FP8 Expert Group:

Services in the Future Internet

Brussels, 28 February 2011

Workshop Report

Supported by Directorate-General Information Society & Media,
European Commission

Contents

Disclaimer

This document has been received by the European Commission. It represents the views of external experts and cannot be considered as representing the opinion of the European Commission or any of its officials.

The experts cited in the document were acting in their personal capacity and the opinions expressed do not necessarily represent the views of their organisations. Opinions expressed here are therefore only informative and have no binding character whatsoever. Where affiliations are mentioned it is for purposes of identification and reference only. Any use made of the information in this document is entirely at the user's risk. No liability will be accepted by the European Commission, the individual experts or their organisations.

1. Introduction

• The Context

Framework Programme 7 will end in 2013, and activities are ongoing for the preparation of FP8, which will shape the future of European research starting in 2014.

The European Commission presented on 9/2/2011 a green paper on a "Common Strategic Framework" for the management of future EU research and innovation funding; it identifies the high-level objectives of smart, sustainable and inclusive growth, which were endorsed by the February 2011 European Council as key to future growth and jobs. This Common Strategic Framework will, in the context of the Europe 2020 strategy, cover the FP funding for research as well as other financial instruments of the European Union. A public consultation has been launched on these themes, and contributions can be submitted at this address: http://ec.europa.eu/research/csfri/index_en.cfm.

In INFSO, several activities are in progress with the objective to identify the key subjects and themes that will be important for research in the coming years. For example, the Future Internet Assembly, a collaboration between projects that have recognised the need to strengthen European activities on the Future Internet, is working on the FIA Research Roadmap, which is the combined vision of the FIA participants about the future Internet research challenges. All the information about FIA Roadmap can be found on http://fisa.future-internet.eu/index.php/FIA_Research_Roadmap.

• Workshop Objectives

The Services in the Future Internet Workshop, held in Brussels on 28 February 2011, was organised by the Software & Services Architectures & Infrastructures Unit of Directorate-General Information Society & Media, European Commission. The Workshop explored the technological and research challenges affecting the area of software and services in the timeframe of the next European Framework Programme for Research and Development (FP8). Specifically, it aimed to identify potential issues and themes that might be addressed under future work programmes in software and services research.

The output of this workshop will be used for two related activities:

1) Starting point for building future workprogrammes in the area of Software and Services.

2) Contributing to the FIA Research roadmap, which will aim at future research activities in the field of Future Internet.

The one-day meeting brought together around 25 invited experts representing the ICT industry and the research community. The experts shared pre-prepared position papers and engaged in 'brainstorming' exercises around key questions. This report is a summary of the themes discussed during the workshop and afterwards, through comments exchanged by email. It should be considered not as an organic document, but as a collection of contributions which may represent different points of view about the themes discussed. It does not represent the position of the European Commission, but it is a document that will contribute to it.

- **Consultation Process for FP8**

The European Institutions are now preparing the next research Framework Programme: FP8. It will run from 2014, and will be a very important element of European policy. FP8 will be linked to the key socio-economic challenges facing the European Union: the economic crisis, unemployment, ageing, health, environment, and will provide significant input for a sustainable development model.

In this context, research in the domain of Software and Services can give an essential contribution. Software-based services are already important in today's economy, and will be even more important tomorrow. The challenge of research is to identify and solve the problems which hinder the provisioning of value-added, software-based services over the Future Internet. This area of research is closely linked to other EU policy activities, e.g. in the field of data protection, standardisation, public procurement, energy efficiency, and cross-border services.

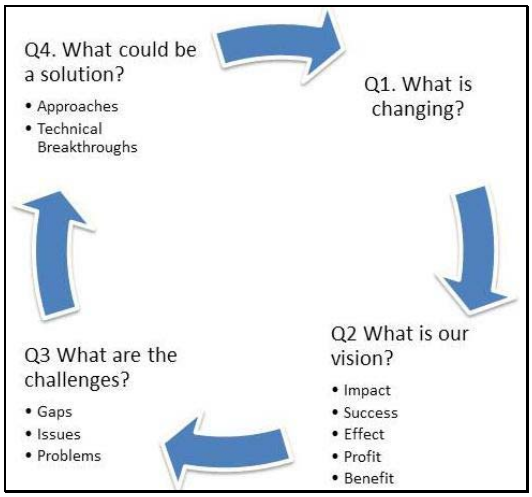
The next generation of software-based services will require appropriate tools, methodologies, models, architectures, and infrastructures; these will be based on computing systems that will probably be quite different from the ones we use today in terms of architectures, distribution, power requirements. Research should ease the development of services that make use of the new capabilities of the Future Internet, such as near-field communication, smart objects, immersive simulation, etc. We need to imagine the future, and to identify the most promising areas where the EU should fund research activities, in order to get useful results that will in the end improve people's quality of life. While there are challenges requiring theoretical work and fundamental research, we should not forget that the final objective of the framework programme is to get practical and concrete results that will allow innovative European companies to grow and prosper.

