A Software & Service Perspective on the Future of Cloud in Europe

NESSI White Paper

July 2012

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1. Executive Summary

The Cloud has reached virtually all areas of society and its impact on service development, production, provision and consumption is manifold and far-reaching. However, recent figures show that Europe is falling behind in its capability to provide innovative ICT services, Cloud services included. Therefore, national and European strategies are currently being developed to address this issue, both by providing a regulatory framework and by offering stimulating measures to increase investment in Cloud technologies and its advancements.

The European Technology Platform NESSI (Networked European Software and Services Initiative) seeks to contribute to the current Cloud discourse with the expertise of its member community. With this paper, NESSI offers a comprehensive view on the envisaged evolution of Cloud and its opportunities for Europe. This includes key aspects for innovation in the Software and Service industry, trends of the current Cloud technology, a vision for future Software & Service Clouds, and the specific position of Europe and European research funding. NESSI's view on cloud can be summarized in three key insights:

Cloud will be the most important innovation driver of the next decade, affecting not only the software and services sector, but all software-intensive sectors that benefit from software innovations.

While early Cloud activities were focussing on basic IT resources and cost reduction, there is a **clear trend towards Software and Service Cloud solutions** and value generation in the areas of agility, collaboration and ecosystem support.

Software & Service Clouds will become the factory for offering, provisioning and delivering of **all kinds of services** – from IT services to full business services – and will **constitute sectorial connection hubs** for all types of business networks, including B2B, B2C, B2G, G2C, B2B2C, and M2M.

NESSI advocates four main areas for future research and innovation, namely (i) product and service innovation through Software & Service Clouds, (ii) advancing agility in design and operation of Software and Services Cloud, (iii) transforming ICT and (iv) adaptive Cloud infrastructures. As a result, NESSI's promotes driving innovation in Cloud environments, through well aligned research initiatives from industry and public bodies, with the following key recommendations:

- Direct significant EU efforts at investing in Software and Services Cloud research to enable the EU Software and Service Industry to provide innovative Cloud platforms, services, and solutions for building healthy business ecosystems.
- Shift the focus from mainly infrastructure / IaaS related research towards an integrated research approach with a strong software and services perspective.
- Support application-domain driven cloud research projects with strong involvement from Software and Service Cloud stakeholders and domain stakeholders such as end users and providers in order to accelerate the uptake of Software & Service Clouds in a variety of sectors.
- Comprehend open source as a specific instrument that can support innovation along well-defined business strategies and use it (or do not use it) in public funded research projects accordingly.
- Develop a strategy for using standardization and open source as instruments to improve the competitive position of Europe, not necessarily for achieving innovation but rather to commoditize in areas where Europe is behind competition or to establish interoperable platforms.

2. Introduction

NESSI, the Networked European Software and Services Initiative, is the European Technology Platform dedicated to Software and Services, aiming to impact the technological future in this sector by identifying strategic research directions and proposing corresponding actions. NESSI gathers representatives from both industry and academia and is active at international level.

NESSI closely monitors technology and policy developments of Cloud as it has a large impact on the software and services domain. Although Cloud is not an entirely new phenomenon it has changed the IT landscape fundamentally over the past years, affecting also other sectors apart from the ICT field. Cloud lowers innovation barriers and thereby impacts industry, small and large businesses, governments and society and offers significant benefits for everyone in the Cloud value chain. Hence, Cloud exists across different sectors as well as different industries and it will have an impact on practically all of them.

The software and services sector experiences rapid changes induced by fast innovation cycles and are at the same time key innovation enabler in other sectors – especially in what is traditionally considered to be separate industries such as manufacturing, logistics and healthcare. It is already evident that faster innovation cycles are taking place in different sectors, to a large extent because of software and services which make businesses more flexible and help them adopt more easily to change and new opportunities.

In this White Paper, NESSI argues that the Cloud will develop into one of the most important places where new infrastructures, new operational models of software, faster innovation cycles with quicker customer feedback loops, collaboration and interaction between all types of stakeholders and massive service-based re-use will happen in the future. The software and services sector will be the driver of this development and the Cloud will be the centre of gravity.

The paper is structured around the following sections:

Section three discusses general conditions and mechanisms for innovation in the software and service industry, identifies key drivers for innovation and discusses the role of standardization and open source.

Section four summarizes the situation of Cloud and Cloud computing as of today, including predecessor and current trends and also comments on the infrastructure-dominated Cloud perspective that many (European) players have.

Section five exposes the NESSI cloud vision and the suggested focus areas for innovation.

Section six discusses the role of role of software and services Cloud research in Europe, in particular aspects of how efforts by industry and governmental bodies can be best positioned and complement each other.

The last section, seven, concludes the paper and provides key recommendations on where to invest into Europe’s competitiveness via a well-focussed Cloud research strategy.

