THE FUTURE NETWORKED SOCIETY

A white paper from the EIFFEL Think-Tank

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Today's Internet was never designed to be a critical part of the European economy infrastructure - but it has become exactly that. In fact, it has become a critical infrastructure element for Society in practically all developed countries.

In the light of these developments, there are many questions today on how the Internet will develop in the future. It is apparent that the Internet must change and that the change is likely to be revolutionary. It is expected that today's Internet will evolve into the "Future Networked Society".

The EIFFEL think tank was established in July 2006 as a group of individual researchers, upon an initiative of the EC DG Information Society, with the intention to address questions as to the how such an ambitious goal as defining the Future Internet can be achieved within the context of pan-European and global, research.

This white paper presents the first findings of the group based on its discussions and intends to serve as a stimulus for future actions towards this goal.

Editors: Petri Mähönen, Dirk Trossen, Dimitri Papadimitriou, George Polyzos, David Kennedy

EIFFEL: Evolved Internet Future for European Leadership

EXECUTIVE SUMMARY

"THE FUTURE NETWORKED SOCIETY"
A GREAT OPPORTUNITY FOR EUROPE

There are many questions today on how the Internet will develop in the future. What has been clearly identified throughout the industry and research community is that the Internet must change, and that the degree of change must be revolutionary. Once we determine what sort of changes are needed, we can start working on how to migrate from today's Internet to the forecasted 2015 Internet, and beyond.

Today's Internet was never designed to be a critical part of an economy's infrastructure—but it has become exactly that. In fact, it has become a critical infrastructure for the overall society in developed countries. Now we can clearly see that the future Internet should be able to sustain an order of magnitude increase of the number of people connected to it, and the addition of billions—perhaps even tens of billions—of devices such as sensors, tags, micro-controllers, etc. With that in mind, the future Internet must not be seen as a mere technical entity, but as an integral enabler of *the Future Networked Society*. This leads to the logical argument that new research paradigms need to be explored and more interdisciplinary research is required in this domain.

One of the key findings of the EIFFEL group is the need for a balanced research agenda towards the Future Networked Society. There is a clear need to support *evolutionary*, applied engineering research, based on present industry needs towards the future. But this is not enough to ensure that great opportunities are grasped by Europe. The evolutionary path has to be supplemented by a portfolio of radical *explorative* research activities that will push beyond the limits of existing systems and open the doors for new opportunities towards the future. For this, it is important to launch a new culture of *risk taking* along this path of explorative and possibly disruptive research.

This EIFFEL report recommends to the EC that a phased approach in the research must be adopted. There is ever increasing consensus that we need to find more radical solutions. As these radical design principles need to be debated, in fact those need to be discovered, Europe should start with smaller and explorative projects, before launching larger and integrative projects that test out different avenues. At all costs we must avoid proposing more short-term solutions or "patches". This has been the evolutionary practice to date which is leading us towards increasing complexity and architectural deterioration without the performance gain we need.

The EIFFEL report also calls for the best possible people to be mobilized and motivated towards this goal. The challenge is to make this happen. Although a lot of good work has been done in Europe, the research is still fragmented. There is a present and clear danger that Framework Programme 7 research in this domain could become even more fragmented unless something radical is done to stop this. This report recommends specifically that some closer technical and social orchestration between research stakeholders is required.

The EIFFEL think tank specifically proposes two actions to be taken:
Firstly, a more permanent, level-field *support agent* is proposed to facilitate technical level orchestration between different stakeholders, including ETPs, in an IPR neutral way. Furthermore, continuous monitoring of outputs along the explorative path and fine tuning of overall roadmaps is recommended as a key activity of this orchestration effort. It is envisioned that for this purpose such support action would also be an academically led operation, but with strong links to industry. The current EIFFEL initiative could serve as a basis for this support action to kick off immediately. **Secondly,** it is proposed to create coordinated efforts around the study of alternative architectures with the ultimate goal of "raising new architects" through a focused research activity of its own. The EIFFEL group is emphasizing that such architectural considerations are required but several parallel smaller efforts on different architectural principles in the first phase might be the most productive, rather than attempting to define the complete new architecture in one project.

Disclaimer:

The contents of this paper are the consolidated ideas of many individuals and may not be taken as the definitive opinions of any those people exclusively, their employers, or the European commission.

This paper, and the opinions expressed within, should be considered as part of the emerging consensus in Europe on the opportunities for significant technical, economic and social advancement regarding the Future Internet.

SECTION 1: DRIVERS FOR THE NEXT GENERATION INTERNET

This section outlines the drivers for the future Internet, some of which are already well recognized. The intention is to introduce this white paper's argumentation, that is, that work is required on what we perceive as the Internet today in order to accommodate all the driving forces described in this section.

Note that this section does not intend to present results of an investigation or study. We heavily borrow from well known facts and predictions regarding the development of technology and its usage in the next 10 to 15 years. For more concrete results with regard to these predictions, we refer the reader to the ample material in the available literature.

Technological Drivers

Technological progress in many areas will continue to drive the usage of the Internet but, in parallel, it will drive the current Internet to its design limits.

There are many technology drivers to be foreseen as driving forces behind the evolution of the Internet. Most of the ones listed below are seen by the Internet community as non-contentious. Even with this basic argumentation, we believe we are already drawing the picture of a future in which today's Internet will reach its limits, and from various angles.

Mobility on different levels: Mobility will become a critical part of the technological landscape of the future Internet. The progress in miniaturization will lead to an increased terminal mobility with an expected 3 to 5 billions mobile devices in less than 7 years. In addition to mobility of devices, functionality on service level will increasingly move between devices and networks. For instance, video streams being re-routed among devices during movement of the user will be commonplace in the near future. This will require functionality to adapt services to the varying capabilities of the devices but also the changing needs for interfacing with the end user. This will lead to a fundamental difference to today's Internet in the sense that relations of devices with their attachments points in the network as well as services with the devices on which they are executed are likely to become much more shorter term. It is important to note that this increasing mobility on device and service level will need careful consideration as to the architectural impacts for the core but also the edge of the network. Hence, the Future Internet must inherently be designed for supporting device and service level mobility, if required. However, it is crucial to understand that this does not imply an Internet with focus on mobile devices only, often touted the "Mobile Internet".

Number of connected devices: While the early Internet was meant to connect just some tens to hundreds of nodes, connectivity needs nowadays have reached the limit of the original design. IPv4 address space is going to run out (with different predictions as to when this is likely to happen, some of them as early as 2008 others as late as 2011), showing that the original inventors' estimates on the number of devices that would connect to the Internet has been exceeded many times over. Mobile devices have outnumbered fixed devices such as PCs, and more is to come, with an expectation to have about 3 to 5 billion devices in less than 5 to 7 years. A further increase in the number of devices will come through the developments in wearables, in sensors, and also in the fact that each person will likely own more than one such device in the future. In addition, an increase in the volume of direct machine-to-machine communication is expected to further fuel the need for connectivity and bandwidth. Technologies such as RFID will push this limit (for example, because of the need for mobile readers) even further. Using IPv6 addresses for RFID numbering would accelerate this push.

Available bandwidth: The available bandwidth per device has been constantly growing in the past ten years. Dial-up has been largely replaced in many countries with broadband connections. Fibre-to-the-home (FTTH) will increase the bandwidth capabilities and requirements at the edges of the Internet even more. In radio technology, we are already pushing the limit of 100 Mb/s aggregate raw bit rate, with some limitations. In the future, it is expected that short-range wireless communications can go over the 1 Gb/s boundary, and even for wide-area communications this limit may be reachable in some specific cases. Spectrum issues will be addressed, for instance through the freeing up of spectrum (from TV bands for example) and through developments in cognitive radio, which allows for localized spectrum re-use and optimization.

Processing power and memory increase: Moore's law will continue to drive the need for more connectivity through the increase of the computational power and memory of devices. In addition, leaps could be expected in computing areas such as quantum computing, the first effects of which are likely to affect the next generation of the Internet (for example, by making it necessary to consider novel security mechanisms that are not based anymore on factoring large numbers). In the mobile space, this increase in power and memory might come about more slowly, because of a mobile device's battery requirements. However, advances in fuel cells and new forms of fast charging (even in public places), and other advances in material science, are likely to fuel the increase despite the necessity to recharge.

Heavy increase in digitized media: There will be an enormous increase of digitized media offered in the Future Internet. While digitization of available (non-digital) data will continue (for example, in the domain of libraries, cartography, etc.), it is now expected that the majority of new media will arrive in digital form, with the analogue form being the exception. Digital photos and videos will not only increase in number, but also in size, due to increases in resolution and the ease of creation and manipulation. Several means with which to easily share these news forms of digital media continue to appear (YouTube being one of the well known pioneers in this).