The Workshop was one of a number of actions designed to probe these issues, together with contributions from EU Member States, research organizations and other stakeholders which are providing their position papers, and the FIA roadmapping activity mentioned above.

Institutional activities in view of the definition of FP8 are ongoing.

- **Methodology**

The FIA roadmapping group has identified four key questions as a starting point for building a comprehensive roadmap for FP8. This same methodology was used for the Services in the Future Internet workshop. The Expert Group was invited to consider these questions, in the context of the research on software and services, regarding the area of services in the Future Internet. Each expert was asked to submit a very short position paper answering these four questions as an input for a series of brainstorming sessions held during the workshop.



2. Software and Services: What is Changing?

As a first step, participants were asked to consider significant changes that could affect the area of software and services between now and 2020 and beyond. What is changing, and what are the drivers of this change? The responses clustered around six main areas.

- **Economy and Society**
  - **Globalisation continues but so does localisation**: The process of global organisation and collaboration seen over the last thirty years is still ongoing, with implications for both people and technology. At the same time, political, socio-economic and environmental developments will drive economies to more localised modes of operation.
  - **Facing up to global challenges**: Global challenges, such as climate change, ageing population, and economic competitiveness, will be at the forefront of the political debate and of citizens' concerns during the period in question.
  - **Digital content as a major economic driver:** The economy is increasingly reliant on pure digital assets, rather than traditional goods and services. As well as consumer markets, these assets affect business service delivery models and account for an increasing share of content industry revenues. Convergence between networks, services and content is reshaping sectors such as media, telecoms and the service industry, while an increasing proportion of content and services are user generated.
  - **New economic models**: The growth of internet services and content delivery networks has the capacity to generate new economic models. Instead of using the traditional business model where a service is delivered through an ISP (with the service owner paying an ISP, and ISPs paying other ISPs to get the service delivered over the entire internet), large service owners now greatly rely on their own servers and peering agreements with other networks to make them independent of ISPs. This gives them the power to reverse the usual model of payment to an ISP paying to connect directly to a service, and in general creates new opportunities for changing existing value chains. Also the new scale of infrastructure, the dynamicity of service provisioning, and the web itself pose new challenges to traditional models, creating a new "Cloud Economics" challenge.
  - **Green ICT**: There is an increasing focus on energy management and on environmental impact of ICT. New environmental concerns and the rising cost of energy require that new infrastructure and devices be more energy-efficient. Also, since most of the devices to access the services will be mobile, with limited battery power, energy efficient applications will become crucial.

- **Innovation and Users**
  - **An increasingly complex innovation ecosystem**: The innovation environment is increasingly complex. On the one hand, the complexity of the web is reducing the ability for small companies to influence the underlying standards. On the other hand, such small actors (individuals and SMEs) play an increasingly important role, innovating on top of commercial platforms and marketplaces. Service providers are not only software companies but also users and even communities.
  - **A new concept of collective or collaborative services**: Innovation is increasingly a process of co-creation and collaboration. There are opportunities to define the notion of ‘service’ based on the emergence of many-to-many relationships between service producers and service

consumers: i.e. 'collective service' where many subjects (people, things, etc) act together as providers offering services to many consumers. Open source communities are a good example of on-line collaboration enabling the creation of products and services which would not be possible if organizations or persons participating in the community would prefer to act autonomously.

- **Personalised and on-demand**: Personalisation will continue, with users wanting more tailor-made products, services and content. Such individualised offerings will increasingly be delivered on-demand. But at the same time this raises more privacy issues, and the question: Who owns the personalisation information? At the moment, all applications collect usage information of their users. Could it be possible that each user controls his/her own data that can be shared in a standard way with applications for personalisation?
- **The Web as a platform:** Moving beyond its initial starting point as a simple hypertext system, the Web is developing in a number of ways. Linked open data is fast becoming the dominant method for sharing data at Web scale. Coupled with a number of other technologies (e.g. Ajax), the Web is transforming into a powerful platform for Internet services providing a hosting environment for applications such as mail clients, office software and others that in the past had to be implemented for native operating system environments. In a nutshell, the Web is moving away from its original implementation as a set of information servers, and **is becoming the operating system for Internet-based services**, spanning various devices, and moving beyond the traditional desktop platforms into new areas such as mobile smart phones, tablets, TV hardware, automotive and other embedded software sectors. Given its traditional strength in embedded software, this is a particular opportunity for European research and industry to increase its role in the Web platform.

