

# **Draft Report of the Task Force on Interdisciplinary Research Activities applicable to the Future Internet**

## **Authors:**

### **DG INFSO Task Force on the Future Internet Content:**

Miguel Montarelo Navajo (INFSO-D1)

Isidro Laso Ballesteros (INFSO-D2)

Anne-Marie Sassen and Sandro D'Elia (INFSO-D3)

Manuel Mateo Goyet and Juan Santaella (INFSO-D4)

Georgios Tselentis (INFSO F4)

Yves Paindaveine (INFSO-F5)

Thomas Skordas (INFSO-F5)

**and**

### **External Technical Experts:**

Gonzalo Camarillo

Schahram Dustdar

Jacques Magen

Sachar Paulus

Report open for consultation and comments at:

<http://forum.future-internet.eu>

Version 4.1 of 13.07.2009

### **Disclaimer:**

**This document is a working draft and a starting point for further discussion. It cannot be held to express an opinion of the European Commission or any of its services or officials.**

# Table of Contents

Table of Contents .....	2
Executive Summary .....	3
1. Introduction.....	6
2. Trends and Challenges for the Future Internet .....	7
3. Towards federated, open, trusted Platforms for the Future Internet.....	9
3.1. Rationale .....	9
3.2. Introducing F-O-T platforms .....	10
3.3. Definition of F-O-T Platforms.....	11
3.4. Research activities for realising the concept of F-O-T Platforms .....	13
3.5. Fertilizing interdisciplinary research for F-O-T Platforms.....	15
3.5.1. Networked digital entities: descriptions and inter-relations.....	16
3.5.2. Context lifecycle and interaction.....	17
3.5.3. Seamless and ubiquitous availability .....	18
3.5.4. Dynamic and autonomic management of networked resources.....	19
3.5.5. Frameworks, methodologies and tools for architecting F-O-T Platforms and the Future Internet.....	21
3.5.6. Governance, socio-economics and policy .....	21
3.6. Experimentation.....	22
3.7. Engineering F-O-T Platforms .....	23
4. Impact of F-O-T Platforms .....	25
4.1. Representative Examples of F-O-T Platforms.....	25
4.2. Impact on the European Economy and Society .....	27
5. Conclusions.....	30
Acknowledgments.....	31
References.....	32
Annexes.....	34
Annex 1: Scenarios .....	34
Annex 2: Short Biographies of the External Technical Experts .....	34

## Executive Summary

A Task Force of the European Commission's DG Information Society and Media (DG INFSO) was created in January 2009 to develop recommendations on interdisciplinary research activities that cut across the many different technological domains of the Future Internet. This task force was complemented and supported by four external technical experts, whose names and profiles can be found in the annex.

The focus of this report is on interdisciplinary research, it does not deal with any of the topics that fall within the scope of singular objectives that constitute Challenge 1 of the current ICT Work Programme. Its recommendations should therefore not be construed as proposals for the research that should be undertaken within those individual domains.

The Task Force took into account various sources, notably white papers, scenario descriptions and functional requirements from the Future Internet Assembly (FIA), the European Technology Platforms, as well as similar reports of national and international initiatives and organisations.

The recommendations of this report are structured around the introduction of a concept, **federated, open and trusted platforms** (or F-O-T platforms) that can enable smart applications for the Future Internet. The term "smart applications" denotes the development and massive deployment, in the near future, of a wide range of Internet-based applications and services in a number of large application sectors. The term "platforms" means technological platforms in the broadest meaning, including infrastructural elements (network-, storage-, computing-related) together with middleware, tools and core services. Altogether, they allow applications and services to be built and run, and provide individuals, communities and businesses with negotiated and agreed quality of service (QoS) and quality of experience (QoE). Core properties of these platforms are:

- **[F]** The platforms should be **Federated** to enable sharing and exchange of information for service or content configuration, composition, consumption or delivery and coordination with each other, according to agreed policies and rules. Federation implies two dimensions: (i) Designing such platforms without unnecessarily replicating functionalities and data, and, (ii) Building inter-connected, inter-operating and/or inter-working platforms. The degree of federation may differ according to the platforms and requirements from each of the applications and underlying business models.
- **[O]** The platforms should be **Open** in order to allow any individual, community or organisation to access and use them or to develop new applications, content and services. Openness is to be viewed from three different standpoints: (i) a technical one i.e. a platform is publishing external programming interfaces in the form of open protocols, open architectures, open interfaces, etc; (ii) a federated one i.e. interoperable platforms using open exchange formats and protocols; and (iii) a policy-oriented one i.e. fair, reasonable, non discriminatory and ubiquitous accessibility to platforms.
- **[T]** Finally, the platforms should be **Trusted** to inspire confidence in their widespread use. Trusted platforms imply that these are: reliable, secure, available and responsive (depending on the type of applications or services they deliver); protective of individuals' privacy and personal data and of businesses' confidential data and processes; permitting to establish accountability, responsibility, and liability of all participating actors; implementing transparent operations and processing; and, usable. Finally, trust may also be supported by appropriate legal and global governance frameworks.

Future Internet platforms that are federated, open and trusted stimulate diversity. They safeguard the basic success principles of the current Internet for the end-users. Not only do they encourage open competition and innovation within a platform itself, but also amongst other platforms. They permit the development of business models without having to apply tiered solutions from the access providers. They lower the entry barrier of the citizens and enterprises and reinforce "freedom of movement" in the Future Internet world. They protect shared European values such as privacy, cultural diversity or social "acquis". Ultimately, they increase a platform's value to its users - whether individuals or businesses, and lead to more choices and help avoid consumer lock-in.

The design and architecting, implementation, testing and validation of F-O-T platforms are a major research challenge for the EU in the upcoming years. Moreover, the development of such platforms will require the leverage of cross-disciplinary research activities and achievements. The above can be achieved through three basic types of research and technology development activities:

- Firstly, the realisation of F-O-T platforms necessitates a lot of advanced **research** to develop the technology components, methods and tools needed for designing and building such platforms. The recommended interdisciplinary, fertilizing research challenges are grouped into the following areas: (a) *Networked digital entities: descriptions and inter-relations*; (b) *Context lifecycle and interaction*; (c) *Seamless and ubiquitous availability*; (d) *Dynamic and autonomic management of networked resources*; (e) *Frameworks, methodologies and tools for architecting F-O-T platforms and the Future Internet*; and, in addition, (f) *Governance, socio-economics and policy* aspects, that are to some extent, themselves cutting across the above five research challenges.
- Secondly, various cycles of large scale **experimentation** will be required to properly test such platforms, and monitor, fine-tune and validate their operation, emerging properties and overall behaviour together with those of the Future Internet as a whole. Experimentation would be aimed at providing a methodology (experimentally driven research) and the necessary environment (experimental facilities) for investigating and experimentally validating innovative and (r)evolutionary ideas that may emerge from the other research activities.
- Thirdly, the integration of these components and tools into coherent entities will permit the **engineering** of prototype F-O-T platforms, which are purpose-oriented, and application-driven. It will also allow understanding in the way these platforms should be managed and how they interact with the Future Internet. The engineering of F-O-T platforms involves the development of the methodologies, capabilities and skills related to the integration and management of complex, heterogeneous and highly dynamic networks, content and objects infrastructures, services, and applications into operational wholes.

Through the analysis and examples of F-O-T platforms provided in this report, it is suggested that such platforms may have the potential to spark a new era of creativity, growth and prosperity for Europe by solving serious social challenges and problems through their use. They can strengthen the economic prosperity and the fabric of the European society. They can improve quality of life, industrial competitiveness of Europe, and empower the latent potential of individuals, organisations and society by further enabling their untapped knowledge.

The members of the Task Force offer this report and its recommendations as a contribution to the coming debate and consultation to take place in the coming months, regarding the definition and content of the next ICT work programme. Its recommendations should not be construed as pre-empting the results of such consultation but rather as a working paper that may serve to prepare and guide the forthcoming discussions.

# 1. Introduction

This is an internal report of DG INFSO that describes the main findings of a Task Force that was set up by Directorates D and F to investigate and provide recommendations on what could be the future interdisciplinary research activities that cut across the many different technological domains constituting the Future Internet.

The work described in this report was carried out in the period January to June 2009. The authors of the report are:

- The members of the Task Force on the FI Content, namely, Miguel Montarelo Navajo, Isidro Laso Ballesteros, Anne-Marie Sassen, Sandro D'Elia, Manuel Mateo Goyet, Juan Santaella, Georgios Tselentis, Yves Paindaveine and Thomas Skordas.
- And the following external "technical experts": Gonzalo Camarillo, Schahram Dustdar, Jacques Magen and Sachar Paulus (see their short biographies in the annex).

The report is structured as follows:

- *Section 2* is a brief introduction to the state of Internet today and the major emerging trends for the coming 5-10 years.
- *Section 3* is the core part of this report. It introduces the main concept on which we recommend future R&D activities to focus, namely, the design, development and engineering of Federated, Open and Trusted (F-O-T) Future Internet Platforms and the related interdisciplinary research activities needed to do so.
- *Section 4* presents some representative examples of F-O-T platforms and discusses their expected economic and social impact.
- *Section 5* summarises the main findings of this report.

This report is based on existing initiatives and reports related to the Future Internet research challenges, visionary development paths, insights, and guidance from different vantage points (see "References"). As such, it should not be seen as "yet another" report trying to show how the Future Internet will further develop and look. It rather tries to build upon existing documentation to recommend a number of interdisciplinary research activities for the Future Internet.

## 2. Trends and Challenges for the Future Internet

Over the last few decades, the Internet and the Web have become a great success story around the world. They are permeating and transforming all aspects of our economy and society. They catalyse new forms of communication, collaboration, creativity and innovation. They deeply affect our communication, interactions and transactions, and the way we deal with information and knowledge.