3. How Innovation Happens in the Software and Service Industry

3.1. Aspects of Innovation in the Software Sector

The software and services sector is depending on several drivers and related processes for innovation which in many areas results in very short innovation cycles. In addition, the move towards continuous delivery models offered by the Cloud fundamentally changes the speed of innovation in the software and services sector.

We clearly observe a methodology shift in the industry, away from a traditional Build-Ship-Install-Use-Maintain model, towards a continuous and short cycled Build-Deploy-Use-Measure-Optimize model, which fundamentally changes known engineering principles.

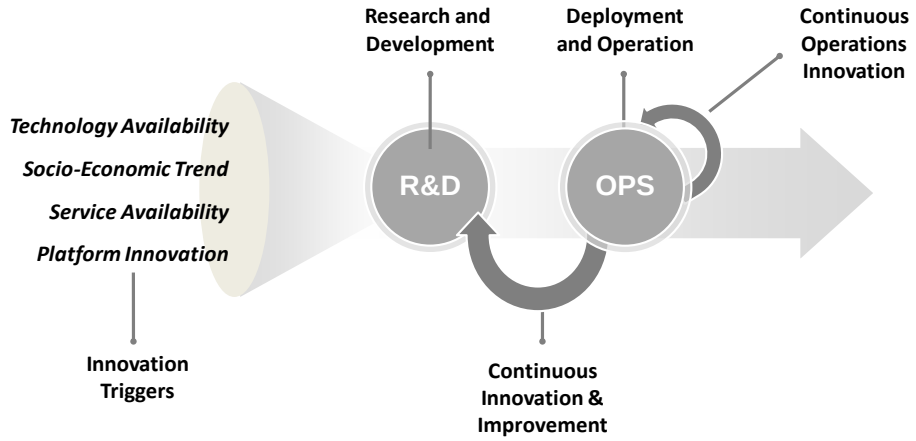
Within other sectors, which are highly technology-dependent such as aerospace, automotive or telecommunication, innovation tend to follow comparably long investment cycles because it is largely driven by innovation and disruption in core technical capabilities (for example new processor architectures, battery systems, materials, or a combination of wireless protocols and related chipsets). For instance, the GSM system (Global System for Mobile Communications) was developed over a period of 10 years, including research, development, tests, go-to-market and standardization activities.

3.2. Innovation Triggers

Certain factors underpin innovation in the form of a new product or service and NESSI is distinguishing the following **innovation triggers** for the software and services sector:

- **Technology availability:** Technology roadmaps in the hardware and network sectors are highly predictable. A continuous challenge for the software sector is to assess these roadmaps, explore potential usage areas and eventually develop new innovative products exploiting the advances brought by the technology sector. The innovation clock speed, however, is largely determined by the underlying technology.
- **Socio-economic trends:** Further innovation in the software and service sector is driven by emerging socio-economic trends. Social networking, for example, had severe impact on data management and processing. New mechanisms for distributed storing and processing of data had to be developed rather quickly, building upon fundamental research results in academia earlier which were advanced by industry and brought into a new industrial application environment.
- **Platform-based innovation:** A further dimension is innovation on top of platforms. Examples of such platforms are the Windows operating system, Facebook, and the Apple iOS platform in conjunction with the App Store and the Android ecosystem. In all these cases the availability of these platforms has significantly lowered the barrier for other players, often SMEs, to innovate quickly, to access a market, and to monetize easily. Generally, innovating a platform tends to have longer cycles than the innovation on top of these platforms, yet the innovation speeds of both are usually faster than in the technology-driven space.
- **Servicification:** The availability of software-based services, accessible over the Internet by means of simple-to-use Application Programming Interfaces (APIs), allow for third parties to quickly innovate new solutions on top of such services. A simple example is the speed of innovation on top of available Cloud-based storage services such as Dropbox and Box.net which both have grown an amazing ecosystem of applications around their basic services and managed to boost innovation through third-parties.

These innovation triggers constitute the initial part of an entire innovation cycle. The triggers kick-start loops of continuous innovation and improvement in the Software and Services sector as illustrated in the following figure:



Continuous Operations Innovation specifically addresses how an innovation can be operated at low costs in a way to keep sufficient margin in the overall business model. With the Cloud, the deployment and operation of software has moved to the centre of considerations impacting even the product and service design and architecture. The overall costs in this phase are usually called Total Cost of Operation (TCO). Especially in areas where the TCO is critical to the overall business model, this area will be subject to continuous innovation of the management and operations of software systems.

Continuous Innovation and Improvement specifically addresses how an innovation can be sustainably improved and optimized after it is accessible to customers, and how it can increase or maintain competitiveness. Key innovation drivers in this part of the process, are the continuous observations of how users use a system, combined with the systematic and constant testing of new or changed features to see how customers respond. This process allows for fast innovation cycles and is made possible by means of a tight integration of the innovation operation and subsequent incremental development phases.

In most areas of the software and services sector, the innovation speed is significantly faster than in other sectors, due to the combination of agile development and tight integration of the development (R&D) and operational (OPS) phases of software. This allows for continuous experimentation of features, based on closed feedback loops with end users, something that other sectors structurally do not have access to.

