMobility

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Working Group on Post-IP Next Generation Internet

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Editors:	Rahim Tafazolli Djamal Zeghlache Luis Muñoz Jyrki Huusko Guillermo Gil Tapio Frantti Tao Cai
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Abstract

This White Papers complement 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.

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Editors: Rahim Tafazolli, University of Surrey (UniS), UK; Djamal Zeghlache; Groupe des Ecoles des Télécommunications - Institut National des Télécommunications (GET-INT), France; Luis Muñoz, University of Cantabria (UC), Spain; Jyrki Huusko, VTT, Finland; Guillermo Gil, Robotiker, Spain; Tapio Frantti, VTT, Finland; Tao Cai; Huwaei, Sweden

Work-package leader: Juha Saarnio

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Executive summary

The objective of the eMobility Specific Support Action is to provide secretarial, organisational and editorial support for the organisation of the Mobile and Wireless Communications Technology Platform, known as the eMobility Technology Platform, in the context of enlarging the membership of the Technology Platform and broadening the participation of stakeholdes. The eMobility Technology Platform aim is to reinforce Europe's leadership in mobile and wireless communications and services and to master the future development of this technology, so that it best serves Europe's citizens and the European economy.

This deliverable presents the latest results of the Working Group on Post-IP Next Generation Internet in form of two White Papers on Experimental Facilities with a focus on Wireless research and requirements. This deliverable is an additional deliverable not foreseen in the DoW.

List of authors

Participant No.	Company short name	Author
17	UniS	Rahim Tafazolli

Future Internet

From Mobile and Wireless Requirements Perspective

eMobility Technology Platform Whitepaper

Editors:

Frank-Uwe Andersen (Siemens Networks)

Frank-Uwe.Andersen@siemens.com

Hendrik Berndt, (DoCoMo Euro-Labs)

berndt@docomolab-euro.com

Henrik Abramowicz (Ericsson AB)

henrik.abramowicz@ericsson.com

Rahim Tafazolli (university of Surrey, CCSR)

R.Tafazolli@surrey.ac.uk

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Executive Summary

This white paper is produced as the results of extensive discussions amongst members of the EU e.Mobility Technology Platform working group on subject of “Post-IP”.

In the e.Mobility SRA, the need for fundamental rethinking of Internet architecture and Internet protocols was identified as one of the most important research agenda item.

The name “Post-IP” or, as commonly referred to Next Generation Internet (NGI), was adopted to emphasis on radical and clean slate approach towards “future Internet” which is wireless friendly without being constrained by current architecture and protocols of the Internet. It does not mean IP version 7 or beyond which normally has connotation of evolution from current IP protocols.

The core research theme identified in the SRA was to focus on techniques and schemes that assist in managing complexity of future networks and services resulting in **S**implicity of operation, creation, usage and to overcome barriers for new and yet unforeseen innovations, thereby achieving end to end **E**fficiency,, **T**rust and robustness. This theme was elaborated in the SRA under the Concept of SET (Simplicity, Efficiency and Trust).

One of the fundamental barriers to realisation of the SET was found to be the underlying current Internet architecture and protocol suits. The Working Group on “Post-IP” was formed to specifically examine from view point of Mobile and Wireless communications and based on future expected usage of services and their dependencies on the Internet, identify and prioritise technical challenges. The working group also examined suitability of the existing standardisation fora and processes based on their current working agenda and how they can help bridge the gap between research and standardisation phases.

The white paper is structured based on discussions of the above three questions; *future usage of services*, *technical challenges* and *standardisation processes and fora*.

As a summary a list of ten recommendations are presented and perceived to be useful for researchers involved, or plan to be, in this important and exciting subject as well as funding organisations for their considerations to be implemented in their programmes and notably EU FP7 and National research programmes.

Services in a Post IP environment

Future use of Information and Communication Technologies (ICT) – here envisioned within a Post-IP environment– will constitute a new service landscape, in terms of new areas of usage, new ways of service provisioning, new user behaviour patterns as well as new dependencies between services and human's and other devices' everyday activities. In addition the ever-increasing demands of applications and network services are pushing a Post-IP environment service landscape for a major grows by several order of magnitudes from today approx. 10^4 services to 10^7 services. Even so service provisioning in general should be communication technology transparent it will be this new landscape of services and usage, which sets the requirements for the next generation of communications technology. The drivers for this development span over not only new service innovations for customer and enterprises but also new methods on how ICT is used to solve the societal challenges ahead, and how to respond to human's daily life-style changes.

The future role of ICT in society

Telecommunications has always been seen as a critical infrastructure. With high penetration and convergence of mobile communication, (broadband) Internet and broadcasting on one hand and an increasing number of addressees based on e.g. machine to machine communication on the other hand it became an even more forceful power to influence the society at large. ICT is now seen as one of the main options available to meet the societal needs ahead – environmental, demographical, healthcare, as well as the production of social services. This is potentially one of the largest growth opportunities for the ICT industry. To fulfil the needs of society changes on such immense scale forces to rethink traditional service provisioning, adding additional requirements, not only but in particular regarding privacy, security and reliability. New actors and new business and operation models are needed, and along with them new ways to collaborate, organize and control services' operations.