Location determination: A new wave of services is foreseen with the availability of location information. Localized search, localized shopping coupons, and other location-based services such as mobile positioning, tracking, mapping, routing, and so on. In addition, interactive voice applications and sensor-based services (e.g. based on RFID) are expected to help develop new sophisticated applications that easily integrate mobile services with existing fixed enterprise systems and applications where appropriate. Using a combination of broadband wireless and wireline devices, users can access any service on demand, using a single identity and single set of service profiles, and enjoying personalized service delivery as dictated by the situation. For this to happen, location determination should first become easy and ubiquitous. Extending location-based services even further will make for the necessary developments to provide a wide range of user context, beyond location, to providers.

End user provided infrastructure and services: Technologies like WLAN have brought the ability to end users to set up their own networking environment, and to configure them to their liking. Beyond single hot spots, we envisage entire communities providing network access to members or visitors of the community. First commercial trials (see, for example, FON) or other local developments are starting to redefine the game played on the last mile of access. On the service level, a similar and much stronger trend of end user empowerment is visible. The Web2.0 wave has brought MySpace, YouTube and other services, where content is provided to users, by users.

Security: The increasing usage of the Internet for private, business and government communication makes security an issue of paramount importance. DoS attacks, spamming and phishing are considerable threats in today's Internet. In order to restore the Internet's intended functionality in many areas, we are likely to see advances in security technologies countering these threats.

Continuing IT revolution: Microelectronics and algorithmic computer science are still advancing at a rapid pace. This is providing us an ever-increasing capability to innovate, in particular with new technological solutions in both network and terminal equipment. Recent advances in the multi-processor environment, probabilistic and machine learning algorithms, context-sensitive data processing and semantic Web, to mention just a few, are driving developments towards intelligent technological devices that can adapt automatically to different situations and user needs.

Service evolution: Services will continue to evolve towards more adaptability, and awareness of user context and preferences. Services will aggregate functionality provided by distributed components in different business domains. Therefore a future Internet architecture cannot rely on routing on IP level alone, but must take into account new parameters such as cost, security, privacy, trust, user and business relations. Such relations may be pre-established, or established temporarily for even only one business transaction.

Socio-Economic Drivers

The Internet, being a crucial piece of the communication infrastructure, will be an integral part of future industry, and society as a whole, similar to any other utility (e.g., electricity and water).

It is expected that the Future Internet will help to shape modern society as a whole, especially in the areas of health, education, and government.

Applications in the Future Internet will require re-examination. Policies for conducting business will shift toward a service-based economy, leading to an increased departure from vertical integration towards enterprise reconstruction and industry deconstruction, flexible value chains for increased efficiency, disintermediation, etc.

The following main drivers are identified from a socio-economic perspective:

- Effect of communication technologies on socio-economic development (e.g., wealth, political engagement), particularly in developing countries, but not limited to them.

- Enabling the use micro payments, particularly in developing countries, but not limited to them.
- The need for privacy in general, driving certain developments for (and against) the preservation of privacy.
- Location determination and its effect on privacy concerns at different levels: that is, the monitoring/tracking desire in governments and businesses (and on a private level also) standing opposed to an individual's right for privacy.
- Security (and the perceived feeling of security).
- The increasingly mobile lifestyle will lead to changes in communication on private as well as on professional level, e.g., in the mobilization of workforces. Being online becomes ubiquitous, changing expectations in human interaction, execution of work and many other areas of our daily life.
- The concept of an online identity, implemented with credentials such as credit cards, but also avatars (as used in the popular game Second Life), will create new forms of identities, merging the real world with the digital one.
- Internationalization of business and trading.
- Desire for end user empowerment (now that the technological means are becoming available), as expressed, for example, by the Web2.0 trend and social networking sites.
- The need to constantly develop new measures to counter new and un-expected "Cyber-crimes" that affect national and personal security

With these drivers in mind, it is expected that the Future Internet will play a dominant role in organizational change by opening up the possibility of new business models for organizing production and transacting business. New products and markets will be developed, and new and far closer relationships will be created between businesses, the public sector, the citizen, and the consumer. This is expected to change the structure of organizations leading from strict hierarchical to network-centred structures, and change the delivery of work. New channels of knowledge diffusion and human interactivity will be possible resulting in a more flexible working environment that can quickly adapt to change.

With this, it is expected that the Future Internet will force businesses to re-examine their business models, cost structure and competition strategies, thereby encouraging streamlined business processes, flatter organizational hierarchies, continuous training, and increased inter-company collaboration, as well as the forming of coalitions and virtual networks. Future Internet-based applications will require the development of new business models geared towards smarter, service/component-based applications and value chain integration.

Services introduce many independent and self-contained moving parts (components), which are reused widely across the Internet, and are a vital part of mission critical business processes that span organizations. This requires that the services consumed by organizations are of high quality, and that when new services are introduced, they be compliant with IT, business and regulatory policies, ensuring, for example, a predictable uptime of a service, and so on. All these concerns illustrate the need for service-oriented application governance. Service governance is about managing the quality, consistency, predictability, change and interdependencies of services across the Internet.

Scenarios

This section aims at outlining possible scenarios of the Future Internet. It is not meant to portray a particular outcome from a particular angle. Instead it is intended to give a balanced outlook as to what could happen, be it "desirable" or not.

Since we are well aware of the plethora of scenarios that have been outlined in many other reports and documents, we refer the reader to this vast literature for a deeper appreciation into what the Future Internet could look like.

Convergence: The Future Internet is expected to integrate high speed wireless and wired networks and provide a production environment that addresses all types of user concerns. Packet switching and transport elements (e.g., routers, switches, and gateways) will be logically and physically separated from the service/call control intelligence (as it happens with New Generation Network Services). This control intelligence can be used to support all types of services over the packet-based transport network, including everything from basic voice telephony services to data, video, multimedia, advanced broadband, and management applications, Voice-over-

Internet Protocol (VoIP), Push-To-Talk (PTT) applications, and, finally, organizational and business processes and transactions, which all can be thought of as just another type of service that that the Future Internet supports.

Smarter Networks: The Future Internet would guarantee for global context awareness as well as localization and control of distant services and data objects, while providing rich bandwidth services over possibly networks of limited resources. It will also be able to configure and manage itself intelligently, select from a wide range of Quality-of-Service (QoS) and bandwidth levels, discover and cache and route data, and allow for fast and reliable sharing of data, all while maintaining security, reliability, and scalability. It would not just rely on the creative routing of connections based on simple database look-ups, but may take on a much broader role. For instance, it could include multimedia session management, coordination of multi-technology connections, intelligent management/operations (providing "network intelligence" and personal service customization and management), advanced security, personal user agents (providing "personal intelligence"), user-installable scripts, and on-line directory services. It will also include more user-friendly interfaces that allow for natural interaction between the user and the communication infrastructure, shielding them from the complexity of information gathering, processing, customization, and transportation. Applications would be deployed over a variety of (hybrid) networks, using novel naming, addressing techniques, and new paradigms of network management. Users and enterprises would be able to obtain online services through the Internet, via a variety of devices, including those that are mobile.

Collaborative and Intelligent Services: Users would be able to dynamically select the most appropriate mode of interaction for their current needs, while enabling developers to provide an effective user interface for whichever modes the user selects. Multi-modal interaction offers usability benefits over uni-modal interaction when hands free operation is needed, for mobile devices with limited keypads, and for controlling other devices when a traditional desktop computer is unavailable. Users would be able to provide input via speech, handwriting, and keystrokes, with output presented via displays, pre-recorded and synthetic speech, audio, and so on.

Traditional services relate to basic access/transport/routing/switching services, basic connectivity/resource and session control services, and various value-added services. It is expected that the Future Internet will enable a much broader variety of service types, which span diverse networks, organizations and heterogeneous computing platforms, including:

- Specialized resource services (e.g., provision and management of transcoders, multimedia multipoint conferencing bridges, media conversion units, voice recognition units, and so on)
- Middleware services (e.g., distributed naming, brokering, coordination, security, transformation, transactions, location-based services, etc.)
- Business services that represent reusable business functionality (value) services across multiple organizations, such as logistics and transportation services.
- Content provision services that provide or broker information content (e.g., information push and pull services, etc.)
- Integration services (e.g., data, process, and application integration services)
- Application-specific services (e.g., e-business applications, supply chain management applications, interactive video games, etc.)
- Management and monitoring services to install, configure, and provision communications/computing networks and application/system services by collecting metrics and tuning them to ensure smooth and responsive execution.

The Future Internet will give the opportunity to service providers to integrate (compose) widely distributed services into adaptable end-to-end business processes, under the desired level of QoS, balancing expenses with revenue flows.

Dynamic Value Chain (including End user Empowerment): As multiple service providers and other business entities all become involved in providing services to end users, federated network and business systems will become increasingly important in the Future Internet. On the business front, globalization of the economy and the markets that are changing due to competition from company vs. company to value chain vs. value chain will force the move towards a third generation of process automation software solutions supported by the Future Internet. These will enhance process fluidity and strategic changes by employing adaptable on-demand process integration technologies thereby reclaiming degrees of freedom lost to proprietary software solutions that were designed for operating within confined environments. This will open tremendous opportunity for dynamic value chain integration by enabling business processes (services) to transcend enterprise boundaries, morph themselves in reaction to market pressure and participate as elements of a collaborative end-to-end process within a value chain across a federation of enterprises. It would require, however, a comprehensive methodology for mapping collaborative business processes to capabilities within the technical enterprise infrastructure, and design techniques, principles and guidelines that achieve a functional service-oriented solution. It is important to note that the dynamic value chain notion will include an increasing empowerment of the end user to become part of this value chain. Today's trends in Web2.0 can only be seen as the beginning of new forms of value chains in which the end user will be an integral part. We expect to see more and more business propositions in the future that will address the user's perceived benefits on a social, environmental and even spiritual level.

