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Foundations of Cloud Computing

Report

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EXECUTIVE SUMMARY

The take-up of Cloud Computing is one of the most controversial developments within the Information and Communication Technologies (ICT) in the last years. While its proponents argue with cost, security and technological advances that will result in more innovation and growth, its opponents argue the opposite way. Therefore the aim of this report is to lay the foundations for the overall project examing the challenges, impacts and benefits of Cloud Computing. This includes:

- to analyse the basic concepts (incl. definitions, characteristics etc.) as well as the evolution of the concept (incl. predecessors and related concepts) and the underlying technologies;
- to review the market situation (incl. on overview of offered services and existing providers) and to analyse the adoption and usage patterns of Cloud Computing;
- to identify driving factors and barriers based on existing literature as well as an initial assessment of indentified factors.

The analysis of existing basic concepts showed:

- that many different types of definition and characteristics exist, but due to the evolving character of Cloud Computing none of them could be seen as the definitive definition;
- that the current definition and characteristics of NIST are most widespread so that the report will be based on it, though there are open issues that need to be reflected carefully in the project;
- that service (IaaS, PaaS, SaaS), delivery (public, private, hybrid), revenues (subscription, usage, dynamic advertisement based) and resulting business models can be used to classify Cloud Computing services, but in particular revenue and business models are still in a flux;
- that because of this blurry situation we will focus on service and delivery models to classify and analyse Cloud services and providers, but that we will take the others factors into account if meaningful.

The examination of the evolution of the Cloud Computing concept underlined:

- that Cloud Computing is not a new concept, because it can be traced back to ideas from the 1960s and there are predecessors and related concepts like Application Service Provision, Utility and Grid Computing in the last decades;
- that the basic architecture is based on a three layer approach, where the physical layer encompass facilities and computing equipment, the abstraction and control layer consists of virtualisation and management tools and the top layer includes the different service models;
- that the technology is mainly based on the two concepts of multi-tenancy and service orientation and there related technical implementations in form of virtualisation and web services, which are fundamental for the functioning of Cloud Computing services;
- that for a properly functioning of Cloud services several requirements are necessary, which includes the availability of sufficient network capacity ensuring access to data and reliable and fault tolerant service offers as well as well-functioning technical infrastructure including abstraction, virtualisation, management and security;

- that the evolving Cloud Computing technology still bears potential for further advances in technology in areas like scalability and flexibility, but that it also need to address several challenges like interoperability to facilitate compelling reasons to use it.

The review of the market situation, existing service offers and suppliers showed:

- that Cloud Computing is beside Mobile Computing and Big Data one of the fastest growing segments of the software and IT services market in the last years;
- that based on the revenues for public Cloud Computing as a proxy for the overall development its share will grew from a few percent to a maximum between 15-20 percent of the overall market in 2020 and thereby impact the existing market structure;
- that SaaS is and will stay the biggest of all three segments due to growing adoption by consumers and SME, while IaaS and PaaS will grow with higher rates, but not overtake SaaS;
- that there is within all segments a clear tendency towards offering more and more complex services. In particular in the SaaS segment the transition of existing applications has reached its peak and now there is a trend of either creating new services based on them or to offer more complex services (business processes);
- that in recent years many new Cloud providers appeared, but that the leading companies like Amazon, Salesforce and Google were also pioneers of Cloud Computing. They were followed by specialised suppliers such as technology providers like VMWare or data centre providers like Rackspace. Others like the IT service providers like HP or IBM followed in the last years, while the classical software product suppliers like Microsoft, SAP or Oracle have been late starters in the segment. A remarkable new development are companies like Dropbox or Evernote, which offers services based on other Cloud services;
- that overall the number of service offerings and the number of suppliers are still evolving, but that the growing number of M&A activities is also a first sign of consolidation within the market;
- that the US are and will remain the biggest market for Cloud services in the current decade, followed by Europe, which has also a slower growth rate than the US, but that the emerging markets are in terms of growth rates the most promising markets in future.

The analysis of adoption and usage patterns of business user, consumer and governments/public services highlights:

- that though there are only few and hardly comparable information available US companies, in particular SME, seem to adopt Cloud services faster then their European counterparts
- that also within the EU member states differences exist in adoption patterns, but that there no typical pattern like geographical location, size or general attitude towards internet obvious which could explain these differences between them;
- that the usage patterns do not differ as much as the adoption patterns between the US and Europe, i.e. many companies start to use simple applications and then advance to further, more complex ones;

- that similar to the adoption in business the consumer adoption of Cloud services in Europe also lags behind the US, but based on the available information it is unclear to state to which extend;
- that in Europe as well in the US most consumers prefer free solutions instead of paid ones as well as a preference to store not to many personal information;
- that consumers and their early adoption are seen in both regions as one driving factor for the advancement of Cloud services due to the customization of IT by consumers;
- that the level of adoption in government and public services seem not do differ as much at a first glance, but that a second view shows that the efforts made in the US are already achieved a more sophisticated level;
- that there are clear differences between in the US and Europe regarding an overall strategy, where the US pursues one federal strategy while the EU member states mostly pursue national strategies, and that as a consequence the US is more willing to use existing offers instead of custom developments;
- that some trends in the coming years like the growing complexity of business offers in Cloud services as well as the consumerization of IT by new consumer offers will continue, but it is unclear if the new services created as Cloud innovations will be more likely an evolution or revolution or none of both.

The identification and initial analysis of drivers and barriers based on existing studies outlines:

- that their is currently a strong research focus on the barriers for adoption and use in Europe, which is mirrored in the in the fact that the number of barriers outnumber the one of drivers;
- that this research also strongly focus on the barriers and drivers for demand side, in particular on the business usage and less on the consumer usage, but that barriers and drivers for the supply side, i.e. Cloud provider, is only addressed in a few studies;
- that the positioning of the different barriers and drivers according to our methodological framework reveals that Cloud Computing already left the early stage of emergence as a new technology and market;
- that cost savings and resulting competitiveness advantages are seen as the major drivers for the business adoption, but that in a long-term other drivers like flexibility and innovation will gain of importance;
- that the identified barriers for the demand side strongly cluster around three focal points, firstly the complex of data security and protection, trust, privacy; secondly the regulatory framework and legal issues, and thirdly the economic and technical complex of vendor lock-in, standards and interoperability;
- that they are strongly interrelated, but focus beside a few exceptions mainly on business concerns;
- that the barriers on the supply side are less concentrated and cover a broad spectrum reaching from a lack of R&D investments to market fragmentation;
- that most of them a not specific for Cloud Computing, but that some still have a high importance for the take up of the supply side;
- that the barriers and drivers as well as the barriers for demand and side and supply side also often strongly interrelated between each other, which needs to be reflected carefully for possible actions in the future;

- that on the European level many activities in the last years were started addressing barriers for Cloud Computing, but due to their ongoing status initial assessments of effects are not possible.

Based on these insights in the foundations of Cloud Computing, the project will focus in the next phase on the research of risks and benefits of Cloud Computing in Europe. This task will be addressed by a consolidation and eventually necessary amendment of the identified drivers and barriers, followed by an in-depth analysis of their impacts on the software and IT industry, consumers, government/public services and businesses as well as its overall impact on economy and society as a whole. Additionally the project will also start its research on Social networks for consumers and business.

1. INTRODUCTION

1.1. Myths and realities of Cloud Computing

Although the introduction of more and more information and communication technology into all spheres of life has always raised discussions, there was only a few as controversial as the ongoing discussion on Cloud Computing. Both, advocates and opponents, use many arguments, such as:

- *"Cloud Computing is a completely new concept."*
- *"With Cloud Computing, no one knows where the data is located."*
- *"Cloud Computing is old vine in new bottles."*
- *"Cloud Computing will change the way we use information."*
- *"Cloud Computing is always less expensive than on –premises computing."*
- *"Cloud Computing is only one more new hype in the IT industry."*
- *"Cloud Computing will help to create new employment and innovation."*
- *"New legislation is needed to allow the growth of cloud computing."*
- *"Cloud computing is less secure than on-premises data storage."*

This list of arguments is only a random sample and can be easily extended and varied. However it already shows that the perception and the way how Cloud Computing is perceived and discussed is characterized by a strong antagonism of arguments. Often it is not clear what of the different arguments are realities and what are myths. It also reveals that there is no clear understanding what Cloud Computing is and how it works. Moreover it also shows that there is only little knowledge on how it is used, by whom it is used and which factors influence the further development. Finally there are also many uncertainties about the benefits and impacts on society and economy.

The project on the potentials and impacts of Cloud Computing is overall aimed at providing this knowledge on Cloud Computing and to differentiate between the myths and realities of it.

1.2. Aims of the report

Consequently this first report of the project seeks to provide a basis for the further project dealing with the questions of what Cloud Computing is, on which technologies it is based and how it is used. Additionally it will also provide details on the related market development and which factors influence the adoption and uptake of Cloud Computing.

Therefore we will in the first part review existing definitions of Cloud Computing and introduce ways how to classify the different Cloud Computing services. This serve the purpose of shaping the understanding what Cloud Computing is, which characteristics are essential and how the different services can be differentiated. Finally we will also shape the focus of the further project based on this review and analysis.

The second part of the report will outline the evolution of the Cloud Computing concept. This includes the historical development of the concept as well as the relation of Cloud

Computing to previous and current other computing concepts like for example Grid Computing. Above that we will also explain the technological foundations of Cloud Computing, i.e. the technologies used by Cloud Computing as well as technological requirements necessary for Cloud Computing. In a last step of this part we will review future trends in the Cloud Computing technology.

The next part of the report will provide an overview on the development of the market for Cloud Computing services. This includes an review of the existing market analyses and forecasts in order to analyse the market development of the different types of services as well as the market development in different regions, in particular in Europe and the United States. Following we will also analyse the patterns of adoption and usage of Cloud Computing by consumers, business and governments and as far as possible their differences in different regions. Additionally we will provide an overview on the most important market players and their services and locations.