Everything in the *Internet Age* is growing fast, often at exponential rates:

- Internet connectivity is expanding rapidly in terms of geographical distribution and size. Now, there are about 1.6 billion Internet users worldwide (from 360 million in 2000) and 4 billion mobile users (from 2.7 billion in 2006), using 570 million Internet-enabled handheld devices. The number of people who surf the net on their phones has doubled since 2006. By 2012, there will likely be more mobile and wireless users than wired ones.
- In 1998, Google indexed 26 million web-pages, today it indexes 1 trillion. Today, there are 400 million web pages and 55 trillion links between these web pages. The Web is processing 100 billion clicks per day, 2 million e-mails and 1 million instant messages per second.
- Popular social video sites add 13 hours of user video content to the Internet every minute. Search engine systems refresh the equivalent of the entire library of US Congress every four hours. User-generated content such as YouTube produced more than 73 billion streams in 2008. Video traffic over the Internet is growing by 60% every year and will be multiplied by 1000 over the next 5 to 8 years. Web 2.0 and social networks with popular social sites are attracting more than 125 million regular users within just 5 years of existence.
- Businesses successfully embrace the capabilities of the Internet. Intra-enterprise as well as inter-enterprise business processes can be, and have been significantly automated and improved through the usage of Internet technology, while their uptake is rising. For example, advanced supply chain management software has increased from 7% in 2003 to 35% in 2007. Similarly, the number of companies in the chemical sector using e-Commerce has risen from ~6% in 2003 to ~27% in 2007.

All these trends would not have been possible without the evolution of the underlying technologies, which are either developed to catch up with the demanding requirements expressed above or drive themselves at exponential growth:

- Routing speeds at 40 Gb/s (trunk routing) are under implementation at the core network; 100 Gb/s are soon to come and will reach the range of 10 Tb/s by 2020. User access rates are now at a few Mb/s, with 1 Gb/s access expected within the next five years and 10Gb/s links by 2020. In the early 2000s, there were even experiments with 160 Gb/s and all-optical routing that would have led to even higher fixed bandwidth, had the explosion of the “Internet bubble” not put a halt to such efforts.
- Evolution of storage and computing capacity (Moore's law, etc.).

The Internet is continually evolving and adapting itself to meet the demands of new users, devices, applications and services that were not foreseen in its original design and to serve as a vital infrastructure in an ever increasing number of human activities. The definition of the Internet and user expectations have also changed significantly over the last years. In its early days, the Internet was understood to be a set of loosely connected computers, providing standardised protocols for information, delivery and mutual communication. Nowadays the

Internet covers, in addition, web services for business processes on an interoperable basis, voice and video communication and content delivery e.g. movies and music, as well as social networks. The definition of the enterprise itself is impacted by the capacity of its stakeholders (clients, suppliers, employees, etc.) to influence the company directions online and new innovation paths on the Internet are re-shaping the essence of entrepreneurship. The market structure, as a result, is profoundly impacted by this multi-channel media and new innovative value propositions are needed. In addition, new challenges are appearing, especially those related to the impact on the environment, which is also likely to have more influence on the way technology is developed, economic parameters are set, and also on user demands. Such changes are likely to modify current business models, leading towards potentially large impacts on the ICT industrial playground.

In the international literature, a significant number of studies have recently been published on the technological, societal and economic trends relating to the evolution of the Internet in the next two to twenty years<sup>1</sup>. The authors acknowledge that the diversity and sheer number of new applications, services and business models supported by the Internet may soon place under strain the existing Internet architecture. Several of them together with many researchers worldwide even question the capability of the current Internet architecture to scale itself, evolve and adapt to new demands and usage patterns and to address emerging security and privacy threats.

This raises the crucial question as to whether the Internet architecture of today needs to be changed. In particular, how should it evolve in order to meet such challenges as: reliability, scalability, mobility, manageability, security, trust, openness and neutrality? At the same time, its evolution needs to guarantee that business and governance models are sustainable and support user creativity, new applications, services and unanticipated, new usages. Corresponding activities are needed to maintain the multinational character of the Internet, yet provide a solid, legal base while doing business for every one.

A number of initiatives are already underway at the national and academic level – see Section “References” – that seek to "re-invent" the Internet. Most of them are in their early stages and it is too early to tell whether they will result in a new Internet architecture that would have universal appeal. A possible way forward for the EU to further position itself in the field of the Future Internet is proposed in the next section.

---

<sup>1</sup> For example, see [Cross-ETP-2009], [INFSO-FI2020-2009], [ISTAG-2009], [ITU-T-2009], [PEW-2008]. Trends and functionalities of the Future Internet for 2015 and 2025 are also reported in Annex 2 of this report.

## **3. Towards federated, open, trusted Platforms for the Future Internet**

### **3.1. Rationale**

Being still at the early stages of the digital revolution, there are a number of assumptions that guide our thinking when we try to understand what will be different – aside the sheer scale – in a few years from now. We expect that the growth trends in the Internet figures presented in Section 2 will continue in the coming years. In particular, there will be a lot more mobile and nomadic users; more interconnected networks, computing, storage and service infrastructures; a substantial increase of bandwidth both in the core network and at the edges; larger and more efficient distributed data storage capabilities; an exponential increase of data; the generalisation of the exchange of digital media content and a large growth of video traffic; further development of social networks, along with a massively distributed creativity with individuals bringing new content, applications and services to the market place; the emergence of the Internet of Things, which will allow the progressive entangling of the virtual and the real world, introducing a wider variety of end-devices, traffic and dynamic information; but also, a further escalation of security and privacy threats and of cyber-criminality.

In the future Internet-based Society, we expect that digital services will become increasingly interlinked with the physical environments of individuals, communities, and businesses. The border between the physical world and the virtual world will progressively become more blurred. Continued convergence between networks, services, and content, allowing transparent handling of all types of information and things, will reshape sectors such as media, broadcasting, telecoms and the service industry, and possibly others (healthcare, logistics, etc.). Such convergence will stimulate the development of new immersive mixed reality environments that will foster social interaction and new business opportunities in leisure and work environments that are today unforeseeable. They will also stimulate the development of new markets for services that permit to sense and react to the physical world, like transport, energy, agriculture, environment monitoring and protection, etc.

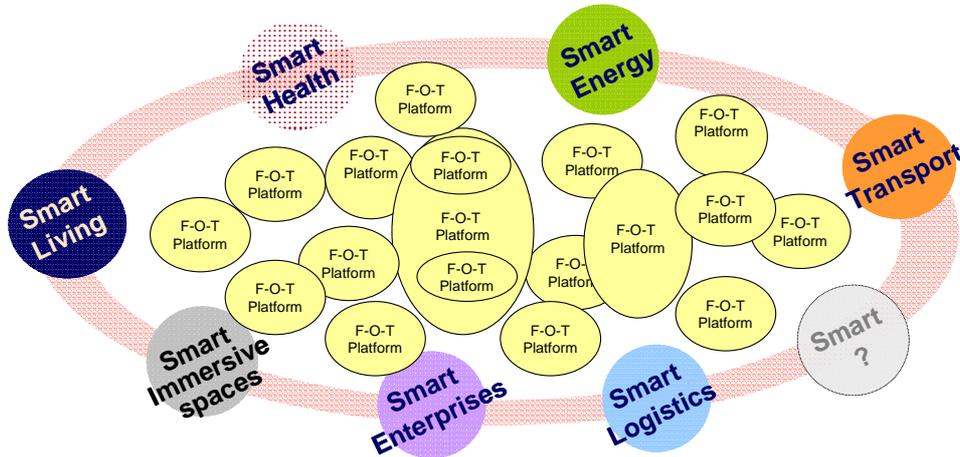
All of the above, and certainly many others, will bring exciting new possibilities and enormous opportunities for innovation, socio-economic growth and - better quality of life. Architectural limitations of the current Internet, however, make the realisation of such a vision difficult and paving the way for the Future Internet requires a more drastic approach. It would involve fundamental architectural changes, together with specific improvements of individual technologies (e.g. more bandwidth, more devices, more content and more services), which, on their own, would not be successful enough to reach such an achievement. It would also require a better alignment between technical capability and business needs.

The European Union needs to play a major role in this (r)evolution. Today, US players dominate the emerging space of information and service storage and delivery. Europe cannot afford to let non EU players generate services and wealth from mostly outside of Europe and alone manage the world's information. European industry and high-level research and education must play their role in preserving and strengthening Europe's industrial competitiveness and shared values such as privacy, common history, cultural diversity or social "acquis". On the contrary, these established values could be a market differentiator and help push Europe's position into a competitive position regarding Internet technology and services.

### 3.2. Introducing F-O-T platforms

To position Europe as a leader in the Future Internet, we suggest that initiatives in Europe should be centred on the development of **Future Internet Federated, Open, and Trusted** (shortly, F-O-T) **Platforms** (see Figure 1).

As shown in the next sections of this report, F-O-T platforms could become the basis on which existing and new “smart” applications could be built that will characterize the Future Internet.



**Figure 1:** Federated-Open-Trusted (F-O-T) Platforms are part of the Future Internet. They will be the basis for building many different "smart" applications that are expected to emerge in the future.

Our proposal for F-O-T platforms is based on the study of many papers dealing with potential future research domains targeting the realisation of the Future Internet and the analysis of a broad range of different scenarios concerning living and working with the Future Internet that we undertook in the course of this work. A common theme across these papers and scenarios is "smart" applications<sup>2</sup>. “Smart” applications will be emerging in different sectors of our economy and society.

Platforms could become the basis for building a wide range of different smart applications. Different types of platforms will be available, allowing specific applications to use the capabilities of one or more platforms depending on their needs. Such an approach will provide the “fundamental enablers” and the broad “ecosystems” that will make this possible. It will also allow for a full system view, which needs to go beyond the mostly vertical approach that is used today in most research activities. This will address the mostly disconnected vertical silos and help establish further interdisciplinary links.