Big Brother – Total Surveillance: Already today, more and more communication and information technology is used for surveillance of some kind, institutionally or governmental driven. Many expect that the Future Internet will increase this level of surveillance and privacy erosions. Monitoring and mining every single transaction of each citizen, coupled with information on the user's context (e.g., location, activity and others), will enormously shift the power structure in our society. For instance, item level tagging with appropriate back end infrastructure will allow for detailed activity monitoring. Black boxes in cars with surroundings information will re-construct every single accident. Prevention of fraud through data manipulation is crucial but critics can be silenced by a perceived belief of "technology that does not lie". Digitization of media can lead to "1984"-type of scenarios, in which history is re-written (and much easier, since paper handling will not be necessary). The right for privacy has been reversed: "they who do not reveal have something to hide" is used as a judicial principle in court. Apart from government-sponsored surveillance, as the ubiquity of the network is increasing and the price of computational power is decreasing, an ever increasing number of organizations and companies will have a surveillance capability in their hands that would have been unimaginable for some intelligence services in the last century.

Future role of "operators" is changing or even disappearing. - In the future where users can access any network at anytime, and where a wide variety of accesses compete or even are provided for free, end-users loyalty cannot be taken for granted. In an increasingly complex communication and service world end-users need "care-takers" whom they can trust and who protect their rights. That role can be taken by new business types, banks, insurance companies, governments, and others.

Evolution or Revolution?

Although explorative research, as called for in this document, could potentially see more disruptive scenarios emerge, it is important to note that the answer to the question of revolution or evolution is not the primary goal for this type of research towards the Future Internet.

This document does not intend to answer the question whether or not the Future Internet will be evolutionary or revolutionary with a definite answer. Not only does such answer depend on the particular viewpoint of the questioner, but even a perspective of the neutral observer makes the task of finding an answer to this question unbelievably hard. For this to understand, consider the technology and industry landscape of about 15 years ago. The Internet was in its infancy, technologically (access was done using telephone dial-up of a few Kb/s, email was rudimentary and rather small scale, there was virtually no Web or personal Web pages) and socially (no Internet payments, no e-Government, no larger scale access deployments). The company landscape at that time included a mainframe-oriented IBM, Digital, AT&T and its baby bells, no Google, no Yahoo, Nokia being a rather small technology company.

With this landscape in mind, the trajectory in development in the economical and technological space towards today's players like Google, Yahoo, Nokia, IBM (without its PC hardware business), eBay (including Skype) and others, illustrates the difficult business of "predicting" the potentially disruptive or evolutionary character of the future. In other words, anything predictable from today seems as much likely to come true as anything else. This is even more amplified through the increasing end user driven innovation (movements like Web2.0), which increases the probability for disruption, while other trends such as convergence and operator consolidation give probable scenarios for evolution.

Based on this reasoning however, it is important to stress that ANY view on the future of the Internet should be as little as possible driven by today's biased view on the technology and business landscape. This is important in the context of this document, which argues for explorative research for the Future Internet. This issue will be addressed again in Section 4, where we discuss the need for future actions.

SECTION 2: TECHNICAL CHALLENGES

Issue 1: Technical starting point

The first issue is the starting point itself. The starting point is not necessarily well defined or agreed upon. Some think that the Internet is completely or partially broken, others that the Internet is perfect. It is difficult to determine whether either of these statements is correct or not, and the reality probably sits somewhere in the middle. The reality the scientific community is currently facing is that there is no common understanding of what is commonly acceptable as "state-of-the-art" in current Internet technologies. Practice has nevertheless shown that proposed enhancements such as IPv6 and IP security (IPsec), and additional capabilities such as mobile IP, multicast, streaming, etc. are difficult to realize in practice in the open Internet environment. Several reasons have been invoked to explain this situation, such as penalization of early adopter ISPs (instead of having the possibility of being rewarded for making the investment), and lack of coupling to a mechanism whereby the user can exercise choice to select the provider who offered the service.

Note that determining how good or bad are the current and future Internet principles, architecture, and protocols, are difficult projects on their own. There is also a strong dependence on objectives, constraints and actors (e.g. depending on specific domain/sector, cumulated experience, interest and perspectives, etc.) However, we can observe—with all due precautions—that, for example, the scaling of the routing system with respect to routing information processing is progressively becoming one of the major challenges to be addressed by the Internet community.

Issue 2: How far away is the future?

There are plenty of challenges ahead in paving the way toward the evolution of the core Internet technologies. Knowing the difficulty in departing from current technological limitations —see issue 1 above— the resulting problem is that there is little consensus on whether the core Internet technology enhancements can be achieved. Hence, that experience is rather limited. Indeed, relying on past experience to determine the gap and overall effort that separates the current, rather stable, situation from an equivalent situation in the future is difficult to assess. We must also underline that most of these technological enhancements are not coupled (for example, the improvements to mobility and multicast brought on by IPv6 are of little value if there is no support of mobility/multicast in the underlying IP infrastructure). Together with the commercialization of the access to the Internet infrastructure, this leads to a decreasing influence on the overall Internet architecture and underlying technology. The underlying issue is: who should be in charge of putting together the new core elements?

Issue 3: What is the trajectory?

There are many technical paths that can be followed to solve any of the challenges that are currently under investigation by the scientific community. See also below.

Design objectives

The objectives listed below range from the base objectives any communication network should provide, to particulars specifics to the Future Internet infrastructure.

- Open, wide-scale accessibility, application neutrality, transparency and generic purpose
- Decouple application from communication protocol(s)
- Decouple network addressing (network graph location) from (upper layer) application identification and user identification/location
- Network security, survivability, robustness, performance, scalability, flexibility/adaptability and ability to evolve
- Facilitate host attachment, and accommodate a variety of access technologies (wireless and wireline)
- Support any type of transport layer protocols (and facilitate mobile communication) and traffic (e.g. multicast, anycast)

- Distributed control and management (enhance network control and management capabilities with new paradigms)
- Cost effectiveness
- Accountability (and trade-off between accuracy and privacy, and anonymity/trust)

These design objectives do not constraint the architecture, because they are driven by principles and models that would themselves deserve dedicated investigation. One could for instance investigate the impact of the erosion and/or future of the end-to-end argument (part current Internet architecture principles), as well as the implication of the erosion and/or future of the hourglass protocol stack model.

Technical challenges

As mentioned in the introduction above, it is probably impossible to detail and determine the exact set of technical challenges such infrastructure would realize and implement. Therefore, it is more appropriate to first have a broader view on the set of domains into which further investigation would be required. The domains of investigation are classified and summarized in Figure 2.

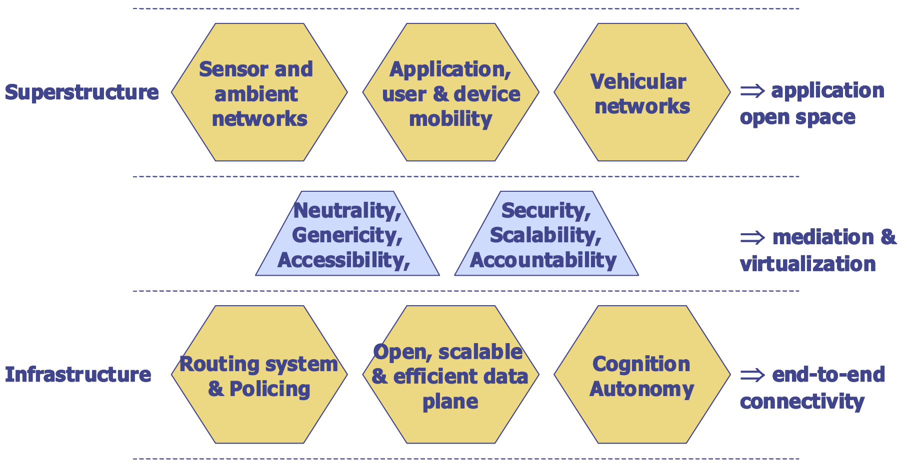

Figure 2

Overall, the ultimate objective is to create a better technical design for the Internet to meet tomorrow's requirements. From this perspective, replacing the traditional protocol layering paradigm with a more general model (many of today's problems appear to be related to traditional layering) is considered as a commonly shared technical challenge. Indeed, the Internet has progressively become an architectural "pretzel factory", with layer violations (e.g. cross layer design), sub-layer proliferation (e.g. MPLS at layer 2.5, IPsec at layer 3.5, and TLS at layer 4.5), feature interaction (which results in complexity), IP addressing space usage overload, and erosion of the end-to-end model (middle boxes such as firewalls, NATs, proxies, caches, etc.). Henceforth, address the architectural foundations and design of the Future Internet as a whole (architecting a solution) with studies on different paradigms, the underlying principles, and the impact on solutions is the key technical challenge per excellence. Indeed, understanding in architectural foundations and their impact on deployability and future proof is crucial when stepping towards the Future Internet. Architecting a solution must become common ground for future solution deployments. Formulation of techniques, development of tools and educating architects is the goal of this area.

