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

Report
Expert Working Group Meeting
Input for the Work Programme 2011 – 2012
Stockholm (Kista), Sweden – 24.11.2009

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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-
fferentiate 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.
Presentation Slides
The presentation slides are organized according to the agenda of the meeting.

Welcome and Overview of the Working Group Meeting
- Paolo Bresciani, EC / Klaus Pohl, Univ. Duisburg-Essen

Session: “Software Technology”
- Awais Rashid: “Software Modularity for the Emerging Digital World”
- Paola Inverardi: “Software engineering and Service Architectures & Engineering”

Session: “Services and the Real World”
- Paolo Traverso: “From Software Services to ‘Real’ Services”
- Schahram Dustdar: “Crowd-sourcing, Context, and Users”
- Dieter Fensel: “Semantic Technology in the Future Internet”

Session: “User Interaction and Socio-economics”
- Mike Surridge / Mike Boniface: “Converged Future Internet (socio-economic) Challenges”
- Neil Maiden: “User-driven Service Exploitation”
- John Domingue: “Fluid Social Services”

Session: “Networks and Infrastructures”
- Petros Daras: “Polymorphic Infrastructure and Service-aware Networks for the Convergence of IoX”
- Alex Galis: “Management of Future Internet Services”
- Thierry Priol: “Autonomic and Energy-efficient Infrastructures”
Work Programme (2011 – 2013) on Service and Software Architectures and Infrastructures (SSAI)

Welcome and overview

Paolo Bresciani / Klaus Pohl

WP 2011-2012 - where are we
Paolo Bresciani, EC

- Work is under way
- The Private-Public Partnership (PPP) will take over the most mature research areas
- Main areas will probably be the following:
  - Advanced Research for Cloud Computing
  - Advanced Software and Service Technologies
  - Advanced Research for Future Internet
- Definition of detailed problems and research issues is still ongoing
- Input from constituency is a valuable tool to help European Commission to identify the right issues
Workshop Goals
Klaus Pohl, Univ. Duisburg-Essen

- Advise on **exploratory and longer term research challenges**

- **Specifically:**
  - How will we engineer and manage service-based systems in ten or more years from now?
  - What are the research challenges raised by the convergence of
    - Internet of Services
    - Internet of Content/Media
    - Internet of Things?
Structure of the workshop

- Four topic-centred sessions

- Structure of each session
  - 3 presentations by participants (25 minutes in total)
    - 8 minutes per presentation
    - 2 key research challenges
  - open discussion and collection of additional research challenges (60 minutes)

- “Wrap-up” session at the end of the workshop
  - grouping of key research challenges
  - initial draft of white paper

The Four Sessions

- **Software Technology**
  Chair: Dieter Fensel
  Bjørn Skjellaug “Executable Models, Simulation / validation, and Service Engineering Methodologies”
  Awais Rashid “Software Modularity for the Emerging Digital World”
  Paola Inverardi “Software engineering and Service Architectures & Engineering”

- **Services and the Real World**
  Chair: Mike Surridge
  Paolo Traverso “From Software Services to ‘Real’ Services”
  Schahram Dustdar “Crowd-sourcing, Context, and Users”
  Dieter Fensel “Semantic Technology in the Future Internet”
The Four Sessions

- **User Interaction and Socio-Economics**  
  Chair: Andreas Metzger  
  Neil Maiden  “User-driven Service Exploitation”  
  John Domingue  “Fluid Social Services”  
  Mike Surridge  “Converged Future Internet (socio-economic) Challenges”

- **Networks and Infrastructures**  
  Chair: Schahram Dustdar  
  Petros Daras  “Polymorphic Infrastructure and Service-aware Networks for the Convergence of IoX”  
  Alex Galis  “Management of Future Internet Services”  
  Thierry Priol  “Autonomic and Energy-efficient Infrastructures”

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Key Challenges Put on Cards

- **We will collect the identified challenges on cards**  
  - Each presenter  
    - One research challenge per card  
    - 2 cards max. 😊  
  - During the discussion  
    - Additional key research challenges also be put on cards

- **The cards will be attached to the pinboard**  
- **We will sort the cards at the end of the workshop**
"Service Prosumers":
Dedicated metaphors, conceptualisations, techniques and methods needed for
- engineering and managing converged services
- consuming converged service by end-users, e.g. to adjust services to consumer (end-user) needs or combine them to usage-specific applications.
- managing the overlaps between the “two worlds” to deal with, e.g., QoS/QoE characteristics, variabilities, etc.
Session: “Software Technology”
Executable Models, Simulation / validation, and Service Engineering Methodologies

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A bird view on Future Internet in context of Enterprises, Business and Service Models

Vertical Compositions

Horizontal Compositions
What do we want to achieve?

Models@runtime

HUMANS
Living Labs and Evidence-based / Validation End User Service Engineering

Business Model-based End-User Interaction Model

Adaptation Models – incl. Execution
- Context of the system
- Sets of services
- Families of orchestrations
- System properties
- Adaptation goals
- Constraints
1) Reflects on the running system
2) Can be changed at runtime
3) Causally connected with the system

Simulation / Validation
Validates the adaptation model through model-checking and simulation at runtime before it is used to adapt the running system

Reasoning / Transformations
Bi-directional connection between the models and the runtime (both can dynamically evolve)

Service platform
services definitions
services discovery
orchestrations definitions
orchestrations executions
orchestrations adaptations

Hardware / networks / sensors / “Things”
To sum up:
Service Engineering Methodologies

- Challenges:
  - Polymorphism of FI and IoX → real interoperability by Ser.Eng.
  - User Empowerment → Evidence based Ser.Eng.

