# Longer Term Research Challenges in Service and Software Architectures and Infrastructures (SSAI)

## Report

### Expert Working Group Meeting
### Input for the Work Programme 2011 – 2012

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# Aims and Overview

This report summarizes the discussion and results from an expert working group meeting held in Stockholm (Kista), Sweden at 24th of November 2009.

The aim of the expert working group meeting was to identify relevant exploratory and longer term research challenges in core areas of service and software architectures and infrastructures (SSAI), thereby advising on the Work Programme 2011–2012. The working group has discussed how engineering and management of software-intensive systems will look like in the Future Internet in ten or more years from now. Especially, relevant impact of the convergence of the Internet of Content/Media, the Internet of Services, and the Internet of Things has been considered. As a result, the key drivers and main research challenges for long term developments of Future Internet systems have been identified.

The working group meeting was organized into four sessions. Each session started with three, short presentations by participants introducing two key research challenges each. Those presentations were followed by an open discussion, during which additional research challenges were collected. The topics of the four sessions were:

- Software Technology
- Services and the Real-World
- User Interaction and Socio-Economics
- Networks and Infrastructures

The outcomes of the expert working group meeting are presented below as a brief summary. Since many research challenges are cutting across the themes of the sessions, the summary does not follow the structure of sessions.

For further information, the participants' presentations and position papers are attached to this report.

We would like to thank the S-Cube Network of Excellence for all of the organisational support provided for this meeting.

# Research Challenges

To pave the way towards the Future Internet, major research challenges on service and software architectures and infrastructures (SSAI) for the next decade need to be faced, driven by the requirements associated with Future Internet systems such as interoperability in an open world, automatic adaptability and dynamic reconfiguration, integration of ultra-large scale, diverse and heterogeneous infrastructures, automatic search and selection of services, the involvement of end-users as producers of software, services and contents, as well as management and governance.

### *Convergence of the Internet of X*

The Future Internet can be considered as a converged "infrastructure" of the Internet of Content (IoC), Internet of Things (IoT), and the Internet of Services (IoS). From a network perspective, this infrastructure represents the evolution from a set of interconnected, uncoordinated networks towards a system of coordinated networks ("Internet of Networks" (IoN)). The convergence of the "Internet of X" requires novel abstractions and primitives for the constituents of Future Internet systems, empowering all involved stakeholders to enable the convergence along different technical layers and aspects. Challenging research questions include whether services can be the all-encompassing concept that enables this convergence, or whether other abstractions (such as generic content objects) are more suitable. In addition, capturing the unpredictable interaction modes between software components, content elements, things and people will become a significant challenge for Future Internet systems development and provisioning.

### *Composition of Converged Real-World and ICT Services*

We need highly scalable mechanisms to describe, discover and compose converged Future Internet services, including interconnection and management of their real-world parts (physical systems and workflows) as well as their ICT and software parts. This requires solutions to model and monitor real-world processes and interactions (including exceptions and governance), and practical approaches to discover, compose and manage services in order to provide reliable and trusted end-to-end utility within very large scale, dynamic and open Future Internet environments. From a software engineering perspective, there is a compelling need for developing open systems which can be adapted to new and unforeseen usage and deployment scenarios. Hiding away complexity must be coupled with – in a systematic fashion – the dynamic adaption of these software elements. Novel software modularity and composition mechanisms must be developed that are driven by the needs of the Future Internet in a world where real-world, ICT and software services will seamlessly morph into each other.

### *Engineering and Managing Converged Internet Systems*

New, fit-for-purpose metaphors and conceptualisations are required for producing and managing software-intensive services used to realise converged systems for the Future Internet. Those metaphors and conceptualisations must go far beyond the concepts currently used for mash-ups or service compositions. In addition, the cognitive distance between software models/techniques and the end-users of the digital world must be reduced enabling the transformation of (mostly) passive end-users to fully empowered producers. End-users will increasingly be enabled not only to participate as consumers but also as producers of Future Internet systems and services. To provide stakeholders with adequate support, it will be important to dif-

ferentiate between producers with different capabilities and experience. Thereby one should differentiate between the professional engineering and adaptation of complex software systems and the search, personalization, adaptation and combination of services through the end-user. Novel concepts and techniques that allow end-users acting as producers to build and configure software-intensive, converged future internet systems are needed.

### *Socio-technical Challenges*

New collaboration and agreement techniques are required to foster the joint, on-the-fly development of software, services, devices and content. This will be driven by concrete, but ad-hoc demand. Bringing together customer demand and producers able to cater for that demand requires new forms of participation and openness. This gives rise to technical challenges such as (1) interoperability mechanisms between diverse solutions (including exploiting open linked data) on timescales too fast to address only through standards, and (2) agreement approaches between various stakeholders and groups. To enable the fair and equal participation of all stakeholders in the Future Internet, socio-economic challenges, such as digital citizenship, justice and sanctions, and the balance between regulatory and technological enforcement have to be addressed.

### *Exploiting Human Resource via the Internet*

Humans will play a special role in Future Internet services provision and service composition, as by far they are the most knowledgeable and adaptable elements of any converged system. Methods are needed to accommodate humans as service providers in self-managed service environments, utilising rather than suppressing their capacity both for service delivery and service management, while supporting their decisions and actions. Key aspects may include support for trust and trustworthiness in human-initiated process management and adaptation, and support for utilising human-encapsulated domain knowledge in service composition and management.

### *Context Sensitivity and Management*

User context and process context are critical elements for the adaptation and management of Future Internet real-world, ICT and software services. Methods are required to engineer software services that can take account of this context, adapting both the implementation (software components, workflows, user interfaces, etc.) and also their management (Quality of Service metrics, key performance indicators, etc.). Aspects to be developed include context-sensitive trust and trustworthiness models, and reliability engineering to make services and software systems ‘fit for purpose’ (good enough in each context) rather than arbitrarily dependable (in any context).

### *Measuring and Assuring the Quality of Future Internet Systems*

There is a strong need for the user- and usage-specific measurement and assessment of the quality of Future Internet systems. On the one hand, traditional, product-centred quality measures as used in traditional software engineering (such as reliability or performance) are not sufficient in the open-world setting of the Future Internet to fully characterise the associated systems. On the other hand, ’perfect‘ software will become less and less feasible in the highly dynamic, changing, complex and open Future Internet (see previous challenge), and thus other system characteristics will have to be employed to differentiate Future Internet systems. Therefore, understanding how to measure, manage and assure Quality of Experience

characteristics such as trust and usability, as well as socio-economic characteristics such as value, utility and environmental impact will increasingly become important.

### *Management of Future Internet Services*

The convergence of current technologies into the Future Internet requires novel mechanisms for the management of Future Internet systems. The requirements of such management infrastructures are far beyond current management possibilities based on today's layered network architectures and will have to include mechanisms for federation, deployment, and interoperability across all types of infrastructures in the Future Internet, including Cloud infrastructures and other federated, open, and trusted platforms.