In the final part of the report we will based on an extensive review of existing studies try to identify driving factors and barriers, which can impact the development of Cloud Computing either positively or negatively. This analyses focus strongly on the situation in Europe, but will also try to reflect the fact that Cloud Computing is a global development. Based on this identification we will then assess the different factors and barriers according to their importance for the further development of Cloud Computing. Finally we will also shortly outline if and how these factors and barriers are addressed on the European level.

Concluding we will provide a short outlook to the next phase of the project in which these factors and barriers will be researched in detail as well as the economic and social benefits and impacts of Cloud Computing in Europe.

2. DEFINITION AND CLASSIFICATION OF CLOUD COMPUTING SERVICES

2.1. Definition of Cloud Computing

Since the rise of the term Cloud Computing around 2006 many people tried to find the right definition of it. In particular early versions of definitions were often very abstract and in man cases vaguely. Moreover many of them were dependent on the viewpoint of the one who defined the term, either suppliers or users point of view. In the latter case also many differences exist between the viewpoints of consumers, management, or corporate IT specialists or corporate end-users.

One example is the definition of McKinsey from 2009, which defines Cloud Computing as *"hardware-based services offering compute, network and storage capacity where: 1) hardware management is highly abstracted from the buyer; 2) buyers incur infrastructure costs as variable OPEX; 3) Infrastructure is highly elastic (up or down)*" (McKinsey 2009). This definition focuses strongly on management aspects like operational costs or flexibility and is therefore one example for a specific user viewpoint. On the other side also suppliers used the term in many ways after it became more and more popular. One strong example for that is the remark of Larry Ellison, CEO of Oracle, in 2008 stating: *"The interesting thing about cloud computing is that we've redefined cloud computing to include everything that we already do"* (Dignan 2012), which clearly shows another extreme viewpoint.

Consequently there is a strong need for a clear definition of the term "Cloud Computing". Though there is still no general definition, there are a few definitions many publications refer to. The first one is the result of a working group at the National Institute of Standards and Technology (NIST), an institution of the U.S. Department of Commerce, the second one was established by Gartner Group as a leading market researcher and finally as a third the definition of EC Expert group on Cloud Computing. While the two first were published in 2009, the latter one was published in 2010.

2.1.1. Definition according to NIST

In 2008 the Computer Security Division within the Information Technology Laboratory of the National Institute of Standards and Technology (NIST) was assigned with the task to define the evolving concept of Cloud Computing and to asses in particular security and privacy aspects in public Cloud Computing.

A first draft definition was already published in 2009. In this document it was defined as *"a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. This cloud model promotes availability and is composed of five essential characteristics, three service models, and four deployment models*" (Mell/Grance 2009, 2). The definition was cited by many other authors and is today the most widespread and accepted definition. It is for example basis for the Federal Cloud Strategy of the U.S.

Government (Kundra 2011) as well as for publication in other countries like the guidelines of the German IT industry association BITKOM (Weber et al. 2010).

In 2011 the final version of the definition was released with no differences in the main definition cited above. Only few changes of minor character occurred within the description of the characteristics, service models and deployment models, which are intended to specify this in general very inclusive overall definition more precisely (Mell/Grance 2011).

The five characteristics are described as the following:

- **On-demand self-service:** *"A consumer can unilaterally provision computing capabilities, such as server time and network storage, as needed automatically without requiring human interaction with each service provider"* (Mell/Grance 2011, 2).
  - means that the customer can directly access and use his data through self-adjusting service without interacting with the provider .
- **Broad network access:** *"Capabilities are available over the network and accessed through standard mechanisms that promote use by heterogeneous thin or thick client platforms (e.g., mobile phones, tablets, laptops, and workstations)"* (Mell/Grance 2011, 2).
  - means that the service can usually be accessed and used through any Internet-capable device, including for example smart phones, tablets or any Internet-connected computer.
- **Resource pooling:** *"The provider's computing resources are pooled to serve multiple consumers using a multi-tenant model, with different physical and virtual resources dynamically assigned and reassigned according to consumer demand. There is a sense of location independence in that the customer generally has no control or knowledge over the exact location of the provided resources but may be able to specify location at a higher level of abstraction (e.g., country, state, or datacenter). Examples of resources include storage, processing, memory, and network bandwidth"* (Mell/Grance 2011, 2).
  - means that in general the cloud service provider resources like storage or bandwidth are shared between the users. However it is also to customize some parts like security requirements. As a consequence customers do not know the exact knowledge on the location of the different resources used.
- **Rapid elasticity:** *"Capabilities can be elastically provisioned and released, in some cases automatically, to scale rapidly outward and inward commensurate with demand. To the consumer, the capabilities available for provisioning often appear to be unlimited and can be appropriated in any quantity at any time"* (Mell/Grance 2011, 2).
  - means that the cloud services can be easily adjusted to changes in the customers' demand.
- **Measured service:** *"Cloud systems automatically control and optimize resource use by leveraging a metering capability at some level of abstraction appropriate to the type of service (e.g., storage, processing, bandwidth, and active user accounts). Resource usage can be monitored, controlled, and reported, providing transparency for both the provider and consumer of the utilized service"* (Mell/Grance 2011, 2).

- refers to the fact the user can control its usage of resources and in case of payments only pay for resources used in difference to software licences and self owned hardware.

Overall we can state that these five characteristics define Cloud Computing much more precisely then other definitions before. In particular characteristics like resource pooling, elasticity or network access help to identify and differentiate Cloud Computing from related services like Outsourcing. Above that introduces as marked before three service models, i.e. Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS) as well as four deployment models, i.e. Public Cloud, Hybrid Cloud, Community Cloud, and Private Clouds. These models are essential parts of classifying Cloud Computing Services and will be detailed in the next section.

2.1.2. Definition according to Gartner

Gartner as a leading market researcher in IT placed Cloud Computing for the first time in 2008 in their well known Hype Cycle for Emerging Technologies (Gartner 2008). Subsequently it also tried to define Cloud Computing, primarily to assess it as a market, and stated that it is *"a style of computing in which massively scalable IT-enabled capabilities are delivered as a service to external customers using Internet technologies"* (Gartner 2009).

Confronted with the increasing problem that the hype around Cloud Computing led to a relabeling of many activities, in particular of hosting or outsourcing providers that declared all services from now on as Cloud Services, Gartner undertook several activities to redefine and specify their understanding of Cloud Computing. In a first step they changed their general definition replacing massively scalable through scalable and flexible resulting in the definition of Cloud Computing as *"as a style of computing in which scalable and elastic IT-enabled capabilities are delivered as a service to external customers using Internet technologies"* (Gartner 2009). Additionally Gartner also released a set of reports in which Cloud Computing and its application were defined more precisely by defining attributes (Plummer et al 2009) and giving insights to the what, why and when (Smith et al. 2009).

In order to define the term more precisely five attributes were introduced, which are described in the following:

- **Service-Based:** *"Consumer concerns are abstracted from provider concerns through service interfaces that are well-defined. The interfaces hide the implementation details and enable a completely automated response by the provider of the service to the consumer of the service. The service could be considered "ready to use" or "off the shelf" because the service is designed to serve the specific needs of a set of consumers, and the technologies are tailored to that need rather than the service being tailored to how the technology works"* (Gartner 2009).
  - means that users should only deal with the offered service, not with details of the underlying technologies.
- **Scalable and Elastic:** *"The service can scale capacity up or down as the consumer demands at the speed of full automation (which may be seconds for some services and hours for others). Elasticity is a trait of shared pools of resources. Scalability is a feature of the underlying infrastructure and software platforms. Elasticity is*

associated with not only scale but also an economic model that enables scaling in both directions in an automated fashion. This means that services scale on demand to add or remove resources as needed" (Gartner 2009).
    - refers to the ability to adjust the resources and services used accordingly to the changing demands of the users.
- **Shared:** *"Services share a pool of resources to build economies of scale. IT resources are used with maximum efficiency. The underlying infrastructure, software or platforms are shared among the consumers of the service (usually unknown to the consumers). This enables unused resources to serve multiple needs for multiple consumers, all working at the same time"* (Gartner 2009).
    - means that the resources of the cloud service provider will be shared by its users.
- **Metered by Use:** *"Services are tracked with usage metrics to enable multiple payment models. The service provider has a usage accounting model for measuring the use of the services, which could then be used to create different pricing plans and models. These may include pay-as-you go plans, subscriptions, fixed plans and even free plans. The implied payment plans will be based on usage, not on the cost of the equipment"* (Gartner 2009).
    - refers to the fact that the usage can be measured precisely and consequently the payment is deopending on the measured extent of usage.
- **Uses Internet Technologies:** *"The service is delivered using Internet identifiers, formats and protocols, such as URLs, HTTP, IP and representational state transfer Web-oriented architecture"* (Gartner 2009).
    - means that users can access the service using devices based on standard internet technologies.

Above these five attributes the different Gardner publications underline two more aspects. According to the widely accepted scheme they also differentiate between the three main service models (IaaS, PaaS, SaaS), but due to the needs as market researcher they introduce several market segments, which sometimes does not really fit into this scheme. Regarding the delivery model it seems like Gartner focus mainly on two models, either public or private Cloud services. This implies that hybrid models are seen as a sub segment of public clouds and other models are judged depended on their implementation.

2.1.3. Definition according to the EC Expert Group

In 2009 the European Commission set up an expert group that should try to depicture the development of Cloud Computing and its impact and relevance for the European economy and research landscape. In 2010 the expert group published a report called "Future of Cloud Computing", where Cloud Computing was defined as *"an elastic execution environment of resources involving multiple stakeholders and providing a metered service at multiple granularities for a specified level of quality (of service)"* (Schubert et al. 2010, 8).

As outlined by the group this definitions is as broad as possible. Therefore they also introduce several criteria including the different service and delivery models as introduced by NIST. Above that they also list a set of key characteristics and capabilities. In difference

to the other definitions they differentiate here between three types of it: non functional aspects, economic aspects, and technological challenges.