- Topics needed to be addressed:
  - “Super Language” approach, where XaaS is a primitive
    - where $X = \text{Models} / \text{Systems} / \text{Services} / \text{Things} / \text{Content} / \text{Infrastructure} / \text{Networks} / \text{Platforms}$, and some other $x$!!!
  - Standardization is a good approach to manage diversity and interoperability.
Software Modularity for the Emerging Digital World

Awais Rashid
Professor of Software Engineering
Lancaster University, UK

The Rise of the Digital World Phenomenon

Digital World
The World has Changed …

…the Essence of Software Hasn’t

Ultra-large Scale
Unpredictable
Adaptive
Socio-technical Nature

Software Modularity

Cross-boundary
Energy-Aware
Morphable
Key Research Challenges

• What are the software modularity and composition technologies for the digital world?
  – To enable effective fusion of IoS, IoT, SmartGrid, etc.
  – Embrace extreme diversity and heterogeneity

• How to reduce the cognitive distance between software modularity techniques and end-users in the digital world?
  – Can the digital world characteristics themselves be used as a semantics for software composition?
Continuous Evolution and *Discovery*\(^n\) for software and services

**Paola Inverardi**

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Setting the context: what we *(do not)* know *(yet!)*

- **Perpetual service life cycle**: discover—assemble—execute.

- **Open software/service architectures and dependability**: static dependability prediction vs dynamic software architecture elicitation, compositional dependability assessment, dynamic software architecture synthesis.

- **User-centrality**: human interaction, understanding users and their contexts, modeling users, domain-expert specification, characterizing user communities.
Two key challenges for developers and users

- **Continuous evolution**: compositionality, incrementality, dynamic adaptation.

- **Discovery**: learning, testing for service model (functional and non functional) elicitation, search based techniques, etc. Service selection based on behavioral and quantitative characteristics (not new).

Key enablers

- **Ontology management for software/services**: extraction and refinement, probabilistic ontologies, ontology mapping, ontology composition and evolution.

- **Decentralization and ultra-large-scale**: decentralized control, scalable service paradigms and technologies.

Session: “Services and the Real World”
From Software Services to a Future “Internet of Services”

Paolo Traverso
Bruno Kessler Foundation (FBK)
Center for Information Technology - IRST

The Claim

- A **key aspect has been underestimated** so far in the research in “Software and Services”

- Software services are software components that provide electronic access to **“real services”**

- **Characteristics** of real services are **very different** from those of the corresponding software services

- The “**Future Internet of Services**” should focus on **real services**, rather than software services.

- This requires a **research paradigm shift**
Example: Flight Service

Flight Service

Book Flight

Flight delay

Your bag is on!

Connecting flights

Time overlap

Travel to London

10:00 – 13:00
Business meeting

14:30 – 17:00
Flight Verona-Lon...

16:00 – 18:30
Flight London-Ver...

18:00 – 20:00
Movie "Batman"
A simple example

And ... what about internet?
The Future Internet of Services

While internet has a minor role for software services ... it provides a convenient infrastructure for publishing, discovering, and executing software components.

Internet is instead a key enabler for “real” services ... it offers a unique capability to ...

- communicate to the user changes in services and in context,
- allow the user to react immediately to this dynamicity

The Need for A Research Paradigmatic Shift

The Future Internet of Services requires a Research Paradigm Shift in:

**Modeling:**
- technical description of the functional & non-functional aspects
- description of how the use of real services affects consumers

**Monitoring:**
- properties related to the execution of software components
- properties of the physical environment where the real services operate
The Need for A Research Paradigmatic Shift

The Future Internet of Services requires a Research Paradigm Shift in:

**Adaptation:**
- reaction to changes in software services
- reaction to changes in the physical environment where services operate, and to users’ behaviors

**Composition:**
- a software engineering task: “task/goal driven” composition of software components
- composition based on emergent needs, constraint/opportunities of the consumers

The Future Internet of Services will lay on top of:
- The Internet of Software
- The Internet of Content
- The Internet of Things
Long Term Research Issues - FI

1. Crowd-sourcing and service-oriented computing
   - provision of virtualized human workforce by means of software service technology.

2. Context lifecycle and interaction
   - the collection of context data, including modelling, management and dissemination of the context data;
   - use of these data for offering services to individual users or communities;
   - building the context-aware environments that serve target users or communities.
3. Trust & Privacy awareness
   - All forms of trust, privacy and reputation for the Future Internet

4. Data Services
   - Quality-aware data integration and licencing via data services (Internet-scale)

5. Distributed, autonomic systems and systems of systems
   - Autonomic (or self*)-aware systems, including adaptive, self-managing, self-healing, and self-protecting systems
Service Web

Dieter Fensel

The Web of documents!

More than a 2 billion users
more than 50 billion pages
More than 1000 billion pages

Static

WWW
URI, HTML, HTTP
Web Service Discovery vs. Service Discovery

Goal: buy a travel ticket from Vienna to Berlin

Web service: sells train tickets for trips within Europe

Reasoning

Europe

Vienna & Berlin

Match!

Travel Ticket

Train Ticket

Data Mediation as part of Web Service Discovery

Instance df
  hasName hasValue “Dieter”
  hasSurname hasValue “Fensel”
  hasTelephone hasValue “+435121234567”
  hasEmail hasValue “dieter.fensel@sti2.at”

Instance mediated(df, Person)
  hasChristianName hasValue “Dieter”
  hasSurname hasValue “Fensel”
  hasContacts hasValue mediated(a_m, contactDetails)

instance mediated(df, contactDetails)
  telephone hasValue “+435121234567”
  email hasValue “dieter.fensel@sti2.at”

ontology o1
  concept Person
    hasName ofType _string
    hasSurname ofType _string
    hasTelephone ofType _string
    hasEmail ofType _string

ontology o2
  concept Person
    hasChristianName ofType _string
    hasSurname ofType _string
    hasContacts ofType contactDetails

concept contactDetails
  telephone ofType_string
  email ofType_string
Web of Data

- Linked Open Data is an initiative to interlink open data sources via dereferenceable URI’s on the Web
  - Open: Publicly available data sets that are accessible to everyone
  - Interlinked: Datasets have references to one another allowing them to be used together
- More than 100 Billion statements providing data and meta data
- Will grow faster than the web of documents!
Linked Open Data

[Domingue et al., 2009]

Composition and Instantiation as part of Web Service Discovery
Linked Open Data
Session: “User Interaction and Socio-economics”
Converged Future Internet Challenges

Mike Surridge, Mike Boniface
SSAI Expert Working Group Meeting
24 Nov 2009, Stockholm

[v2 including speakers notes]

Future Internet Heterogeneity
Connectivity, Access, Interoperability

- Infrastructure?
- Engineering?
- Standards?
Future Internet Heterogeneity
Connectivity, Access, Interoperability

- Future Internet infrastructure
  - very heterogeneous
  - rapidly evolving
- Conventional standardisation
  - addresses specific areas of consensus
  - very slow to formalise and converge
- Future Internet interoperability engineering
  - cannot depend on slowly evolving and narrow standards
  - what are the correct interoperability paradigms

Future Internet Resources
Cash → Currency → (Market) Value
Future Internet Resources

Cash → Currency → (Market) Value

• How should we quantify FI applications
  – heterogeneous resources (unlike von Neumann resources)
  – diverse impact (business, societal, personal)?
• How can we add and demonstrate value
  – more efficient use of energy?
  – human rights for service operators?
  – quality of life for service consumers?
• What are appropriate metrics / benchmarks
  – balancing personal and societal metrics?
  – describing resource competitiveness?
  – differentiating between products and services?