**Platforms that are federated, open and trusted will permit keeping European values upfront, and help new players such as SMEs and “prosumers”, whether individuals, organizations, or communities, enter the Future Internet applications and services domain in a way that only US companies have successfully achieved so far. They provide an opportunity for Europe's industry and research communities to take advantage of their current technological, business and scientific strengths.**

<sup>2</sup> The term "smart applications" denotes the capability to develop and massively deploy, in the near future, a wide range of Internet-based applications and services in a number of large application sectors (called smart applications, as for example in entertainment, health care, transport, energy, enterprises and businesses, etc.). Such an evolution will be made possible by several generic technology advances and capabilities of the Future Internet. Their emergence and their application to the specific needs of these application sectors will enable the efficient design, engineering and operation of dedicated applications and services with fast development and deployment cycles through an optimised integration, co-operation and inter-working across the value chain.

F-O-T platforms are seen as an integral feature of the Future Internet. Sets of networks, content and objects infrastructures, services, and applications can be plugged-and-played in a seamless way, and they can interact with each other. Their availability will make it easier for enterprises, individuals and communities to address problems in a specific application or business process area and to develop and run specific smart applications.

The concept of F-O-T platforms is explained in detail in the next section.

### 3.3. Definition of F-O-T Platforms

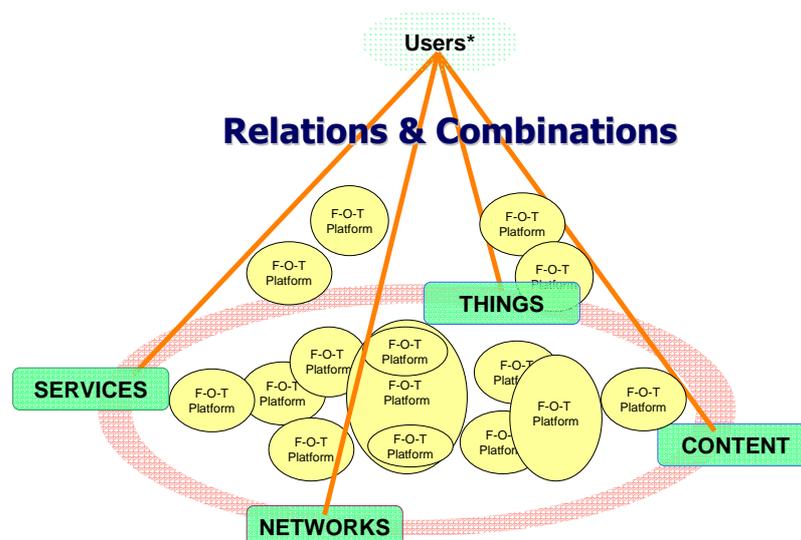
By Federated, Open and Trusted (F-O-T) Platforms we mean the following:

**Platforms:** The term means technological platforms in the widest possible sense: they comprise infrastructural elements (network-, storage-, computing-, service-, content- or objects-related) together with middleware, tools and core services. Altogether, they allow applications and services to be built and run, so as to provide to individuals, communities and businesses negotiated and agreed quality of service (QoS) and quality of experience (QoE). They can serve both for experimental and operational purposes.

Such platforms rely on architectures that are suitable for "smart" applications. They are based on combinations of the Internet of Networks, the Internet of Services, the Internet of Content and the Internet of Things (see Figure 2). They utilise the underlying resources to enable services and experiences, which are based on the discovery, creation, manipulation, integration, sharing or delivery of any kind of entities (networks, servers, services, computing resources, things, processes, information, content, etc.), with the appropriate level of trust and privacy.

The platforms could be using different protocols (at different levels) that are best tailored to the specific application, service or experience they provide. As an example, various network protocols could be used, whether IP-based or not.

Platforms could be suited for specific vertical applications or for more multi-purpose usage scenarios.



**Figure 2:** Federated-Open-Trusted Platforms are integral parts of the Future Internet. They will be built by combining different capabilities from the Internet of Networks, Internet of Services, Internet of Content and Internet of Things, according to specific needs.

\*Users comprise individuals, communities, businesses and organisations, as well as machines.

**Federated:** Many different types of such platforms will be available in the Future Internet. Most of the “smart” applications will need to make use of an appropriate combination of platforms to access data and services on-demand.

Federation implies two dimensions:

1. **Inter-connected, inter-operating and/or inter-working platforms. In this way, they can share and exchange certain information for service or content configuration, composition, consumption or delivery (for example, enabling the discovery of existing services together with their usage policies).**
2. A prerequisite is to design the platforms in such a way that they can share and coordinate among each other, **without unnecessarily replicating functionalities and data** about the subjects and objects dealt with, but **accessing these resources on other platforms when needed.**

**The degree of federation may differ according to the platforms and to the requirements from the applications and the underlying business models.** There might be loosely federated platforms, i.e., loosely coupled platforms that are simply connected to each other. Others will need to be fully federated platforms, i.e., they know how to connect instantly, share information in the context of specific (user-driven) needs, and behave according to jointly and commonly agreed policies and rules. In particular, such fully federated platforms have the following properties:

- A distributed infrastructure (sharing data, content, services and resources) establishing inter-platform references/dependencies) without the need to integrate the data/content/services/resources into a single "system".
- Accessing and integrating data, content, services and resources from disparate systems without having to hop around these repositories and manually integrate from each; and, providing a scalable approach in accommodating new data/content/services/resources sources to the existing platforms independent of the technology.
- Providing value added services (like common authentication/authorization methods, QoS provisioning, interfaces to specify query and data, content, services and resource integration rules).

This is the most complex form of federation. Fully federated platforms are fully interoperable. They provide full transparency to the stakeholders and users and stimulate competition and open innovation.

**Open:** openness is a platform property that can be viewed from three different perspectives: The platform itself, the federation of platforms, and finally the accessibility of the platform.

The first perspective of openness is the platform itself *from a technical standpoint*: a platform is open when it has published external programming interfaces that allow a third party to use them and integrate with the platform to include additional functionality than that intended by the original developers. Although this may depend on business models or community needs, platforms should be encouraged to use open protocols, open architectures, open interfaces (including APIs) and publicly available standards or specifications, so that the platform's internal components could be provided by different parties. Open platforms promote competition and innovation and, in general, increase a platform's value to its users.

The second perspective of openness comes from the *federation standpoint*. As mentioned above, federated platforms require interoperability. This can be achieved when platforms can exchange data via a common set of exchange formats, and to use the same protocols at

different levels. Exchange formats and protocols should be open, so that new platforms can become part of the federation, thus enabling and further stimulating the creation of open federations. This encourages competition and helps avoiding consumer lock-in.

The third perspective is related to the *accessibility* of the platform *from a policy standpoint*. In the Future Internet, platforms need to be accessible in a fair, reasonable, non-discriminatory and ubiquitous<sup>3</sup> manner. The more users can access a particular platform the higher their social impact. A good example is when content and services can be added, requested, and integrated into a platform without the exclusion of any relevant party (e.g., companies, or individual service or content providers). This situation leads the way to taking full advantage of a wide range of creative community trends. This will also further boost the emergence of open universal collaboration for individuals, businesses, and societies. Consequently, the EU should promote platforms whose usage is appropriately open so that they can be used by most individuals and communities. Open access encourages competition, in a platform itself but also among platforms, and that leads to more users' choice and more economic value.

**Trusted:** These platforms need to inspire confidence in their widespread use. For this, the services offered on the platforms need to be reliable and thus the platforms need to provide users a specified or negotiated and agreed QoS and QoE. Their degree of availability and responsiveness may depend on the type of applications or services they deliver, which may span from simple ones to very sophisticated and mission-critical ones.

Trusting these platforms implies that they are secure and protective of individuals' personal data and privacy and of businesses' confidential data and processes. Trust also means: well established *accountability*, *responsibility* and *liability* of users and organisations participating in the value chain; rules for *transparency* in operations and data processing; and, *usability* (in terms of user access and interaction).

The trust will need to be created in different ways: the underlying architecture must be able to promote trust; the platform's protocols and interfaces must be trustworthy both for the service providers and users; its engineering must be checked for an acceptable level of security; and trusted authorities (with limited areas of control) need to be defined during the architecting of such platforms.

Trust implies not only technology development aspects but also appropriate legal frameworks, global governance aspects, and transparency of operations for the users, in particular when such operations cross trust domains within Europe or beyond, to other regions of the world.

### **3.4. Research activities for realising the concept of F-O-T Platforms**

The design and architecting, implementation, testing and validation of F-O-T platforms are a major research challenge for the EU for the years to come. Moreover, the development of such platforms will require the leverage of cross-disciplinary research activities and achievements.

We propose to focus the R&D activities of the Future Internet around the development of F-O-T platforms that will:

- (i) provide the levels of **reliability**, **quality of service** and **quality of experience** that the current Internet is not able to provide today;

---

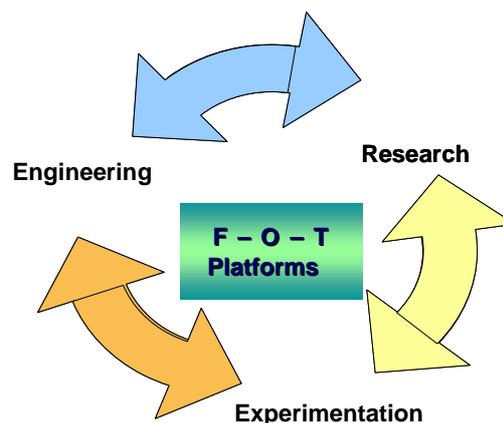
<sup>3</sup> Ubiquitous access means that users may access platforms through any medium, anytime, in the course of their ordinary activities and they may not necessarily even be aware that they are doing so.

- (ii) be based on **open** and **standardised environments** that seamlessly interact and grow and where anyone authorized can have access to, develop, register and add services and/or content to be consumed or re-used by others;
- (iii) be based on **interoperability and trust frameworks** that ensure **accountability, responsibility, transparency, usability, privacy and security**;
- (iv) enable the **development and trusted provisioning of end-to-end ICT solutions** and "**smart applications**" that best draw on underlying and optimally coupled network, service, content and objects related infrastructural resources;
- (v) be able to cope with the **massive scalability, complexity** and **usability** perspectives underlying their operation and functioning.