• Social Networks

- **Social networks raise opportunities for sharing and participation**: The Internet of People – a trend that includes Web 2.0, social networks and social computing – promotes the internet as a fundamental channel for allowing users (individuals, groups, communities) a more and more active role as providers of data, content, and services. Service-oriented computing becomes socially enhanced, as well as community-driven open source development.
- **Social networking platforms reveal new insights**: The digital footprints left by social networks allow us for the first time to draw a social graph, showing the connections between people and things. Social media are also important in a commercial context, allowing businesses to mine and exploit new information about their customers and react quickly to safeguard their reputation. Some social networks enable to subscribe to social streams to analyze social opinions as they happen.
- **Social connectivity goes mobile**: Increasing popularity of social networks and online services (twitter, blogs, forums etc), is leading users to expect not just internet connectivity but also social connectivity anytime and anywhere. Increasing penetration of smart devices (see below) allows people to make their (virtual) social participation mobile.
- **Growing interest in 3D devices**, leading to augmented reality and eventually full 3D immersion. This will not be restricted to social and recreational contexts but also to working environments, leading to services that can overcome spatial boundaries. Already systems of enhanced reality e.g. allow remote surgery with unprecedented precision and success rate.

- **Mobile and the Internet of Things**
  - **Growth of the mobile internet**: Mobile broadband is rapidly gaining market share in Europe and in developing countries its penetration is often higher than that of fixed broadband. India and China are both expected to be mobile broadband oriented.
  - **Smart devices enabling more advanced services:** End-user devices become ever more powerful with improved autonomy and bandwidth. These smart personal devices will facilitate anywhere/anytime access to the internet and to the services it will provide.
  - **The Internet of Things**. Widespread deployment of sensor networks and communication devices in cities, roads, homes, etc, will generate massive flows of data needing to be processed in near real-time. The same effect will be generated by the sensors integrated in commonly-used devices like cars and telephones.
  - **Machine-to-machine (M2M) and Web of Data**: The Future Internet will not be only for humans but for machines, with many more machines connected than people ("Internet of Things"). M2M communication systems will make it possible to read out sensors and to send commands to actuators, enabling control systems to be built using the internet. Alongside this is the rise of the web of (linked) data, an extension of the current web. Contrary to the current web, which uses web pages which are mostly being processed (read) by human beings, the web of data is designed for being processed by computer programmes. Hence, the Future Internet needs to be optimised for automation.

- **Trust, Security and Privacy**
  - **Dependability of ICT is an economic issue**: ICT infrastructures are becoming more and more vital to the economy and society, while their complexity and the political environment makes them more vulnerable to accidental damage and malicious attacks.
  - **Consumers losing control of their data**: Many issues arise relating to the management and ownership of private data, especially in the context of cloud computing and personalisation. The legal framework in EU does not provide yet adequate guidance for cloud computing.
  - **Safeguarding digital identity**: Major commercial players are already investing in digital identity services. Who will and should own such services?

- **Technology**

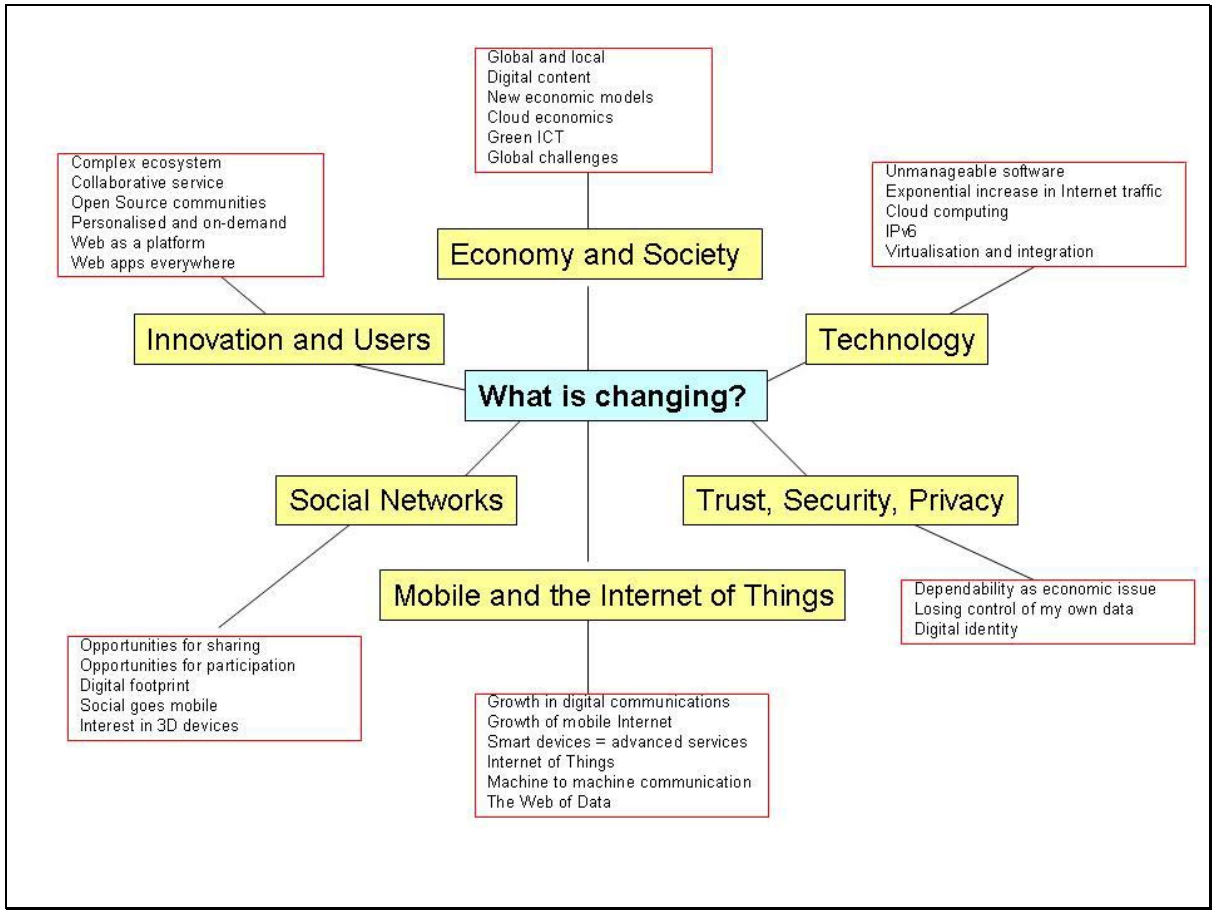
(Many of the above factors are implicit here)