Future Internet Systems

Emergent, Uncoordinated/Competitive, Multi-stakeholder Behaviour

End user

System 1

System 2

System 3

Resource-driven direct federation

User-driven indirect federation
Future Internet Systems
Emergent, Uncoordinated/Competitive, Multi-stakeholder Behaviour

- Emergent FI systems will have
  - multiple stakeholders whose actions can change the system
  - no stakeholder coordination or overall control
- What does this mean for system engineers
  - need for novel design/analysis paradigms?
  - need for novel lifecycle engineering paradigms?
- What about socio-economic implications
  - can emergent systems have responsible ‘owners’?
  - are hackers just another type of stakeholder?
  - should systems be designed with rules of membership?
  - can we avoid/control/manage creating emergent critical infrastructure?
Future Internet Openness
Economic Power, Fairness and Governance in the Digital Economy

• Open = accessible to all on fair terms
• How do we define and enforce ‘fairness’
  – technology: e.g. privacy enhancing technology?
  – architecture: e.g. peer-to-peer discovery?
  – Internet governance beyond naming?
• How can we prevent people/organisations/states
  – controlling technology / standards?
  – controlling (too much) personal data?
• Do we need new social contexts, e.g.
  – new crimes against Future Internet standards?
  – new models of digital citizenship, digital justice, digital jails?
The service consumer in control: An agenda for user-driven service exploitation

Professor Neil Maiden

Service Consumers are Designers
Right here, right now

Reusing apps invoking services
Directly compose apps
One Constraint and One Trend

End-user development

Service providers

End-user development is elusive
Most mash-up techniques cannot work
End-user development will continue to need designer input
But how?

More providers than expected
Numbers will increase
Can provide the design input needed…

Genuine Collaborative Development

Service consumers and providers
– Spontaneous, short-term agile partnerships

Virtual marketplaces of services, and services about services
Corporate and open?
Research Agenda Implications

Seamless collaboration
- For requesting and offering services
- At design-time and at run-time
- Interoperable with future social media technologies

New means of communicating services
- Precise but simple and quick to express

New forms of partnership
- Communities of online support for service users
- Enshrine in new forms of agreement?
November 4, 2009 7:51 AM PST

Apple reaches 100,000 apps, 2 billion downloads

by Jim Dalrymple

More than 100,000 apps are now available for download from Apple's App Store, making it the largest such retailer in the world.

The App Store **launched in July 2008 with just 500 applications.** The store is now available in 77 countries, which has contributed to what Apple said Wednesday is well over 2 billion downloads.

Apps from the App Store work with both the **iPhone** and **iPod Touch.**

When **introducing its new iPod Touch** in September, Apple positioned the device as a superior gaming platform to Sony's PSP or Nintendo DS. Apple said its rivals charged too much for games and didn’t offer enough selection. At the time, Apple had more than 21,000 game titles in the App Store, while Nintendo had 3,600 titles and Sony had 600.
Facebook applications

- 33,000 Facebook Applications
- 400,000 registered developers

Fluid Social Services

- Migration across networks, devices and software platforms
- Adaptability to preferences, constraints and task of individual user
- Communal adaptability (culture and norms)
- Coalesce/aggregate and interoperate
  - Ensuring privacy, security and trust
- Broadly usable and manageable by users and communities
Capturing ‘Service Life’

- Comprehensive representation of all aspects of a service throughout its life
- Service Creation
  - Developer, capabilities, intended usage
- Service Provision and Usage
  - Where has the service been deployed, quality, monitoring
- Service Maintenance
  - Who has adapted the service and how
Summary
Thanks
Session: “Networks and Infrastructures”
Polymorphic Infrastructure and Service-aware Networks for the Convergence of IoX

Petros Daras
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Work Programme (2011 – 2013) on Service and Software Architectures and Infrastructures (SSAI)

Background

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CCIACCIA

Infrastructure

Content/Service Aware

Virtual Clouds

Distributed Content/Services Aware Overlay/Cloud

Information/Service Overlay/Cloud

Content

Server 1

1

Prosumer

Applications

Overlay/Cloud

Applications

Overlay/Cloud

Information/Service

Overlay/Cloud

Distributed Content/Services Aware Overlay/Cloud

Infrastructure

Sensors

Network

Mobile

Network

PAN

Network

Applications will use efficiently the services, the information and the media/content provided by the content-centric architecture and offer novel media experiences to the users.

Content-Aware Network Nodes (e.g. core routers, edge routers, home gateways, terminal devices) will be located at this overlay. These nodes will have the intelligence to filter the content and Web services that flow through them or identify streaming sessions and traffic.

It will consist of intelligent nodes or servers that have a distributed knowledge of both the content/web-service location/caching and the (mobile) network instantiation/conditions. These nodes may vary from unreliable peers in a next-P2P topology to secure corporate routers or even data centres in distributed carrier-grade cloud networks.

It will consist of nodes with limited functionality and intelligence. Users are connected to the infrastructure (Prosumers). Content will be routed, assuming basic quality requirements and if possible cached to some degree in this layer.

*Towards a Content-Centric Internet, FIA Stockholm 2009 (Poster Session)
**Background – Content Objects**

- **Media** can be anything that a human can perceive/experience with his/her senses (a speaking person, a violin, a tear on your cheek, etc.)

- **Rules** can refer to the way an object is treated and manipulated by other objects or the environment (discovered, retrieved, casted, adapted, delivered, transformed, presented).