The change of User behaviour

As users are becoming more empowered by technology advances and increasing availability of services their usage patterns will vary, leaving the traditional roles of a passive user consuming services provided to him. The interactions with the service provisioning system are going to change in a way that user's expectation are diverted from pure services consumption towards goal driven service solution that forces composition of complex services out of several single service components, to meet users' needs. Along goes the emergence of active producers out of passive consumers. With new technology opportunities at hand user are eager to change their role from just using services to a service and content provider, including self-presentation on everyday life logs, using popular social media such as blogs, vlogs, podcasts, etc. We envision a strong uptake of community based service scenarios and information sharing amongst members who join into a common interest. This process represents on a service level the technology developments from client/server, web services and mashups towards P2P solutions.

Enhancement of service meanings

Whereas Web 2.0 is commonly characterised by the rise of folksonomies where Web-based communities are established in which users label and share their self generated content, future solutions such as the smart Web will provide additional semantic enhancements to services. Based on ontologies it will allow for better understanding of the true intentions behind the users service invocation, allow for inference of implicit information and perform an unprecedented leap in quality level of service provisioning. Further combined with reasoning components will allow for conflict detections and resolutions. It will be possible to offer services such that it increases the satisfaction of users considerably.

The transformation of service provisioning

With the changing business models that will allow for evermore players, acting as 3rd party service providers, service brokers and service composer to blend into the service provisioning market, myriads on services will be available. That requires new methodologies for service provisioning support, namely sophisticated service discovery mechanism, which not only deliver the required service but also provide them tailored according to the user's preferences. Herby gradually relax preferences and constraints if necessary.

Equally important is to offer assistance to the user based on usage patterns of previous service requests. That will in the simplest case avoid service flooding in case of underspecified user needs or empty responses in over specified cases, and provide a step by step guidance to the user in more sophisticated scenarios.

Context-aware service delivery

Services that are delivered to the user will in the future consider the situation the service invoker is in, including user's, network's, service's as well as business' context. The service provisioning will be tailored according to such situation, which is determined by location, places and time as foundational context elements, but equally important also by scheduled and predictable events, e.g. weather, etc. and social roles and settings. Thus context –aware service delivery will ensure that users get what they want and when it is needed in form and shape applicable to the situational circumstances at hand. In addition in a Post-IP environment context aware networks are envisaged, where service components execute in the context of an environment, can influence it, and can be influenced by it and new services may be composed and dynamically provisioned from existing network services according to a business process in which both reliability and the need for system evolution and customization are required.

Open Ubiquitous Services

We envision a proliferation of ubiquitous services based on the software components that are small and hidden in the environment. These services are distributed, network- and context- aware, capable of dynamically reorganizing and communicating ad-hoc and provide communications to the users and mobile devices in a pro-active way. These services are subject to decentralized management and can dynamically change their structure and flow of control function of changes in context.

Service-Networks

Currently IP is essentially a neutral network, which does not favour particular network destinations or classes of applications or services over others. In a Post-IP environment service-networks are envisaged, where service specific network self- adaptation, -optimisation, -organisation and -management would be permitted, enabling both services and the network infrastructure to evolve with user requirements and adapt to dynamically changing contexts and conditions with minimum of human intervention.

Approaching a new service world trough enabling technologies

For the future we can expect higher performance and lower prices. One of the high potential areas of new service enabler are represented through the unification of real world objects and near field communications, together providing the “Internet of Things”

Post-IP life-style

Here we foresee to find empowered active users in a ubiquitous service and networking environment, which will support the creation of new generation of services that span from work environment to entertainment including virtual realities with a particular increasing involvement of gaming, social networks and critical global planetary issues.

How to get there

New service solutions will emerge, however they build on a migration path from today’s service setting e.g. Web 2.0 and add new functionalities and new service execution environments. Thus complementing and enhancing existing solutions and embracing new user trends to create unprecedented service scenarios.

With the expected grows in services a particular concern is the introduction of new complexity in service components design and deployment. New service solutions are envisaged in order to simplify the *service control* (i.e. the components of service systems would be autonomous and based on proactive loci of control), *the service interactions* (i.e. despite living in a fully connected world, service components would interact with each other accordingly to geographical or logical patterns), *the service programmability* (i.e. service capability for activating on demand new service functionality or control) and *the service provisioning*.

Technical Challenges for Post- IP

The predecessor of today's Internet, the Arpanet, started in the late 1960s as a network of four university networks. The number of users increased steadily and so did the need for security measures in what started as an entirely open network. Today, Firewalls, Network Address and Port Translators, as well as Session Border Controllers decouple the different IP networks at various layers, helping to protect from misuse, but also creating severe problems for protocols that have not designed with middle-boxes in mind. The capabilities of end nodes to provide "server" services have been continually reduced. IPv6 has been the first but unsuccessful attempt to "restore the Internet".

"Current-IP", i.e. the contemporary, limited and balkanized Internet has been founded on a basic architectural premise: a simple network service is used as a universal means to interconnect intelligent end-systems (this is also called the "end-to-end paradigm"). It is centred on the network layer capability of dynamically selecting a path from the originating source of a packet to its ultimate destination, with no guarantees for traffic characteristics and packet delivery.