  - **Software is becoming unmanageable**: Software (and hardware) is becoming increasingly complex, to the extent that it is becoming more and more difficult to manage. New approaches to software and service development are urgently needed, as well as tools and techniques for self-management of software, i.e. the capability of the platform to deal with the program.
  - **Internet traffic is facing an exponential increase:** especially personalised and on-demand video (immersive communication, 3D video...) is leading to an enormous increase of networking and computing demands. New frameworks will be required to deal with that in an economical way and minimising the energy cost of data transmission.
  - **Clear market moves towards 'cloud computing'**: In recent years, cloud computing (variously defined) has moved from a vision into a marketplace reality – cloud-based infrastructure, cloud-based applications, and cloud-aware/enabled networks. IaaS providers are operating

large cloud-based infrastructures, and many SaaS providers are leveraging these infrastructures to develop and deliver services to end-users, gaining cost and time-to-market advantages. As a virtualisation infrastructure, cloud computing offers unique opportunities to reduce the costs of delivering services over the internet, thus extending this possibility to much wider classes of users.

- **Widespread take-up of IPv6**, enabling truly ubiquitous computing, reducing roaming costs and allowing users greater freedom. The increased address range enables a plethora of connected objects, forming a continuum of information and data for the user to navigate.
- **Virtualisation and seamless integration** of compute, storage, network resources and services (and soon devices as well) are affecting all industries and sectors.

A summary of the main ideas and concepts expressed above is shown in the diagram:



What is changing in software and services?

3. Services in the Future Internet: What is Our Vision?

Building on these insights, participants formulated their visions for the evolution of this area through to 2020. The visionary statements clustered around five main aspects.

- **A New Concept and Role for Services**

The definition and scope of 'services' are being redefined, going beyond IaaS, PaaS, SaaS and SOA. We have to think of services not just as software entities but as **economic and social entities that bridge between two worlds**: 'service platforms' and 'real life'. Digital services should be **accessible, usable and composable by everyone**, as ubiquitous and universal as electrical power, and no longer an IT tool for a tech-savvy few. Services will be easily accessible from any device at any location and at any time.

There are opportunities to define **new economic and business models**, such as having the service provider pay rather than the user; or collaborative/co-operative services offered by many to many. **New business markets will arise**, scaling with this new ecosystem, and small companies will be looking for means to monetise internet applications. More generally, we need to look closely at the whole area of **incentives in service provision**. **Processing data on-the-fly**, as it is produced, will be an enabler for new services and business areas. **Virtualisation and the cloud** will bring opportunities to use remote resources as if they were local.

- **A User-Centric Internet Fostering Innovation and Collaboration**

The Future Internet should be **user-centric**, with users having an active role in defining the services they require depending on the context in which they will be used. Within this ecosystem, there will be many services available, **transparently orchestrated for the user**. A service consumer will also become **a creator (and even an innovator)**, and a range of **added value services** (faster, better, cheaper) will be available to improve the user experience.

The Future Internet of Services addresses the **collaboration needs of individuals across organisational boundaries** on a global and real-time level. It fosters the **growth of virtual organisations** – beneficial environments for SMEs to participate in mash-ups and provide competitive solutions. A network of interoperable clouds covers everything, creating a mesh of users and usage. Social platforms replace search as an internet application component.

Open Source is a key element of this vision for several reasons: it allows SMEs to go beyond their own capabilities and benefit from building complete solutions integrating available open modules; it is important for research efficiency because it makes the re-use of previous results easy; it is important for governments that can take advantage of an open ecosystem and contribute back to it.

- **The Internet of Services for the Internet of Things**

The Internet of Services will be closely connected to and will interact with the Internet of Things. New services and apps will be able to be **composed on top of real-world objects interacting in real time** as easily as today's data mash-up compositions. The Internet of Services should be able to process the large amounts of data that will be generated by Internet of Things scenarios. Many of these scenarios require near real-time processing of the data generated from the devices.