- **Behaviour** can refer to the way the object affects other objects of the environment.

- **Relations** between an object with other objects can refer to time, space, synchronisation issues.

- **Characteristics** meaningfully describe the object.

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**Research Challenge 1**

- Plethora of IoX Architectures: NEXOF, MANA, SoA4All, SLA@SOI, MASTER, SEA, COAST, SECSE, SHAPE, FAST, IRMOS, OASIS, DONA, SIENA, PARC, OPENCDN, OSCAR, AKAMAI, SODA, AMIGO, AutoI, ...

- Evolution from communication-centric, content-centric, service-centric, resource-centric isolated infrastructures to a polymorphic infrastructure, where the boundaries between *-centric systems are changing and blending and where the emphasis is on the integration, interrelationships and interworking of the architectural elements through new service-based interfaces and converged FI Architectures.
Research Challenge 2

Service-aware networks & service-aware content including:

- On the fly, just-in-time content creation and delivery with prosumers’ involvement and control -> a paradigm shift towards content-and-human centric networking as social, content and service networks;
- Fulfillment of business and other service characteristics such as Quality of Service (QoS) and Service Level Agreements (SLA) -> a paradigm shift towards more intelligence within the network;
- Composition and decomposition on demand of control and network domains -> a paradigm shift towards cooperative managed networks with increased level of self-manageability;
- Interrelation and unification of the communication, storage, content and computation substrata -> a paradigm shift from capacity concerns towards increased and flexible capability with operation control.

More Open Issues

- Content could be stored/cached closer to the end users
- Routers could identify/analyse what content is flowing through them and are able to replicate it.
- Network could dynamically identify what is the best end-to-end path.
- Content could be interactively adapted to the user/terminal

- Network structure complexity vs. engineering design
- Simplicity, scaling vs. delivering quality,
- Response time, efficiency vs. user friendliness
- Services and content location vs. user and network mobility
- Societal aspects vs. trust and security
Research Challenges
Management of Future Internet Services

Presented by
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Expert Working Group Meeting 24.11.09, Stockholm

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Producer/consumer facing services

Intelligent artifacts
Producers / Consumers
Things
Applications & Services

Orchestration Systems

Management Systems & Platforms
Self-management, Service-awareness, Service Enablement

Virtualization Systems
Programmability / System dynamics
Virtual Resources (pools of resources)

Resources
1. Fixed and wireless transport;
2. Forwarding;
3. Computation;
4. Storage;
5. Content

δ - Service Interfaces
β - Service Interfaces
α - Service Interfaces
1. Hourglass model / layering works well in creating a data plane without the management mechanisms for different prosumers to influence or control what is inside the networks and how to deploy services; it has fade away and it needs to be berried; it would be replaced with resources centric services and prosumers centric services.

New architectural models applicable to FI are needed. They should provide:

- Approaches for mapping programming interfaces, operations, and interoperability of services and networks over any given resource (networking, computation, storage, content) technology.
- New control infrastructure, incorporating both management and service enablement functionality while keeping the current IP mainly for communications.
- Inter-related and unified communication, storage, content, and computation sub-strata of FI.

The development (refinement and validation) of such FI architectural models is one of the key research challenges identified.
2. **System Management research goal:** develop ambitious converged research in system management and integrated implementations

Currently SSAI Internet management is characterized by

- Lack of status and fitness Internet information, a voluminous, ambiguous, inconsistent and low validity period data; imprecise control actions whose impact is hard to predict.
- Concealed functional and operational dependencies are common in systems
- Fragmented approaches for managing networks, services and system resources (networking, computation, storage, content resources)
- Lack of optimality in the utilisation of system resources and virtual resources
- Relative high costs for management (i.e. up to 80% of the life-cycle costs of systems)

Research is needed to assess and manage the complexity and life-cycle costs for FI systems and their operations. Increase level of in-system self-management functionality is one of the key research challenges identified

Embedded and inherent management functionality in most systems in the FI, such as in-infrastructure management, in-service management.

- Mechanisms for dynamic deployment on-the-fly of new management functionality without running interruption of any systems. The operations required are: Plug-and-Play, Unplug-and-Play, and (re)programmability of the forwarding and control planes.
- Mechanisms for dynamic deployment of measuring and monitoring probes for service and network behaviours, including traffic.
- Mechanisms for distribution and use of monitoring probes information; configurable and programmable distributed real-time monitoring of all subsystems.
- Mechanisms for conflict and integrity-issues detection and resolution across multiple self-management functions and policies.
- Mechanisms for intelligent and efficient decision-making where there are multiple participating entities.
- Mechanisms for self-adaptation of management functions.

3. **System Oriented Cloud Infrastructures research goal:** rethink and redesign computing, networking, storage, resource and content planetary-scale infrastructures.

Research is needed in

- Mechanisms for mapping and fast deployment of applications to cloud infrastructures
- Resilience mechanisms at every level of operations in the clouds
- Federation and interoperability mechanisms between clouds
- Increasing degree of control and management of the infrastructures;
- Inherent in-system management functionality, specifically self-management functionality; increased level of self service management capabilities in cloud infrastructures
- Mechanisms for controlling workflow for all infrastructure systems ensuring integrity and well run of all operations including: bootstrapping, initialisation, dynamic reconfiguration, federation, adaptation and contextualisation, optimisation, organisation, and closing down of system components.
- Mechanisms for allowing conflicting interests and operations
- Mechanisms for orchestration of trust, security, and privacy for service resources, and mechanisms to protect distributed data
Thank you
Autonomic and Energy-efficient Infrastructures

Thierry Priol, INRIA

Why autonomic infrastructures?
Research challenges

- Internet of Services should follow the same design principles than for the Internet
  - Distributed design and decentralized control
  - Scalability

- New paradigms to design autonomic systems have to be investigated

- Distributed architectures instead of centralized ones
  - Is the datacenter approach the right and only one ???

- Distributed execution of workflows

- Autonomic service adaptation

Why energy efficient infrastructures ?

- Energy / Green-IT
  - In 25 years from now, Internet will consume the same quantity of energy than the humans today
  - In 2010-2011, energy consumption of servers and data centers is estimated to 100 billions KWh (2.5 percent of all U.S. consumption)
  - A Google request costs 150 Watt !
  - Humans have to be ready to fight against computers to get access to the energy...