3.3. The Role of Standardization and Open Source on Innovation

3.3.1. Standardization

Standardization is mostly of value in later stages of the software and service innovation cycle and rarely a driver of innovation at the early stage.

Understanding the role of standards for the IaaS Cloud market is indeed crucial, as industries, such as telecommunications with long investment cycles, benefit from standards via improved investment security. In many areas, market relevance and success even heavily depends on a standards-based approach, like for example in the mobile network sector.

However, the role and value of standardization is of quite different relevance to the software and services industry. Innovation in the software and services industry is typically driven by the fastest market entrant, that even might set a certain de-facto standard. One reason for this is that customers, experimenting with new software and service innovations, largely look at the innovative functions and do not expect standard-based interoperability in the first place. Therefore, during the early phases of software innovation, many companies value speed-to-market higher, and often have little interest in defining standards at this stage, as this would weaken their competitive position.

The ICT landscape has changed dramatically over the last decade, especially with the introduction of Cloud services, which is making appropriate ICT standardization policy crucial. Any EU standardization policy has to be adapted to the fast market developments and rapid shortening of innovation cycles, especially within the software and services sector, in order to efficiently drive innovation and competitiveness in Europe.

NESSI therefore supports the idea to evaluate the European standardisation system to see if it actually captures the fast moving ICT environment, to make sure that it truly contributes to facilitate innovation and technological development in Europe[1].

European standards are in some cases very effective policy tools, but it should be further investigated if standards are actually driving innovation in all ICT sectors. Thus, NESSI promotes the need to differentiate the Cloud market in this respect and to see the different standardisation needs of the Cloud. This includes the standardization activities often expected to be performed in research projects.

3.3.2. Open Source

Open Source Software is an important model in the software and service industry but not a superior development model per se. It is rather complementing proprietary models in the market, for specific business tactical reasons.

The role of Open Source Software (OSS) can be twofold. In its first role, open source, often serves for *commoditization* of certain solutions, and is either driven by a user or developer community or as a strategic activity by organizations that want to commoditize features which are not at their own core business. OSS projects of this kind typically choose a free OSS licence in order to support the widest possible adoption.

In addition, open source may serve as basis for an alternative *OSS based business model*, where the open source leads to lowering adoption hurdles by effectively removing license fees. The actual business model however is then based on services around the OSS package.

Today, the second role of open source has found a related business model, the so-called *freemium models* in the Web. Here, organizations offer Web-based solutions for free but later centre their business on value-adding features or services. OpenStack and OpenNebula are examples of Cloud infrastructure software platform projects under OSS licences.

Rather than being a competing, or in any way superior model (which is sometimes claimed by OSS followers), OSS is mostly seen by the Software Industry as a pragmatic and

[1] European Commission, COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL AND THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE, A strategic vision for European standards: Moving forward to enhance and accelerate the sustainable growth of the European economy by 2020, Brussels, 1 June 2011, COM(2011) 311 final, p 5.

complementary way of developing and marketing software and services – and many market players engage in both.

For successful innovation in a particular technology and business context, the specific roles of open source versus closed source have to be understood and the appropriate policy strategies should be chosen accordingly.

4. The Cloud as of Today

4.1. Preceding Technology Trends: Internet of Services and Grid Computing

Two major predecessor trends have partially anticipated Cloud in the past decade: Internet of Services and Grid Computing.

The Internet of Services (IoS) is based on the idea of a strict service-orientation in all kinds of areas, including IT but also many other business domains. In contrast to a traditional product-oriented view, the service-oriented view allows consumers to focus on the solution they eventually consume, rather than taking care for the way how the solution is performed. A major innovation driver was the service-enabling of traditional products, one example is the company Hilti – a drilling machine manufacturer who started to offer "holes as a service" to his customers by delivering equipment to construction places in a rental/on-demand fashion, rather than just selling the machines for doing so.

The Internet of Services positions the Internet as the main place where services can be traded and where many phases of a service lifecycle are managed. However, the Internet of Services turned out to be insufficient in providing concepts for the actual service delivery, in particular the dynamic provisioning and configuration of related resources. As a response to this, the shift to the paradigm of Grid computing introduced the provisioning of compute resources as a utility. The shift was primarily driven by the high performance computing community and its need for extremely large resource pools.

However, the Grid computing community did not come up with adequate complementary operations and business models around Grid resources, attractive for real enterprise businesses, which eventually hindered a larger economic breakthrough.

Cloud computing is thus the natural successor of the Internet of Services and Grid Computing, because it successfully combines the concepts of service-orientation, Internet-based trading and provisioning of IT resources as a utility into a consumable model meeting customer demands, and underpinning them with a viable business model.

4.2. Origin of Cloud and Current Trends

Early Cloud activities were focusing on basic IT resources, but there is a clear trend visible towards high-level Cloud solutions and value generation dominating the future of Cloud evolution.