Within the context of the above high level classification (in terms of infrastructure and superstructure), each of the domains of investigation can itself comprise a set of technical challenges. In between these holistic structures providing for end-to-end connectivity of the open application space, novel and innovative approaches for network infrastructure mediation and virtualization will allow for new business models between network providers and the other players. The description below is not exhaustive and has been limited on purpose to representative technical challenges related to the infrastructure and the superstructure. For each of these topics, its positioning with respect to Figure 1, and a brief description is provided, followed by a brief explanation on why such topic is important and needs to be addressed from a technical perspective.

The purpose is to provide for an insight of the gap that separates the current perception (with all its subjectivity) of the Internet capabilities and some of the technical challenges that various actors (ranging from Universities to SMEs and other vendors) would like to address in order to improve it.

1. Inter-domain Routing and Relationship Management	
Positioning: Infrastructure - Routing system and policing	
WHAT	Address complex inter-domain structure (e.g. routing) in an easy-to-manage way since it is impacting traffic predictability in carrier networks. Address routing system scalability and policy (e.g. BGP) to support multi-homing and mobility, but also multi-path (resiliency and traffic engineering). SLA calculus is needed for the provisioning of multi-provider services and concepts for dynamic and automated negotiation of SLAs between two or more parties. Simple and efficient resource management mechanisms are required that differ from previously studied quality of service mechanisms.
WHY	Increase in traffic volume hard to control and to predict, especially with increasing access capacity, new applications and increased user mobility. Routing information increase (impact on network equipment scaling) due to o IP address usage overload, e.g. subnet (network graph location) but also application ID, user-ID/terminal-ID o IP address semantic overload, e.g. identifier vs. locator. o Complex inter-dependency between routing policy (traffic engineering) and addressing space processing (from allocation to distribution and processing). SLAs between providers are static as they are negotiated and configured manually. Redirected traffic from an increasingly complex topology of autonomous systems makes a decent resource management for network providers a hard to manage task

2. Cognitive networks	
Positioning: Infrastructure - Cognition/Autonomy	
WHAT	Control/management of large and complex systems. Autonomous learning (as opposed to supervised). On-line learning (as opposed to off-line). Distributed learning (as opposed to centralized). Dynamic/automated knowledge representation (as opposed to static).
WHY	Self-awareness: discovery (heterogeneity). Self-(re-)configuration: automation. Self-tuning: performance monitoring. Self-organizing: adaptation/accommodation of new user needs. Self-adaptive: protection against external events. Self-healing: protection against internal failures. Accountability (requires user-network communication).

3. Edge-based Service	
Positioning: Infrastructure - Data plane	
WHAT	Efficient mechanisms for edge nodes to define and control service offerings (self-organizing control; own namespace and routing) Offer resources to edge nodes managed in a sophisticated way, in small time scales.
WHY	High and symmetric access capacities (wireline, terrestrial and satellite wireless). Service support where edge nodes have multiple roles and may form coordinated groups/communities. Edge nodes embedded in communities or overlays where the participants/communities complement and/or profit from each other.

4. Future Transport - Optical Networks	
Positioning: Infrastructure - Data plane	
WHAT	Packetization of the transport layer and protocols. Role of circuit-/analog-switching, e.g. lambda/photonic switching and evolution (burst switching, optical label switching, etc.) Fail-safe transport network configuration and operation, inherently self-healing approaches, robust network planning.
WHY	Increasingcapacity requirements Efficient adaptation, multiplexing and aggregation of higher layer data traffic

5. Accountability	
Positioning: Mediation & virtualization	
WHAT	IP best-effort network with no possibility to account for different behaviours of the network in different operating conditions (hence the requirement for network accountability). o Anomaly detection. o Feedback (resource utilisation). User accountability. o Anomaly detection. o Traceback (source). Application awareness of traffic profile and quality expectations. o Applications receiving feedback from the network on the quality of the current data delivery (accountability feedback). Cross-layer logging and analysis.
WHY	Enforce network reliability (misbehaviour analysis). Enforce communication reliability among users/applications. Applications to adapt their communication behaviour to traffic.

6. Security, Privacy and Public Protection and Disaster Relief (PPDR)	
Positioning: Mediation	
WHAT	Increasing dependence on a secure and safe Internet for all aspects of our life More and more mission-critical use of the Internet for all aspects of life, replacing closed application networks/infrastructures (leading to extensive risks). Need for public protection, emergency and disaster relief. Opportunity to do it (even) better than before (traditional applications/technologies, such as telephony, etc.). Potential high increase of entities (even individuals) providing infrastructure/ services (to the general public/user) with unknown intent and capabilities.
WHY	Standardize a European “circle of trust” solution and guidelines to interoperate with national and other trust solutions. Selectable degree of anonymity and trust. Network-to-network security/trust vs. user privacy/anonymity. Application-level privacy/security not adequate for some risks (location/movement privacy, others).

7. Global and Generalized Mobility	
Positioning: Superstructure - Application, user and device mobility	
WHAT	Facilitate multi-attachment to the network & accommodate variety of wireless access technologies in support of host/ terminal, user and application mobility in ground, water and air environments. Transport layer protocol to facilitate mobile host-host communication (avoid network layer involvement). Harmonize application-, network- and link-layer mobility solutions. Support moving network nodes (network mobility) and accommodate variety of wireless network technologies (terrestrial and satellite).
WHY	Limit integration of mobility to transport layer (ability to deploy additional services without changes to the infrastructure). Prevent creation of sub-layers for network-layer based mobility operations (prevent complex inter-dependencies). Minimize operational disruption to the network layer operations (reduce upper layer impacts and increase performance).

8. Distributed Multi-modal Service-based Middleware	
Positioning: Superstructure - Application, user and device mobility	
WHAT	Composition of a particular service using separate components provided by different networks. Extend Web application to allow dynamic user selection of the most appropriate mode of interaction of distributed application components. o Context-awareness (going beyond location awareness). o Platform-programming language and protocol independence. o Extensibility and modularity. o Self-adaptability.
WHY	Future applications based on automated collaborative services to perform complex and sophisticated tasks. o Example: tasks involving middleware (technical) services utilizing all kinds of physical equipments (e.g., sensors) and resources (including humans and software) that are widely dispersed over the Internet, which would be seamlessly integrated and coordinated. Services requiring specialized middleware support to span heterogeneous computing infrastructures and networks, and to cross geographic borders.

9. Sensor/Ambient networks	
Positioning: Superstructure - Sensor and ambient networks	
WHAT	Integration of physical with digital world. Expand reach of network toward “any terminal/device”. Classical networking paradigms to be revisited for e.g. o Infrastructure-less (host-based network)/Vehicular networks o Wireless sensor network o Home networking (intelligent household device self-organisation, home security and automation)
WHY	Source of traffic not limited to traditional computers, but expands to any object with a capability to interface in the digital domain. Limited capacity/processing, but extremely high number of sources. Accommodate Delay Tolerant Networking.

Observations

Many observations can be made from the above set of technical challenges but some key ones are highlighted here:

1. More than a simple delta

The difference between the state of current Internet technology and that of the Future Internet is not negligible. The above technical challenges are not just small steps forward, but translate into very challenging and complex, albeit not impossible tasks to be realized.

The realization of these tasks leads to the following questions: are these the final steps or just intermediate toward further objectives? Within what time scale should they be achieved? What is their respective impact (evolution or revolution of the Internet core technologies)? Does their deployment require any specific migration process?

There is a need to provide the right set of tools (ranging from networking theory to test beds), to make them openly available, and to use them at the right moment to realize these technical steps. There is a strong correlation between the relevance of these tools and the technical objectives. In addition, there is a clear indication that all these tools are not necessarily technically oriented.

2. Orchestration

A couple of representative technical challenges concerning the core Internet technology evolution leads to a broad technical trajectory that will require appropriate support, flexible structure and long term proactive effort to sustain. Indeed, as this trajectory will be composed of multiple step evolving objectives and achievements, a broad, technically oriented, feedback will be expected in order to maintain consistency of the overall effort and appropriate positioning and valuation of the corresponding achievements.

3. Positioning

Two major issues on positioning can be summarized as follows. Each of them provide for an incentive on the ultimate rationale for departing from the current situation.

- Positioning, perspectives, role and motivation of actors vs. the set of technical challenges (some of which are unknown today)
- Positioning and relationship of these technical challenges vs. the set of (r)evolution scenarios

4. Complexity

Layering results from the modularization principle and tackles the complexity of system inter-communication. However, several technical challenges such as cognitive networks and generalized mobility challenge the traditional layering model (that is reflected by the end-to-end model in the Internet context).