While current work on the Internet of Things has focused on lower-level network technology, there is currently little experience with building applications for this new, emerging ecosystem of IP-enabled devices and objects. Application development is currently at the level where the "traditional Internet" was before the advent of the Web. The Web played a pivotal role in facilitating application development and use for the "traditional Internet." Web technology has a similar potential to unleash the potential of the "Internet of Things" by making it accessible and programmable by developers that are not necessarily experts in ubiquitous computing. The ideas behind the Web of Things and the Internet of Things are highly relevant and applicable to areas where ICT added value is significant in Europe, such as automobile, consumer appliances, health and medical.

- **A Future Internet Based on Privacy, Security and Trust**

Issues of privacy, security and trust should be centre stage in the Future Internet. Such aspects must be at **the centre of the design process for the Internet of Services**, and we must ensure that the **internet roadmap is open and democratic**.

Individuals (as consumers, users, patients, citizens) are looking for **control of their personal data**, whilst the boundaries between professional and private life are becoming fuzzy. Whenever data are stored and processed in public clouds it should be done in **a privacy preserving manner**.

- **New Service Environments and Infrastructures**

New **global service delivery infrastructures** are required to cope with services and data growth and with the **diversity of software and hardware platforms** in an economic way and with low environmental impact. Such infrastructures should offer: universal, resilient network access; seamless integration of networking computing and storage resources; and dynamic and intelligent allocation and distribution of software and data according to context (user needs, security, requirements etc.).

We need **a user-focused, self-adapting service landscape**. Systems should be built in **a goal-oriented way** by integrating available software and services of which the producer has practical knowledge. We should find **innovative new programming models** for composite systems (ones combining human and software services); and for distributed secure data cloud applications. The ability to provide maps and objects to deploy (mixed) reality applications should also be investigated.

New, faster, more responsive approaches to software and service development are also required. We have to find easier ways to develop applications that can be distributed and shared across a global infrastructure or resources.

4. What are the Gaps and Challenges?

Next, participants considered the gaps, challenges and barriers to achieving this vision. Key points, according to the segmentation used above, were:

- **A New Concept and Role for Services**
  - From a cloud point of view, all existing software can be considered as legacy software, a major barrier to the widespread take-up of SaaS. Such **legacy systems need to be evolved and adapted** in order to be executed as a service.
  - **Interoperability and pervasiveness of services** remains a key challenge which is far from being solved. Efficient and practical methods for describing the interfaces of services, usable by machines, are required.
  - Need for **new metrics** to assess costs, risks, values and dependability of software-based services, including human-provided services.
  - Make **software engineering for web applications a discipline** that can more easily deliver internationalised, accessible and device-neutral applications.
  - A new holistic approach is needed to **merge IoS and IoT approaches**, including into a coherent framework all the resources from low-level sensor to high-level services.

- **A User-Centric Internet Fostering Innovation and Collaboration**
  - **Building working service compositions** across technologies and across organisational boundaries, so as to support new business models and opportunities on the web.
  - **Immersive collaboration** exploiting upcoming 3D technologies.
  - **Socially enhanced** services computing.
  - New paradigms to handle the **vast amounts of data generated** and to **manage digital assets throughout their lifecycle** so as to bring instant value to end-users.
  - **Fully mobile services**, reflecting the fact the majority of internet users will be mobile.
  - **Bootstrapping the Internet of Services** i.e. populating it with a critical mass of services necessary to create new business opportunities and new research ideas.
  - **Availability of public test suites for web specifications**, so as to encourage interoperability of diverse implementations.
  - **Broader participation in web standardisation**, beyond the ICT industry to include European sectors such as automotive, consumer electronics, health and medical.

- **The Internet of Services for the Internet of Things**
  - **Applications for the Internet of Things** – use of web technology to make a 'Web of Things' accessible and programmable by developers that are not necessarily experts in the field.