- It is not a mater of designing new low power hardware... it is necessary but not sufficient

- Software can help reducing power consumption
  - Combination of distributed systems mechanisms and software engineering techniques have the potential to reduce energy consumption
    - It should be considered as a non-functional property like performance, reliability, ...
    - It should also be considered within a QoS and even within a SLA
Research challenges

• Service adaptation to reduce power consumption of mobile devices

• Energy-aware service provisioning for clusters and large data centers that host services
  • It make the optimization problem even more complex (NP-hard)
  • New heuristics for resource allocation, scheduling, load balancing

• Need for a better integration/communication between hosted services and the infrastructure

• How to estimate the energy consumption of a software service?
Position Papers
(in alphabetical order)
The Future Internet is considered as a convergence of the physical and digital worlds, into a completely new reality, where richer real-time and mobile communication modalities will arise. Services will play a key role as building blocks, providing abstraction and virtualisation, not just of data storage, processing and networks, but also of devices, connectivity, physical goods and applications, content and associated intellectual property, and even physical presence. Systems will be dynamically composed from these building blocks, operating on federated, open and trusted (F-O-T) platforms, where services and software will provide the required “glue” between the systems’ building blocks. The European approach to the Future Internet considers it as an evolution of current Internet into a complete ecosystem, which constitutes the results of the convergence between the “Internet of Services” (IoS), the “Internet of Things” (IoT), and the “Internet of Content” (IoC). The Future Internet will thus be able to interconnect and handle an ever increasing number and variety of networked applications, software & business services, edge devices, networks and environments needed in a modern society. Towards this convergence the following aspects/challenges should be taken into account:

- Evolution from communication-centric, content-centric, service-centric, resource-centric isolated infrastructures to a polymorphic infrastructure, where the boundaries between *-centric systems are changing and blending and where the emphasis is on the integration, interrelationships and interworking of the architectural elements through new service-based interfaces and converged Future Internet Architectures.

- Service-aware networks & service-aware content including: Delivery of content and service logic with consumers’ involvement and control - a paradigm shift towards content-and-human centric networking as social, content and service networks; Fulfilment of business and other service characteristics such as Quality of Service (QoS) and Service Level Agreements (SLA) - a paradigm shift towards more intelligence within the network; Optimisation of the network resources during the service delivery - a paradigm shift towards communication resources as managed shared commodities and utilities; Composition and decomposition on demand of control and network domains – a paradigm shift towards cooperative managed networks with increase level of self-manageability; Interrelation and unification of the communication, storage, content and computation substrata – a paradigm shift from capacity concerns towards increased and flexible capability with operation control.

- Consideration of the socio-economics of sustainability, innovation, and growth in the context of 'glocalisation', 'coopetition', and protectionism (e.g. IPR, Copyright) vs. openness (e.g., Creative Commons, Open Access).

- The Future Internet should formulate consistent and usable security, able to meet diverse requirements, and keep pace with the struggle for dominance between network operators, content owners, services and things (including people).

Future Internet pillars expert groups and initiatives propose new architectures and claim the right that theirs will govern the Internet being eventually the core of the Future Internet. This scenario would hinder further industrial growth and innovation, limit business opportunities, and confuse end-users. From a functional point of view the different perspectives are emphasising different aspects rather than expressing opposing statements, i.e. they are not exclusive ones, but complementary and should be merged into an all-encompassing perspective to make the right design choices for the Future Internet.
**John Domingue, The Open University, UK**

**Introduction**

We are witnessing the emergence of a new type of service. This is driven by:

- The convergence of the Media/Telecoms/Software and Service Industries.
- The fact that the dominant platform for connecting to the Internet soon will be handheld – a descendant of the Apple iPhone or Google Android.
- The impact of Web 2.0 principles on the service world. Services will be made for and used by social communities and the distinction between service provider and service consumer will become blurred.

The above will lead to a number of research challenges which include:

**Service Fluidity and Sociability**

Services will need to become fluid and sociable.

- Able to seamlessly migrate across networks, devices and software platforms.
- Able to adapt to the preferences and constraints of an individual user.
- Able to adapt to the culture of a social community (e.g. an ethical community may have constraints on types of service providers).
- Able to coalesce/aggregate and interoperate with other services whilst ensuring and preserving security, privacy and trust considerations.
- Be usable and manageable by the broadest range of users and communities. This will include ease-of-control and ability to be monitored.

**Capturing ‘Service Life’**

Scalable and usable semantic representations will be required to comprehensively capture ‘service life’ in a broad fashion to support the above. Relevant aspects to be covered here include:

- Service Creation – details on the service developer (individual/organisation/community), capabilities, intended usage (e.g. particular application domain, target user).
- Service Provision and Usage – where the service has been deployed, the contexts of usage including quality aspects and service monitoring.
- Service Maintenance – how the service is adapted either manually or automatically to new contexts of use.

The emergence of fluid social services will see services become ubiquitous within the emerging Internet of Services and a key component of the Future Internet architecture.
Crowd-sourcing and service-oriented computing

Recent developments of Internet technologies, that increase content quality and user participation, have fostered the virtualization of manpower. The so-called Web 2.0 gave rise to the phenomenon of crowd-sourcing. Organizational work is digitally represented and delegated to the vast user community of the Web. Specific solutions to delegate innovative work are already existing, e.g. in the case of Wikipedia. Current approaches extend ideas of crowd-sourcing towards generic solutions for highly efficient production processes. Amazon first addressed this issue with its Web marketplace Mturk (www.mturk.com), on which organizations can publish open calls for Human Intelligence Tasks (HITs). Any Internet user that meets certain skill criteria might act as a “virtual human resource” and provide HITs as individual Web services. Such platforms make first steps towards fine-grained organizational coordination of a virtually unlimited pool of temporary workforce as resources for highly optimized and automated work processes that might be changed and scaled in so far unthinkable magnitudes. The vision is that the next generation of crowd-sourcing is integrated into service-oriented computing platforms, enabling the provision of virtualized human workforce by means of software service technology.

Context lifecycle and interaction

We can expect that the provisioning of context-aware services and experiences will be the norm in the Future Internet. 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 (Federated, Open, Trusted) 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.