The above can be achieved through three basic types of research and technology development activities:

- Firstly, the realisation of F-O-T platforms necessitates a lot of advanced **research** for developing the technology components, methods and tools needed when designing and building such platforms. A detailed description can be found in Section 3.5.
- Secondly, various cycles of large scale **experimentation** will be required to properly test such platforms, monitor, fine-tune and validate their operation, as well as their emerging properties and overall behaviour together with those of the Future Internet as a whole. More details can be found in Section 3.6.
- Thirdly, the integration of these components and tools into coherent entities will permit **engineering** prototype F-O-T platforms and understand the way these should be managed and interact within the Future Internet. The different activities related to the engineering of F-O-T platforms are described in Section 3.7.

Figure 3 shows the interdependence between these three types of activities, which should ideally lead to a sustainable, iterative process.



**Figure 3:** Interdependency of the suggested research activities. The three types of research activities shown (Research, Experimentation and Engineering) are indispensable for realising the concept of F-O-T platforms.

In this cycle, the engineering part is an essential phase required for innovation towards the FI. However, attention is drawn to the fact that such activities or parts thereof may fall outside the remit of R&D and hence would not be eligible for funding under the EU Research Programmes.

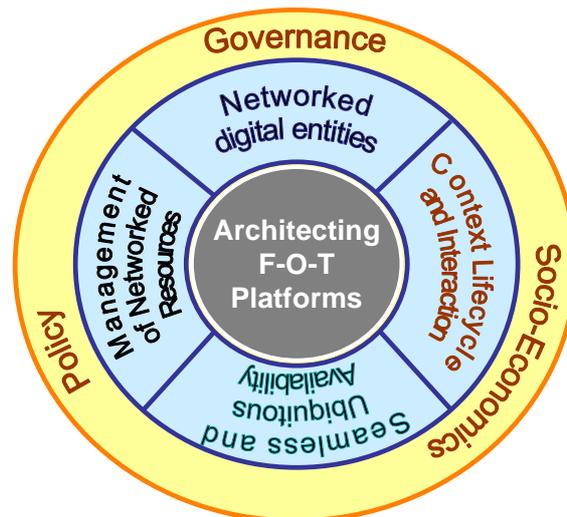
### 3.5. Fertilizing interdisciplinary research for F-O-T Platforms

As mentioned in section 3.1 above, in the course of our work we analysed many different scenarios of living in and working with the Future Internet (see annex). Thereby, we collected a large number of functional requirements that are necessary to implement these scenarios and group them into a number of research challenges at a certain level of detail. Moreover, our team undertook a detailed analysis of many existing international and national initiatives and reports related to the Future Internet research challenges and visionary development paths (see "References"). By confronting these challenges to what is needed to realise the concept of F-O-T platforms, and by further analysing their inter-disciplinary character, structuring and grouping them, we were able to identify a set of six complementary and inter-related inter-disciplinary research challenges (see Figure 4):

- The handling, addressing and usage of **networked digital entities** (whether these are content, services, things, devices, etc.). The corresponding research challenge is called *Networked digital entities: descriptions and inter-relations* and is described in Section 3.5.1.
- The real-life value of these interworking entities becomes available as soon as they are understood and used in a specific **context**. *Context lifecycle and interaction* is described in Section 3.5.2.
- The need to guarantee and maintain service and content **availability** ubiquitously and independently from physical means (on- or offline, wired or wireless, etc.). This is addressed in Section 3.5.3, *Seamless and ubiquitous availability*.
- The sheer number of networked entities requires their intelligent, autonomous **management**. The research challenge is entitled *Dynamic and autonomic management of networked resources* and is described in Section 3.5.4.
- *New frameworks, tools and methodologies* are required to **architect** the F-O-T platforms. These are addressed in Section 3.5.5.
- Finally, to use the F-O-T platforms in a **societal context**, we need to address *Governance, Socio-Economics and Policy* aspects. See Section 3.5.6.

These represent a preliminary list of possible interdisciplinary challenges. A broader consultation yet to be carried out, within each of the current Objectives concerned with the Future Internet, will most likely reveal additional interdisciplinary challenges.

Due to the inter-disciplinary nature of the above research challenges, some research topics appear several times in the different sections. However, these are addressed each time from a different perspective.



**Figure 4:** F-O-T platforms and six fertilising inter-disciplinary research challenges: (1) Networked digital entities: descriptions and inter-relations (Section 3.5.1); (2) Context lifecycle and interaction (Section 3.5.2); (3) Seamless and ubiquitous availability (Section 3.5.3); (4) Dynamic and autonomic management of networked resources (Section 3.5.4); (5) Frameworks, methodologies and tools for architecting F-O-T Platforms and the Future Internet (Section 3.5.5); and (6) Governance, socio-economics and policy (Section 3.5.6)

### 3.5.1. Networked digital entities: descriptions and inter-relations

The provisioning of Future Internet services requires extended abilities in "handling" and combining any number of digital entities (whether in the form of networks, servers, computing resources, services, content, or things). There is an essential need to move from today's raw content and information to higher levels of abstraction (e.g., metadata) for describing digital entities, their status, their functioning, their likely relations with other entities and their behaviour under certain conditions.

Data presentations will range from plain data on different sheets and databases to multimedia documents and models capturing relationships, or other emerging forms, whichever humans and machines can perceive. The managing, indexing, and retrieval of rich data will be facing grand challenges in dealing with various data formats. For example, it will be particularly difficult to identify and analyse the relationships between large sets of heterogeneous data.

Main research priorities to address include:

– *Digital entity discovery and retrieval:*

- *Data representation* - the metadata which can support sharing knowledge between different data formats and for human users and machines alike, e.g., multimedia and plain text;
- *Searchability* - ability to search for and retrieve any type of content, information, or document distributed over heterogeneous networks and servers;
- *Automatic generation of metadata* - to ensure digital entities are easily searched and found; searching and indexing techniques helping users find relevant content among the massive amounts of content that will be available, and this independently of its location on the network (thus allowing users to fetch content from the most convenient location based on their requirements, e.g., minimizing download time or latency for real-time content);

- *Discovery and retrieval techniques* - to track, trace and find networked digital entities based on usage governance/contract constraints; Data mining techniques that help extract relevant information from different types of raw data. Instant availability of required data wherever they are stored, especially for critical applications; management/storage/access of data seamlessly across multiple devices (multiple copies, automatic versioning & backup, policy based protection).
- *Understanding, linking and combining large numbers of networked digital entities*; in particular, discovering their inter-relations and interoperability potential (through common description layers like RDF and its follow-ups), detecting similarity among different data objects under different forms, supporting the "forgetting" of information in specific contexts, scalability of entities. For example, one fundamental issue is how to connect data sources on the Internet based on various aspects, including forms of licences and copyrights. Transparency of data existence concerning anything related to people and possibility to anonymise or pseudonymise data, or being oblivious.
- *Defining policies and rules related to data/entity protection, manipulation and use* (privacy, copyright, IPRs, etc.). Data/entity protection will be a collaborative effort between security technologies and regulatory efforts. Existing technology of protecting data as encryption and access control will be adaptive to extensive formats, but should not compromise usability from user perspective. Data provenance should be treated first and be part of any data objects. Research should also focus here on modelling of virtual copies for every physical thing, information updated automatically (if available using sensors); Privacy of all the data produced by sensors monitoring a user and his or her environment. Ubiquitous policy-based protection of services, content etc. (incl. privacy). Finer granularity access control with respect to data consumption and provisioning.
- *Lifecycle of networked digital entities*: In the current Internet, functionality of a digital entity is generally tightly coupled to its delivery channel and device. Research is needed to devise new models to represent such functionality so that the underlying digital entity remains usable over time (i.e. it can be produced, consumed or distributed on devices and channels that do not yet exist, by respecting underlying usage policies and rules).

### 3.5.2. Context lifecycle and interaction

We expect that the provisioning of context-aware services and experiences will be the norm in the future. For example, the delivery of immersive networked experiences will require context-aware dynamic provisioning. Research priorities relate to: (i) the collection of context data, including modelling, management and dissemination of the context data; (ii) use of these data for offering services to individual users or communities; (iii) building the context-aware environments that serve target users or communities.

Research should address technologies for creating context-aware networks, objects, devices, content and services and, more broadly, context-aware F-O-T platforms. Context-awareness depends on everything related to **me** - my behaviour/preferences/emotions/ needs and **my** devices where such services will be delivered (whether mobile devices or home environments; device rendering capabilities; etc.), or to **we** (i.e. focusing on specific issues of direct relevance to specific types of users or social or business community) as well as to the **surrounding environment** (location and time, but also the situation, the status of the environment – noisy – friendly – stable – rapidly changing, etc.). This environment may be the real one, an intended virtual one or any combination thereof that ensures users enjoy immersive experiences moving seamlessly in and out from one context to another.

Main research priorities to address here include:

- ***Security- and privacy-aware context management systems and their interaction with users.*** With the enrichment of pervasive devices, context is extending its scope and form. To maximize the understanding of situations reflected by context, is a challenge to context management. Technology will not only manage data and distribute context information, but also merge and process context to provide meaningful input to context-aware services. The multimedia character of immersive experiences especially requires a high level of composition to ensure integrity of data and the integration of various types of media. This includes inter-client and complex inter-media synchronisation. To extract and filter information from vast amounts of potentially unstable context sources will be a major issue to address in context processing. In addition, to provide trustworthy context information, partially based on quality of context, is another issue. Particular research priorities here include: context specification and modelling, conditional computing, attribute and parameter description, quality of context.
- Aside from the citizen context, ***business context*** should also be covered in this activity field. This includes the modelling, structuring, and automatic adaptation of business processes according to context conditions. Business context and citizen context share the same context-aware methodology, particularly context description and context lifecycle. However, the implementation environment is largely different. Research priorities are context collection and sharing in multi-organization environments, interaction approach between business entities and context-aware services.
- ***Security- and privacy-aware systems that record events and the interaction between a user and the environment*** embody a digital record of the user's trail in the Internet. Particular research priorities include: event specification and modelling, conditional computing, attribute and parameter description, event-management, handling and storing for life, event retrieval, as well as intelligent learning and forgetting. Digital records can also be associated with digital entities (services, content or things). They record how an entity is used by a particular user. They can also enable the communication of product-related information along the whole value chain from production to consumer. Collecting and making information available regarding an entity can help enterprises improve their business processes. Consequences for privacy and security must be understood, and correspondingly privacy-enabling technologies must be taken into account for any form of digital trail.