This observation results in the issue of how to limit/control the complexity introduced by these technical challenges. To tackle this aspect it is recommended that research on the technical challenges (not only those described in Section 2) should be conducted in parallel with (fundamental) research on the complexity of networks, both in terms of formal complexity analysis (mathematical sciences) but also of practical experience.

Tools

There is an absolute need for the right set of tools to become available and used at the right moment to aid research on the technical challenges. These tools can be classified as follows:

1. Networking Tools

- Meta-routing: a high level declarative language to specify routing protocols in such a way that implementations can be generated automatically.
- Network information model and theory (e.g. analysis of routing dynamics): formal network analysis is required in order to achieve better understanding compared to current “ad hoc” tools.

2. Monitoring/Measuring Tools

In order to have verifiable network environments (user-understandable diagnostics) and prevent manual intervention, automated and autonomous tools are required that would benefit from so-called, cognitive, capabilities.

We must also step beyond the empirical models (and their inherent limitations), which is one of the main experimental approaches due to the lack of analytical models, and also one of the major hurdles in validating new technical approaches.

Such tools would be provided for:

- Data gathering: efficient, type-safe, distributed processing (temporal dimension).
- Data repository and management: combination of host- and network-based measurement (unified measurement data repositories)
- Data analysis and processing: mining structure (relationships from data), machine learning techniques (robust automated processing)

3. Testbeds

Testbeds for research into the Future Internet should be provided for public, verifiable simulation environments and data through e.g. virtualization (split of software & hardware), co-existence of diverse meta-networks within a shared substrate, and co-existence of various network architectures/ protocols and services.

4. Demonstrable environments (by practice).

More open/usable environments

- involve a large number of end users directly to networks.
- provide suitable applications deployment and programming interfaces for different communities.

Conclusions on Technical challenges

In summary, as part of the value proposition, the following are the elements on which the EIFFEL think tank can act on from a technical perspective:

- Thinking: providing support and structure and sustaining an open and broad technical trajectory.
- Steering: evaluating objectives, achievements, and feedback.
- Equipping: providing appropriate tools, and seeing that the right tool is used at the right moment.

SECTION 3: POLICY CHALLENGES, RISKS AND OPPORTUNITIES FOR EUROPE

Background

In the technological community there has been historical tendency to, if not ignore, at least downplay the discussion on the policy and governance issues. In planning of the future networked society this is not an option. There is a strong debate on-going about the governance of the Internet. For example several nations have, through United Nations, questioned the current status quo, where ICANN has an oversight over some of the critical parts of Internet. The situation is even more difficult, when one enters into legal issues and law enforcement. There is no good understanding, how to handle different conflicting interests and legal and cultural limitations. The network itself is spanning the whole globe, but servers are located within specific jurisdictions, with highly different legislation. This “tussle” in the policy space will be increasing in the future.

Moreover, policy and governance issues have a clear feedback loop towards technology development and even value chain design in the business domain. Predictable policies and constant governance are required to ensure that investment decisions and sensible planning can be done in this domain. It is anticipated that if and when we move towards the new networking paradigm, this would be also a good time to revisit many enshrined policy and governance issues, and try to bring in more balanced views into governance of the global network.

Observations

Regardless of where and how the future network(s) will develop technically and whether or not human communication will remain dominant, the future networks will play an ubiquitous, yet pervasive role in the daily life of people. That is where rules, policies, and laws become important.

The number of policy issues, central or peripheral to the future networks, is growing at a rate both legislative bodies and executive forces do and maybe can not follow up. These include variability of national rules, possible temptations towards censorship, governance, lawful interception, goverment inspection, spectrum management, patent licensing, and standards.

Although people claim to have a strong demand for privacy and security, little or no awareness about technical assets for anonymity exists and little or no privacy enhancement is being facilitated. Public interest seems to conflict with commercial interest, where the former asks for protecting people from fraud through information release, whereas the latter requires transparency to increase user experience.

Digital media and networking by far ease the sharing of information, but the question of who shall control whether this information sharing is legal and who protects legal usage of network resources, remains unclear. Instead network providers store access data, networks do not per se protect against snooping, Web servers collect and share user data, and tracing tools follow users through the net, to name only a few of the questionable approaches and habits. Strangely enough, standard encrypted network services and trustworthy communication means are treated as if communication hiding is criminal.

Part of the difficulty to define, implement, and enforce clear rules lies in the different view of the future network. Some see and treat it as infrastructure, with a focus on ownership, maintenance, regulation, legislative and executive authority. Some others emphasize the service component of the future network and argue about costs, access, availability, reliability, security, privacy, and anonymity. Whereas others are just concerned about the architecture of future networks. All in all, the challenges are to be highlighted.

The plan of actions to guide decisions and actions for a future network will have to consider many, not always free-of-conflict areas. Spectrum planning is one of those challenging policies, especially when it comes to frequencies to be shared among satellite and terrestrial use. Licensing is another one, especially when it comes to non-discriminatory use. Convergence of services is one of the strongest driving forces behind it, but international regulation is required beyond the borders of the European Union, and is a must for global communication.

In addition, a number of risks exacerbate the policy development. If the number of actors is too large decisions tend to take too long and results tend to be the least common denominators, without visionary aspects. Too much bureaucracy complicates the decision making process further. Libertarianism could guarantee that regulation serves both keeping the operating environment generally safe, but at the same time, keeping monopolies or oligopolies from emerging. Regulative issues should not touch specific pieces of technology too much, since the same technology probably will be used in multiple networks or devices. Clearly, it is not in the interest of

European citizens to create legislation that works against common integration of technologies and services for landline, mobile and satellite technologies.

There is a potential need for a (European) network(ing) policy. Embodied as an agency it could well incorporate a think tank acting as intermediary for the various stakeholders, but at the same time being entitled to enforce policies within and at the EU borders. This sort of mechanism should be experimented and planned through FP7. The experience has shown, e.g. the on-going, often very chaotic tussle between stakeholders on digital rights protection domain, that policy makers would require more balanced and impartial views on all facts in the economical, legal, technical and policy domains.

Need for Action and Debate

One of the findings of the EIFFEL think tank has been that there is not enough interaction between the technology and policy driving communities to debate and outline the future needs. This is a less than optimal situation, since cross-fertilization in ideas and expertise is required to solve tough issues related to policy, privacy and enforcement of network rules. Moreover, although the group has recognized that there is discussion going on in this domain, this discussion and related research should be intensified in Europe. In fact, the EIFFEL group itself was a micro-cosmos experiment on this. There is a certain lack of urgency on having policy makers to join into the discussion on the future governance and related legal framework.

One of the key aspects out of the governance of the technical rules and infrastructure, there is also an issue of how to agree on some guidelines on the network use and enforcement of those rules. The majority opinion was that a completely freewheeling approach can not continue, and instead of relying purely on technological solutions, one should also consider how to enforce rules. This has a clear implication on the traceability. One cannot enforce rules, unless they are able to trace back to the rule breakers. This obviously is then related again to the discussion on the Big Brother surveillance.

In general, the EIFFEL group felt that there are more questions and recognized interdependencies on the table than good answers. This means that there is an urgent need for action and debate.

It is time to revisit many enshrined policy and governance issues and try to bring in more balanced views into governance of the global network. Regardless of where and how the future networks will develop technically and whether or not human communication will remain the main application, the future networks will play a ubiquitous, yet pervasive role in daily life of people. That is where policies and laws become important.

SECTION 4: REALISING THE FUTURE INTERNET

Future Internet and Networked Society

There are a number of different initiatives towards next generation networks (NGN). In some sense the whole term of NGN has been used so much that it started to lack any meaning and feeling of urgency. Most recently, the GENI initiative and FIND projects in the USA have attracted a lot of attention on their approach towards a, so-called, “clean slate” design. The EIFFEL think tank believes that regardless of the existing work and other initiatives there is still an urgency to get European research moving towards this direction. Moreover, we believe that there are still opportunities that are overlooked within other initiatives, or not fully considered within existing projects.

Taking into account the large amount of different issues that must be tackled, not only in the technology domain, but also in governance, policy and business, it may be better not to refer simply to the “Future Internet”, but to the “Future Networked Society”. The R&D issue, and, in fact the actual deployment issue, is not to make technology an end in itself, but to enable a true information society, where the pervasive network technology provides the right kind of services without violating our privacy and fundamental rights. Moreover, leaving out the term “Internet” highlights the true radical disruption compared to a simpler evolution.

The required scope for the work is very wide but we summarize the main aspects below:

Technology is clearly the most recognizable aspect of the work. Section clearly determines the need for an appropriate balance between evolutionary and truly high risk - high gain revolutionary research. Technology research needs to be intensified, but not by forgetting the other aspects.

Policy and Governance are very important aspects for the future of networking as outlined in this white paper. Previously, there has been tendency to leave these issues to be handled after the technology has been developed. In the case of the global networked society, this is not a desirable approach. Moreover the different problems related to policy and governance are at such a high level, that we believe that new debate and interdisciplinary research between technology and policy experts is urgently required.