The end-to-end argument has served to maintain this simplicity by pushing complexity (if required) into the endpoints, allowing the Internet to reach an impressive scale in terms of interconnected devices.

However, while the scale has not yet reached its limits, the growth in functionality (the ability of the global system to adapt to new functional requirements) or the growth in size (the ability of the global system to support 10^{12} mobile devices and users) has slowed or reached capability or capacity bottlenecks over time.

In addition, the ever increasing demands of applications and network services, and the envisaged future global ambient and ubiquitous services are now faced with the relative inflexibility or lack of service support functionality of the current Internet infrastructures as the current IP is totally agnostic to applications and services with no in-build management facility.

"Highlights" (abbreviated form of the challenges)

- Since the mobile, wireless Internet has additional requirements (intermittent / dynamic connectivity, several mobility modes, as well as different topologies and low power requirements) than the fixed line Internet, the new design should ideally start off in mobile wireless environments (chall. 1). Network elements should be enabled (if required by a service) to do more than routing. (chall. 5+9)
- We need to integrate QoS, Security and Mobility (and others) from the start because it is highly unlikely that otherwise these functions will interoperate later or can be used simultaneously, as required by SET (chall. 3).

- Flexible architecture (beyond OSI) to overcome static layering and its disadvantages. It should be inherent in the new architecture. Together with (2), it may enable a new way of thinking and truly innovative approaches. (chall. 4)
- Network management and operation should preferably be done in a distributed, autonomous way by self-organisation/mgmt (chall. 6)
- Specify migration strategy between past and Post-IP without precluding clean-slate approaches (new)
- A key component of post-IP is the approach of univocally identifying the nodes. Additionally, this identification should facilitate to other protocols and mechanisms to perform the corresponding functionality" (chall. 8).

Challenge #1: Explicit protocol design for a mobile wireless world

The Internet's main transport protocol (TCP) has been designed for wired networks. In mobile environments, its end-to-end flow control and error congestion techniques are wrongly assuming low-delay and almost error-free services. TCP is also unaware of any advanced services the lower layers may provide. How do we project the needs derived from the existence of heterogeneous links, both wired and wireless?

Transmission capacity is expensive in mobile radio networks, but abundant in wired networks, yielding a different trade-off between performance, efficiency and cost. Channel coding, link layer control schemes and application's needs have implications on the computational capabilities of portable devices as well as energy efficiency.

The challenge lies in designing post-IP protocols that are able to utilize the mechanisms offered by lower layers, especially Medium Access Control (MAC) layer capabilities as well as scalable and adaptive link layer (or equivalent) mechanisms which allow to shield some of wireless channels constraints from the behaviour of the higher layers' post-IP protocols.

Challenge #2: Integrated Functional Design

Also sometimes called the "holy grail of networking" or "magic triangle", this problem space is spanned by the ensemble of quality of service (or quality of experience), mobility (several types thereof), and security (authentication, authorisation, auditing, accounting, and charging).

The operator should be enabled to offer these three services or subsets to their customers in an integrated way. Solving the interaction will define the basic elements of an operator-architecture.

Up to now, the solutions to implement QoS, QoC (Quality of Context), mobility and the aforementioned other sub-services come in the form of additions to a previously existing architecture, i.e. the Internet architecture, because they were constrained by backward compatibility. Some of these solutions, given their complexity and generic scope, structure a certain logical portion of the global network.

The challenge is to integrate them in the high-level design principles that will govern Post-IP and also to consider them as a whole from the beginning and also in a modular way.

Since combined, i.e. parallel, simultaneous use of e.g. IP security with Quality of Service and Mobile IP and Multicast is completely infeasible today, such a combined service should be considered from scratch in the new architecture to come. This is a fundamental aspect to make people rely on future networks in their everyday activities and in line with the SET ("Simplicity, Efficiency & Trust") paradigm of the SRA

Challenge #3: Alternative Stacks

In mobile wireless environments, what is known as cross-layer communication may significantly increase the performance and efficiency. However, providing extensive information to other protocol layers raises significant scalability and privacy issues: The cross-layer information needs to be carried to all corresponding protocol entities, thereby generating additional network load.

New approaches are needed for the trade-off between the benefit for applications and the combined effort for generating and delivering such information. *The challenge lies in delivering exactly the right type and amount of cross-layer information to the right applications*. It is the ratio of effort and application performance increment that needs to be maximized.

Challenge #4: Data-aware network equipment (Service-aware Network)

The new multimedia services for mobile users, either audio or video flow or access to information (à la WEB) transmit the same information end to end from the content provider to each user – thereby multiplying the data rate than what would be needed (i.e. one single stream). This is a particular problem for wireless environments (costly spectrum). As implemented today in specific service such as TV over ADSL, smart data manipulation functions (i.e. elementary flow extraction, data cache) should be distributed down to the appropriate border router.

It paves the way to infocentric networks; Combination of short range, infrastructure-less ad hoc networks (user-managed) with mid-range links to infrastructure (operator-driven) frees the infrastructure from short distance intra-group communications. When associated with augmented transport protocols (with infrastructure) and/or middleware (when infrastructure-less) it provides reliable data sharing on the move, support of business- and leisure-oriented groupware with intermittent connectivity.