### **3.5.3. Seamless and ubiquitous availability**

Service and content availability should be ubiquitous and guaranteed and maintained seamlessly across different network technologies using fixed, mobile, and/or wireless *networks* and networked service *platforms* and *devices*.

Main research priorities to address here include:

- The adaptability of the Internet should make it able to decide ***the best connection approach, best quality and efficient handling of media content according to a real situation***. Maintaining connectivity would thus mean utilization of networks, content, and services intelligently, in a way, it guarantees their appropriate *availability* and also considers the needs of the user. This includes stable and trusted coupling of any sort of local networks with low delay and jitter. It also includes smart content caching and automating adaptation of available functionality to dynamically identify what is the best path to the user considering the network status (e.g., less congestion, lower delay, more

bandwidth, seamless to the user asynchronous synchronization), in cases of limited network availability<sup>4</sup>. It includes as well routers that will identify/analyse what content is flowing through them and are able to replicate it efficiently.

- The incorporation of several *different sets of user-controlled devices for sharing content storage or for collectively providing better services to their users*. To achieve this, the following needs to be addressed: (i) dynamic connection of devices to other devices as well as to various networks by taking into account that such connections will be largely heterogeneous in terms of channel, bandwidth, jitter, time delay, reliability, mobility, and security. (ii) data and content may reside somewhere spread over the network, making today's purely consuming devices to servicing entities<sup>5</sup> (iii) dynamic "associations" and "coalitions" of neighbouring devices for collectively servicing one or several users.
- *Developing connectivity/availability frameworks to the Future Internet* according to predefined, "adjustable" or dynamically negotiated SLAs with e.g. Quality of Service (QoS), Quality of Experience (QoE), and billing defined according to dynamic requirements of a user or a community (e.g. may be different in the home or business environments and on the move). The Future Internet will provide simple and consistent access interfaces to users by hiding the large variety and dynamicity of the underlying networks.

Examples of additional research priorities include:

- Privacy-friendly, trustworthy, device-independent, network-independent connectivity; Connectivity of ad-hoc Personal Area Networks to the whole Internet.
- Network "dynamicity": fixed or dynamically forming wireless and wired networks interoperating seamlessly with each other; Network handover: Dynamically handover of user devices or user interface between heterogeneous networks, e.g., to handover the access point of a user, adapt user to better network when possible (from fixed to mobile).
- QoS of the connectivity and billing: Automatic management of the different ways to connect to the network based on the user's preferences and needs (e.g., a user may want the best connection at any point in time while another user may want the cheapest one); QoS and other critical services and applications are charged accordingly in a dynamic manner (e.g., a similar service on the move could be charged more than in a home environment; a simple Internet access could be charged according to a given QoS and/or reliability rate).

#### **3.5.4. Dynamic and autonomic management of networked resources**

F-O-T platforms are relying on architectures that combine the Internet of Networks, Things, Content and Services. They need to securely combine and optimally manage the underlying resources. Research priorities therefore include technologies for:

- ***Resource discovery and management:***
  - Discovering available multiple resources at different contexts; orchestration, adaptation, optimisation and management of resources; service configuration; optimisation of resource utilisation; addressing scaling issues.

---

<sup>4</sup> Future Internet devices will have the needed autonomy to provide some kind of limited service even when not connected to any network, as for example when operating in remote locations or underground.

<sup>5</sup> The management of these peered storage structures needs to be understood and developed under the requirements of Section (networked digital entities).

- Monitoring of resources in distributed, dynamic, and ultra large-scale systems. The monitoring technology itself should be an integral part of the system, adapt and evolve with services and platforms. Monitors should provide high-level behaviour monitoring with abstract models of resources, services, networks, and user interactions.
  - Resources will not be passively provided as static entities. Resources themselves will be able to adapt to ever-changing requirements. Self-management of resources will be the key enabling technology in resource management. For example, services, things, data, content can self-administer according to pre-defined policies, and networks can self-heal themselves.
  - The awareness of sustainability will challenge the current paradigm of service management and development in many aspects but the most important is to manage resources with consideration of sustainability in terms of direct energy consumption as well as extending the life of resources.
- ***Virtualisation, programmability and composability:***
- Virtualisation of networked service infrastructures. Virtualisation is an important driver enabling the delivery of core infrastructure services as a 'utility-like service' to the business layer independently from the underlying platform. Virtualisation techniques will provide an illusion of infinite capacity of the networked service infrastructure and "elasticity", i.e. the capacity can be scaled instantaneously to the demands.
  - Programmability (programmatic provisioning) of the (network) transport, computational, storage, service and content resources based on capabilities for virtualisation of these resources and their efficient and flexible management and control;
  - Secure composability of real and virtualised resources (networks, servers, computing resources, digital objects, etc.), compliant to application needs;
  - Opportunistic programming support for users. The users should easily program their applications based on opportunities (by discovering relevant networked digital objects and program them together in specific situations).
- ***Multi-dimensional trust management:*** Management of trust and security in F-O-T platforms and in the underlying infrastructures: intra- and inter- platform trust and reputation management, including management of identities, managing the lifecycle of secure software systems, privacy-protection, sandboxing and secure policy-making, etc. Technologies to ensure trust are desirable at different levels of the Internet and have to present, in a non-intrusive way, all the interactions among diverse entities. The cooperative provisioning of end-to-end trust by connecting multiple security technologies and cross multiple layers and trust zones will be a fundamental requirement. The identification technology will be applied to enormous entities which need to be accessed through the Internet.
- ***Distributed, autonomic systems and systems of systems:***
- Cognitive and autonomic (or self\*) systems, including adaptive, self-managing, self-healing, and self-protecting systems
  - Systems that cooperate and negotiate with other surrounding systems for collectively managing in an optimal way available resources and acting towards

common interests and goals (e.g., for enhancing their collective security and resilience).

### 3.5.5. Frameworks, methodologies and tools for architecting F-O-T Platforms and the Future Internet

Each F-O-T platform may have very different architectural requirements. Architecting and federating such platforms may require addressing issues relating to their reliability, massive scalability, complexity, interoperability and usability. There is a need for advanced frameworks, methodologies and tools for understanding how to design, dynamically configure, and to run such platforms and their inter-relation and inter-operation with other platforms. Main research priorities are linked to the following:

- *Advanced modelling and simulation frameworks, methodologies, tools and architectural patterns for designing F-O-T platforms* that are reliable, scalable, trusted, secure and resilient, and for understanding how they will be composed, configured, executed and operated, and how they will be inter-operating with other platforms (e.g., designing new protocols and inter-working frameworks to securely interact with known or foreign frameworks); models and frameworks to manage the services of a platform;
- Frameworks and tools for *understanding the complex interaction among networked digital entities* in F-O-T platforms;
- Frameworks and tools for *monitoring, measuring and assessing F-O-T architectures* and models, for (formally) verifying and validating them and for taking corrective actions;
- Frameworks and tools for *measuring trust and security assurance* (e.g., context-sensitive risk assessment and management methodologies and tools);
- Frameworks and tools for *identity, accountability and traceability* at all layers of the F-O-T platforms and among different F-O-T platforms.

### 3.5.6. Governance, socio-economics and policy

Governance, economics, business, policy and user aspects are issues that are cutting across all the other above mentioned research challenges. They are related to individual F-O-T platforms or to their federated dimension. Research priorities to address include:

- *Policies* needed for governing trillions of available heterogeneous entities and resources;
- *Governance of Future Internet services*: guiding the services to fit the social-economical environment. The core issue here will be to understand the more and more heavy social impact of Internet, and in turn improve the contribution of Internet services to social development;
- *(Global) Naming of entities*
- *Addressing accountability* (pseudonymous provable accountability information on all online transactions); addressing responsibility in the value chain (especially for platforms spanning across individual jurisdictions and national borders). In particular: addressing ethical models (e.g. when transferring responsibility to our avatars or machines - in case of problems, who is responsible for this?); and, development of the required international codes and legal agreements similar to the aviation industry;

- ***Studying, managing and encouraging change by improving the process of innovation and value creation***; supporting the development of new challenging, collaborative and sustainable business models; supporting particularly competitiveness of SMEs; understanding the underlying economics and user/societal aspects (e.g. user expectations and user-centric delivery mechanisms, impact of technology development and regulation over society and creative contribution of society to the further evolution of the Internet);
- ***Ecosystems of governance, economics, business and policy compliance***: Constantly adapting regulations, laws, business models and economic models, to new technologies, so that the EU can shape the position of Internet services in the global society.

### **3.6. Experimentation**

In the context of F-O-T platforms, experimentation would be aiming at providing a methodology (experimentally driven research) and the necessary environment (experimental facilities) for investigating and experimentally validating ideas in all areas described under the other two types of research activities (i.e., "Fertilizing interdisciplinary RTD for F-O-T Platforms" and "Engineering F-O-T Platforms").

The experimental facilities represent the evolution of today's test beds towards service facilities for testing for example innovative networks, new service and content discovery and media distribution solutions, security and trust developments, new business models, etc. Experimentation in F-O-T Platforms would need to be stimulated both at individual technology levels and at system level.

Present experimentation infrastructure facilities would need to be expanded to cover areas that do not only tackle connectivity as they mainly do today, but enable:

- Validation throughout the whole range of research activities. The priority objectives could be to test the “federated”, “open” and “trusted” features of each F-O-T platform, and promote inter-F-O-T platforms experimentation.
- Wide system level experimentation. Experimentation facilities could thus become the “glue” between disciplines and research communities.