- **non-functional aspects** represent qualities or properties of a system, rather than specific technological requirements. Implicitly, they can be realized in multiple fashions and interpreted in different ways which typically leads to strong compatibility and interoperability issues between individual providers as they pursue their own approaches to realize their respective requirements, which strongly differ between providers. (Schubert et al. 2010, 13-14). These aspects include:
  - Elasticity, i.e. the ability to adjust dynamically to user demands.
  - Reliability, i.e. the capability to ensure safe operation of the service,
  - Quality of service, i.e. the overall quality of the offered service,
  - Agility and adaptability, i.e.
  - Availability, i.e. i.e. the capability to ensure continuous operation of the service.
  - overall these aspects refer to different types of properties of the offered services. Given the fact that modern IT technologies allow different ways to achieve them, the result is that Cloud Computing services can vary strongly though they in principal offer the same service.
- **Economic aspects** are one of the key reasons to introduce cloud systems in a business environment in the first instance (Schubert et al. 2010, 14-15). These aspects include:
  - Cost reduction, i.e. the possibility to save expenditures due to an adjusted use of services,
  - Pay per use, i.e. the fact that users are only billed for their actual usage,
  - Improved time to market, i.e. the ability to provide resources in very dynamic manner if needed for example to develop and introduce new products,
  - Return on investment (ROI); i.e. the fact that necessary investments in Cloud services are contrasted by higher benefits,
  - Turning CAPEX into OPEX, i.e. the possibility of turning fixed costs into operational costs to improve flexibility,
  - "Going green", i.e. the effect that not only energy consumption, but also carbon footprint is reduced.
  - these aspects clearly refer to the users interest to reduce the costs and increase the productivity of IT operations.
- **Technological challenges** "implicitly arise from the non-functional and economical aspects, when trying to realize them" (Schubert et al. 2010, 15-16).
  - Virtualisation, i.e. the challenge of reducing technological complexity for users while increasing flexibility, in particular by an ease of use, infrastructure and location independence and flexibility and adaptability of the platform.
  - Multi-tenancy, i.e. the architectural principle that users share the same platform (resources, software, etc.)
  - Security, privacy, compliance,
  - Data management, i.e. challenges related to the distributed storage and use of data and code,
  - API or programming enhancement, i.e. the challenges related to the development of tools enabling the exploitation of the advantages of Cloud Computing,

- Metering, i.e. the challenge of measuring and managing use of services to enable related pricing concepts.
- the technological challenges refer to aspects of the realization of Cloud Computing solutions enabling the economic and non-functional aspects. Consequently these realizations can vary due to the technological possibilities, i.e. there are always more than one technical solution.

Concluding we can state that the definition of the expert group is more detailed as the other two, in particular by using different sets of aspects and challenges they try to underline the interrelation of different characteristics.

2.1.4. Towards a unified definition of Cloud Computing?

All three highlighted definitions show many similarities, in particular the ones from NIST and Gartner. The definition of the EC Expert Group differs foremost in its degree of differentiation, e.g. the separation and accordingly the total number of characteristics, but not in its overall meaning. Therefore it seems obviously that there could be a possibility to merge them into one definitive definition. But as shown for example by the follow-on report of the Expert group on Cloud Computing published in 2012 (Schubert et al. 2012), Cloud Computing is still a moving target. Reasons are the dynamic development of the underlying technologies, but also the dynamic development of the market and in particular in the marketing of Cloud Computing services.

Hence there still is no general agreement on one definition and a specific set of characteristics. Such an approach would have to deal with several challenges. A first one is the fact that the growing popularity and usage in the recent years led to a more and more services offered like for example Business process as a Service or Security as a Service. This explosion and differentiation of services led to the development of term of Everything as a Service (XaaS) that was also introduced to spotlight the underlying problem of marketing as much as possible under the term of Cloud. Other challenges are the new forms of usage that were not foreseen in the early phase of Cloud Computing. Examples are they rise of different models of hybrid usages of external and internal resources as well as highly specialised offers. Finally also advances in the underlying technology like new developed platforms and standards were made (Schubert et al. 2012, 7-22).

Concluding, we can state that that a definition of Cloud Computing one the one hand needs to be precisely enough to differentiate Cloud Computing from other existing service offers like hosting services. On the other hand it needs enough flexibility to deal with the fact that Cloud Computing is still an evolving concept and technology. Faced with this problem the Expert Group comes to the conclusion that existing definitions like NIST, Gartner or their own definition from 2010 mainly reflect the current state of Cloud Computing, but not the essentials of Cloud Computing. In the following they try to sort out many points, but end up with three different definitions for users, providers and developers as well as minimal definition aimed at eliminating all superfluous characteristics that are not essential for Cloud Computing. It defines that *"an environment can be called "CLOUDified", if it enables a large dynamic number of users to access and share the same resource types, respectively service, whereby maintaining resource utilisation and costs by dynamically reacting to*

changes in environmental conditions, such as load, number of users, size of data etc." (Schubert et al. 2012, 22).

Although one can share their critics of the existing definitions, the offered solutions are also whether fully convincing or really convenient. One reason is that the minimal definition could be used for a great variety of services. This creates the possibility to include future developments, which can not be foreseen at the moment, but also bears the risk that the term could be attributed to offers that are not necessarily Cloud services in the eyes of most people. The only way to avoid this would be the comparison with the additional three definitions, which might be helpful but also complicated. As a consequence the added value of this new approach is limited.

2.2. Classification of Cloud Computing Services

As important as the question how to define Cloud Computing is the question how to classify the different identified Cloud Computing services. The literature offers a broad variety of answers (see f. e. Yang/Tate 2012). The spectrum ranges from simple classifications for example based on the NIST service model to multilayered, complex taxonomies (f.e. Hoefer/Karagianis 2010).

In the following we will try to identify important essentials for a classification. The aim is to develop a concise system that should be use for all stakeholders: users/customers, providers, operators as well as policy-makers or regulators.

2.2.1. Elements for a classification

Typically business models are often used to classify different service offers. Though, in the IT and software industry business models are seen by mistake equal to the way how services and software are priced. In theory and practice business models consists of broad set elements including for example strategy, revenues, offers, partnerships (see Osterwalder 2004), but there is also final consensus on the number and naming of these elements. Additionally research has shown that some elements only relate to specific industries or specific activities. However within the field of software and IT several projects tried to research business models in these fields. In general they also show a broad variety of approaches with different foci. While for example Rajala et al. (2003) try to reduce the number of elements into only four (product strategy, revenue logic, distribution and service/implementation), others try to be comprehensive like Buxmann and Schief (2012), who name in total five areas (strategy, revenue, upstream, downstream, usage), each with at least five sub elements. Each of these approaches follows its own purpose, f.e. in the case of Buxmann and Schief it serves as theoretical basis for business model wizard, and therefore a final evaluation is not possible

Nevertheless there is as outlined by Rajala and Westerlund (2007) a possibility to reduce the number to three essential elements. They define them as:

1. *„value propositions or offerings;*
2. *various assets and capabilities as resources needed to develop and implement a business model; and*

3. *the revenue logic (including sources of revenue, price-quotation principles and cost structures) that is characteristic of a particular business" (Rajala/Westerlund 2007, 119).*

With regard to the field of Cloud Computing we conclude that parts of these elements are already known. The offerings or value proposition of Cloud Computing are the different types of service models offered and which are detailed for example by NIST. The attribution of the second element is more complicated due to the fact that there is still an ongoing discussion on the dimensions of assets (internal resources) and capabilities (external resources) (Rajala/Westerlund 2007). In particular in complex value systems like Cloud Computing it encompasses several aspects like the technological, organisational and managerial resources within a company as well as the network with partners and customers outside of the company. One aspect expressing at least a configuration of internal and external resources are the different delivery models. Each of them incorporates some features like the specialisation of the supplier as well as their relation to their customers. Finally there is the element of the revenue logic, which was only partly addressed in terms of pay-per-use or measured services in the previous sections. The challenge is this case is that these aspects are still in flux since Cloud services are still an emerging market, where on the one hand new technologies continuously impact the possibilities of service offers and on the other hand many suppliers start try-outs of new and old revenue models.

2.2.2. Service models

Most spread within the literature is the differentiation into three service models, Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS). They can be seen as a way how and what is offered by the different suppliers. As already mentioned most definitions also refer to these service models, which are shortly explained in the following:

- **Infrastructure as a Service (IaaS):** in this case the supplier provides processing, memory, storage, and network transfer capabilities for customer. Typically the customer does not control the actual underlying hardware infrastructure but has possibly limited control over selected components (Mell/Grance 2011, 3). However intelligent management mechanisms allow him to control the capabilities. The model allows customers to implement and run their own software including operating system and applications. The resulting high flexibility for customers are contrasted by the required high level of understanding in usage. Therefore these offers are considered to address mainly IT administrators (Weber et al. 2010, 16).
- **Platform as a Service (PaaS):** in this case the supplier provides an platform or environment for deploying applications (Mell/Grance 2011, 2-3). This can range from operating systems for the installation of normal applications to complex runtime environments including programming languages and tools for the development and test of new applications. All provided supported by the provider. As in the case of IaaS the customer does not control the underlying infrastructure and platform, but is in control over self-installed applications. According to the literature this model mainly adresses IT specialists (Weber et al. 2010, 16).

- **Software as a Service (SaaS):** in this case the supplier provides working applications running based on its own cloud infrastructure to the customer (Mell/Grance 2011, 2). Typically the customer can access these applications via different internet based technologies like web interfaces or apps. Customers are neither in control of the underlying infrastructure nor in control of the used applications. This means that suppliers mostly offer standardised software packages, where no or little customization is possible. Only few things like for example industry-specific solutions within enterprise software are available. Consequently these offers are directed at consumers (Weber et al. 2010, 16).