Challenge #5: Handling service and network complexity

The Internet architecture allows combining all underlying data link technologies into a single whole and makes it feasible to run any application on top of it. However, the variety of underlying technologies and the increasing amount of services makes network complexity raise levels up to which human management might not be feasible. In this sense, future architectures should appropriately combine human control and autonomous decision-making so as to allow network entities seamlessly move across this network despite the administrative burden associated to network switching. Furthermore, network capabilities and data transfer requirements of each service should be taken into account together, so that network entities decide in a clever way the path followed based on the capabilities of the underlying technologies, the characteristics of the information being transferred, and the preferences of the user.

Challenge #6: Identifiers (Addressing and Naming)

Name spaces belong to the core elements of any networking system. Any changes are directly affecting the stacks and are therefore costly. It is very challenging to combine the existing address schemes and versions on all current layers with the ones to be developed now and also those currently evolving in the context of the semantic web. A number of proposals for naming and addressing exist, today mostly implemented via overlays. The drawback of overlays is that they work sub-optimally, and the associated Post-IP challenge is to make, for example, the anticipated “information object names” an integral part of the overall design. How can multiple address schemes co-exist and still work efficiently? Past-IP service identifiers are based on physical interfaces. It implies different IDs per interface and terminal, based on the IP address. In a wireless world, Post-IP will decouple the service and user identifications from the terminal and physical interfaces (such as proposed e.g. in HIP).

Furthermore, the process of routing should be separated from addressing.

Challenge #7: Architectural enablers

In designing the future Internet, the issue rises how to enable appropriate inter-networking among today's communication networks including cellular, wireless, fixed and IP networks. This leads to an extensive architectural challenge encompassing the logical node architecture, the protocol architecture and the messaging architecture.

Today's communication networks are characterised by different types of nodes: user devices, routers, servers, access and core network controllers. It is likely that today's heterogeneous and poorly coordinated scenario will tend in the long term to converge in terms of architecture. Therefore, the architecture of a future Internet needs to be discussed: what future internet nodes do we expect? What would their expected functionality be, and how could it be configurable according to varying requirements? How would existing networks migrate to the future Internet?

The future Internet may define a completely new layer that does not naturally map to current ISO/OSI layers. What is the role of current internet protocols (IPv4, IPv6) going to be in the future Internet, and how will layer 2 technologies relate to it?

Post-IP requires new enablers for:

- Fast and programmatic addition of new functionality (i.e. capabilities for activating on demand new protocols, services or control)

- Orchestration of security, reliability, robustness, mobility, context, access, service support and management of the communication and services

- In order to meet the mobile wireless requirements, DTN (Delay tolerant / Disruption tolerant Networks) technology should be supported

Challenge #8: Design of Security Enablers

Viruses, phishing, spyware, and identity frauds risk reducing users' confidence in the network and therefore its usefulness. As such security is the biggest imminent problem facing the Internet. In addition, security mechanisms are currently located in nearly all layers of the Internet stack. Future end-systems will be mainly mobile and will have limited power resources; this means that several security mechanisms running in parallel are quite doubtful. New architectural enablers are envisaged in the Post-IP to overcome the security risks. As such security is the biggest imminent problem facing the Internet. In addition, security mechanisms are currently located in nearly all layers of the Internet stack. Related problems are spam, and the handling of any kind of unsolicited "push" information.

The target design

The future Internet or "Post-IP" is an optimised network- and service- layer solution to the ubiquitous, mobile service-enabled communications between ~1012 mobile devices and billions of human users with guarantees and built-in orchestrated security, reliability, robustness, mobility, context, access, service support and management of the communication and services.

This is, as roughly and generally formulated as it is possible at this early stage, the visionary design target to be solved.

Technical Recommendations

In order to achieve the overall design goal, the following set of technical recommendations is proposed:

1. Design an overall system with integrated core functionality (simultaneous Mobility, QoS, Security & more), since the Internet cannot be sufficiently improved by add-ons any more.
2. Combine (1) with the specifics of wireless, such as limited bandwidth, higher costs and intermittent, dynamic connectivity and tackle this as the central, challenging problem of the project.
3. Create and evaluate alternative, breakthrough and beyond-OSI architectures, in order to address the primary design challenges, and to overcome static layering and its disadvantages. Enable services to exploit network context information, and use self-organizing technology.
4. Decouple the IDs of information objects from their addressing, incl. users, nodes, documents, interfaces, domains and other structures. A key component of post-IP is its univocal identification structure.
5. Specify a migration strategy between past IP and Post-IP

Roadmap for Europe impact

The current drive of redefining Internet started in US based very much on problems mostly from fix networks perspective. The great opportunity that Europe has is its great knowledge and leadership in cellular networks. We have currently a ratio of 5 to 1 in mobile users versus fixed internet users.

We shall for this reason drive a future internet from the mobile and wireless requirements which are also the main new requirements for a future internet approach. We shall build on our strength and competence in mobile networks and also to provide a holistic architecture approach which is the norm in telecom networks compared to the patchwork in IETF.

The approach that we shall take is from start prepare for how to exploit the research results. A major advantage that European research projects have is that they lend themselves more easily for consensus building and forthcoming standardisation compared to the other regions way of handling research. This means that we shall from the start target standardisation and prepare for this.