There is a lot of value in putting these experimentation facilities into place in such a way that end users participate as active testers at an early stage of the R&D cycle. They could, therefore, provide feedback from research regarding the usability and functionality of the elements and technologies. With this approach, the R&D cycle would be shortened, and innovation could be co-created with early users.

Real life and large scale experimentation with users could also provide views on the effect that the usage of these platforms will have on different social groups and communities.

These facilities and test beds should themselves act as model implementations and proofs of concept of the suggested innovative mechanisms and technologies of the Future Internet. This means that there could be a responsible "one-stop-shop" organisation that will offer configurable test beds "as a service". Activities like test management, choice of test users (ideally amongst real users), repeatability etc. could be “standardized”.

### **3.7. Engineering<sup>6</sup> F-O-T Platforms**

The engineering of F-O-T platforms involves the development of the necessary methodologies, capabilities and skills related to the integration and management of complex, heterogeneous and highly dynamic network, content and objects infrastructures, services, and applications into operational wholes.

These engineering activities or parts thereof may not necessarily be considered as activities eligible for funding under the EU Research Programme.

Engineering F-O-T platforms is a challenging task of its own. On the one hand, it will permit the effective analysis, design, implementation, integration, validation and delivery of early validated research at large scale (i.e., system or even system of systems). On the other hand, it will address the platform aspect, where the products to be engineered are services or applications making use of (one or more) platforms. Engineering F-O-T platforms in fact encompasses two complementary dimensions:

- One more upstream-research oriented focussing on:
  - Understanding basic architectural, functional and operational principles of F-O-T platforms and developing theoretically well-founded (but also practically useful) methods and rules that govern their operation and functioning;
  - Dynamically programming their operation, and understand and manage their dynamic behaviour, relations, interactions and interdependencies with different users and with other platforms: this includes managing their dynamic evolution and adaptation so they can adjust to, and respond to, changes in their environment, evolving requirements, obsolescence of existing or introduction of new technologies, and newly gained knowledge;
- A second one, of more downstream nature, that involves building a platform from a more result-oriented approach. Indeed, the nature of the interworking and modular, independent, yet interoperable technologies, involved in the development of a platform, requires the engineering of practical and working solutions by supporting the interworking of projects coming together in the platforms. Focus here is also on:
  - Effectively building working (operational) prototypes of F-O-T platforms, addressing their seamless plug-and-play capabilities, and demonstrating their capabilities, notably: robustness, reliability, massive scalability potential, interoperability, complexity management, quality of service, quality of experience, usability, etc. Specific challenges here are: technology selection, assembling technology, monitoring, proactive capacity building, management, governance frameworks and control tools for systems integration and validation to build smart applications in an environment of complex and federated platforms.
  - Analysing their impact on the functioning of the whole Future Internet.

The engineering of F-O-T Platforms requires the involvement of multidisciplinary communities. This would permit the necessary engineering discipline to make the platforms truly federated, open and trusted with the adequate "ecosystem" for its growth and further

---

<sup>6</sup> Engineering is the discipline of acquiring and applying technical, scientific and mathematical knowledge to design and implement systems and processes that safely realise a desired objective or to forecast their behaviour under specific operating conditions. Engineering encompasses the transfer of research-grade outcome to delivery-grade results.

development, with a view on building smart applications making use of F-O-T Platforms, whether for individual or for business purposes.

Such effort will permit the exploitation of knowledge and technological innovations and their translation into innovative processes, applications, and services. This is a necessary condition to take the successful research and its validation up to a higher maturity level before engaging into deployment. Europe will thus gain very significant experiences, and skills needed for the later, very large scale implementation and deployment of such platforms into all sectors of social and economic activity. The early adoption of F-O-T platforms for intra- and inter-enterprise business processes will support understanding on how to develop strategic business advantages through technology innovation. In summary, and for all the above reasons, we believe that the engineering of F-O-T platforms is a grand challenge per se.

## 4. Impact of F-O-T Platforms

In this section, we present some representative examples of F-O-T platforms that further support their definition provided in section 3.2 above. In addition, these examples serve to better understand the profound economic and social impact that F-O-T platforms are likely to have in all areas of human activity.

### 4.1. *Representative Examples of F-O-T Platforms*

F-O-T Platforms are the basis and the enablers when developing many new smart applications and services in the Future Internet era. By interacting between them and enabling sets of network/service/content/objects infrastructures, services, and applications to be plugged-and-played in a seamless way, such platforms could underpin the secure, reliable and trusted service provisioning in all possible areas of human activity: from home, business, working, education or leisure and social networking environments, to many others like health, finances, administrations, transport, energy, agriculture, environment, etc.

From discussions amongst the participants of the Future Internet Assembly, it is clear that the specific properties of certain types of applications will determine, at least to start with, what the optimal architectural choices are. For instance, service oriented architectures (SOA) might be suitable for building software applications based on existing services in the Internet. The "publish, find and bind" principle might be useful in that context, but thinking about a large sensor network where data aggregation needs to take place, other principles might be preferable than the "publish, find and bind" of SOA. The same accounts for networking: sending discrete packages of data needs another way of transport other than large sets of streaming data. It is, therefore, highly unlikely that all possible applications of the Future Internet will be based on a single architecture.

#### **"Focused Platforms"**

It is likely that at first, F-O-T platforms may try to solve fundamental questions of the Future Internet from only one angle, i.e. things, services, content, or networks. Such F-O-T platforms will likely use the basic underlying architectural principles of the selected "angle".

Examples of such "focused" F-O-T platforms could include: a platform providing an "always available" network (i.e. including any type of fixed or dynamic network); a platform with the right properties for managing (multi-)sensor networks; a platform for broadcasting television programmes over the Internet; a platform for securely managing a social network; a platform for managing high volume streaming data over the Internet (applications to be built on top of that platform could be 3D games or broadcasting television over the Future Internet); a platform for managing "Things" on the Internet; a platform providing virtualisation technology such that service providers can use this to provide cloud services on the Future Internet; a semantic search platform; a personal entertainment environment platform; etc.

As shown in the examples above, the level of granularity of each F-O-T platform may greatly vary. However the real added value of F-O-T platforms to constitute the basis for the Future Internet will most certainly lie in the possible combinations of such "focused" platforms. It is indeed the combinations of the capabilities developed for the Internet of Things, Internet of Services, Internet of Content and Internet of Networks that will lead to many different possible platforms. Such combinations will be stimulating the development of new applications and services, while, at the same time, taking full advantage of all innovative solutions offered by the "fundamental enablers" provided by the Future Internet through these platforms.

## **Combinations of platforms**

Platforms could be combined in different ways, such as acting as peers, in a hierarchical structure, etc. Two paths will likely emerge in this second stage:

- i. A first path will probably focus on specific application areas, trying to combine F-O-T platforms when addressing questions related to different classes of applications within the same domain. Such platforms will underpin the delivery of existing generic enabling services, providing application sectors such as energy, transportation, health care or education, ways to procure, extend, or repurpose services in ways that cannot be achieved with the current Internet environment.

Examples of such “application-oriented” platforms could include: (Multi-)Logistics platforms; Health-related platforms; Transport platforms; Household management platforms; City navigation platforms; etc.

- ii. A second path, which is likely to start in parallel, will take advantage of various combinations of F-O-T platforms to offer new opportunities and solutions to individuals, businesses, and the society as a whole, rather than focus on specific application domains. Such “global” platforms could be used to provide:
  - A way to fully immersive worlds, using e.g. trusted platforms for enterprises and business communities; “multi-interface” user platforms (i.e. holograms, 3D, touch, smell, etc.); fixed and/or on the move gaming communities platforms; massive (scalable) data management (i.e. with multiple networks and servers allowing distributed storage and management);
  - A way to better communicate through platforms offering presence information, collaboration tools (e.g., shared white-boarding), and different ways of interactions (e.g., instant messaging, audio, and video).

This second path is certainly the one which should be looked upon more thoroughly. It is the one leading the way towards real innovative applications and services for the Future Internet and that F-O-T platforms eventually target.

## **Examples for innovative applications**

- Exploiting technologies that understand the meaning of information and facilitate the accessibility and interconnection of content. Data from various sources and different formats will therefore be easily combined and processed resulting in a wealth of new, innovative, Internet-enabled, personalised, service mash-ups. From the personalised newspaper subscription to a high-definition broadcast facility, or to a play of a customised network game, all of these tasks will utilise multimedia services to provide new media experiences tailored to the needs and personal profile of the user. . In the coming few years, the majority of such media experiences will rely on rich video content, whether for communication, information, social networking or entertainment. Later on, media experiences may evolve into total immersion with increased quality of experience. Media-rich experiences will therefore be everywhere and consume large chunks of the Future Internet resources.
- Becoming a crucial business and societal enabler, as they will allow a flow of new information and service offers that will be based on real world "objects" that communicate and interact with each other. Information will become morphed with the profile, exact desires and inclination of the user and will change to become a unique offering. Service transformations can be envisioned for all sorts of physical objects and products: cars, clothes, appliances, garden furniture, and home decorations – the list is

endless.

- Serving as the platforms when providing new, innovative services, based on the rapid and secure composition, integration and configuration of existing ones, in new social and business contexts and sectors. For example, gaming and social network platforms can converge to total immersion virtual environments by combining the existing knowledge of legacy systems and the dynamics of each community. Moreover, social networking could evolve towards trusted and interoperable social platforms supporting future presence, immersive collaborative spaces and entertaining environments.
- Fostering new, universal wiki-like environments and contexts for individuals and the society adding value and new usage dimensions on top of existing ones. Groups as well as individuals increasingly become information providers, through media such as blogs and community resources or open wikis. Such efforts could provide a quasi-universal, real time, audio and video coverage of events across the world. F-O-T Platforms could support the wide availability of open and trusted infrastructures that provide adequate enablers to these new social and technological requirements.