Already in the 90s, the term "Cloud" was used to describe the capability of dynamic traffic switching to balance utilization ("telecom Clouds"), and to indicate that the telecoms infrastructure is virtualised – and where the end users do not know or care over which channels their data is routed. Later, Amazons' way of offering virtualized compute resources as service has triggered the broader evolution of this area. Today, the most commonly adopted definition for Cloud describes "Cloud computing is a model for enabling ubiquitous,

convenient, on-demand network access to a shared pool of configurable computing resources, such as networks, servers, storage, applications, and services that can be rapidly provisioned and released with minimal management effort or service provider interaction."[2]

This definition builds upon a business perspective in which the initial value driver for adopting Cloud has been cost savings and the replacement of capital expenditures with operational expenditures. However, today, there is a clear trend that Cloud is increasingly seen as an enabler for other value drivers. Achieving higher productivity and agility have become key competitive factors. A recent study by Forrester supports this shift of perspective with the following numbers taken from interviews with IT leaders who shared their perspectives and named their most important strategic considerations:

- The drive to **save overall costs** by using Cloud has gone down from 71% (in 2009) to 60% (in 2011). [3]
- In comparison, the drive to **improve business agility** by using Cloud has increased from 32% (in 2009) to 72% (in 2011).[4]
- Beyond agility, these IT leaders consider Cloud to eventually become a driver for **faster innovation and improved business collaboration** on data, documents, and processes.[5]

This general trend towards software based Cloud solutions and value generating areas can be also clearly seen by the expected evolution of market shares, depicted below:

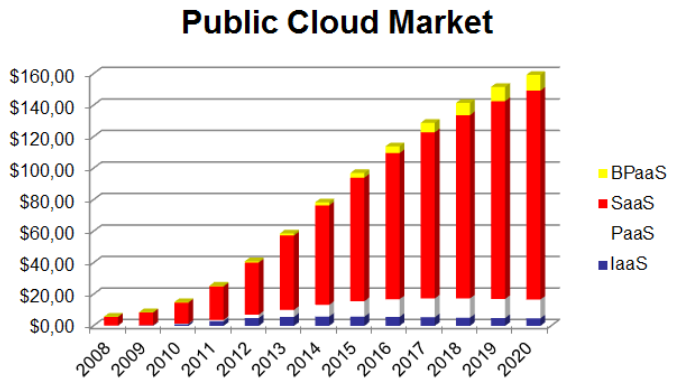


Figure 1.1 Software as a Service market share within the Public Cloud Market [6]

[2] "*The NIST definition of Cloud Computing*", Recommendations of the National Institute of Standards and Technology (NIST), Peter Mell and Timothy Grance. Available at: http://csrc.nist.gov/publications/nistpubs/800-145/SP800-145.pdf

[3] "*The Changing Cloud Agenda*", Forrester Research Inc, Holger Kisker, 24 April 2012, p. 4.

[4] "*The Changing Cloud Agenda*", Forrester Research Inc, Holger Kisker, 24 April 2012, p. 4.

[5] "*The Changing Cloud Agenda*", Forrester Research Inc, Holger Kisker, 24 April 2012, p. 7

[6] "*Sizing the Cloud*", Forrester Research Inc, Stefan Ried and Holger Kisker and 21 April 2011, Figure 3, p.9.

4.3. The Need for an Extended View of the Cloud

The current European Cloud discourse needs to pay more attention to the development of the Cloud towards Software and Services ecosystems, because this development will drive future socio-economic innovation. Thus, it is important to extend the view on Cloud to not only focus on the infrastructure feature.

NESSI welcomes the recommendations put forward in the Cloud Expert Group report "Advances in Clouds" from 2012[7]. However, the report needs to be substantially complemented with sections on major benefits offered by the Cloud, such as innovation enablers, business agility and speed of implementation and deployment. Furthermore, an analysis from a service-oriented perspective with an emphasis on the associated Cloud business ecosystems would mature the Cloud concept presented in the report.

NESSI has developed a broader understanding of Cloud and sees it as the central hub in the future ecosystem from which relevant innovation in Europe – and for Europe – will emerge. This view is necessary to set the appropriate future research priorities, clearly positioning the innovation-enabling aspects of the Cloud into the focus of Horizon 2020.

5. NESSI Cloud Vision

5.1. The Future Role of Software, Services and Cloud

Software, services and Cloud technologies will have a significant impact on the future evolution – not only of the software and service sector but for all kinds of industries and sectors. In particular, we anticipate the further uptake of Software and Service Clouds, which means that Clouds will be focused on the delivery of application and process-level, software-based, services and solutions.