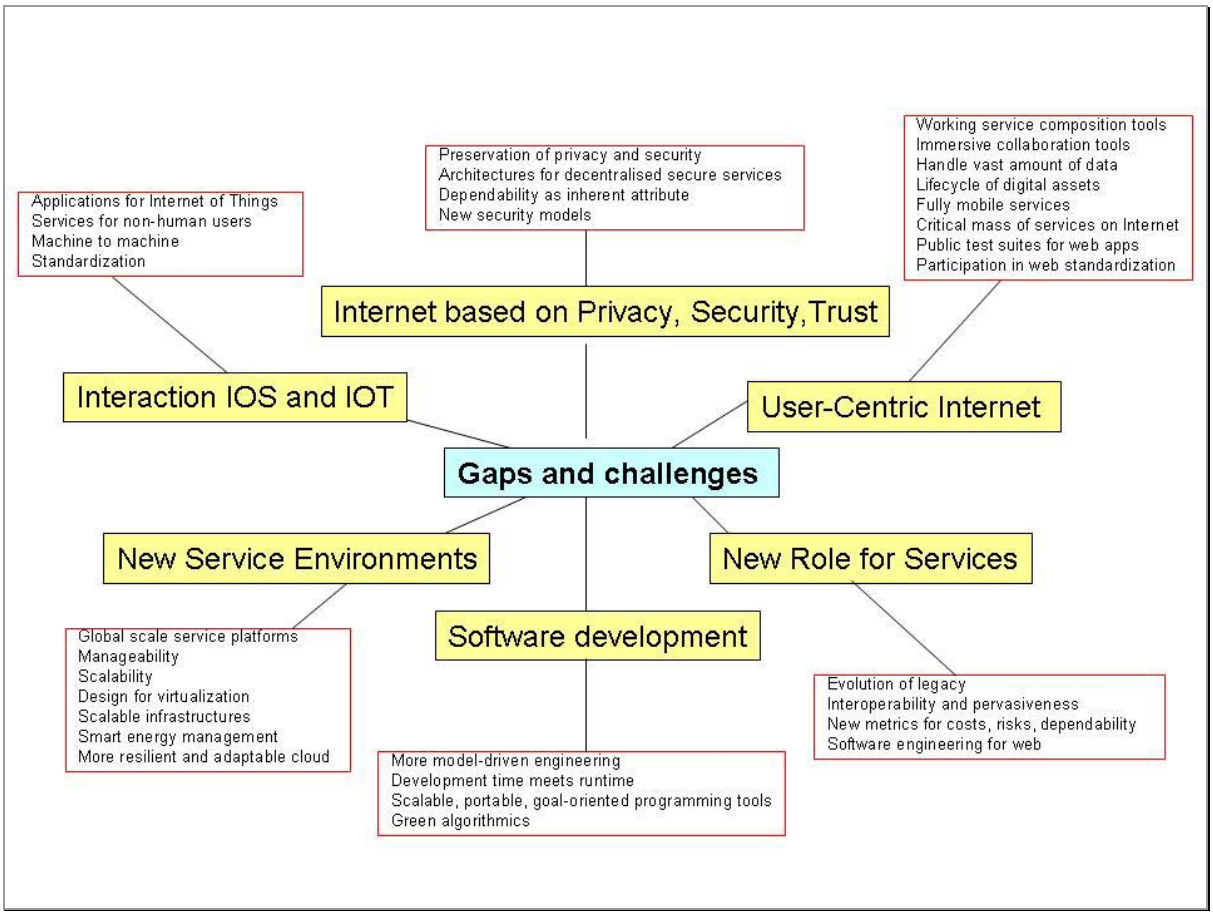
- Reflecting the potential growth in connected devices, **services to support and manage a vast majority of non-human internet users** (i.e. M2M services).

- **A Future Internet Based on Privacy, Security and Trust**
  - **Preservation of security and privacy**: Security, privacy and trust are the foundations for service capabilities and user experience, especially for accessing services and data on shared and exposed resources. Systems should be able to query, aggregate and correlate sensitive data in ways that preserve privacy.
  - Architectures that make it **easy to develop fully-decentralised secure services** offering the necessary levels of security and trust. A related but separate issue is getting consumers to trust such open distributed systems competing against established brands.
  - The new service platforms should be inherently dependable, i.e. **dependability should be an inherent attribute** rather than an intrusive 'add-on' as in most current infrastructures.
  - **New security models**: In the Future Internet, the boundary between correctness, safety and security tends to disappear. This decentralised paradigm presents a major challenge for verification, which currently relies on a global view of system behaviour. Furthermore, analysis performed at design time can only be partial, since Future Internet services will be open and dynamic by nature: verification at runtime will also be required.

- **New Service Environments and Infrastructures**
  - **Global scale service platform** with new business/revenue models that reflect the shift towards very large service providers, with space for small agile providers focusing on innovative services.
  - **Manageability** of large-scale virtualised platforms and the tools and services they support.
  - **Integration** and exploitation of various types of resources, at different levels of complexity.
  - **Design for virtualisation** – the design of platforms/infrastructures and services/applications optimised for virtualisation; as well as issues of availability, dependability and security for virtualised infrastructures.
  - More **scalable infrastructures**, where scalability leads to a non-linear increase in costs. Scalability is especially significant in view of the growing number of devices, the exponential increase in data, the increasing need for processing data on-the-fly, and the pervasive need for security. Elasticity is a key requirement for cloud-based infrastructures, but is currently poorly supported.
  - **Smart energy management** is an issue that spans from data centres to mobile devices. Services should communicate better with the infrastructure to have them energy-aware with self-adaptive energy efficient networks and computing resource management. At programming level, the energy consumption of an algorithm should be appropriately manageable ("green algorithmics").
  - **Making cloud infrastructures more resilient and adaptable**. Autonomic systems could enable large-scale infrastructures to cope with failures and improve maintenance while preserving services to the users.