Some background on standardisation could be useful.

Standardization in retrospective

Traditionally, standardization in telecommunications has been carried out by ITU, International Tele Union, a very old organization dating from 1865. Its main objective was standardizing telegraphy and later on also telephony, and always on a worldwide scale. ITU is built of several departments, for example ITU-T dealing with fixed network oriented standardization and ITU-R dealing with radio issues including spectrum management. Members of ITU were originally the "old" PTTs, that is national administrations representing its respective country. Only quite recently, in the 1970s, private companies were allowed to participate as observers without voting rights. This mode of operation has become obsolete with the advent of new technology very much driven from the IT world. It has been proven that a quicker pace for standardization has become increasingly important as a business pre-requisite within the telecom world. For this reason ITU has been reformed to take into account these changes, but this has also given room for creation of a number of other organizations specifically acting in the three main regions US, Europe and Asia. In the US T1, IETF and IEEE 802 are perhaps the ones best known, in Europe there is ETSI and in Japan TTC. Even if some are regionally oriented they have received a global impact and participation is generally by worldwide companies and operators. This means that ITU and particularly ITU-T has decreased in importance.

Overview of Standardisation

Currently the most relevant and active organizations are:

- 3GPP dealing with cellular standardization,

- OMA for applications and services,
- IETF that is standardizing Internet protocols, and
- IEEE 802 standardizing wired and wire-less local area networks.

There are also a number of industry fora that generally specialize on a certain topic only, for example ATM Forum, and TM Forum for systems management.

3GPP (3G Partnership Project) is made up of a number of regional organizations, currently the organizational partners are ARIB, CCSA, ETSI, ATIS, TTA, and TTC and of market representation partners, that is, GSM Association. The individual member of the respective regional organization is also member in 3GPP, which means that most Telecom vendors are involved. 3GPP's main task is the standardization of UMTS on a world-wide scale and the development of UMTS also known as LTE (Long Term Evolution) and SAE (Systems Architecture Evolution).

OMA, Open Mobile Alliance, is dealing with the delivery of technical specifications for application and service frameworks, with certifiable interoperability, enabling deployment of rich mobile applications and services. Besides Telecom vendors and operators most IT vendors and SW houses are member in OMA. In total OMA has 300 members.

The Internet Engineering Task Force (IETF) is a large, open international community of network designers, operators, vendors, and researchers concerned with the evolution of the Internet architecture and the operation of the Internet. It is open to any interested individual.

IEEE 802 was originally formed to standardize fixed local area network, such as Ethernet and Token Ring, but it has expanded into also wireless LAN and regional networks.

The EBU, European Broadcasting Union, is the largest professional association of national broadcasters in the world.
It should be noted that the most successful standards organisation is actually 3GPP if one considers that there are more than 2 billion users worldwide connected to 3GPP standards like GSM and UMTS.

Driving forces for standardizations

The overall purpose with standardization is to ensure interoperability, but interoperability has commercial implications. The question is; how should a standard be designed; very detailed and rigid and therefore easy to implement but difficult to evolve? or with a low level of standardization and with greater freedom for business actors but less effective in terms of interoperability? There is a delicate balance between the two approaches. Standards business interfaces generally mirror the business relation between different business roles.

It is also important to have an architected view on standards as this will lead to a layering of standards so, for example, standards that are radio-and network-oriented will not impede the speed with which application oriented standards are developing. The product life cycles of infrastructure is much longer compared to applications.

Decoupling of the applications from infrastructure is thus beneficial to the overall business.

Standardization and business interdependency

A major implication is that standards and open interfaces determine where the competition will be in a business ecosystem and thus have very significant economic as well as technical importance.

Defence Advanced Research Projects Agency, DARPA, financed a technical report named Future Generation Internet Architecture, during year 2000 to 2003, see reference (Final Technical Report: New Arch: Future Generation Internet Architecture, 6/30/00-12/31/03).. A quotation from that report that emphasizes this point is:

> “Because architecture and the placement of interfaces define the parts that can be produced, sold, and operated by different parties, architecture defines a marketplace. Only when the different producers in a market know their roles can there be an organized market. It is architecture that provides this structure”.

In general, the Internet paradigm is very simple and minimally specifies packet transfer service, without any quality performance. Instead a “best effort” approach is taken. One of the factors that made the Internet protocols so successful is that they could work over almost anything, and for almost any type of application.

In the telecom industry, the word "architecture" is understood to mean "network architecture", or the kind of "architectures" that show functional units, such as "SGSN", "GGSN", "Node-B", and abstract interfaces in between such as "Gn" or "Gi".

The IETF has never done that kind of "network architectures". In IETF those kinds of "architectures" are not called architectures at all. They are called network configurations, and in the IETF community’s opinion everybody should be free to configure their networks in any way the want, within some "architectural principles" and the "natural architecture" that emerges from the protocols. IETF has instead concentrated on the protocol or “stack architecture”.