## **4.2. Impact on the European Economy and Society**

F-O-T Platforms add an enormous range of new industrial opportunities to ICT equipment manufacturers, solution and service providers, as well as professional and private customers and consumers. Their impact on Europe's economy and society is expected to be significant for various reasons:

- By supporting the research and innovation activities that will be required for their development and deployment, Europe can become the leader in Future Internet technologies and usage. This will make it easier for enterprises, individuals and communities to address problems in a specific application or business sector and to develop and run specific smart applications. It will help enterprises to develop novel infrastructure and services – generic or tailored to specific applications, or customize equipments and services provided by others to dedicated markets.
- By safeguarding and advancing shared key values of the EU (such as Privacy, Inclusion and Cultural Diversity), F-O-T Platforms can guarantee that EU citizens enjoy the rights and freedoms that such values underpin, while developing new business and social development opportunities.

The added value coming from F-O-T Platforms can be summarized as follows:

- Federating the platforms ensures diversity of networks, content, service and application offers, while maintaining interoperability.
- A free and healthy competition is ensured on the future markets for Internet-based content and services.
- Infrastructures, services and applications are tuned in an optimal way to address the issues of the specific application and consequently better address the needs of the users.
- Enables new revenue streams for the European platform providers in key sectors of the European economy, as well as achieving major productivity gains.
- Allows keeping European values upfront, and helps new players such as SMEs and “prosumers”, whether individuals, organizations, or communities, enter the Future Internet applications and services domain in a way that only US companies have so far successfully achieved.

## **The Agile Internet**

The proposed F-O-T platform concept aims to improve the current Internet model where networks provide access and connection, while applications and content are mostly monolithic elements on the edges. The F-O-T platforms would enable the development and provision of new services, the efficient delivery of, and interaction with media content, the exploitation of new capabilities and a better use of the Future Internet resources for better user experience.

By the very nature of being federated and open, F-O-T platforms will also trigger the decomposition of services into a rich collection of smaller services along the value chain and will lead to requirements to value and deploy these “services”.

Content, applications and services can first be registered and then discovered, ordered, negotiated for pricing, composed, settled/fulfilled, rated and consumed by others in a same or in different business sectors within different platforms and "domains". They can be accessed from different parts of the network and in different and unforeseen scenarios.

Similarly, devices, digital entities (objects and things of any kind) and other service delivery artefacts will also form an integral part of the interconnected world of F-O-T platforms comprising linked objects and services. All these resources can be harnessed in any combination, as part of new or better applications.

**The changes we are advocating fill the gap of the current Internet which exists between applications, content and services on the one hand and networks on the other hand.** In addition, they enable the delivery of improved process performance, visibility, and scalability, higher levels of automation, increased cost efficiency through real-time, high-resolution data, enhanced process, product or service performance management, better transparency of physical flows and detailed status information, etc.

## **New value chains and business models**

**We need to move forward from the current Internet imbalance between the heavy infrastructure investments and the revenues from applications at the edges.** Although F-O-T platforms do not solve entirely this problem, they can provide a richer environment for competition and a better mapping to the value chain.

The modularity and "easy-to-register" and at the same time "easy-to-be-discovered" principle can stimulate the emergence of a rich variety of business value chains and business models. It will enable the emergence of an ecosystem of infrastructure and service providers, around which will gravitate new businesses specialized in the re-composition of services for dedicated professional and private applications. For example, F-O-T Platforms facilitate the Internet end-users to become producers, often referred to as *prosumers* (producers–consumers), a trend already emerging with the current Internet. This will be achieved through an improved easiness to register new services and products and the enriched environment through the competition among platforms. At the same time, a large scale provision of services and products will lead to overall better prices for the consumer.

Current Internet markets remain fixed in oligopolies, limiting further service and content growth beyond proprietary platforms and business models and within stringent governance boundaries. F-O-T platforms could help remove some proprietary barriers and allow a competitive level-playing field for service development, deployment and access. Due to the ubiquitous nature of such a model, the barrier to entry for the future content and services industry could be very low and the potential reach very large.

F-O-T platforms and their applications and services will be major users of the future European broadband telecoms network infrastructure. They will provide revenue streams essential to the financing of new infrastructure development, thereby contributing to overcoming the "digital divide".

Moreover, F-O-T platforms can become the basis for the network, content and services industry in Europe to be able to address the requirements of our society like health, aging, environment and mobility.

### **Towards a trusted Future Internet**

Trust will be a key element for the wide acceptance of F-O-T platforms. Having services based on trusted platforms which cater for accountability and privacy by design, and not only as added features, will make using and providing services more secure and trusted for everyone. This will also improve the possible offer of public services for the citizens, for example in the fields of health, transportation or e-government.

Federated and trusted dimensions of F-O-T platforms will encourage a collaborative approach to working with the "Future Internet" research initiatives in other major regions.

Legal and regulatory frameworks related to security, privacy, accountability and liability will play an important role in the success of F-O-T Platforms. The trusted nature of the platforms will ease the implementation of the appropriate regulations and laws.

### **A Future Internet for all**

The ease of access and use of services, content and applications derived from F-O-T platforms will permit increase of the perceived and real usefulness of the Future Internet for the majority of EU citizens interested in getting support for their daily needs. This will broaden Internet usage to all citizens.

Moreover, the shift from professional users to *prosumers* will require significant adaptations in the user interaction, which can address the requirements of citizens with specific needs like elderly, children, etc.

Creating and using services will be easier than today, and will allow citizens with no particular technical skills to access digital services, contributing to the reduction of the digital divide. Moreover, the lower barriers to the creation of services will make it economically viable to provide targeted solutions for smaller communities, thus preserving cultural diversity.

Overall, F-O-T platforms will permit the multiple actors involved in R&D to come together and jointly approach problems which require the consideration of multidisciplinary skills and domains. As such they overcome the fragmentation which characterises projects working in single technological silos. A better and more coherent understanding of the problems at hand will surely contribute to economic growth and innovation in Europe, reducing digital divide, optimizing business processes, opening new and simple ways to offer and consume services, increase the level of trust and widen the user base for on-line services.

## 5. Conclusions

From January to June 2009, the members of the Task Force, supported by four technical experts, have worked intensively to define cross-cutting, interdisciplinary research challenges for the Future Internet.

Our findings, as presented in this report, are structured around the concept of Federated, Open and Trusted (F-O-T) Platforms. We advocate that such platforms will provide the basic elements to enable citizens, companies and governments to use the Future Internet in an efficient, privacy friendly and trusted way, stimulating creativity, business and social values.

We discussed that the concept of F-O-T platforms can be realised through three basic types of inter-dependent RTD activities: (i) Advanced research - focusing on six interdisciplinary, fertilising research challenges and related research priorities, necessary for developing the technology components, methods and tools needed for designing and building such platforms (ii) Large-scale experimentation facilities - for properly testing and validating F-O-T platforms (iii) Engineering F-O-T platforms, which are purpose-oriented and application-driven. .

Framing multidisciplinary activities in the context of the Future Internet as a set F-O-T Platforms, provides a vehicle which will complement the on-going research activities into the Future Internet. This report is issued at a time which coincides with the beginning of the process to develop the next work-programme of FP7. How F-O-T platform research should be incorporated into the wider perspective of the work-programme is an open question at this stage. An additional open question concerns the concept of F-O-T Platforms in itself and how it should be shaped to best suit the needs of the market place. A consultation phase is now open to all stakeholders associated with the R&D activities around Future Internet, whom will no doubt contribute to the refinement of the concepts exposed in this report.

## **Acknowledgments**

In the course of this work, DG INFSO Task Force on the Future Internet content, had numerous fruitful interactions with representatives of the working groups of the Future Internet Assembly to develop a vision, starting with scenarios that depicted working and living in the Future Internet. We would like to warmly thank them for the multiple inputs and very constructive feedback provided throughout the duration of this work.

The members of the Task Force would also like to sincerely thank the four technical experts for their invaluable input during the process of developing the F-O-T platform vision. We believe that it has been a productive and enjoyable experience that has laid a firm foundation for shaping future Internet research.