Socio-Economic Aspects have been outlined with some details (also in this white paper). The sociological aspects are, naturally, related also to policies and governance models. As we are moving towards an information-driven society and networking capability becomes pervasive, it is important that socio-economic aspects are considered not only as ‘lip service’, but in true research fashion. Moreover, there should be mechanisms to generate discussion by the users and citizens themselves. Ensuring that these issues are taken care of is extremely important.

Business Considerations are part of the economic aspects, but should be emphasized on their own. The future network needs to be built upon the foundation that it can be used for commercial purposes and will be run by commercial organizations under the oversight of proper governance and policy rules. This is a reason why both evolutionary and revolutionary approaches are required at the same time. The transition towards any new paradigm cannot be completely disruptive; a “day zero of the new network” cannot exist, since the network itself is already a critical part of the functioning society. The economical and commercial issues need to be taken into account. That said, those considerations should not become a hurdle to innovation. We believe that disruptive research should challenge business developers to see opportunities instead of threats. This means that we believe that there is need for true business and economic forecasting and research in this domain. We emphasize here that this goes beyond “simple” scenario trajectories and right towards more specific analysis and research on the value chains, business opportunities and networked society economical models. Of particular interest are new tools and methods required for business model evaluation and economic forecasting of the effect and impact of offerings in the wider societal context, inherently incorporating societal concerns into the evaluation.

Research in FP7

It should be recognized that a vast amount of work has been done in Europe, also in the FP5 and FP6 programmes, towards next generation networking paradigms. Admittedly, a large part of this work has been more evolutionary, but nevertheless it has built out competence and useful building blocks for more radical designs. There has been, justifiably, criticism that certain amount of cohesion and coordination has been missing between the different approaches. This needs to be addressed in FP7, but in a fashion that does not curtail innovation and freedom of action under the control and coordination mechanisms.

Europe has a recognized track record and leadership on wireless communications, but this leadership should not be overestimated, nor should we forget the need for innovation in the core network. In fact, if there is a large paradigm shift in overall networking this means that there is a unique opportunity for renewal in the business, where current stakeholders' positions can shift, and even new companies can emerge into the core networking markets.

The previous sections have been outlining the diversity of different approaches that are required. The scope is so wide that this alone is proving that European-wide research supported through FP7 is required. It is not foreseeable that any business entity or nation state alone could tackle all the related problems, at least not in Europe.

Apart from requiring more innovative research and coordination between those, there is also a need to emphasise more interdisciplinary research. The interdisciplinary research should be stimulated with different mechanisms. The interdisciplinary research should be seen as a multifaceted concept. It should be encouraged that interdisciplinary approaches are supported within single projects, especially in the case of more risky longer term STREPs. However, the project should not been seen as the primarily responsible for ensuring the interdisciplinary research in FP7. Mechanisms will be needed to promote interdisciplinary approaches over all the future networking (Future Internet) R&D that is conducted in FP7. Some of the mechanism may be to ensure that there are different supporting entities that ensure that there is enough sharing of information and debate between projects and different communities, but ultimately it is the responsibility of the EC and its directorates to develop mechanisms and seek professional advice to ensure that the project portfolios and overall research in Europe is covering all the necessary aspects in a true interdisciplinary fashion. That said, one should note that interdisciplinary research itself cannot be a goal, and it needs to be justified, and artificial non-expertise-based movement of "terminology" from one field to another should not be encouraged, as the resources for the future research are limited.

The key finding is that instead of trying to build the "Future Internet" or "doing the next Internet", which may be emphasizing the technological aspects too much; we could go beyond that and say that FP7 should move from the "Future Internet" to

"Enabling the Future Networked Society"

The challenge stays the same, but the target outcome is then to meet current and future needs for inclusive societies. If we deploy disruptive technologies, whatever those might be, they need to be acceptable to the public. Therefore, the disruption maybe technological, but we should not disrupt users on purpose. This means that underlying technology may exhibit a strong paradigm shift, but, for the users, the support for existing applications and functionality, and then evolving movement towards new opportunities, should be ensured.

Stakeholders and competences to be motivated

FP7 and future Internet research should motivate different stakeholders to engage in lively debate and to provide the highest quality R&D in the field. The debate within the EIFFEL think tank has shown that different developer groups have highly different motivations and boundary conditions. Instead of ignoring this fact, we should recognize it, and proper mechanisms to motivate all different stakeholders and competences should be explored. There is a need for both long term research that is pushing the boundaries of our knowledge and providing innovations based on fundamental research, as well as a need for more evolutionary research that is industry-driven. Both academic and industry segments need to be motivated based on their respective fundamental interests and competences.

This leads to a logical conclusion that a "one size fits all" approach will not work in the domain of future Internet research. Our recommendation is that in order to motivate all the stakeholders and to ensure that very high quality work is done the following aspects need to be addressed:

- **Better cooperation and coordination mechanisms** need to be explored so that the overall resources provided by the EC are used efficiently. Instead of the further fragmentation of research efforts, there need to be some forces that provide cohesion to ensure that at least the visions and longer term goals are shared between the projects long after the initial period.

- **A full complement of different instruments** needs to be used. “The bigger is better” approach will probably not work, and neither will “small is agile”. There is need to agree that all different funding instruments have their pros and cons. That said, it is believed that a number of agile projects are needed for exploratory research and it is not foreseeable that purely consensus-driven, large projects could alone ensure the competitiveness of European R&D in this field.

- **Excellence should be encouraged and rewarded**. The EC should also see to that a strategically balanced portfolio of projects and instruments are built and accepted. There should be mechanisms to ensure that excellent and enthusiastic researchers get personally involved into the projects and can feel that these projects will motivate them.

- **Evaluate the potential impact of the projects as one of the key factors.** The evaluation of the impact should be, however, fair, and one has to be careful not to “kill” innovative and disruptive projects through disbelief. In this domain, one has to be again clear to understand that different stakeholders have different primary impact goals. Hence, the impact evaluation should be adjusted based on the goal of the projects and the perceived motivation of the stakeholders.

Revolution vs. Evolution: encourage the culture of risk taking

In the EIFFEL think tank there has been a lively discussion on the subject of revolutionary vs. evolutionary research. We emphasise that the primary goal is not disruption; equally the goal cannot be evolutionary research. The real goal is enabling the future networked society, with whatever means are right. The consensus within the EIFFEL think tank is that different instruments are required to handle to challenges and opportunities related to the Future Internet and Networked Society. We are not in the position to state with any kind of certainty if the future network will be based on major disruptive technologies or combination of evolutionary approaches and innovations.

The figure below, based on Christensen’s view on disruptive technologies, is trying to emphasise that in FP7 we need to ensure that both evolutionary and revolutionary research tracks can contribute towards the same goal, if rich interaction between different approaches and stakeholders are ensured.

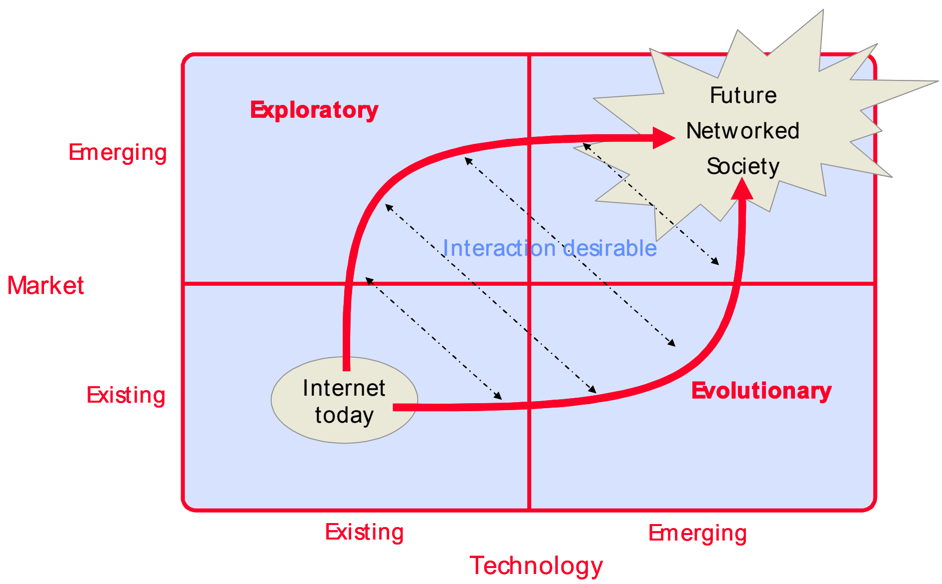

Figure 3: Different paths to the future Source: Nokia

That said, it was equally strongly felt that more emphasis should be put towards high risk, high impact research, at least in the beginning of FP7. In general, it was projected that a larger number of small projects (STREPs) should emerge that will go towards high risk, exploratory research to challenge fundamentals both in technology and socio-economic domains. For this purpose, there should be a new culture of risk taking and from the participating organizations side the culture of accepting risks. It is clear that all such projects cannot be 100% successful; otherwise they would not fulfil their mandate of aiming towards disruption. It is equally important to understand that risk itself is not a goal, and careful monitoring of such projects should be done, so that only the most promising ideas will continue and cross-fertilise later, larger projects with ideas. It is highly desirable that some sort of informal coordination between different suggestions and project proposals is done. Here one should understand the word "coordination" as an exchange of information and voluntary positioning between projects, not as coordination by some central authority or forum concerning what is acceptable or not. In fact, we envisage that totally surprising proposals may have a great potential to go beyond the present paradigms.