IETF is thus working mainly with specification of protocols. This has some advantage as it is easy and quick to standardize, and also adds flexibility in implementations. The drawback is that it might create duplication of functionality and might also lead to interoperability issues. Architecture, and architecture design principles (such as the end-to-end principle), are rather imposed than made explicit when developing new protocols. This means that in order to have a working system someone will have to organize and configure the stack of protocols, which becomes an increasingly more complex task with number of available protocol options. This work is generally done by vendors during product development. The scope of IETF is mainly related to basic connectivity although a lot of additions have been, made e.g. in the security area.

Roadmap

The roadmap for success can be envisaged in 3 phases.

The 1st phase is very much an exploration phase with the following items:

- Business Scenarios and agree on requirements
- Scenario driven approach,
- Roles , models and incentives,
- Identify key technical problems,
- Agree on concept and principles,
- Architecture framework,
- Reference model,
- Initial architecture validation,
- Initial standardisation activities (might be to understand where a potential standardisation activity might take place)

The 2nd phase could be more about systems engineering with the following topics:

- Architecture
- Business interfaces
- Migration aspects
- Detailed technical specifications for different topics
- Dynamicity, scalability, performance
- Protocols
- Functional prototype
- Real Standardisation starts

The 3rd phase would deal with the systems synthesis such as:

- Architecture tuning
- Consistency checking
- Optimisation & Performance
- Validation
- Large scale test-bed
- Market dissemination
- Standardisation

Standardisation process

The standardisation process has been described above and the real question is whether there is a right body and process in place ensuring successful transition between research and commercialisation. IETF does not seem to be the right body for pursuing architecture standards and does not have a holistic approach. IETF standardisation has furthermore developed into a protection of current status and is thus quite slow in taking up new architecture and has become quite inert.

3GPP as described has been very successful with cellular standards and has a holistic approach but has not really embarked on developing datacom-oriented standards.

Possibly 3GPP can be evolved to also take into account a future internet standards and Europe has a good experience in network architecture oriented standardisation.

To provide a timely commercialisation and exploitation of research results, standard is essential and there might be ways of expediting the process. Alternatively one can discuss new fora in order to facilitate such process this, but it seems this is too early.

Recommendations

R(1): Future research has to provide the means to overcome the IP limitations and allow for management of new level of complexity.

R(2): Allow for a wide spectrum of horizontal and vertical services offerings as options within a general service framework as well as for new business interfaces to freely embrace current Internet and mobile world and future service solutions, without restricting the degree of freedom the Internet provides today.

R(3): Future service provisioning solution have to take into consideration human mentality and customer behavior patterns that ask for carefree services that provide discovery mechanism, personalization, guidelines on "how to use" and a recognizable party that is responsible for overall customer care.

R(4): Design an overall system with integrated as core functionality (Mobility, QoS, Security) supporting intermittent and dynamic connectivity with energy and frequency constraints in mind.

R(5): Create and evaluate alternative, breakthrough and beyond-OSI layering architectures, to overcome static layering and its disadvantages. Enable services to exploit network context information, and use self-organizing technology for optimisation.

R(6): Decouple the IDs of information objects from their addressing, incl. users, nodes, documents, interfaces, domains and other structures. A key component of post-IP is its naming and addressing structure must not be restricted or tied to the architecture.

R(7): Specify a migration strategy between current and Post-IP.

R(8): Build on **FUTURE INTERNET** on European strength and competence in **mobile networks** adopt a holistic approach to future architecture design.

R(9): Coordination across different projects with a well established support action

- Build on European **pre-competitive research tradition – large FP projects** for consensus building, a good mechanism for preparation of future standardisation

- Ensuring collaboration between research projects and test-bed activities
- **Global collaboration** supported by the EC and support action in order to take initiative internationally

R(10): Identify **early** a suitable **standardisation** process and forum (European driven, but aiming globally)

Contributors

Co-editor

Hans Einsiedler; hans.einsiedler@telekom.de (Deutsche Telekom Laboratories)

Peter Tabery, peter.tabery@alcatel-lucent.de (Alcatel Lucent)

Luis Muñoz, luis@tlmat.unican.es (University of Cantabria)

Andre Cotton, Andre.cotton@fr.thalesgroup.com (Thalesgroup)

Alex Galis a.galis@ee.ucl.ac.uk (University College London)

Carles Anton-Haro (carles.anton@cttc.es),

Josep Mangues-Bafalluy (josep.mangues@cttc.es) (CTTC)

Francesco Meago, francesco.meago@siemens.com (SMC, Siemens Mobile Communications S.p.A., Italy)

Luis Correia

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

Co-Authors and Contributors

Rahim Tafazolli	University of Surrey (UniS), UK	R.Tafazolli@surrey.ac.uk
Djamal Zeghlache	Groupe des Ecoles des Télécommunications - Institut National des Télécommunications (GET-INT), France	Djamal.zeghlache@int-evry.fr
Luis Muñoz	University of Cantabria (UC), Spain	luis@tlmat.unican.es
Jyrki Huusko	VTT, Finland	Jyrki.Huusko@vtt.fi
Guillermo Gil	Robotiker, Spain	guille@robotiker.es
Tapio Frantti	VTT, Finland	Tapio.Frantti@vtt.fi
Tao Cai	Huwaei, Sweden	tao.cai@huawei.com

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eMobility

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.