Trust- 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.

**Trust - and privacy-aware systems that record events and the interaction between a user and the environment**

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.

**Data Services**

Data and service integration has been one of the key topics in recent research and several approaches have been developed. However, important quality aspects of data integration have been largely ignored, while such aspects are critical in Internet-scale, multi-organizational data integration. In addition to the actual data provided by data sources, the consumers also need meta-information describing the data which allows them to assess the usefulness of the data and to automatically process and combine this data with data from other sources. Therefore, advocate the use of quality-aware data services for Internet-scale data integration. In future research, we need to identify requirements and the main research challenges on the way to the realization of such services. In particular, key SOA-concepts like quality of service and licensing have to be extended and combined with data quality and data licensing. This not only affects the service interface itself but also the actual data network underlying the data service as well as the data service selection and service combination layer which may be built on top of quality-aware data services.

**Distributed, autonomic systems and systems of systems**

- 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 trust and resilience).
Dieter Fensel, STI Innsbruck, Austria

Thesis - The Future Internet will provide

- (1) world wide access to services
- (2) a platform where the underlying network, hardware, and software infrastructure are transparent.

This will have two major technical implications:

**Implication 1 – Who will consume a service and how?**

Services need to be designed, implemented and provided in a manner where they are usable in unforeseen usage scenarios.

**Implication 2 – Who will provide a service and how?**

Services need to be designed, implemented and provided in ways where they can be deployed and executed within a variety of unforeseen network, hardware, and software infrastructures.

In conclusion, services must be designed and implemented in a fashion which embeds extreme flexibility into their consumption and provision and also allows dynamic combination with other service offers. Dynamically adapting and combining services can be carried out manually, semi-automatically, or automatically, however, a manual approach will not scale and automatic methods will not work.

In conclusion, we are left with one final hope. We need pragmatic approaches towards formal semantics that provide partial descriptions of resources, services, and requirements, transforming the computer into a partial matchmaking mechanism brokering between service offers and service requests. Humans are not excluded in this scenario, rather computers should act as more than simple web page renderers as currently envisioned within Web 1.0 and Web 2.0 settings. *Semantic Technology is the fascinating research challenge concerned with how far a semantics of infrastructure, software, and data can be captured in a machine processable fashion that it is both feasible and useful.* Or spoken in a nutshell:

*The Future Internet is much more than just Semantic Technology, however, it will neither work nor scale without it!*

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1 Instead of building monolithic applications, independent services will be combined dynamically to achieve certain goals.
The following recommendations are made towards realising the convergence of Future Internet and the needed research and development plans of Service and Software Architecture and Infrastructure (SSAI) and the Workprogram 2011-13

**System Architectural research goal**

Develop a set of coherent system convergence architectural alternatives and implement them.

The current and well-established Internet architecture is commonly presented as an hourglass shape. It covers the data plane functionality of the Internet, but omits the capabilities and the mechanisms needed for the control or management or interoperability of systems. Future Internet (FI) is a system of interoperable and interconnected systems. New architectural models applicable to FI are needed. They should provide:

- Approaches for mapping programming interfaces, operations, and interoperability of services and networks over any given resource (networking, computation, storage, content) technology.
- New control infrastructure, incorporating both management and service enablement functionality while keeping the current IP mainly for communications.
- Inter-related and unified communication, storage, content, and computation sub-strata of FI.

The development (refinement and validation) of such FI architectural models [1] is one of the key research challenges identified.

**System Management research goal**

Develop ambitious converged research in system management and integrated implementations. Currently Internet management is characterized by

- Lack of status and fitness Internet information, a voluminous, ambiguous, inconsistent and low validity period data; imprecise control actions whose impact is hard to predict.
- Concealed functional and operational dependencies are common in systems
- Fragmented approaches for managing networks, services and system resources (networking, computation, storage, content resources)
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Research is needed to assess and manage the complexity and life-cycle costs for FI systems and their operations. Increase level of in-system self-management functionality [1] is one of the key research challenges identified.

**System Oriented Cloud Infrastructures research goal**

Rethink and redesign computing, networking, storage, resource and content planetary-scale infrastructures.

Research [1] is needed in

- Mechanisms for mapping and fast deployment of applications to cloud infrastructures
- Resilience mechanisms at every level of operations in the clouds
• Federation and interoperability mechanisms between clouds
• Increasing degree of control and management of the infrastructures;
• Inherent in-system management functionality, specifically self-management functionality; increased level of self service management capabilities in cloud infrastructures
• Mechanisms for controlling workflow for all infrastructure systems ensuring integrity and well run of all operations including: bootstrapping, initialisation, dynamic reconfiguration, federation, adaptation and contextualisation, optimisation, organisation, and closing down of system components.
• Mechanisms for allowing conflicting interests and operations
• Mechanisms for orchestration of trust, security, and privacy for service resources, and mechanisms to protect distributed data
• Mechanisms for dynamic deployment of measuring and monitoring probes for service component behaviours in clouds. Adaptive SLA-aware infrastructures. Use of monitoring services in support of the self-management functionality.

References:
The following list of topics identifies the challenges to be faced to overcome the limitations of the current software and services technologies developed in the domains of software engineering, service architectures & engineering, service infrastructures, adaptive service-based systems, software & service quality.

- **Perpetual service life cycle**: discover—assemble—execute.
- **Open software/service architectures and dependability**: static dependability prediction vs dynamic software architecture elicitation, compositional dependability assessment, dynamic software architecture synthesis.
- **User-centrality**: human interaction, understanding users and their contexts, modelling users, domain-expert specification, characterizing user communities.
- **Continuous evolution**: compositionality, incrementality, dynamic adaptation.
- **Discovery**: learning, testing for service model (functional and non functional) elicitation. Service selection based on behavioural and quantitative characteristics.
- **Ontology management for services**: extraction and refinement, probabilistic ontologies, ontology mapping, ontology composition and evolution.
- **Decentralization and ultra-large-scale**: decentralized control, scalable service paradigms and technologies.
Neil Maiden, CITY University London, UK

The service consumer in control: an agenda for user-driven service exploitation

Future service-centric systems will be requested, developed and invoked by end-user service consumers without involvement of systems developers and integrators. This future vision goes beyond service mash-ups to full control over the procurement, management, sharing and use of services, and creates a new research agenda to enable it to happen.
This paper is focusing on some scientific challenges dealing with the infrastructure.