Although this differentiation is widely used, there is still also a strong tendency to differentiate the list of service models even more. In recent years many other service models like Storage as a Service (Fielder et al. 2012, 19) or Business Process as a Service (BPaaS) (Forrester 2011 (after Dignan 2011)). But there are much more and already the Wikipedia entry for Cloud Computing lists more then ten different variations as examples[1]. As already mentioned some even name Service as a Service or Everything as a Service as other concepts (XaaS). In particular the latter is sometimes used as an indirect critic to this inflation of services. However some other also try to summarise all models under the umbrella of this term (f. e. Esteves 2011).

Nevertheless the situations indicate some problems. The first one is that in fact the used differentiation into three service models shows a high level of abstraction. Consequently many people criticise that within each of these three models great difference exist for example in the case of PaaS between simple operating platforms and runtime environments or in the case of SaaS between single applications and complex systems enterprise software (f. e. Schubert 2012). On the other hand a more differentiated view would create the problem to find an appropriate level of abstraction, which is hardly to achieve in such a complex topic. Another one is that many of the terms were introduced or used by single firms or groups of firms for marketing and differentiation reasons. Therefore the adoption of these terms can create other problems. Finally there is the point that it is not sure that all of these services will continue respectively succeed in the next years or if they will be stopped or replaced by other services in the next stage of Cloud evolution. Concluding we can state that based on this ground the advantages of such an abstract level outweigh its disadvantages.

2.2.3. Delivery models

The choice of a delivery model includes as already hinted many information on the different assets and capabilities of a supplier. The point is that the decision on the model implies also a decision on the product or service strategy. For example a supplier with a strong service orientation and maybe already experiences in developing customised applications would normally tend to offer its customers private Cloud solutions or at least customised public Cloud solutions. This requires a close relationship to the customer and furthermore close collaboration with them and possible partners involved in the project. Normally it would also lead to specific and customised agreements. On the other hand suppliers with a preference for standardized products in mass markets would tend to offer such as a public

[1] See http://en.wikipedia.org/wiki/Cloud_computing.

Cloud service with standardized agreements between them and the customers. This implies that the relationships to the customers are not as tight as in the case of service orientated suppliers. However there are also supplier that offer more than one solution and cover different kind of services, which is after all also a statement on their capabilities. Consequently we will use delivery models as a way to indicate assets and capabilities.

From the supplier point of view there are two basic delivery models, the public Cloud or the private Cloud. All other models introduced by different suppliers, researcher or agencies are somehow are variations or subcategories of these two models. Following the different definitions the following models can be separated:

- **Private Cloud:** In this case the infrastructure is provisioned for exclusive use by a single organization. It can be owned, managed, and operated by the organization them self, a supplier as a third party, or some combination of them. Additionally it can exist on or off premises of the organisation (Mell/Grance 2011, 3; Schubert et al. 2010, 10-11; Quian et al. 2009). Therefore special forms which are listed by some researchers like virtual private Clouds (f.e. Ried et al. 2011), where the cloud is hosted on dedicated, virtual machines in a Cloud providers data centre can be considered as private Clouds.
- **Public Cloud:** In this case the infrastructure is made made available to the general public and is owned, managed and operated by a third party specialised in providing such services at their premises. Customers therefore share the resources of the infrastructure n organization (Mell/Grance 2011, 3; Schubert et al. 2010, 10-11; Quian et al. 2009). This is what in public is mainly seen as Cloud Computing.
- **Hybrid Cloud:** in this case the infrastructure is a composition of two or more distinct cloud infrastructures. They can be of same type or of different types like public or private, but the have to be unique entities. Normally they are connected standardized or proprietary technology that enables data and application portability (Mell/Grance 2011, 3; Schubert et al. 2010, 10-11; Quian et al. 2009). In general this is a very strict definition, because in popular literature as computer magazines situation where a company uses one or more, mostly public Cloud services together with their own IT infrastructure, which does not necessarily need to organized as Cloud are also called hybrid solutions. Another point is from the market point of view it can not be differentiated and consequently each part of the used services is accounted either as public or private Cloud services.

Above this the NIST definition and also some other definitions also list the **Community Cloud** as a delivery model. In this case the *"infrastructure is provisioned for exclusive use by a specific community of consumers from organizations that have shared concerns"* (Mell/Grance 2011, 3) and can be own, managed and operated either by one of the participating organisations or a service provider as a third party involved. Therefore depended on the actual implementation this would be either accounted as virtual private Cloud (third party as supplier) or a private Cloud (organisation as supplier) due to the fact that it is no public offering. For the using organisations it may be a hybrid Cloud, due to the fact that may have also other capacities. However this type seems to be rather seldom.

Regarding the challenges of defining hybrid Clouds we will not follow the very strict definitions like the one from NIST. Instead we use a broader and open approach where already the mix of public Cloud services with traditional IT systems in companies will be also seen as hybrid solution as long as data are transferred between them.

2.2.4. Revenue models

There is a broad range of publications dealing with revenue models, which mainly features two aspects: the cost model and the pricing model. Since the pricing mechanism are more obvious then the cost structure of suppliers, we will focus on the first part for the classification. In general there is a consensus on the actual pricing mechanism like pay per use/pay as you go, flat pricing/subscriptions or auctions, but their categorisation varies strongly. Osterwalder (2004, 95-101) for example differentiate for example between fixed, differential and market pricing, while Harmon et al. (2009) in their approach for pricing of IT services differentiate between cost- and value based pricing strategies.

In the literature regarding Cloud Computing the pricing mechanisms are also often discussed. These discussions focus mainly on the different types of pay per use/pay as you go mechanism (f. e. Weinhardt et al. 2009a&b; Yeo et al. 2010), which is as already indicated by some of the definitions and characteristics seen as an essential novelty of Cloud Computing in contrast to earlier pricing mechanisms in the software and IT industry. They also often discuss the complementary model of subscription based pricing mechanisms, which is also often used (f.e. Youseff et al. 2008; Weinhardt et al. 2009b). Only few publications also discuss other forms of pricing mechanism like for example market based pricings or so called dynamic pricing mechanism (f. e. Anandasivam et al. 2009). This includes for example auctions as introduced by Amazon Web Services with the Amazon Spot Instances, where customers can bid for free capacities of Amazon.

Although it seems like pay as use/pay as you go models are predominant and that they are also future of Cloud Computing, there is also some argumentations against it. Durkee (2010) argues that the ongoing price competition based on the pay as use models will create problems for suppliers in the future. Therefore his belief is that suppliers are in need for value-based approaches that would also result in other pricing mechanisms. The fact is that Durkee's observations are right in particular for the markets of IaaS and PaaS. Here some big suppliers like Amazon or Google offer their infrastructures as bulk ware and are engaged in a price competition. In opposite to this the market for SaaS is dominated by other pricing models like subscription based mechanism. For example Salesforce as well as SAP by Design offer services on a user per month-fee base, where prices can vary depended on the extent of used services and/or total number of users.

Based on the literature review as well as review of suppliers offer, we identified four basic pricing mechanism categories that can be used for classification. Each of them can contain several different pricing mechanisms:

- **Subscription based pricing:** this category includes all services offered with fixed fees . Possible examples are fees per user/month as well as fixed fees for a certain

amount of service like for a certain amount of data storage etc without. As already mentioned this pricing mechanism can also contain elements of differentiation to certain extent.

- **Usage based pricing:** this includes all pricing mechanism based on the actual usage of services. In this case usage can be measured in different dimensions dependent on the service offered as well as the measurement system. Examples are the amount of data storage, instances or similar. Although this is often claimed as being the novelity of Cloud, comparable pricing mechanism existed before like the performance pricing based on MIPS as used by IBM.
- **Flexible or dynamic pricing:** it includes all mechanism like auction or reverse auctions or spot markets, where prices are formed dynamically in market-like structures. At the moment only a few of them exist as already mentioned. Some publications even state that the method though it is enabled by features of Cloud Computing, will not retain due to its complexity for the user (see for example Khajeh-Hosseini et al. 2010).
- **Advertisement based pricing:** this category, which is not often reviewed in the typical business literature, encompass all services that are offered without any kind of fees. But since there ain't no such thing as a free lunch, customers get advertisement presented, sometimes even based on the analysis of their usage. While pure advertisement based services are seldom, one can find a hybrid version, the so called "freemium" services, where a basic service is financed by advertisement, but upgrades enabling extended services are subscription or usage based. One example for such an approach is Dropbox.

Overall the review shows at least two points. Firstly, it is obvious that nearly all identified categories show some developments towards a hybridization of pricing mechanisms. In particular this tendency is obvious in the case of subscription based services. Somehow it seems at least for this category this **hybrid models** are one way to replace the classical model of licences and maintenance fees. However it is hard to create a fith category for them due to the fact that the hybrid models differ strongly. Secondly the review showed that some pricing mechanism are as already hinted more related to a certain type of service model or customer , like usage based pricing and IaaS or freemium services and private consumers. This shows that although most people think of one dominant model, the reality is diverse. This could also explain a kind of uncertainty for users, but also for Cloud suppliers who are not certain how to plan future investments in Cloud.

Concluding we can state that the critic of the expert group on the fact that pay as use as an essential characteristic of Cloud Computing is justified (Schubert et al. 2012). Although many people see it as the dominant model, the reality is more complicated. Moreover it seems that it is still unclear which models will retain or gain of importance. Most likely are those different services will result in different revenue and pricing models. Therefore we can expect still some developments within this dimension.

2.2.5. Business models and types of actors

Based on their general considerations Rajala and Westerlund (2007) identify four types of business models for the software and IT services along two dimensions: the level of homogeneity of offering and level of involvement in customer relationships.

- Type 1: software tailoring, i.e. low level of homogeneity, but high level of involvement with customers. Typical examples are IT service companies, which built individual solutions for customers.
- Type 2: applied formats, i.e. high level of homogeneity and high level of customer involvement. Typical examples are software companies that use a highly standardized core product, but allow customization of specific modules like for example ERP companies such as SAP or Oracle.
- Type 3: resource provisioning, i.e. low level of homogeneity and low level of involvement with customers. Examples for this are companies with a broad range of offerings mainly for mass a mass market.
- Type 4: standard offerings, i.e. high level of homogeneity and low level of involvement with customers. Examples for this are software product companies that sell commercial-off-the -shelf products to a mass market like for example Microsoft Office.