## References

- [Cross-ETP-2009] Future Internet – The Cross-ETP Vision Document, January 2009, [http://www.future-internet.eu/fileadmin/documents/reports/Cross-ETPs\\_FI\\_Vision\\_Document\\_v1\\_0.pdf](http://www.future-internet.eu/fileadmin/documents/reports/Cross-ETPs_FI_Vision_Document_v1_0.pdf)
- [ES-FI 2009] Spanish Technology Platform es.Internet (Future Internet)
- [FIA-MANA-2009a] Position Paper Management and Service-aware Networking Architectures (MANA) for Future Internet System Functions, Capabilities and Requirements, May 2009, [http://www.future-internet.eu/fileadmin/documents/prague\\_documents/MANA\\_PositionPaper-Final.pdf](http://www.future-internet.eu/fileadmin/documents/prague_documents/MANA_PositionPaper-Final.pdf)
- [FIA-FCN-2009a] FIA Future Content Networks (FCN), Why do we need a content-centric Internet? Proposals towards content-centric Internet architectures, May 2009, [http://www.future-internet.eu/fileadmin/documents/prague\\_documents/FIA-FCN\\_Internet\\_Architecture\\_20090507.pdf](http://www.future-internet.eu/fileadmin/documents/prague_documents/FIA-FCN_Internet_Architecture_20090507.pdf)
- [FIA-FISE-2009a] FIA Future Internet Socio-Economics (FISE), Future Internet Socio-Economics – Challenges and Perspectives, March 2009, [http://www.smoothit.org/wiki/uploads/FISE/FISE\\_position\\_paper\\_final.pdf](http://www.smoothit.org/wiki/uploads/FISE/FISE_position_paper_final.pdf)
- [FIA-FIRE-2009] FIA FIRE White Paper, May 2009, [http://www.ict-fireworks.eu/fileadmin/documents/FIRE\\_White\\_Paper\\_2009\\_v1.02.pdf](http://www.ict-fireworks.eu/fileadmin/documents/FIRE_White_Paper_2009_v1.02.pdf)
- [FIA-RWI-2008] FIA Real World Internet (RWI), Position Paper, December 2008, [http://rwi.future-internet.eu/images/c/c3/Real\\_World\\_Internet\\_Position\\_Paper\\_vFINAL.pdf](http://rwi.future-internet.eu/images/c/c3/Real_World_Internet_Position_Paper_vFINAL.pdf)
- [FIA-T&I-2009a] FIA Trust and Identity (T&I), Position paper, December 2008, [http://www.future-internet.eu/fileadmin/documents/madrid\\_documents/TI/FIA\\_Madrid\\_Trust\\_Identity\\_session\\_consolidated\\_v4\\_changes\\_accepted.pdf](http://www.future-internet.eu/fileadmin/documents/madrid_documents/TI/FIA_Madrid_Trust_Identity_session_consolidated_v4_changes_accepted.pdf)
- [FIA-FISO-2009] FIA Service Offer (FISO) Position paper, December 2008, [http://services.future-internet.eu/images/e/e0/Future\\_Internet\\_Service\\_Offer\\_v4.pdf](http://services.future-internet.eu/images/e/e0/Future_Internet_Service_Offer_v4.pdf)
- [FI-SHOK-2009] The Finnish Future Internet programme (ICT SHOK), <http://www.futureinternet.fi/programme.htm>
- [INFSO-FI2020-2009] Future Internet 2020 – Visions of an Industry Expert Group, May 2009, [http://www.future-internet.eu/fileadmin/documents/reports/FI\\_Panel\\_Report\\_v3.1\\_Final.pdf](http://www.future-internet.eu/fileadmin/documents/reports/FI_Panel_Report_v3.1_Final.pdf)
- [INFSO-FM3DI-2009] DG INFSO report on "Future Internet and NGN Design requirements and principles for a Future Media and 3D Internet", February 2009, [ftp://ftp.cordis.europa.eu/pub/fp7/ict/docs/netmedia/20090220-fid-rp-3-dg\\_en.pdf](ftp://ftp.cordis.europa.eu/pub/fp7/ict/docs/netmedia/20090220-fid-rp-3-dg_en.pdf)
- [ISTAG-2009] Revising Europe's ICT Strategy, ISTAG, February 2009, [ftp://ftp.cordis.europa.eu/pub/ist/docs/istag-revising-europes-ict-strategy-final-version\\_en.pdf](ftp://ftp.cordis.europa.eu/pub/ist/docs/istag-revising-europes-ict-strategy-final-version_en.pdf)
- [ISTAG-2008a] Report of the ISTAG Working Group on "Future Internet Infrastructure", January 2008, [ftp://ftp.cordis.europa.eu/pub/ist/docs/future-internet-istag\\_en.pdf](ftp://ftp.cordis.europa.eu/pub/ist/docs/future-internet-istag_en.pdf)

- [**ISTAG-2008b**] Report of the ISTAG Working Group on "Web-based Service Industry", February 2008, [ftp://ftp.cordis.europa.eu/pub/ist/docs/web-based-service-industry-istag\\_en.pdf](ftp://ftp.cordis.europa.eu/pub/ist/docs/web-based-service-industry-istag_en.pdf)
- [**ITU-T-2009**] The Future Internet, ITU-T Technology Watch Report 10, April 2009, <http://www.itu.int/oth/T230100000A/en>
- [**JP-NWGN-2009a**] Japan's New Generation Network – beyond next generation network, Andreas Göthenberg, December 2008, [http://www.itps.se/Archive/Documents/Swedish/Publikationer/Rapporter/PM-serien/2009/2009\\_001%20webb.pdf](http://www.itps.se/Archive/Documents/Swedish/Publikationer/Rapporter/PM-serien/2009/2009_001%20webb.pdf)
- [**JP-NWGN-2009b**] Diversity and Inclusion – Networking the Future, New-generation network vision, NICT, January 2009, <http://nwgn.nict.go.jp/>
- [**JP-AKARI-2008**] AKARI, Architecture Design Project for New Generation Network, October 2008, <http://akari-project.nict.go.jp/eng/index2.htm>
- [**NatICT-Directors-2008**] Report from the National ICT Research Directors, Working Group on Future Internet (FI), December 2008, [http://www.future-internet.eu/fileadmin/documents/reports/FI\\_Rep\\_final\\_281108\\_.pdf](http://www.future-internet.eu/fileadmin/documents/reports/FI_Rep_final_281108_.pdf)
- [**PEW-2008**] PEW Internet & American Life Project, The Future of the Internet III, December 2008, <http://www.pewinternet.org/topics/future-of-the-internet.aspx>
- [**u-Korea-2007**] u-Korea Master Plan: To Achieve the World First Ubiquitous Society, Ministry of Information and Communication, Republic of Korea, 2007, <http://www.unapcict.org/ecohub/resources/u-korea>
- [**US-GENI**] The NSF GENI initiative, Exploring networks of the future, <http://www.geni.net/>
- [**US-NETSE-2009**] The NSF's Network Science and Engineering (NetSE) program, [http://www.nsf.gov/funding/pgm\\_summ.jsp?pims\\_id=503325](http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503325)

## Annexes

### **Annex 1: Scenarios**

→ See document entitled "Annex 1 - Trends & Functionalities for citizen-centric scenarios" describing trends and functional descriptions for incremental and visionary scenarios that are citizen-centric.

→ See four documents entitled respectively: "Annex 1 - Scenario BUS-INC - Care4u", "Annex 1 - Scenario CIT-INC - video and services", "Annex 1 - Scenario BUS-VIS - The Modalia Times" and "Annex 1 - Scenario CIT-VIS - me, anywhere, aboveware", which describe the incremental and visionary citizen-centric and business-centric scenarios prepared by the DG INFSO Task Force.

#### **→ Links to Scenarios from the FIA Groups:**

- FIA Management and Service-aware Architectures (**MANA**), Scenarios for Future Internet, May 2009, [http://www.future-internet.eu/fileadmin/documents/prague\\_documents/MANA\\_Scenarios-Final.pdf](http://www.future-internet.eu/fileadmin/documents/prague_documents/MANA_Scenarios-Final.pdf)
- FIA Future Content Networks (**FCN**), Scenarios, May 2009, [http://www.future-internet.eu/fileadmin/documents/prague\\_documents/FIA-FCN\\_Internet\\_Scenarios\\_20090507.pdf](http://www.future-internet.eu/fileadmin/documents/prague_documents/FIA-FCN_Internet_Scenarios_20090507.pdf)
- FIA Future Internet Service Offer (**FISO**), Scenarios, February 2009, [http://services.future-internet.eu/index.php/FISO\\_Scenarios](http://services.future-internet.eu/index.php/FISO_Scenarios)
- FIA Real World Internet (**RWI**), Scenarios, March 2009, [http://rwi.future-internet.eu/index.php/RWI\\_Scenarios](http://rwi.future-internet.eu/index.php/RWI_Scenarios)
- FIA Trust & Identity (**T&I**), Scenarios, May 2009, [http://security.future-internet.eu/images/1/1d/TI\\_Scenarios.pdf](http://security.future-internet.eu/images/1/1d/TI_Scenarios.pdf), and [http://www.future-internet.eu/fileadmin/documents/prague\\_documents/FIA\\_Prague\\_TI\\_Sessions\\_Agenda\\_and\\_ToR\\_new.pdf](http://www.future-internet.eu/fileadmin/documents/prague_documents/FIA_Prague_TI_Sessions_Agenda_and_ToR_new.pdf)
- FIRE Use Scenarios (**FIRE**), May 2009, [http://www.ict-fireworks.eu/fileadmin/events/FIA-Prague/1\\_Avessta.pdf](http://www.ict-fireworks.eu/fileadmin/events/FIA-Prague/1_Avessta.pdf)
- FIA Future Internet Socio-Economics (**FISE**), FISE Scenarios and Effects, February 2009, <http://www.smoothit.org/wiki/pmwiki.php/FISE/Scenarios>

### **Annex 2: Short Biographies of the External Technical Experts**

**Gonzalo Camarillo:** Gonzalo is the head of the Multimedia Research Laboratory, which is part of the NomadicLab, at Ericsson Research in Finland. He is a member of the IAB (Internet Architecture Board). His research interests include signalling, multimedia applications, transport protocols, network security, and network architectures.

**Schahram Dustdar:** Schahram is Full Professor of Computer Science with a focus on [Internet Technologies](#) heading the Distributed Systems Group, Institute of Information Systems, Vienna University of Technology (TU Wien) where he is director of the [Vita Lab](#). He is also Honorary Professor of Information Systems at the [Department of Computing Science at the University of Groningen](#) (RuG), The Netherlands. He is Chair of the IFIP Working Group 6.4 on Internet

Applications Engineering and a founding member of the [Scientific Academy of Service Technology](#). From 1999 - 2007 he worked as the co-founder and chief scientist of Caramba Labs Software AG ([CarambaLabs.com](#)) in Vienna (acquired by Engineering NetWorld AG), a venture capital co-funded software company focused on software for collaborative processes in teams. Caramba Labs was nominated for several (international and national) awards: World Technology Award in the category of Software (2001); Top-Startup companies in Austria (Cap Gemini Ernst & Young) (2002); MERCUR Innovationspreis der Wirtschaftskammer (2002). More info at: [www.infosys.tuwien.ac.at/staff/sd](http://www.infosys.tuwien.ac.at/staff/sd)

**Jacques Magen:** Jacques is an independent consultant who just created his own company InterInnov ([www.interinnov.com](http://www.interinnov.com)) specializing in international research & innovation. He has been working for 25 years in ICT as technical expert and consultant, more specifically in telecommunications and networked media, and more recently in general innovation policies at national and regional levels. While coordinating collaborative programmes and universities relationships at Alcatel for eight years, he initiated and chaired the CELTIC European programme dedicated to end-to-end communications, and contributed in the set-up of the eMobility and NEM European Technology Platforms.

**Sachar Paulus:** Sachar is an independent Management Consultant ([paulus.consult](http://paulus.consult)) on Security in the Information Age, and Honorary Professor for Security Management at University of Brandenburg. Member of RISEPTIS advisory board and of the ENISA Permanent Stakeholders Group. Previously, he was 8 years with SAP in various positions, amongst others, SVP Product Security and Chief Security Officer.