The future role of software and Cloud technologies is characterized by four main elements which outline NESSI's Cloud vision for the end of this decade:

1. **Cloud will become the major driver for innovation and productivity gains in the software and service industry, as it naturally supports all kinds of innovation aspects.**

   Cloud can directly support almost all innovation aspects, in particular the innovation triggers, but also the operation and improvement. As an example, newly available technology, integrated into an infrastructure Cloud can be directly exposed to a large community of adopters. Socio-economic trends can be most easily tested with selected user groups via the Internet. Platform-based innovation is supported as the Cloud easily allows for building platforms respectively. Servicification is directly supported by Cloud for all kinds of solutions. The Cloud operation model provides an ideal basis for constantly monitoring, analysing and improving the operation of solutions. Last but not least, it offers the possibility to directly observe the usage of solutions and features, thus providing an ideal basis for continuous improvements.

[7] "*Advances in Clouds – Research in Future Cloud Computing*", Expert Group report, Public Version 1.0, Editors Lutz Schubert [USTUTT-HLRS] and Keith Jeffrey [STFC], 2 May 2012.

2. **The Software & Service Cloud is the dominating Cloud innovation field of the future.**

   This simply follows from the general Cloud trend which demonstrates that costs are not any longer the main reason for adopting the cloud – however, speed and agility is. This goes hand in hand with the changing value drivers that are supported by Software & Service Clouds.

3. **In the future software will be to a large extent Cloud-based, i.e. designed for and operated in a Cloud.**

   While the past was characterized by discussions on how to move (traditional) software into the Cloud, we will see a new class of software directly designed for running in the Cloud and thus benefiting from underlying Cloud technologies much more. Overall, the majority of future software will reside either in the Cloud or on (mobile) devices.

4. **Software & Service Clouds will penetrate all major industrial sectors**.

   Currently, the usage of (infrastructure-centric) Clouds is still dominated by the software and service sector as this sector has the best understanding of the underlying technologies and their implications. In the future, we will see a larger uptake of Software & Service Clouds by many other industrial sectors, as such Clouds can better deliver directly value-generating solutions to those industries.

   This is particularly relevant for Europe with its strengths in a variety of domains such as transportation & logistics, business processes, energy management, collaborative engineering, production & manufacturing, health care, etc.

5.2. NESSI Cloud Vision by 2020

NESSI's vision is that by 2020 Software & Service Clouds will become the centre for offering, provisioning and delivery of all kinds of services – from IT services to full business services.

The Cloud infrastructure will by then have evolved into a system of industry platforms – comparable to operating systems or social network platforms – that provide global access to software and services via different types of devices, including sensors and machines. De-facto standards have been emerged and a sufficient number of engineers will be well-skilled in using and adopting Cloud-based services platforms. Software engineering will have adopted a new way to design, develop and maintain software and services for the Cloud throughout their whole technical and business lifecycle.

Software & Service Clouds will constitute sectoral connection hubs for all types of business networks, including B2B, B2C, B2G, G2C, B2B2C, and M2M.

Cloud platforms in 2020 will be at the centre of vibrant ecosystems in multiple areas including business to business (B2B) networks (for example procurement or collaborative engineering networks, transportation and logistics, production manufacturing), business to consumer (B2C) networks (such as retail, insurance, banking networks), business to government (B2G) networks (like public private partnerships or cross-border trading networks), government to consumer (G2C) networks (for instance regional or municipal community networks), business to business to consumer (B2B2C) networks (such as invoice or recall networks), or machine to machine (M2M) networks where the majority of all events generated by machines and devices will flow through Clouds (for example traffic management networks).

Software & Services Clouds will bring together platform providers, application and service providers, brokers and other intermediaries and the end customers and enable them for

emergent innovation at a high speed. The innovation process will be inherently supported as the Software & Services Clouds allows for easy creation of value-adding solutions in a networked context and with direct inter-linkage of all relevant stakeholders, in particular the eventual customers.

5.3. Cloud Innovation Focus Areas

In order to best understand the most relevant Cloud innovation focus areas for the future, NESSI suggests a distinction of two main views.

- **Software & Service Clouds** address all kinds of Clouds and Cloud based solutions delivering business solutions which go beyond pure technology. In contrast to this, **Infrastructure Clouds** serve for delivering ICT-related resources along the service paradigm. NESSI believes that such a distinction clarifies the eventual value that a Cloud shall produce, much better than the traditional distinction via multiple XaaS aspects such as IaaS, PaaS, SaaS, and BPaaS.
- NESSI sees two main perspectives relevant for the understanding of Clouds. The first perspective is the **"product & service" perspective**, focussing on the assets that are actually delivered through a Cloud. However, there is a second equally important aspect, looking at the way how Cloud solutions can be **engineered and governed**. We already saw the relevance of aspects like agility, cost of operation, and continuous improvement in Section 3 and clarified how they are directly related to innovation.

The figure below summarizes the NESSI view on the main Cloud innovation areas, clearly distinguishing the areas of Software & Service Clouds vs. Infrastructure Clouds and the perspectives of "Product & Service Innovation" vs. "Engineering & Governance Innovation". Detailed discussions of all these four areas follow in the subsequent sections.