New and innovative services available through the Internet have attracted the attention of a large public audience as well as the industry. We are thus more and more dependants of such services for our day-to-day life (Google Apps, Twitter, to name a few, social networks, ..). Although the Internet, mainly its communication infrastructure, has been designed to avoid centralization as much as possible and to cope with failures (naming service, dynamic routing), the service paradigm, and its supported infrastructure, tends today to an excessive centralization. This increases the probability of having failures that could have a damaging impact both on people and the economy. This is not just a prediction, it is happening today! Amazon Web services suffered a major outage in February 2008 and in June 200, the Google Gmail service went down for 4 hours last February, Salesforce suffered an outage for nearly a day. Moreover, centralization is just a boon to hackers: twitter, hosted by Google datacentres, was hacked and confidential documents were posted online. Recent research studies by MIT & UCSD researchers have shown that datacentres, those offering the Infrastructure as a service thanks to virtualization, are introducing new vulnerabilities. If the Internet of Services is one of the pillars of the Future of Internet, will it make sense to stay with such a situation? As the number of datacentres being deployed is increasing very quickly, it is expected that outages will happen more and more and new vulnerabilities will be discovered. It is thus important to overcome the situation by embedding autonomic behaviours within the infrastructure, by fostering new strategies and new paradigms that do not require centralization but a more peer-to-peer or decentralized approach and by managing resources in datacentres that will make them immune from attackers.

Another important challenge is power consumption. The next ten years will see an escalation in electricity consumption to support the communication infrastructure, to store and to process data using large-scale data centres. In 2020, the annual electricity consumption of ICT will reach 400 TWh. In 2035, Internet will consume as much as electricity as humans consumes today. If nothing is done, humans will compete against computers to get access to the electricity. This is not only an infrastructure matter, but the applications themselves should be energy-aware. The applications should better communicate with the infrastructure to have them energy-aware with self-adaptive energy efficient networks and computing resource management.
Software Modularity for the Emerging Digital World

The Internet has become pervasive in our day-to-day lives through wide availability of broadband as well as its ubiquity due to the proliferation of mobile devices. This ubiquitous access to the Internet coupled with innovations such as social networking and Web 2.0 has given rise to the digital world phenomenon. Social networking sites such as Facebook, Myspace and Twitter, virtual worlds such as SecondLife and massively multi-player online games such as The World of Warcraft have blurred the boundary between the online world and the physical world. We live in an always-connected world, with an increasingly larger number of services accessible online. We conduct business online, watch our favourite television programmes, engage in interaction with friends and family and make new social contacts. On the one hand, this emerging digital world phenomenon improves accessibility of services and communal interaction, but on the other hand, it also poses a number of new challenges in terms of how we build modular software and compose such software to deliver effective services.

Even though the purpose of software has evolved – in fact, transformed completely, the very essence of software has not changed. We still build software using the so-called generalised procedure approach [1], which does not effectively scale hence compounding complexity. This is not to say the established principles of software modularity [2] and separation of concerns [3] that have served us well over the decades ought to be discarded. However, the unprecedented large-scale, unpredictable, adaptive and socio-technical nature of the digital world thus presents both new challenges and opportunities for innovation that lead us to reconsider the fundamental basis of software modularity and associated composition techniques.

In the digital world, software modules do not operate within a single administrative, organisational or platform boundary. They must also exhibit the ability to morph themselves to rapidly changing environments, for instance, to be energy-aware or to reduce the cognitive overhead experienced by the end user. As such established principles need to be revised or even redefined to enable software and service engineering methodologies that are better aligned with the digital world phenomenon.

There are a number of key research questions in this regard, the most prominent being as follows:

- What type of software modularity and composition mechanisms are needed to address key characteristics emerging from the very nature of the digital world, for instance, modules able to service cross-boundary contexts, modules that are energy-aware, and so on.
- What mechanisms can be employed to deliver software modularity that reduces the cognitive distance between the end-user and the modular representation of the software?
- Can the above digital world characteristics driving the reconsideration of the essential nature of software modularity can themselves be used to provide a semantic basis for composing software modules that form the basis of services in the digital world?

References:


**Bjørn Skjellaug, SINTEF ICT, Norway**

**Introduction**

The area of Services and Software Architecture and Infrastructures (SSAI), i.e., Objective 1.2 in the current Work Programme, is a vital foundation for the Future Internet. It is important to emphasise the need for building on top of this foundation also for other research objectives related to the Future Internet.

Below we also address some important future research topics for the SSAI work programme.

**Important future research topics**

*IoS as a foundation for IoT, IoC and IoP – and Security/Trust*

The Internet of Services (IoS) should be the foundation for an integrated Future Internet where important areas like Internet of Things (IoT), Internet of Content (IoC) and Internet of People (IoP) is build on top of, and extended from/embedded in the Internet of Services (IoS). Also the security and trust technologies should be created with a firm foundation in IoS. As these topics today are addressed by separate research objectives from 1.2 – it should be a mandate for the future for these objectives (in particular 1.3, 1.4 and 1.5, and some subtopics for 1.1) that they shall build on the IoS foundation from the Objective 1.2 area.

*Executable models and models at runtime for managing open service systems*

Multi view perspective and multi stakeholder support with weaving/integration of models from context models to executable system models. Specification of suitable conceptualisations for multiple viewpoints based on domain specific executable languages customised for different kinds of usage as well as users and their variety of perspectives.

*Multi stakeholders User Empowerment*

Future Internet economy will depend heavily on the role of, and the trust and experience of the end users and other stakeholders. That is, the more dependent the users are on the use of Internet based services, the more expectation the users will have that the services in use meets the demands of the user. This will be related to how the services are designed and how they look like, to what extent they can be trusted, how easy the users may change and deploy new service compositions, and to what degree this is supported by run-time adaptation and flexibility to fulfil users own preferences to perform their own tasks. There is a similar need to empower other stakeholders tools for SSAI being from a business perspective or an operational perspective.