Although it is possible to describe the different actors in the Cloud Computing market according to this scheme, it is better suited for the analysis of the classical software and IT services market. Newer research argues that due to the dynamic and evolving stage of the Cloud Computing market business models are also still in the flx and have to adjust to the underlying developments (Leimeister et al. 2010; Zhang et al. 2010). Consequently some argue that each service ty lead to an own business model (Zhang et al. 2010, Marston et al. 2011). Others argue based on the assumption that Cloud Computing is an evolution of outsourcing that a value chain approach is most suitable to describe business models, actors and the resulting ecosystem. One example is Leimeister et al. (2010), where there is differentiation into five types of actors and models:

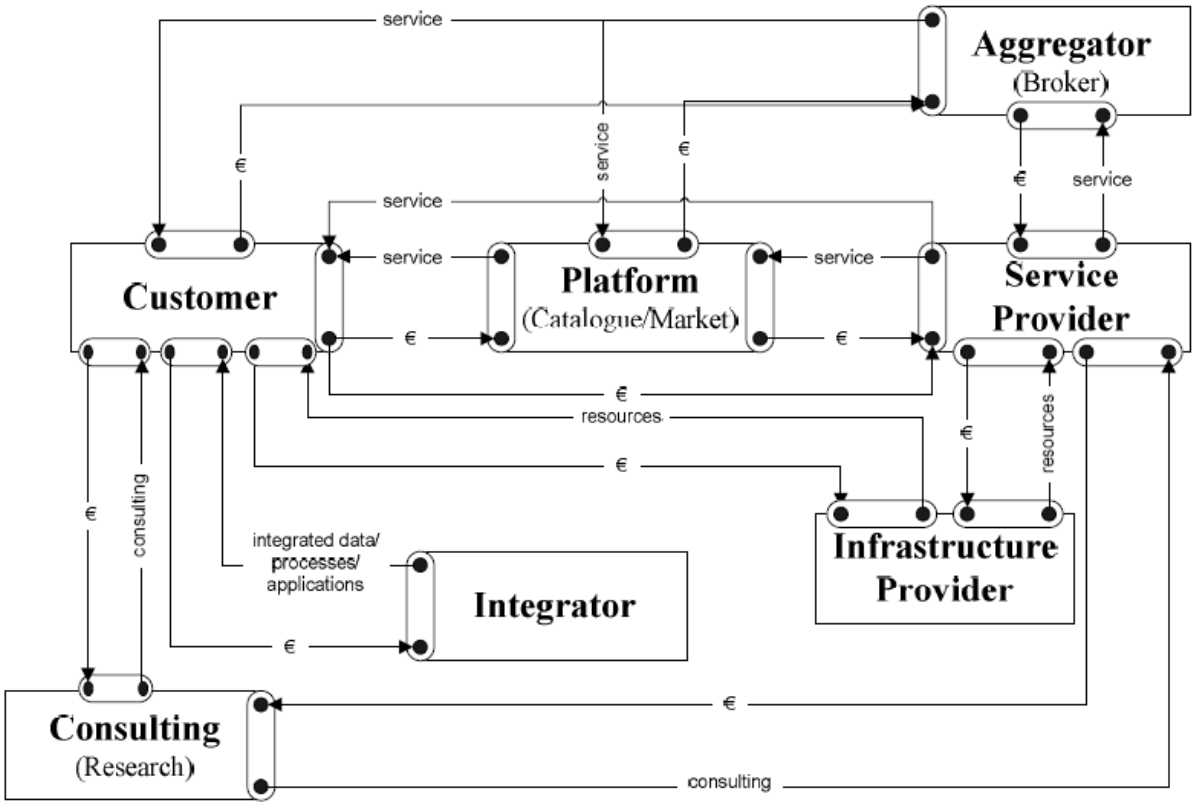
- **Consultants**, which support customer in selecting, implementing and integrating offered services;
- **Service provider**, which develop and operate services offered and deployed on cloud computing platform;
- **Service aggregator**, which develop and operate services based on other existing Cloud services. Sometimes differentiated into service and data integrators;
- **Platform provider**, which provides an environment where cloud applications can be deployed;
- **Infrastructure provider**, which provide the necessary, scalable hardware and related computing and storage services for the services

The resulting value network (ecosystem) is only a generic snapshot of possible models and actors. In reality many companies combine several types of actors, sometimes even the full value chain like for example HP with its own public Cloud offers. Another point is the appearance of new actors and business models. One good example is Zymory, a spin of the

Deutsche Telekom T-Labs, that act as broker or intermediary between data centres who want to offer unused resources in order to increase thei revenues and companies in search for computing or storage capacity. In the value network of Leimeister et al. (2010) They would be placed somewhere in-between infrastructure and service providers.

Recently such developments were taken up by the NIST reference architecture, which differentiate into five distinct types of actors: 1. Cloud consumer, which uses services; 2. Cloud provider, which makes offers available; 3. Cloud auditor, which independently assess different functionalities (operations, performance, security); 4. Cloud broker (including service intermediation, service aggregation and service arbitrage), which additionally manage and negotiate relationships between providers and consumers; 5. Cloud carrier, which provides connectivity and transport (Bohn et al. 2011, 4-9). Similar it also underlines the possibility that actors can take more then one role and that as a consequence possible relationships can vary strongly. Therefore it is in most points comparable to Leimeister et al. (2010), but takes a more technical perspective in the description of actors.

Value network of Cloud Computing, Source: Leimeister et. al. 2010, 10



Finally there also the high probability that like in the software market strategic and technical alliances or partnerships as well as different types of special arrangements will evolve over time. This will lead to a shaping of existing and possibly a creation of new forms of ecosystems and underlying business models and actors.

2.3. Conclusion: Shaping the focus

Based on this extensive review of different aspects how to define and classify Cloud Computing, the final step is to shape the focus of the STOA project on potentials and impacts of Cloud Computing in accordance to the aims of the project.

Firstly, given the need for a "working definition", we will orientate towards the definition of NIST. In detail we will use the first part defining Cloud Computing as *"a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction."* (Mell/Grance 2011, 2). Above that we will also relate to the five characteristics introduced by NIST for the identification of Cloud Services. However we will bear in mind that some of them as outlined in the previous section may require changes and adjustments to the future developments in Cloud Computing. Therefore we will reflect them critically during the project.

Secondly, with regard to the dimensions of classification for identified Cloud Computing services we will scope the project in several ways. A first way of scoping is that we stick to the three generic service models. Although the discussion has clearly shown the limitations in terms of the great variety of each of the three dimensions and resulting business models, we will keep them for two reasons. First of all, there is no agreement on other ways of differentiations and additionally by applying some of them we risk getting a victim of specific trends or the marketing of specific groups. The second reason is that a more differentiated classification of service models would not automatically enable deeper insights into the potentials and impacts of Cloud Computing. On the contrary it could lead into the opposite direction and make it difficult to realize the underlying challenges. However, within the assessment of barriers and drivers as well as in our in-depth analysis of potentials and impacts, we will reflect wherever it is necessary to the different levels of complexity within the service models. Regarding the revenue models it is obvious that these models are still in a flux. Therefore we will according for example to the results of expert group consider the resulting challenges and limitations more as part of our analysis rather than a way to exclude or include services. Due to the fact that the same argument is valid for business models and types of actors we will also only use them if necessary to classify suppliers in the following sections.

Concerning the delivery models we will finally clearly focus the project on the review of public and hybrid models. Given the overall focus of the project these models that mainly address consumers and small and medium sized enterprises, which are not able to afford own solutions, are of a public interest. In opposite to that private clouds are solutions for bigger companies. Due to the nature as a company internal solution many implications resulting for example the involvement of a third party (supplier) like the control of data security and integrity are not given. However we are aware that some challenges like for example localisation regulations for data privacy, i.e. the fact that data related to persons need to retain in the jurisdiction of one country, are also valid for them and for example affects the possibility of multinational companies to reduce the number of data centres. In such cases we will denote and reflect it, but we will not focus our analysis on it.

3. EVOLUTION OF CLOUD COMPUTING

3.1. Evolution of the Cloud Computing concept

The idea and concept of Cloud Computing already evolved in the 1960s. In 1961 John McCarthy had the idea to offer computer-services as public services (McCarthy 1961). At this point of time computers were giant time-sharing mainframes with terminals and they were mainly used in science and industry. In the 1980s the first personal computers evolved.

Important for the evolvement of Cloud Computing was also the technical development in internet technologies, hardware and distributed systems. Moreover Service oriented Architectures and web services had an impact. In the 1990s Grid Computing evolved and in 1997, the term "Cloud Computing" was first used by Ramnath Chellappa. He defined it as a *"computing paradigm where the boundaries of computing will be determined by economic rationale rather than technical limits alone."*

The first services that nowadays can be seen as Cloud services started 1999 (salesforce.com and Google). In 2002 Amazon started its Cloud services (Amazon Web Services) and provided services like storage and computation. This can be regarded as the start of Cloud Computing as it is understood today. 2006 Google Docs was one of the first platforms for working together in groups in an online environment and offered specialized software (Software as a Service). In 2006 Amazon Elastic Cloud Computing (EC2) followed. It is designed for large computations in the Cloud where especially capacity can be quickly scaled. In subsequent years all the big players became active in Cloud Computing and when Microsoft, Oracle and Hewlett-Packard launched their services in 2009, Cloud Computing has become main-stream.