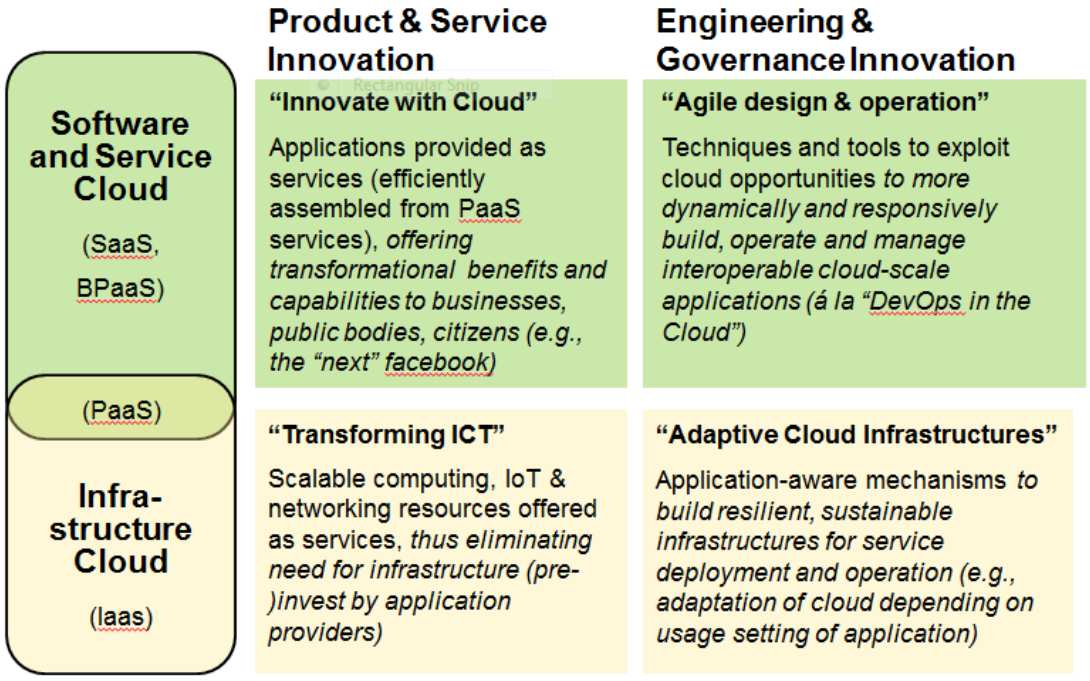


Figure 1.3 NESSI Service Centric View

5.3.1. Innovate with Cloud

The goal of this area is to improve the uptake of Software & Service Clouds by enabling delivery of innovative higher-level solutions (services, applications and platforms) which offer transformational benefits and capabilities to businesses, public bodies and citizens.

The area directly addresses the software and service industry but shall also pave the way for broad Cloud adoption in all other sectors. Furthermore, it directly relates to the innovation triggers of platform-based innovation, servicification, and the quick exploration of socio-economic trends.

Major research issues and challenges in this area are:

- Collaborative cloud platforms with built-in support for service networks data, document, and process collaboration.
- Higher-level software and service abstractions that relieve developers from technical details and allow them to concentrate on actual solution functionality.
- Domain-specific Cloud platforms (even families of those) for different areas and sectors that directly entail the most relevant concepts of their domain. This could be on the one hand dealt with on a generic level on the other hand in a nicely combined way together with application domain research activities.
- Higher-level abstractions for (lower-level) non-functional characteristics such as performance, scalability, reliability, security, trust and privacy, which are understandable for domain experts.
- Integrating advanced infrastructure services (as developed in the area of "Transforming ICT") with containers offered as part of a Software & Service Cloud environment.
- A Cloud based service innovation paradigm allowing businesses to understand and realise the economic benefits of using Cloud to enhance existing applications and services and create new ones.
- Services and technologies for interoperability and semantic based interpretation of data.
- Data traceability as the cloud user expects audit services that would guarantee him to get full reports and investigation means to identify what data has get out of the Cloud. Such a feature would include mechanisms such as data leak detection/prevention, or even data lineage support, being able to trace data flows and data copies, or derived data copies.

5.3.2. Agile Design and Operation

The goal of this area is to increase the clock speed of innovation by improving agility in designing and operating Software and Service Clouds, in particular their dependability and manageability.

The area directly addresses the software and service industry but is even more important for achieving trust in Cloud adoption by other sectors – which are from their competency no Cloud experts. Furthermore, it directly relates to the innovation areas of Continuous Operations Innovation and Continuous Innovation and Improvement.

Major research issues and challenges in this area are:

- Cloud based system and service engineering.