*Experimental and empirical evidence of QoS and QoE for SSAI.*

Novel results should be supported with more rigorous methods to actually show their quality, and prove their QoS and QoE by empirical evidence, ideally coupled with an experimental facility to actually get the true users / stakeholders in the loop.

*New design and modelling – through interactive simulation and validation*

In several other engineering disciplines behaviour simulations, visualisations and virtualised reality models of complex artefact are used to ensure consistence with requirements. Software and service systems are also very complex. Interaction with 3-4 D models where the designer can interact with some model parts of the system in more detail and only have a course grained picture of the rest, move around in the model as in a virtual reality like scenario, execute part of the model on demand, etc.

*Future Service engineering methodologies*
To build complex, adaptive, flexible, trustworthy, and secure service, the engineering methodology (process, procedures, methods and techniques) is a key issue. Traditional software engineering methodologies need to evolve to cope with the increased complexities and new issues coming with the Future Internet, and new processes, procedures, methods and techniques need to be created to deal with the open models and multi stakeholder perspectives that are required. In particular new conceptualisations of the concepts in IoS, IoT, IoC and IoP needs to be formulated and introduced as basic for new software and service engineering principles and patterns for the Future Internet.
Converged Future Internet (FI) properties

The converged Future Internet should exhibit the following properties:

- architectural and technological heterogeneity: involving a wide range of persistent entities (devices and stored data) linked by more ephemeral ICT artefacts (workflows, services, etc);
- openness: providing platforms with which any individual or business actor can engage, and which can be federated in a trustworthy fashion;

These twin attributes cannot be provided using existing technologies and solutions and in the current cultural and socio-economic context.

Heterogeneity challenges

The architectural and technological heterogeneity will provide several research challenges:

- what programming models can be used with such a diverse and distributed system of systems – i.e. what is the ‘lambda calculus’ of the FI?
- how can resources (and the consumption of resources) be modelled and managed within these programming models – i.e. what is the ‘von Neumann model’ of FI computational resources?
- how can virtualisation and SOA be used effectively in the FI, given that the primary entities of interest are persistent entities, not services, messages and network endpoints?
- what standards are needed to ensure interoperability in the FI?

Finally, how strongly should different elements of the FI be coupled in solving these challenges, e.g. does it make sense to separately tackle issues in the IoT, IoC, IoS and FI networks, or is it a waste of time if we don’t address all aspects together?

Openness challenges

The property of openness is needed to allow arbitrary stakeholders to engage in FI applications, expressing different motivations and seeking different outcomes. This poses additional research challenges:

- how can FI architectures and platforms by truly ‘open’, by addressing technological challenges in such a way that users of all kinds can still exercise freedom of choice?
- what interoperability challenges will need to be addressed at application level, affecting persistence and process aspects rather than protocols?
- what technical (or other) measures are needed to ensure that businesses and citizens can trust the FI and be accountable when using it to conduct their professional and personal lives?
- how can the FI support and manage disagreement between FI application stakeholders?
- how can FI system engineers and users deal with the fact that many (possibly most) applications will emerge as ‘one off’ compositions driven by the (uncoordinated) actions of multiple, independent stakeholders?
Finally, is the Semantic Web as currently envisaged sufficiently powerful yet also understandable and manageable by users to deliver FI openness? If not, what role should it play?

**Socio-economic challenges**

These issues of heterogeneity and openness cannot be addressed only through technical means. The socio-economic implications of a pervasive convergent FI will also need to be addressed, e.g.

- environmental impact of the FI
- impact of (and on) globalisation trends
- innovative business models (ways to create value) and business roles (ways to contribute to or exploit that value)
- emergence of new markets
- impact on (and of) social and cultural values and value systems
- social inclusiveness
- impact on personal privacy and freedom
- ownership and accountability of FI-based assets
- impact of the FI on government and citizenship (of nation states)
- governance of the FI itself beyond naming

For some FI challenges (at least in specific areas) socio-economic innovation may be the most important development to address FI challenges.
Paolo Traverso, Bruno Kessler Foundation (FBK), Italy

From Software Services to “Real” Services

Service Oriented Computing is based on the idea that software applications can be constructed by composing and configuring “software services”, i.e., software utilities that can be used but that are not necessarily owned by consumers. This idea has raised novel research challenges and researchers have proposed some interesting solutions. However, a key aspect has been dramatically underestimated so far, namely the fact that - in most cases - software services are software components that provide electronic access to “real services” (e.g., a software service for travel booking allows us to access the actual service behind it, namely “the possibility of travelling”). Some main characteristics of real services are often very different from those of the corresponding software services, such as their duration, their accessibility, their constraints and conflicts, and their connection with the real world, which makes them highly dynamic. As a consequence, the research challenges are radically different.

A Research Paradigmatic Shift

The concepts used to describe “real” services and the approaches for “composing and configuring” them are radically different from those proposed for software services.

- Modelling should move from a technical description of the functional and non-functional aspects of services (interfaces, behaviour, quality, security, and so on) to the description of how the use of real services affects their consumers.

- Monitoring should move from properties related to the execution of software components to properties of the physical environment where the real services operate.

- Adaptation should move from reaction to changes in software services to reaction to changes in real services, in the physical environment where they operate, and to users’ behaviours.

- Composition should move from a software engineering task, i.e., from a “task/goal driven” composition of software components, to a composition based on emergent needs, constraint, opportunities of the consumers.

Internet of Service on top of the Internet of Software, Things, and Content

Our claim is that research on “Internet of Services” should focus on real services, rather than software services. While Internet has a marginal role for software services, it is a key enabler for real services. It offers a unique capability to communicate in real time changes in real services and in their context, and allows the user to react immediately to these changes. The Future Internet of Services will make changes in dynamic real services immediately visible to consumers, in a very similar way to what happens to the traditional Internet of Web pages, where changes are seen immediately by everyone who connects to the Web. It will allow the world to change at a higher and higher speed. In this sense, the “Future Internet of Services” is much broader than the Internet of software services foreseen in most approaches. Indeed, it will lay on top of an Internet of Software, with provides applications and electronic access to real services; and it will also lay on top of the Internet of Content, which provides the ability to extract relevant knowledge from a huge amount of data and information; and on top of the Internet of Things, which can connect to Internet objects of our everyday life and let them become active elements for accessing real services.