3.2. Predecessors and related concepts of Cloud Computing

3.2.1. Predecessors since the late 1990s

The concept of Cloud Computing is not entirely new and had several predecessors, mainly Application Service Provisioning, Grid and Distributed and Utility Computing. They mainly have in common that they use web interfaces to interact with the user and focus on distributed web-based service offering. and their importance for the Concept of Cloud Computing

Application Service Provisioning

Application Service Provisioning (ASP) provides IT-based services over a network and is accessed online via web browsers. The software or application is installed on an external server, a local installation is no longer necessary. The service is accessed independent from the user's location but internet access is nevertheless necessary. Also "use on demand" is part of this concept and ASP also brought a new billing model: The service is paid per-use or a user dependant fee is charged. Data processing is shift to the server and thin clients

are used. A thin client has the function to display the output and to deliver the user's inputs to the server.

One advantage of this concept is the reduction of maintenance costs due to centralized software installation. One of the key features of ASP is that software maintenance and installation is done by the service provider. So for example companies can save time and concentrate on their core business. Another benefit is the increased flexibility through the on-demand offering of software.

ASP generated high expectations which could not be fulfilled. Weak networks at that time could not handle real-time operations and high data exchange rates.

Distributed Computing

Distributed computing components (or nodes) communicate over a network and make up a distributed system of computing resources. The software components run on different autonomous computers but are combined to one single system to solve tasks. The main problem is divided and solved parallelised.

An advantage of distributed computing is the expandability of the system through adding further machines. Another point is that a distributed system consists of several components connected over a network but for the user it seems to be one system. Now middleware, for the first time, plays an important role as interface between user and components. It coordinates the information flow and is a fundamental requirement to hide the complexity from the user as well.

Grid Computing

Another concept is Grid Computing that evolved in the early 1990s. Distributed resources are aggregated and provide computing power on demand. Access is provided over standardized protocols. A supercomputer is constructed through the networked loosely coupled computers to perform large tasks. Grid Computing is based on three characteristics (Foster 2002): decentralized resource control, standardization, non-trivial qualities of service. One challenge concerning Grid Computing is the interface to the service. This is very complex and difficult to handle because Grid has a strong scientific orientation and the middleware to access the service is very complex.

The difference between ASP and Grid Computing is that they address different kinds of service models. While ASP mainly offers Software as a Service, Grid Computing has a focus on offering computing power through the aggregation of resources (Platform as a Service).
An advantage of Grid computing is the improved usage of computing resources. Cloud Computing evolved out of Grid Computing and is a kind of advancement. In Cloud Computing the effort to get access is short-term, while in Grid Computing more time is needed. Grid Computing only offers computing power and no software or virtualization. Grid Computing is especially a Platform as a Service (PaaS) model.

One famous grid project is SETI@home[2]. Within this project computing resources are combined to search for extraterrestrial intelligence.

Utility Computing

Another concept that can be seen as predecessor of Cloud Computing is Utility Computing. In general it refers to the delivery of particular IT services as a metered service, i.e. IT services were delivered and charged based on usage. In this context utility refers to the type of services like electricity or water. The concept itself started to evolve at the same time as ASP and others internet based services. Like ASP it did not become main-stream until the mid of the 2000s. But while ASP experienced a relabeling into SaaS, utility computing as a term started to gain impact in 2005 by an article of Nicolas Carr forecasting the end of the corporate computing (Carr 2005). The article and the following discussion sketched out many basic principles of utility computing 8sometimes also labelled as hosted services) like virtualisation, service orientation or similar, which are nowadays central parts of Cloud Computing. However, at this point it was still seen as a niche development like Grid Computing, which were both often closely connected (LaMonica 2005). However with the raise of the term and concept of Cloud Computing the term utility computing started to disappear. Only sometimes it is still used to mark differences between consumer and corporate aspects of Cloud Computing.

3.2.2. Related concepts to Cloud Computing

There are several related concepts to Cloud Computing. In the following pervasive computing and ambient computing are further explained.

Pervasive Computing

In pervasive computing the computing resources are integrated in small devices and are incorporated in daily life. Drivers in this field are mobile internet and mobile devices what increase the amount of possible services. The devices used do not have enough computing power to solve intensive tasks. So they use the connection to the Cloud to outsource computing resources and storage.

Ambient Computing

Ambient is an enhancement of pervasiveness. In ambient intelligence environments are sensitive and can react to people. The devices are embedded and get smaller and smaller. They are needless inserted in the environment. Also in ambient computing the resources and services of Cloud can enhance the concept.

[2] See http://setiathome.ssl.berkeley.edu/.

3.3. Technological foundations and requirements of Cloud Computing

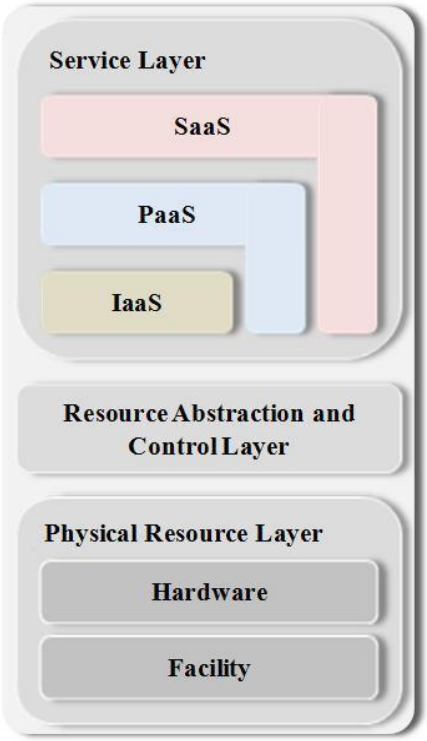
3.3.1. Technological foundations

The overall concept in Cloud Computing is the Cloud architecture. Another point is the way to offer services in the cloud. Here the principles behind Service oriented Architecture and web services are explained. Finally, multi-tenancy and virtualization as basic feature are explained.

Cloud architecture

The Cloud architecture according to the NIST reference architecture knows three layers (Bohn et al. 2011, 12-14).

Picture: Cloud Architecture, Source: Bohn et al. 2011, 13



The top layer consists of the three services IaaS, PaaS, and SaaS, which were already explained in the previous chapter. It might be important to mention that the control of the user raises from SaaS to IaaS. All three can have a dependency in terms of that SaaS services build on PaaS or IaaS services, but it is only optional because SaaS can also be direct implemented without the usage of others. Finally this layer offers also access to each service, normally based on a web services (Bohn et al. 2011, 13).

The middle layer encompasses the resource abstraction and control. The first enables the Cloud supplier to provide and manage the usage of the physical computing resources by different users. It is achieved by software abstraction enabling multi-tenancy. For that purpose different types of software are used typical for virtualization like hypervisor, virtual machine etc., which should help to enable ensure efficient, secure, and reliable usage. the

latter part relates to different types of Cloud software enabling resource allocation, access control, and usage monitoring (Bohn et al. 2011, 13).

The physical layer contains all physical computing hardware like computer, network, storage and other computing equipment as well as the resources provided by the data centre facility like air condition, power and other things (Bohn et al. 2011, 13-14).

Web services and Service oriented Architecture

Services in the Cloud are offered as web services. They mainly rely on Service oriented Architectures. SOA and Cloud are independent approaches but both technical concepts are explained in the following.

Core concept of Service oriented Architectures (SOA) is the service offering over a network. The fundamental elements of the SOA architecture are open standards, security and simplicity. The pillars are distributed services, loose coupling, registry and process orientation. Open standards and interfaces in machine readable manner are fundamental requirements for a broad acceptance of the architecture. The services are loose coupled. If needed they are searched dynamically. The main challenge is the embedding of services to the runtime. In the registry the services are listed.

SOA is not a predecessor of Cloud Computing but a related concept. They are different but have a certain overlap. Both offer web-based services and are fully dependent on the internet while SOA is more an architectural paradigm.

Web services[3] are the implementation of a SOA and are prerequisites for Cloud service offering. Web services communicate using open protocols. The W3C defines it as *"software system designed to support interoperable machine-to-machine interaction over a network. It has an interface described in a machine-processable format (specifically WSDL). Other systems interact with the Web service in a manner prescribed by its description using SOAP-messages, typically conveyed using HTTP with an XML serialization in conjunction with other Web-related standards."*[4]

They are discovered using UDDI (Universal Description, Discovery and Integration) which is an XML-based registry where information about web services is listed. XML is also the general basis for web services. Also WSDL (Web Services Description Language) and SOAP (Simple Object Access Protocol) are central in the context of Web Services.

WSDL[5] is written in XML and used to describe and locate web services. It also specifies the operation the service can make. WSDL describes a web service with the four XML-elements: <types> (mainly data type), <message> (communicated data), <portType> (operations supported by endpoints) and <binding> (protocol/data format specification). The <portType> element is the most important of the WSDL-elements. Within this element

[3] See http://www.w3schools.com/webservices/ws_intro.asp.
[4] See http://www.w3.org/TR/ws-gloss/.
[5] See http://www.w3schools.com/wsdl/default.asp

the web service is defined, the performable operations are specified and the messages are contained.

SOAP[6] is a communication protocol that is used by applications to exchange information over HTTP and is based on XML. It has a simple format for the exchange of messages. Another important point is that it is platform as well as language independent. Soap messages have a fixed format: envelope, header and body.

Multi-tenancy and virtualisation

Multi-tenancy is seen as essential part of cloud computing. Resources are pooled to serve many customers at the same time. Each customer is called a tenant and the same resource or instance is assigned to multiple users. So they share the same physical IT-infrastructure and can customize parts of the application but not the code of the application. A single instance serves many customers. One approach to solve the problems mentioned is virtualization.

Virtualization is the basis of Cloud Computing. By definition a decoupling from physical local machines to virtual machines is done. Physical resources are aggregated in pools so that they are manageable as a whole. An abstract logical view on physical resources is offered. Through this step software is used on servers instead of a local installation. As an effect virtualization hides complexity from the end user. A virtual machine is a software implementation of a real machine and has mainly two realizations: System virtual machines where complete operating systems are executed as well as process virtual machines that only run single programs.