- Tools and techniques for rapid prototyping keeping the human in the loop and supporting models for advanced human interaction with Cloud based applications; including built-in feedback channels from operations back into development, for example along the DevOps principle.
- Platform and ecosystem management concepts for understanding relationships between different entities, and for lifecycle management for service networks spanning across different components and stakeholders.
- Abstractions and support for hybrid Clouds, harmonizing different private and public Clouds, in particular supporting interoperability and heterogeneity of services and platforms.
- Management and visualisation of big data across multiple infrastructures and data sources.
- Variability management and adaptation built into the platform and infrastructure to enable the application to benefit from context information and optimise with respect to extra-functional requirements like cost, location, scalability and speed.
- Security, privacy, and trust supporting agility and transparency in accessing data and running processes in the Cloud
- Trusted PaaS that simplifies formal validation and security certification of applications
- Support for compliance to national and European regulations or security policies

5.3.3. Transforming ICT

The goal of this area is to improve the low-level infrastructure for service-enabled, scalable software and hardware platforms.

This area primarily addresses the providers of Software and Service Cloud platforms which may belong to either the software and service industry or, if sector-specific infrastructure is involved, for example in a logistics domain, to another sector. Furthermore, it directly relates to the innovation trigger of technology innovations and allows them to be directly exposed to a large community of adopters.

Major research issues and challenges in this area are:

- Infrastructure Clouds for the Internet of Things
- Convergence of Internet of Things and Internet of Services towards a common cloud service approach bridging differences such as event-based design of IoT solutions and the function-oriented design of IoS.
- Advancing the notion of network as a service, in particular exploiting software-defined networks as next paradigm for building application-aware networks / network-aware applications.
- Basic mechanisms to support very large data sets (big data), possibly across multiple infrastructures and data sources.
- Scalable security solutions such as adaptive Virtual Machine (VM) Security, VM to VM Security, Hardened KVM (Kernel-Virtual Machine) Hypervisor, Hardened VM and Software firewall.
- Data confidentiality exploiting new approaches such as homomorphic encryption schemes which allow data to be processed without being decrypted, would offer

interesting features, but is not applicable today because it still requires too much computational effort.

5.3.4. Adaptive Cloud Infrastructures

The goal of this area is to improve the adaptiveness of Cloud infrastructures by better linking between the capabilities and the management of lower-level infrastructure Clouds and the higher-level Software & Service Clouds.

As above, the area primarily addresses the providers of Software and Service Cloud platforms which may belong to either the software & service industry or to another sector. This area directly relates to the innovation areas of Continuous Operations Innovation and Continuous Innovation and Improvement.

Major research issues and challenges in this area are:

- Application-aware mechanisms to build resilient, sustainable infrastructures for service deployment and operation, such as adaptation of Cloud depending on usage setting of application.
- New architectures and mechanisms for application-aware networks / network-aware applications.
- Exposing transparency and management features to understand and influence non-functional aspects of infrastructure elements; this includes in particular trust and privacy considerations.
- Applicative security as a service: security add-ons on IaaS, PaaS or SaaS security modules to support secure application design
- Data disposal: the objective is to avoid any data remanence even when an associated physical storage medium is reallocated to other cloud users.

6. The Role of Software and Services Cloud Research in Europe

6.1. The Opportunity for Europe

The EU public Cloud market is expected to grow from 4,6 B€ in 2011 to 10,9 B€ in 2014, out of which 8,2 B€ is dedicated to Public Cloud software.[8] Thus, it is evident that software plays an important part for the European economy and for future innovations in the Cloud area.

However, the European (software) industry has a couple of peculiar characteristics which includes the fact that there is a large number of SMEs with very specific expertise, and that they are often world market leaders in their domain. Furthermore, Europe has strengths in building sophisticated solutions and value chains, while at the same time being less strong in commodity type offerings.

Taking these characteristics into account, the NESSI Cloud vision offers the opportunity for Europe to leverage domain expertise from its SMEs at broader scale, for example into Cloud based markets, it enables the most vibrant ecosystem of software and service providers, via

[8] "*Quantitative Estimates of the Demand for Cloud Computing in Europe and the Likely Barriers to Take-up*", IDC report on behalf of European Commission DG INFSO (executive summary version), February 2012, p. 7.

Cloud-collaboration platforms and it increases Europe's competitiveness by providing Cloud platforms for faster innovation.

6.2. European Research Focus

Almost all industries and the public sector will rely on software and services in their business operations – in 2020 even more than at present. NESSI already experienced that advanced sectors such as ICT, telecom, energy, transport, health, food, environment, space and automotive, rely more and more on advances in software and service technologies because their products and business operations are heavily software and service intensive. This happens at the same time as Europe seems to lack software and service engineers who actually have the competence to meet current and future requirements, such as green products, smart solutions, and agile processes. For a more long term perspective beyond 2020, we will encounter these basic technologies to be Cloud-based, and there are many fundamental research challenges to be dealt with. Research in these software and service technologies, which are basic to most sectors in a modern society, needs to have a prominent position in research priorities, enabling Europe to provide the competences and engineers needed in future.

The Software and Service Cloud has the higher growth potential and is yet not much investigated. As it is also more dependent on the domain, it offers also good opportunities for the broad and diverse European Software and Service market consisting mainly of SMEs. In order to be successful it is important to address all aspects of the Software and Service Cloud. This includes generic and domain-oriented research, establishing communities and education of a holistic approach.