The current EIFFEL think tank, through its Work Group 4 (WG4), is willing to help on building contacts and bridges between different stakeholders and consortia.

Overall we believe that it is important that the right capabilities are leveraged. In the following we outline some of the key points to show that there is need to ensure that we have the:

- Right instruments,
- Resources to succeed,
- Processes to facilitate success, and
- Aligned organizational and stakeholder values to prioritize the innovation.

Role of the ETPs

The current ETPs represent a large number of different stakeholders and have a particularly strong emphasis on the industrially relevant and evolutionary R&D. They are particularly strong and well suited to build up large consortia and to reach consensus through different mechanisms inside the ETP structures. It should be also noted that ETPs are not primarily aimed towards the future Internet action, but are covering a wider scope of topics, and, as such, they provide a high added value on building bridges towards different stakeholders in the commercial domain. Particularly in the evolutionary area, ETPs can serve operators and software manufacturers efficiently, and the value is almost diametrically opposite, on average, compared to smaller disruptive research based projects – which would not have the volume or the technology to provide experimental capability required for such stakeholders.

ETPs present a strong combination of experience and industrial relevance. It is anticipated that in the future Internet domain there will be a number of different players and projects emerging, some of those will overlap with ETP memberships and some not. Independently of the multitude and diversity of projects, there should be mechanisms to ensure that different EIFFEL-inspired projects will have interaction with relevant ETPs. This is required in order to ensure that these projects can provide research findings to ETPs for further exploitation and for exchange of idea between ETP-based projects.

Reflection on the US Perspective

The research community in the United States of America has also started to consider the requirement of reengineering the Internet on a radical scale. This is also reflected by increased funding, and most notably by the recent establishment of the NSF GENI and FIND initiatives. The approach is clearly based on the thinking that even radical, "clean-slate" design is allowed. Moreover, the current approach is to support both "innovation in the small", i.e. single principal investigator and small group, and extremely large coordinated assaults on long-term objectives. This includes also plans to develop large-scale experimental test bed facilities. One of the key issues is that these initiatives have generated core groups of excellent researchers that are exchanging ideas and regularly debate on radical design paradigms. There are two key lessons to learn from the US. First lesson is that *radical innovation is not easy to bootstrap, and it requires a supportive environment for that.* The second lesson for Europe is that revolutionary research is required in order to keep innovation chain fill at the right level. The evolutionary approach requires that there are enough long-term results waiting in the pipeline. Not supporting the fundamental and revolutionary research, will inevitably jeopardize also industrially relevant advanced development. The current U.S. community is open for collaboration, but the European one needs to harmonize its approach in order to be able to collaborate in a more cohesive manner.

Portfolio of Projects and Time Frame

As outlined above there is a requirement of having a portfolio of different projects using different instruments. In the present document of the EIFFEL think tank, we do not venture to present any specific project portfolio recommendations. It is too early for that, and in any case, we would not like to "close doors". Generally speaking, however, there are some issues that we believe could and should be taken in account:

- There needs to be **phased introduction of the projects**, and projects need to have different time-frames and objectives for their success. Taking into account that a part of the research is aimed to be high risk and long term exploratory research, and there is no consensus on what are the best possible avenues for larger scale testing, it is believed that funding decisions need to be made in two or three different calls. Roughly speaking it may make sense to first bias towards high risk, and generally but not exclusively, **smaller projects** that will try to explore the "opportunity space". These projects should have a limited life span and one must accept that there are high research risks involved with these projects.

- A massive scale single testbed approach maybe beyond our resources to achieve. In fact, it seems that taking into account a large amount of existing different testbeds and European Research Networks (such as GÉANT), we already have a very strong base where to start the future work. Hence, the best funding instrument might not be to fund very large scale networking building, but instead to support actions that raise awareness of existing capabilities, lower the barriers to **open up these testbed capabilities for large scale usage**, and finally provide some specific and targeted funding to build peering between disjoint experimental capabilities. Some targeted funding probably will be needed to establish some missing capabilities that maybe recognized in the later analysis. For example, testbeds to experiment with spectrum agility, 60 GHz wireless deployments, or cognitive wireless networks technologies.

- **Larger scale excellent integrated projects are also needed**, especially in the later phases, to consolidate work and to explore real deployment and implementation issues. It is also believed that IP projects could provide a better home for doing research on business models and value chain logistics. We should emphasise here that there are also basic research components in such work.

Finally, in order to address the critique and recognized threats on fragmentation of resources and research, there needs to be mechanisms that will encourage better orchestration and coordination between researchers and projects. Here, we emphasise the point that we need to provide better road mapping and think tank activities in this emerging field. One of the findings of the EIFFEL think tank is that clearly more **focused think tank-type** exchanges of opinions are required. Although there are different activities doing these both internationally and at the European level, many of these current instruments are more domain-specific. We believe that providing a road mapping and monitoring service on impact would be a useful service for the EC, both for planning and for quality monitoring purposes. Moreover, there is probably a need to have mechanisms to bring together the different industrial stakeholders and networking capability owners outside the actual project and ETP context. For these purposes the EIFFEL think tank is further discussing different mechanisms that could make sense in this domain, whether those being SSA-, CA- or STREP-type of instruments, or combinations of those that need to be agreed after detailed analysis.

Orchestration of project proposals

EIFFEL members as individual researchers would like to emphasise the need to orchestrate better the project proposals in this field. Naturally, there needs to be competition; nevertheless, competition blocking coordination would not be in anyone's long term interests. However, there seems to be clear and present danger that without some orchestration there will be too many overlapping projects on "land grapping fashion". This would mean not only overly strong competition, but also a danger that the research domain would be highly fragmented, limited talent would be spread thinly and, due to this, also a number of important research topics could be left out even from the proposals, as only the main stream topics could fit in.

Thus, EIFFEL believes that there is need to orchestrate openly some of the proposal work taking into account the different needs and objectives of the stakeholders. The discussion group itself is considering some mechanisms to this end, but will also provide a platform for discussions on this in meetings during December (Brussels) and February (Cologne).

Test Infrastructures

As mentioned previously, there is a clear need for discussions on test infrastructure capabilities that are already available and what are the missing technological and policy mechanisms to exploit them to the fullest extent. This discussion is required before any far reaching funding decisions should be made in this domain. Moreover, the existing international, pan-European and national test infrastructure capabilities should be favoured, whenever possible, instead of starting all over again. This means that different COST actions, PanLAB, PlanetLAB, GÉANT and National Wireless Testbed capabilities (such as the large open testbed capabilities in Finland, Germany, and Norway) should be mapped. The current SWOT analysis indicates that it is not possible, or even advisable, to envision a European GENI network at a similar funding scale.

In the first phase, it is important to determine mechanisms for getting the discussion started on these facilities and the requirements for the test infrastructure work. The “demonstration only”–type of network structures should not be encouraged through the future Internet activities, especially if these demonstrators will not be peered with other networks and cannot be guaranteed to stay open for long periods of time for further experimentation. There is also a challenge, on how to generate enough true traffic, end users and services for any realistic scale test infrastructure. There are a number of policy issues related to test infrastructures, such as how to decide between possibly conflicting and overlapping needs, and how to enforce that the data is shared mostly in an open fashion, without harming the legitimate interests of the original principal investigators. There are many existing mechanisms on these issues both in the networking domain (e.g. Internet2 and CAIDA) and even more in other big science domains.

Other Existing Instrument

There are other instruments in the existence that have been fostering discussion among different stakeholders, notably different NoEs (Networks of Excellence) and COST actions. Although many of these are relevant, none of them have specifically worked towards the goal of radical engineering of the future Internet. However, many of those have generated valuable knowledge exchange on specific sub-domains. Especially the NoEs in the case of photonic communications and next generation networks are useful platforms to take in the consideration on extending the scope of EIFFEL activities. For example Euro-NGI project (NoE) has been recently launched its second phase, named Euro-FGI. Although this project is not focused for on the orchestration and coordination of the future Internet, it could be a valuable partner for a more specific coordination and orchestration activity

Coordination of running projects

Coordination of running projects is needed in an orchestration sense, just like for the proposals. A number of different possibilities have been discussed in the EIFFEL context. First, there is need to generate a body of people around a suitable funding mechanism, who is technically tracking the advances made by different projects. This group should provide very high quality roadmaps and peer review on the advances made. As this group should look into the issues from a scientific and advanced development point of view, they should not limit the monitoring activities to European projects, but true and critical benchmarking against the best worldwide research should be done. Another requirement out of the road mapping is to have think tank type of projections, especially on the architectural considerations. On road mapping activities, apart from the academic and basic research community, it is anticipated that advanced research & engineering units of operators will have a lot of active and latent knowledge on relevant problems and boundary conditions.