In the context of Cloud Computing different kinds of virtualization are distinguished (Baun 2011, 5). One of the concepts is operating system virtualization. Here a number of different identical system environments run on the same kernel but are completely isolated. The storage is dynamically scalable (storage virtualization). Platform virtualization makes it possible to run any application or operating systems in a virtual environment. Further concepts are network virtualization and application virtualization.

Virtualization supports several features (Schubert et al. 2010). Complexity is hidden so it gets easier for the user to develop new applications and also the effort to control the system is reduced. Another point is the independence of the infrastructure whereby the code gets independent. The offered services is location independent and accessible from everywhere.

3.3.2. Technological requirements of Cloud Computing

Due to the functionalities and basic principles of Cloud Computing, there exist some critical requirements, which should be explained in the following.

[6] See http://www.w3schools.com/soap/default.asp.

Networking and availability of data

Cloud Services fundamentally rely on a working network infrastructure and a stable internet connection. When the Server where the data is stored is not available the whole approach does not work. One of the main technical requirements is a stable and secure network connection between Cloud system and the device or end-user. Network outages are a problem. Also the (insecure) connection is an attractive target for attacking the system.

Another point is the network capacity. A strong limitation of the performance is the bandwidth of the internet connection. In local networks the speed is much higher which should be considered when moving to the Cloud.

Reliable Cloud Service Offering and Fault Tolerance

When data is stored in the Cloud environment, it is access-protected and encrypted. The data is stored in virtualized pools. There are mainly two ways to run a database on the Cloud: Virtual machines and Database as a Service. In virtual machines the database runs independently in the Cloud but the time is limited. Within Database as a Service access to the service is purchased from the provider. An example is Amazon Relational Database Service (Amazon RDS). The data model generally varies and is based on SQL (in this case it is relational) or alternatively on NoSQL where the data model is non-relational.

Beside data storage another point is the reliable hosting of the service on the provider side. The system must be fault tolerance to be reliable. It has to cope with network outages and failures on nodes. Most often the data storage is replicated on several data centers all over the world to offer a reliable system. Details concerning these points are regulated in Service Level Agreements (SLA) (Wieder 2009) which include Quality of Service requirements. SLAs are set up between provider and customer and include details, like for example the availability and also the penalties.

The reduction of any single points of failure is one of the main challenges to offer reliable Cloud services. So many parts of the Cloud infrastructure are replicated.

Critical issues of multi-tenancy

Multi-tenancy is important for the perception and the evaluation of data security. According to (Schubert et al. 2012, 12-13) the problem has mainly three aspects:

- The usage information needs to be completely isolated
- Data security and privacy should be kept.
- Consistency is a main challenge, especially eventual consistency. Strong and weak consistency can be distinguished (Vogel 2009). Within Strong Consistency after a transaction all following accesses have the written value. This is not guaranteed in Weak Consistency, not until a specific time interval (inconsistency window). Eventually Consistency is a special form of Weak Consistency where inconsistency window depend on factors like load, replication nodes or reaction time of the system.

Security issues

Information security in the Cloud is an significant issue especially because of the acceptance of the Cloud service offering. Cloud Computing environments should be as save as in-house IT-systems. When data is moved to the Cloud it can be hosted everywhere on the world so legal issues arise. Depending on the location different national laws and regulations are applied (Voorsluys 2009, 35).

Interactions and communications between two parties should be trustful, especially because in Cloud Computing many third party services are used and trusted they play an important role. Though the data in the Cloud is encrypted, the provider should be trustful anyway because he also has access to encrypted data.

There exists also a range of Cloud certificates. They could help to overcome legal and organizational barriers.

3.3.3. Challenges and future directions in Cloud Computing technology

Cloud Computing has still potential for future developments, but there are also a number of challenges that need to be addressed. In the following selected technological trends and research directions as well as challenges ahead are listed.

Interoperability and standards

With the increasing number of Cloud providers also the systems vary a lot. Their disadvantages are the lack of standards and incompatible interfaces between different services. There is a discussion about common standards to improve the interoperability and portability of and between Cloud offers. This is especially a point due to missing standard protocols what makes a change of the service provider partially difficult. Data lock-in is a concern of many users. Applications and data can't be moved to other providers and switching costs are high. So the need for federated systems still increases and the related software and code should be developed. Federated systems need specialized research efforts in security, migration, services and Quality of Services. Federation brings interoperability and portability of Cloud services (Schubert et al. 2012, 46). An example is eucalyptus which is an open Source platform to build hybrid and public clouds[7]. Also appscale is an open source implementation of Google App Engines' scalability technique[8]. beside this technological approaches there are at the moment some initiatives are ongoing to develop standards and interoperability frameworks for Cloud Computing. Most well known might the approach of the Organisation for the Advancement of Structured Information Systems (OASIS), which is an industry led initiative, but there are also others like the Distributed Management Task Force (DMTF), another industry led organisation, or the ones from the European Telecommunications Standards Institute (ETSI).[9] Given this development it will be also a challenge to coordinate the different developments to avoid the risk of fragmentation.

[7] See http://www.eucalyptus.com/.
[8] See http://code.google.com/p/appscale/.
[9] For a first overview see http://cloud-standards.org/wiki/index.php?title=Main_Page.

Quantity of data (Big Data)

The size of data is constantly growing. Big Data is a challenging factor for storage and computing resources. 1.2 zettabytes of data are produced in 2010 and will increase to 8 zettabytes[10] in 2015 referring to a market research study of IDC (Gantz/ Reinsel 2011). Traditional relational databases can't cope with this amount of data. Since recent years the NoSql movement offers techniques to store large amount of data but lack in guaranteeing consistency of data. So further research is necessary in this field. Especially within update intensive applications the offered support is very restricted because to guarantee consistency and integrity is difficult (duplications, concurrent access…). The amount of data is growing faster than storage and bandwidth do. In this field also the increased usage of mobile devices is challenging for the existing systems.

Scalability

Efficient scalability is still a challenge in Cloud Computing because data as well as the code are both not structured optimally. Due to this resources are wasted and resource utilization could be far more optimized in future. The problem of these systems is that user behavior and demand are not predictable to estimate the needed resources and achieving an effective usage (Schubert et al. 2010, 50; Schubert et al. 2012, 59).

Security and auditing

Another major challenge for enterprises are security concerns when data is stored externally and not in their own data centres (Schubert et al. 2010, 50; Schubert et al. 2012, 63). Furthermore there are legal challenges when storing data in different countries. For example sensitive data has different protection levels in different countries. Moreover there are security issues arising due to multi-tenancy, varying security standards of the providers and technical restrictions. On the one hand there must be research in technologies preserving security in the Cloud. One example is homomorphic encryption that enables the possibility to calculate encrypted data (Gentry et al. 2010). On the other hand common audit standards should be developed to ensure high security standards for Cloud services.

3.4. Conclusions: Patterns in the technological development of Cloud Computing

From a technological point of view the ideas and concept underlying Cloud Computing are nothing new. Already in the early 1960s ideas and concepts foresaw the shared use of computing capacities through networks. most of it went into the multi-access operating systems, which started their take up on mainframes in the late 1960s and early 1970s. Though the technical implementation was very basic, the ideas behind were the same. Some of the researchers even described far more complex concepts closer related to Cloud as it is today, but these were applicable at that time. Due to the miniaturization and personalisation of computing these ideas and concepts became less notice.

[10] 1 zettabyte = 10^6 petabytes

A new wave of concepts related to these ideas started to evolve together with the growing diffusion of the internet in the 1990s. In particular the availability of more and increasing better network connections led revived the idea to use computing capacities and applications via networks resources. Most important to mention were ASP, Distributed and Grid Computing. Although these approaches differ in their scope as well as their technical architecture from Cloud Computing, they started to lay the ground for it and some companies involved in it became early adopters of Cloud Computing.

In principle Cloud is based on a three layer architecture encompassing the physical layer, the abstraction and control layer, and the service layer. The service layer consists of the three service models IaaS, PaaS, and SaaS as explained before. Main underlying technology here is the access via web services to enable user (customer or aggregators and broker) to access the services. These services are based on a service oriented architecture and enable machine-to-machine interaction based on internet standards. The abstraction and control layer enables the resource pooling and sharing (multi-tenancy) through the means of specific software solutions. Most likely a set of virtualisation tools are used for abstraction. Finally the physical layer encompasses the all physical computing hardware as well as the resources provided by the data centre facility to enable the operation of it.

Consequently the main technological foundations are based on the two concepts of multi-tenancy and service orientation. While the first one describes the ability to manage the access and use of computing resources by different users, the latter one describes the principles how the services are designed and implemented. Both concepts are closely connected to specific technical implementations. In the case of multi-tenancy this solution is at the moment the existing virtualisation and management software, which enables the abstraction required for an efficient use of computing resources by many users. The other solution is web services, which enable customers to use easily the different service offers.

There are several technological requirements given that need to be in place to ensure the well function of Cloud services. On the one hand this encompasses basic infrastructures such as sufficient network capacity. They are required to enable a reliable and convenient access to data, information and services. Additionally also reliable and fault tolerant service offers itself are required to offer customers high quality services. On the other hand technical aspects like different issues related to multi-tenancy are required. This includes aspects of the management and virtualisation of computing resources as integrity and consistency of of data. Closely related to the latter one are security issues, which have a high relevance for the service quality. For example the security of confidential data, but in particular for companies also the technical implementation of compliance to existing regulations. Overall this shows that there is a broad set of technical requirements that can impact the functioning of Cloud services strongly. Therefore the underlying concepts, but also the technical implementations should not be taken for granted.

This lead directly to the fact that Cloud Computing is not only an evolving concept, but that it is also still an evolving technology. Consequently it bears a strong potential for further research and advances in technology. the literature on possible further research directions

is huge and varies dependent on the point of view of the author. therefore only a few points can be highlighted. One area are basic technologies like scalability, flexibility or other technological components like data bases or analytics. However beside this there are also a set of challenges that need to be addressed in order to ensure the convenient use of Cloud Computing offers. One prominent example for it is the question of standards and interoperability, which are essential for the cooperation between different services, but also for the migration of data from one service to another one. Finally it should not be neglected to research the intersections of technology to business and society to ensure that technological solutions are accepted and used as well as economically meaningful.