- **New Ways of Developing Software**
  - **More model-driven engineering:** The abstraction level currently used in programming languages needs to be improved; model-driven development has proven successful in abstracting complexity in larger systems, but for systems-of-systems hierarchical modelling is needed. It is also easy to see that the global optimum for the full system might be suboptimal for its parts and vice versa. Thus, there is a need to enable model-based continuous optimisation and adaptation at various levels and in real-time. The weak part in model-driven engineering has always been the code generation, and research should be invested into making the platform-specific mapping fully automatic for different platforms. Software today runs in clouds on parallel hardware and grids. The change from sequential software to multiple entities running in parallel will bring new challenges for code development that may be handled by clever code generation and automated support for deployment on parallel platforms. Finally, research should be invested into formal methods for correctness proofs of mission-critical models.
  - **Development time meets runtime:** The development of Future Internet services will be characterized by the disappearance of the boundary between design time and runtime. This has a deep impact on software engineering activities such as, evolution, maintenance, testing and verification that, until now, leveraged models produced at design time. It is thus necessary to offer effective means to retrieve and maintain models at runtime in order to drive all these activities online.
  - **Scalable and portable** programming tools that maintain efficiency and deal with the delocalization and decoupling of code, data and resources, while allowing more goal-oriented ways of defining software behaviour.

A summary of the main ideas and concepts expressed is shown in the diagram.



What are the gaps and challenges?

5. Solutions and RTD Needs

Finally, participants considered potential solutions and RTD needs to address these issues. What radical approaches, disruptive technologies, new ideas might be solutions to these challenges? Suggestions were divided into three timeframes: short-term (2012-2014); medium-term (2014-2018); and long-term (2018-2022); in the summary below we report simply "short" and "medium-long term", because only very few issues were identified by experts as long term needs. This is an interesting insight on the speed of research in this area.

The lists below are in draft format, and may require further editing and categorizing work, which could not be done in the context of the workshop.

- **Short Term (2012-2014)**

Software & Service Engineering

- Lifecycle model of software/services end-to-end
- Software aggregation over 'uncertain', 'unreliable' services
- Software modelling and programming of distributed systems
- Highly scalable and portable programming languages
- Standardisation through common architectural model
- Tools, methods and standards for developing services for the Internet of Things

User Experience

- Services for reality spaces
- Social networking middleware
- Social network as a service (API –business)
- Social network as the interface to personal data
- Social network as the single-point-of-entry to all online systems
- Interface with real-world services
- Describe reality to create mixed-reality applications
- Augmented reality and 3D integration into collaborative interfaces

Privacy

- Privacy-preserving service infrastructure
- Ephemeral and self-destructing data
- Location control for data and code

Business Models

- Cloud related economic models
- New definitions/terminology and concept for "content" on the web - data/code/context beyond services
- Definition of content/goal/information
- Definition of problem domains "expertise gathering"
- Creation of sustainable communities and businesses around Open Source software and freely-licensed hardware. Free licensing simplifies the creation of communities and enables pay-as-you-go service development. It means you (often) pay for service development/evolution and not for the usage. Another advantage of free licensing is that it prevents vendor-lock in.

Infrastructure

- New ways of looking at and modelling the infrastructure

- New programming models/concepts for decentralized systems
- Data streaming for event-driven service infrastructure
- Distributed and segmented data maintenance
- Annotation of context parameters and semantic discovery
- Cross-platform resource management of potentially heterogeneous resources
- Federation of platforms also requires standards

Complexity

- Distributed heterogeneous IOS
- Unreliability of data/sensors measure trust
- Intelligent compilers

- **Medium and Long Term (2014+)**

Software and Service Engineering

- Intelligent self-executive components ("agents")
- Goal-/problem-driven development (programming paradigms)
- Semi-autonomous components (involving humans)
- Reusability and sharing of "software components"
- Decentralised & delocalised execution of software/components
- Vertical software architecture (stack) and development
- Simultaneous build-time run-time development and experiment
- 'Pay-as-you-go' service development (i.e. incremental service development with developers and prosumers sharing the effort and costs)

User Experience

- Dynamic virtual communities support...
- Assisted configuration of services for personalization

Business Models

- Communities as service providers
- Pay-as-you-go service development
- Real world services meet social services
- Inhibitor: 'vendor locks' => needs an ecosystem for supporting (co)innovation

Privacy

- New cryptographic techniques for shared data
- Lifecycle of information and data and services

Infrastructure

- From network-centric to information- / content-centric
- Intelligent compiler/conversion concepts
- Automatic and dynamic self-configuration of services to the user context
- Automated maintenance for distributed systems
- Fully distributed heterogeneous service platform
- Goal: open world infrastructure (all means necessary to realise dynamic and flexible code execution over a dynamic, large scale, heterogeneous, global infrastructure involving any type of resource)