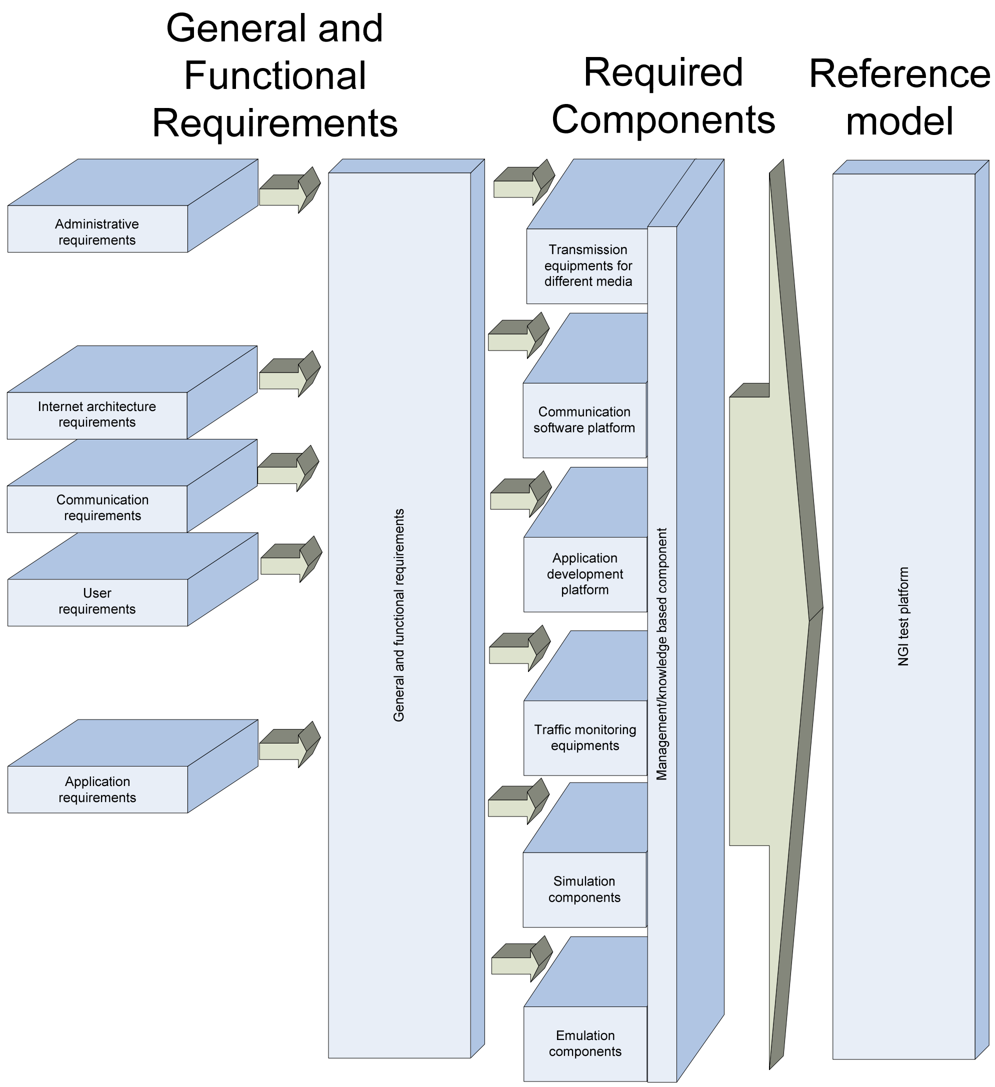

Figure 1. Reference Architecture to derive a reference model for setting up NGI experimental facilities

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.