There is also need to innovate the coordination and orchestration process. The talent is already a very limited resource within all the organizations and in the future the time of the most talented people would be even more valuable. A large number of meetings is not the right avenue to achieve overall long term goals. Hence, we give a dire warning against choosing the number of meetings or the number of attendants as an impact factor to evaluate the projects.

Another coordination activity that is required is to ensure that there is a mechanism to disseminate information between projects and researchers in a sensible manner. There needs to be some “easy” dissemination towards the public-at-large and also to high level decision makers. Another aspect is that the top research talents need to have a mechanism to keep them informed on what is going on in different projects. This means something more than organizing simple project presentation days.

Finally, there is need for more traditional coordination and support that should be more industry based, where different coordination through high level meetings and some market studies could be achieved. The imperative, however, during the first stage is to ensure the high level “doers” are empowered with the right instruments for their success.

Conclusions on Recommendations

Europe should play its role on paving road towards the networked society of the future. This work requires coordinated effort not only in technology R&D but only calls renewed research and debate on policy, legal framework, governance, and business studies. This is work is required as the networked society and related networking technology paradigms are both opportunity and threat for the European Union.

EIFFEL group emphasis that a large amount of relevant work is done towards this during Framework 6 and 5 projects, but the levels of concentration, ambition and cohesiveness should be increased in Framework 7 in order to increase the impact of the work and to use limited resources more efficiently. In the sense of structural means, we recommend to consider following points

- **The EC itself has take leadership role on starting to shape policy and governance recommendations.** This can be done, in part, by asking help from the relevant experts, but the governance and political leadership can only come from EC and member countries. Single projects with their scientific or economical goals cannot have a mandate for this.

- **The project portfolio and working items therein needs to be monitored and designed better.** The EC itself, with the help of independent scientific advisors above any doubt of bias, has to take a responsibility and leadership on seeing that the project portfolio is in phased manner build to present a good balance between revolutionary disruption aimed research, and more evolutionary and experimental advanced development work.

- The phased approach means that supported project portfolio should be build step-by-step based on observed development. Specifically it is to be expected that

    - During the first phase more exploratory research should be emphasised, especially this means 1st call of proposals. The exploratory research projects should adopt a new culture of risk taking. As such these projects should be smaller, with limited time span, and the consortium members should exhibit high quality **not only organizationally but through principal investigator(s) and participants CVs.**

    - At the second phase (3rd and 2nd call) larger and more integrative projects should rise. These projects should prove that they have learned lessons from the previous projects in Europe and worldwide. It is imperative that the later project portfolio is strategically synchronized so that all projects from different stages form a cohesive collective.

    - **The needs for experimental testbeds need to be considered more carefully**. It is probably not the best approach to launch any massive spending for testbeds during the first call, before a clearer picture for needs and goals will emerge.

- **The on-going work needs to be monitored and impartial feedback on *general level* in peer review fashion would be required.** The traditional instruments that have organized different meetings and summits may still have their place, but especially in the domain of the future networks and disruptive research in particular more science and quality control oriented monitoring may be required.

- **Avoid the well known problem of "me too" research.** The EC needs to avoid getting trapped on the repeating existing research and also needs to ensure that the best possible people resources are doing the relevant work. In the case of small and risky projects the proven *domain specific track record, quality and innovativeness* of individual project partners should be emphasised.

- **Avoid of following only the known and safe path, and renew the objectives dynamically**. In the first phase, more innovative and not well understood paradigms should be tested. The common weakness of following only the safest path, especially economically justified, should be recognized and avoided within reasonable limits. Also the technological objectives should be updated dynamically, if need to be. Already during framework 6 some opportunities have been lost due to slow response time and bias towards supporting known technologies.

- **Follow holistic and wide spectrum approach.** The Europe should not fall in to the trap of defining its future on watching rear view mirror. There are some domains, where Europe may have perceived leadership. However, the ambitious goals of the future networked society will not be reached through piecemeal and/or fragmented approach or by taking an biased starting point. **Specifically the wireless and mobile communications role should not be overestimated.** For example Korea has in short time made huge leaps towards the future by focusing only to fibre optic based infrastructure and research. That said mobile and wireless needs to be taken in account in the architecture, and in appropriate projects.

Specific Actions by EIFFEL

In order to continue to address some of the outlined actions in proactive fashion, and to provide more continuous advice for different stakeholders, EIFFEL continues its work and tries to provide a level discussion forum towards

1st call proposals. Moreover, as discussed there is a need to provide novel roadmapping, peer review and think tank capability that goes beyond the previous meeting based SSAs and focused differently than existing NoEs. Towards this goal EIFFEL is planning to extend its existence by getting organized first as a core project facilitating debate, and later considers possible extension mechanisms.

As a first instance, the core EIFFEL group is considering to provide a continued support to other projects and EC through a proposed **Specific Support Action** (SSA). This SSA would comprise a core group on coordinating SSA, but the actual technical discussion forums would be open to all technical stakeholders. The EIFFEL SSA should be specifically designed to provide a “level field” for participants regardless of ETP or other forum memberships. SSA is planned to build a strong liaison with ETPs and key NoEs such as EURO-FGI in order to provide voluntary coordination, evaluation, and information exchange at technical level. Synergies will therefore to be established between EIFFEL group and the ongoing and the future “classical” orchestration activities.

Secondly and quite sepecfically there is also a proposal on setting out from EIFFEL group a project called **“School of Architects”** (SoA) that is aimed to be a technological nexus project to bring in cohesive platform for people to debate on architectural issues and enhancing the processes themselves that are required on architectural design. This is some of the domain, which majority of EIFFEL participants have recognized as a possible opportunity, but also a threat in the coming FP7 research. It is opportunity, since a new architectural paradigms could lead to new possibilities both technological and business domain through a paradigm shift. It is also an organizational threat, since if we allow large projects to start too early from single architectural point of view only an incremental and slow progress may be possible. Moreover, the good quality architecture work itself requires both innovativeness and experience, hence the special environment and partnership of the best suited researchers is required to foster thinking. SoA-project is in part aiming towards revolutionary design concepts, but most notably it can be seen as a “service project” for many other projects as it is aimed to provide “food for though” from architectural level quite openly for other projects to consider. The School of Architects do not limit itself to technology itself, but with EIFFEL SSA it would consider also policy and governance related issues.

These specific actions will be later outlined with more details separately[1]. In the open fashion, the EIFFEL is very much open on discussing these specific actions with other stakeholders, and can also align its aims with other emerging project proposals and project consortia in order to build out the best possible synergies.

[1] Interested parties can meanwhile contact EIFFEL and specifically Petri Mähönen on the topic, if necessary.

BACKGROUND READING

This list of background material is intended to give an impression of the breath and scope of information available on this subject. We would recommend that those interested in progressing this discussion consider reading some of the reference material available. This material supports some of the claims and statements made in this document and questions others.

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The list of participants to date includes:

Adam Kapovits,	Eurescom
Anastasius Gavras,	Eurescom
Andreas Kirstädter,	Siemens
Bernd Reuther,	TU Kaiserslautern
Bernhard Collini-Nocker,	Global Communication & Service GmbH
Bob Brisco,	BT
Bruno Crispo,	Vrije Universiteit Amsterdam
Christophe Diot,	Thomson
Dabbous Walid,	INRIA
Daniel Kofman,	ENST-GET
David Kennedy,	Eurescom
Dimitri Papadimitriou,	Alcatel-Lucent (Alcatel Bell)
Dirk Trossen,	Nokia
Frank Reichert,	Adger University College
George C Polyzos.	Athens University of Economics & Business, Dept of Informatics
Gerard Mula Rodriguez,	Telefonica
Göran Malmgren,	Ericsson
Gummadi Krishna,	MPI
Halid Hrasnica,	Eurescom
Hans J. Einsiedler,	Deutsche Telekom Laboratories
Hermann De Meer,	University of Passau
Janne Riihijärvi,	RWTH Aachen University
Jon Crowcroft,	University of Cambridge
Juha Oinonen,	CSC
Kurt Tutschku,	University of Würzburg
Marina Petrova,	RWTH Aachen University
Markus Hillenbrand,	TU Kaiserslautern
Maurizio Casoni,	Unimore
Michael Menth,	University of Würzburg
Michael Papazoglou,	Faculty of Economics and Business Admin., Tilburg University
P. Tran-Gia,	University of Würzburg
Paul Mueller,	TU Kaiserslautern
Peter Kirstein,	University College London
Petri Helenius,	F-Secure
Petri Mähönen,	RWTH Aachen University
Rahim Tafazolli,	Univ. of Surrey
Sandro Scalise,	DLR
Scott Kirkpatrick,	Hewbrew University Jerusalem
Serge Fdida	Unic Pierre et Marie Currie
Thomas Plagemann,	University of Oslo

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