Complexity

- Goal-oriented autonomous system management
- Autonomous platforms creation. Dynamically look for resources/required services, self-*
- Complex system modelling and simulation for automation, complexity … automated maintenance
- Collaborative development framework for multiple software editors, integrators, service providers, contents.
- Distributed constraint solving with negotiation
- Self adaptive systems: autonomous components

6. Conclusions

The Workshop addressed a very wide range of issues and many interesting and provocative ideas were floated. While it would be precipitous to try and sum up such diverse thinking, some of the main themes were the following:

1. **Community-driven Innovation**: The importance of innovation in an economic and social context is growing. Increasingly, innovation is driven not by individual users but by communities and social networks. We must find approaches to software and service development that support and facilitate such community-driven innovation. Open Source is already a key element of this and can become even more important in the future, as we can see an ongoing merging of business models based on Open Source with those based on proprietary software. Social media and mobile internet can increase the ability for social groups to solve problems that are overwhelming for individuals or traditional organizations.

2. **Services for the Real World**: The convergence between the 'Internet of Services' and the 'Internet of Things' is clear for all to see. We are instrumenting the world with sensors and networks, creating a mass of data that is the basis for new knowledge and services. We must find ways of bringing the two together that preserve openness and address the need for different levels of reliability and trust; an approach that we might call an 'Open World Infrastructure'.

3. **Privacy-Preserving Infrastructure**: Issues of privacy, security and trust arise in many contexts and must be central to our view of the Future Internet. Novel service-based architectures should allow users to retain control over their data at all times, including where required, for it to be ephemeral and self-destructing.

4. **A Decentralised Operations Paradigm:** Cloud computing tends to centralise data and applications; this creates legal and privacy issues, and also may not be the best option in terms of latency, energy consumption for data transport, resiliency, and primarily data and application control. A new operational paradigm, building on the peer-to-peer concept to create truly distributed applications, could be a solution.

In addition, some contributions addressed the European research and innovation environment for ICT more widely and the implications for projects and activities under FP8. Key points here were:

- **A focus on business models**: Research should include a strong emphasis on business model composition – in other words, on an 'internet of business actors'. Technology supporting co-innovation/composition/business-level mash-up at high speed and high quality will provide a fertile stage for increasing the number of innovations in Europe. 'Cloud economics' is another emerging field, i.e. the challenge of developing means (theory, algorithms,

software) to determine how to price a given cloud service, based on a variety of factors (e.g., cost of setting the service, supply and demand, service life expectancy and more).

- **Creation of sustainable communities and businesses around open source/freely-licensed software and hardware**: open communities can enable innovative business models and prevent vendor-lock in. Given that much innovation in software development and use comes from SMEs, a working open source ecosystem can not be overlooked. Public administration is more and more based on open software, at least in countries where this is a conscious policy. Open source is also important for the efficiency of the research system, allowing researchers to build on the achievements of others rather than start from scratch.

- **Populating Internet of Service 'islands'**: The IoS must be 'bootstrapped' at local level, from the bottom up. Europe could support research and development initiatives that target the massive generation and exposure of services. These ecosystems of interoperable, web-accessible services will federate and a global European (and worldwide) solution will progressively emerge. Their creation and continuous improvement should be supported through the creation of testbeds and living labs.

- **Public administrations as innovation champions**: Public administrations can be rallying points for innovation and must make strategic ICT decisions. Open platforms are to be preferred and stepwise improvement through the ecosystem of software and services providers should be encouraged.

- **Addressing barriers beyond research**: Beyond the research sphere, critical barriers such as high roaming charges and fragmented legislation with respect to data management, service provisioning and other aspects need to be overcome.

- **Standardisation**: In order to develop new standards, the availability of high-quality test suites and test results are extraordinarily valuable in encouraging interoperability of diverse implementations. The ability of implementers to apply test suites while developing products ensures higher quality of the implementations. The ability of players in the market to apply publicly-available test suites to products that they intend to purchase creates strong incentives for implementers to deliver interoperable implementations of specifications, and helps to address interoperability issues. The Commission should encourage the creation of public test suites for the Web platform and intended for multiple devices. It should foster the development of appropriate harnesses and frameworks to facilitate the use of those test suites in products and in the validation of those products. Given the interdependence and complexity of the evolving Web and Internet specification stacks, that is a substantive task.

Annex 1: List of Participants

ALLOTT Nick
COUPAYE Thierry
DE PANFILIS Stefano
DINI Paolo
DOMINGUE John
DUSTDAR Schahram
FIKOURAS Ioannis
GROTHOFF Christian
HORN Geir
HOSCHKA Philipp
INVERARDI Paola
JIMENEZ PERIS Ricardo
KILIAN-KEHR Roger
LECINA Gerard
OBERLE Karsten
PAVLOVA Irena
PEZUELA Clara
PISTORE Marco
PRIOL Thierry
SCHUBERT Lutz
VARVARIGOU Theodora
WOLFSTHAL Yaron

SCHAFFERS Hans – Workshop Animateur
SHARPE Mike – Workshop Rapporteur