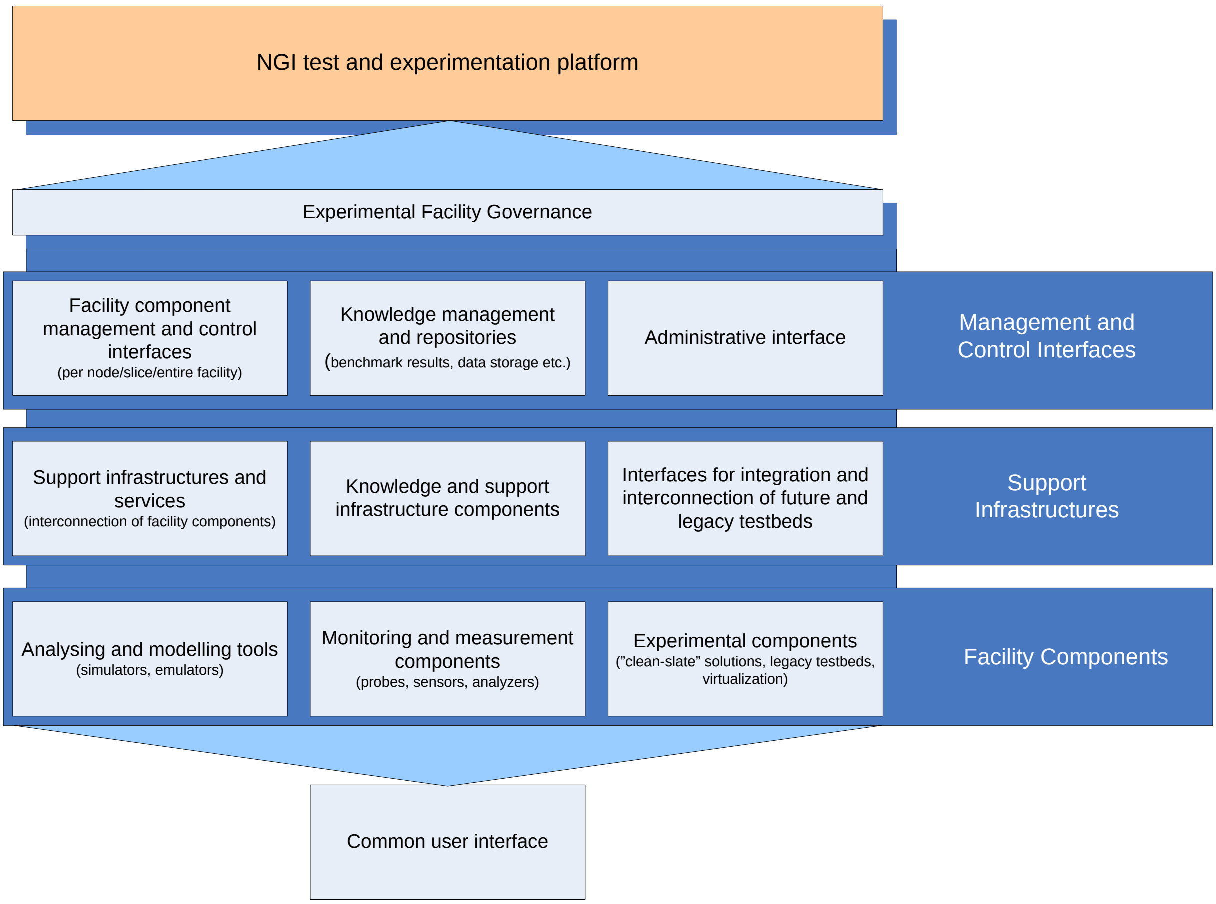

Figure 2. Reference Model for NGI experimental facilities

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.

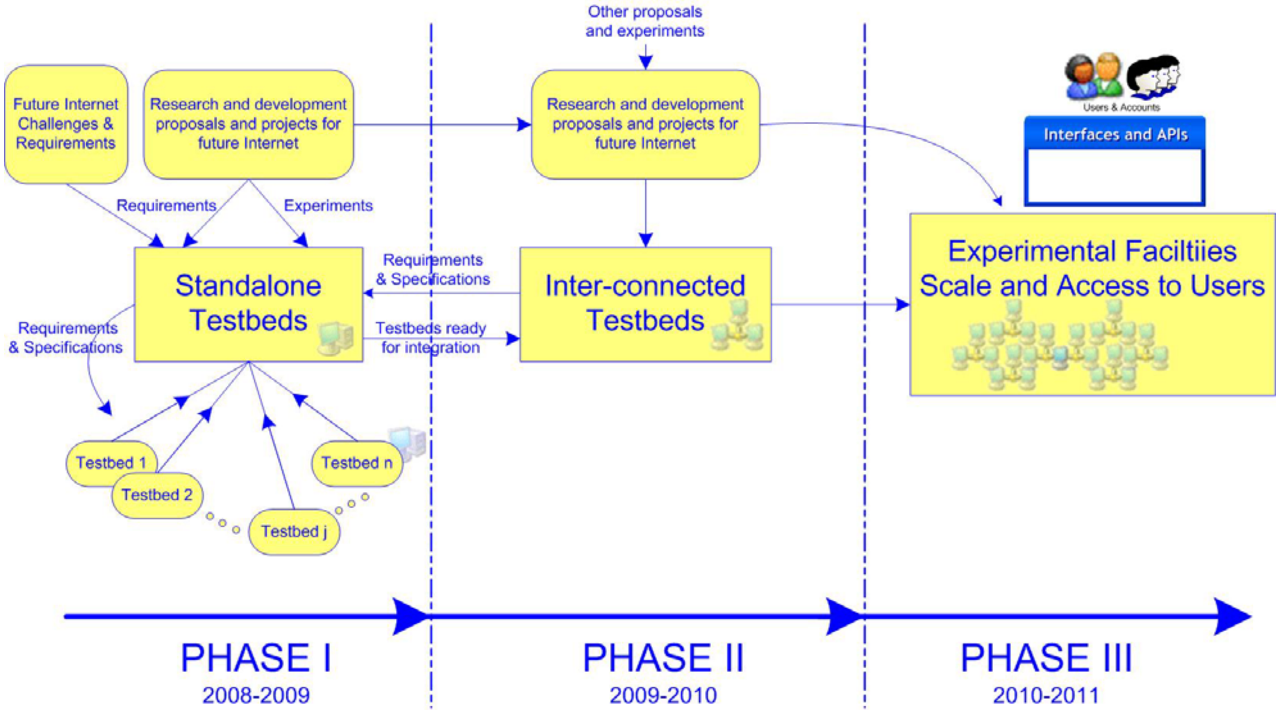

Figure 3 – Phased approach to the Experimental Framework

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.