6.3. About the Roles of Industry and Public-Funded Research

Advances and innovation in the Cloud could be best made if the respective strengths and advantages of industry-driven innovation and public-funding driven innovation are carefully balanced. The NESSI view suggests the following separation of duties.

Industry should directly invest into:

- R&D of concrete Cloud solutions which have a clear go-to-market strategy.
- Fast experimentation and innovation along short-term socio-economic trends.
- Creation of sophisticated Cloud platforms which require solid and professional driven development processes and structures.
- Building of highly customer or domain-focussed solutions with only little opportunities for generalized adoption.

Public funded projects can provide distinct value in two dimensions, namely within

- **advancing fundamental technologies** and
- **exploring long-term socio-economic trends.**

Advancing fundamental technologies could either happen along the requirements from long-term socio-economic trends, where again the multi-disciplinary nature of a public funded project would allow to bring the required mix of expertise together into one setting. Second, advanced technology research could also happen in a technology-driven context. Following the innovation drivers discussed in Section 3 research activities could be centred on known roadmaps of future infrastructure technologies, simplified building of platforms, or servicification of traditional ICT resources. Furthermore, it could directly aim at innovations in the continuous optimization or even the continuous improvement of cloud-based solutions.

Scouting, road mapping and exploration of future/emerging socio-economic trends is important because, rather than relying on the ideas of individual organizations, multi-disciplinary projects combining strengths from different players and parties could be a great forum for open exchange on and invention of the future. However, to do this in a systematic and sustainable way, a sound project approach is needed rather than just a (series of) single workshop(s).

Again, combining strengths from different players and parties in a multi-disciplinary way would allow for exploring emerging socio-economic trends but also major innovation mechanisms in a holistic and broad way. No single industrial player could do this easily by itself and even pure industrial consortia would have difficulties in composing a sufficiently broad insight on such topics. Instead, public funded projects could provide:

(a) conceptual and methodological insights which eventually supports people education, i.e. enables relevant stakeholders (decision makers, engineers, and researchers) in understanding the full potential of Cloud computing;
(b) Cloud solution prototypes which can be directly exploited by industrial players in order to define their specific role and offering in the future Cloud business;
(c) Open source tools and communities offering useful assistance fostering rapid Cloud-based service innovation and agile development of Cloud services.

7. Recommendations

7.1. Top-Level Recommendations

The discussion in this paper has revealed the important role that Software and Service Clouds will play for the future innovation in the software and service industry and in particular for the European market – including all kinds of non-IT sectors, where nevertheless software and Clouds will be a key innovation driver. NESSI believes that it is crucial that any policy efforts are properly adjusted to best capture the growth potential for Europe vis-à-vis the global Cloud market. To this end, NESSI suggests the following recommendations to improve Europe's competitiveness via a well-focused Cloud research strategy:

- Direct significant EU efforts at investing in Software and Services Cloud research to enable the EU Software and Service Industry to provide innovative Cloud platforms, services, and solutions for building healthy business ecosystems.

- Shift the focus from mainly infrastructure/IaaS related research towards an integrated research approach with a strong software and services perspective.

- Support application-domain driven Cloud research projects with strong involvement from Software and Service Cloud stakeholders and domain stakeholders such as end users and providers in order to accelerate the uptake of Software and Service Clouds in a variety of sectors.

- Comprehend open source as a specific instrument that can support innovation along well-defined business strategies and use it (or do not use it) in public funded research projects accordingly.

- Develop a strategy for using standardization and open source as instruments to improve the competitive position of Europe, not necessarily for achieving innovation but rather to commoditize in areas where Europe is behind competition or to establish interoperable platforms

7.2. Focus Areas for Driving Innovation in Service-based Cloud Applications

On a more detailed level, we see four main Cloud innovation focus areas (as part of the NESSI service centric view described above) which should be addressed by future research activities.

Innovate with Cloud: Develop advanced, higher-level abstractions for Software and Service Clouds which support collaborative, networked and domain-specific scenarios while reducing the degree at which technical aspects needs to be considered by the cloud user.

Agile design & operation: Develop a comprehensive Cloud based system and service engineering approach which supports agile and rapid development combined with an end-to-end lifecycle management approach that bridges development and operation, supports ecosystems and transparently links infrastructure capabilities to the non-functional aspects at higher levels.

Transforming ICT: Advance the service-enabling of emerging infrastructure technologies such as Internet of Things, Software-Defined Networks, and Big Data resources and develop appropriate service interfaces that simplify the usage by Software and Service Clouds.

Adaptive Cloud Infrastructures: Develop advanced, adaptive infrastructures via application-aware infrastructure management mechanisms, by improving the transparency on infrastructure capabilities to higher levels, and by radically rethinking the architecture stack towards a new class of resource-aware, and distributed applications and application-aware resources.