Concluding, this section underlined clearly that Cloud Computing is not only an evolving concept, but also still an evolving technology. Hence, it is obvious that Cloud Computing will experience further technological developments in the coming years, though the basic principles will remain. Promising areas are for example research and development in data management technologies, where the growing number of stored data will permanently challenge existing approaches, resource management and description, which needs to to be able to address and adjust all types of existing and possible future iresources available in the infrastructure, or federation, which based on standardisation and interoperability allows the combination of different types of Cloud environments (Jeffery et al. 2012, 13-17). However, these are only some examples of current and future areas, where technological developments can take place. Although there exist some roadmaps and research agendas (see for example Jeffery et al. 2012) the factual development will be strongly interrelated with future business developments like for example business and revenue models as well as competition or other factors and future usage patterns, which can turn technological developments in total new directions as shown by the example of the short message system (SMS). Both, business developments as well as usage patterns are subject of the previous and successive sections, which also try to outline possible future directions. In the same way existing roadmaps and agendas try to incorporate these developments like personal clouds, service composition on the fly or sensor clouds and others, but there will remain a high degree of uncertainties.

4. MARKET SITUATION OF CLOUD COMPUTING SERVICES

4.1. Current and future market situation – overview and analysis of existing studies

4.1.1. Challenges

At a first glance it is no problem to find actual numbers on the current market situation of Cloud Computing at different levels, but a second and closer look reveals some difficulties related to the comparison and analysis of the available numbers.

A first challenges is related to the market segmentation. Based on a review of several market reports several markets can be identified:

- (Public) Cloud services market: it covers spendings of commercial and private consumers for Cloud services offered by a third party (Cloud provider). Consequently it also covers all spendings related to hybrid cloud models. Mostly it covers the main sub segments (IaaS, PaaS, SaaS). Additionally some of them cover BPaaS as an additional section. Additionally different regional levels as well as main costumer groups (business, state, private) are partly covered, but vary between the different market researchers. Most often researchers focus on business spendings.
- Market for IT services related to Cloud Computing: it covers mainly spendings of customers (end-users) for training, integration, consulting and similar services related to introduction and use of Cloud Computing. Therefore there is no clear separation between spendings on such services neither for different service models (IaaS, PaaS, SaaS) nor for different delivery models (public, hybrid, private).
- Market for Cloud technology: it covers spendings for technology enabling Cloud Services, i.e. hard- and software that is necessary to build up Cloud infrastructures and to offer Cloud services. Therefore it covers mainly spendings of Cloud Service providers, but also spendings of companies who buy their own private Cloud.

As already hinted the second challenge is related to the underlying methodology, i.e. the question in which market and market segment different activities are counted. This problem can occur either within a market or between different markets. An example for the first is the question whether the spendings for virtual private Clouds are part of the public Cloud services market or not. An example for the latter one is the question how to judge complex public Cloud service offers that can be customized and therefore contain a high percentage of related services like integration and customization like for example SAP Business by design. here customers can decide either for standardised solutions or for customized versions, which are significantly more expensive. The list of examples could be continued, but in general it is to expect that that in the next years a harmonization of the general categories between at least the bigger market researchers can be expected.

Finally there is the challenge of availability, which includes two dimensions. The first one is that some very detailed and interesting market research only exist in very specific and/or non-comparable datasets for several reasons. One reason is that some smaller market

researchers only offer data for specific countries due to their size and customer base. Another is that even not all bigger market researcher cover all markets for different reasons that only can be guessed. Consequently there is in particular the challenge to measure markets for Cloud technology and Cloud related services. While the first one can be partly found in terms of market reviews for private Cloud models or as spendings on hard- and software, the latter one most likely disappear in-between the general category of IT services. The second dimension is the factual availability of such reports. Most often the market researchers only publish some sneak previews to their reports, while the full report with the detailed numbers are only available for purchase. Only a few reports, mostly results of governmental contracted studies to market researchers, are freely available. Anyhow, these studies also often show only a few detailed numbers, but not the full market picture for obvious reasons.

Against the background of these challenges we will mainly use the public available data for public Cloud services[11], which covers at least also the part of the market for hybrid models that are using public services as well. However there is only little information on the markets for private Clouds or on the markets for Cloud technology in general. In the case of services related to Cloud the situation is even worse since there are only few, single numbers available. Therefore only few market researcher measure and list these numbers separately. Most common is that for example Cloud related services are one segment of the overall IT services market and that Cloud hard- and software can be found in the related segments. However we believe based on the review that the public Cloud market is the biggest and that the others markets will grow in relation to it as it is the main driver of Cloud Computing. Nevertheless we will show numbers as far as possible to the other markets and reflect and possible changes due to current market trends.

4.1.2. Overview on existing market studies and forecasts

According to all main market researchers the market for public Cloud Computing services is beside Big Data and Mobile Computing (Apps, etc.) the fastest growing segment in the software and IT services market. All three are expected to have a considerable impact on the market landscape as well as on the use of computers in the coming years (for example EITO 2012). Moreover all three are interrelated, because for example Big Data analysis require big data storage and computing capacities, which many companies could not afford for such purposes. Therefore Cloud Computing is an essential enabler for it. A similar, but more multifaceted relation also exists between Mobile and Cloud Computing. Vice versa Cloud Computing need both segments as drivers and show cases of its usefulness. All three show considerable growth rates beyond the normal growth of the overall market. In total size it outweigh the both others clearly

Overall market development

The review of existing market studies shows that there is broad spectrum within the different forecasts. One reason for this are different methodologies, which in- or exclude

[11] Please note that this includes citations of market research reports from different web sources. Normally we name the market research company as well as the source of of information.

different segments. Another one are the basic assumption like overall economic growth for different regions and similar.

Table: Overview on forecasts in billion US-Dollar for the development of the Public Cloud services market, Source: Gartner 2012, IDC 2012, Forrester 2011 (after Dignan 2011)

	2011	2012	2015	2016	2020
Gartner	91,4	-	-	206,6	-
IDC	-	40,0	-	100,0	-
Forrester	40,7	-	97,0	113,9	241,0

Though the forecasts vary in terms of absolute amounts clearly for these reasons, there is one thing in common. All researchers forecast an annual growth rate (CAGR) beyond 20%, which shows the strong dynamic of the market. Due to the fact that this growth is outpacing the growth of the overall market for software and IT services all three market researcher believe that the overall share of public Cloud Computing will grew from a few percent at the moment (~3-5%) to a range of more then 10% (5 years horizon) and more then 20% (10 years horizon) in the next years (Gartner 2012, IDC 2012, Forrester (after Dignan 2011)). The actual value depends again on methodology for both, Cloud Computing as well as for the overall market. Concluding it can be stated that Cloud Computing will become an essential part of the overall market. In particular since these forecasts do not include segments like the IT services and consulting related to Cloud Computing as well as the software licences for Cloud technology required by the Cloud service providers. Moreover this development will also impact the market for IT hardware like for example a shift within the different server segments (see for example Cattaneo 2012c).

While parts of this enormous growth will result from the overall growth of the software and IT services as well IT hardware market, but it will also replace parts of existing markets, in particular for example the classical segment of software products based on licenses and maintenance contracts as well as IT service segments like Outsourcing. However, there is a little bit of uncertainty about the extent of these impacts. In an early forecast commissioned by the European Commission on Mobile and Cloud Computing, PAC and Idate stated that both developments will lead to stagnation and decline of revenues from IT services and licences after 2016 (Aumasson et al. 2010). Other forecasts do not touch this question in detail, but Gartner (2012) as well as IDC (Bloomberg 2012) clearly state that Cloud Computing will be the driving force of the overall market. In the long term the implications are the same. Nevertheless some open questions remain. One example is the question if the loss in the IT services due to the shrinking of outsourcing services will maybe compensate by the growing need for Cloud related services like integration and implementation. In case of growing tendency towards hybrid models (Rüdiger 2012) this increase could be even stronger then the loss and lead to further grow.

Development of the different service models

Similar to the situation of the forecasts for the oerall market for public Cloud services, the forecasts for the different service models segments vary in the same way. Most obvious is

that the segment of Business Process as a service, which we defined as part of SaaS, varies between gartner and Forrester extremly, while IDC does not introduce this category. this might be one reason for the huge differences in the overall market size and underlines the challenge of the different methodologies.

Table: Overview on forecasts in billion US Dollar for the development of the Public Cloud services market by segments, Source: Gartner 2012, Forrester 211 (after Dignan 2011)

	2011				2016			
	IaaS	PaaS	SaaS	BPaaS	IaaS	PaaS	SaaS	BPaaS
Gartner[12]	4,27	0,9	11,88	71,94	24,44	2,92	26,55	144,74
Forrester	2,94	0,82	21,21	0,53	5,65	11,26	92,75	4,28

According to all major market researcher the market for SaaS (in our case including the different BPaaS segments if available) is the biggest one in terms of absolute value at the moment and will remain the biggest in future (Gartner 2012; IDC 2012, Forrester 2011 (after Dignan 2011)). The both other segments, IaaS and PaaS will be in absolute values only small markets in comparison to it. Nevertheless there is tendency within all forecasts to state that both segments will grow with a higher rate than SaaS in the next years (Gartner 2012; IDC 2012, Forrester 2011 (after Dignan 2011)). As one reason for that Gartner sees a growing trend of more experienced user towards PaaS solutions in sub segments like for example Business Intelligence and Big Data, where such offers give more possibilities to adjust and customize the applications to their own needs (Gartner 2012).

The trend towards SaaS is obviously a result of the current adoption and usage patterns. With a growing number of companies, in particular SME, and private consumers starting to use Cloud services it seems normal that standardised product solutions gain of importance. Most of them are already used to standardized products like the Windows Office family. Moreover the flexibility of IaaS or PaaS also requires more knowledge on the basics of the technology, in particular it also requires more time for implementation and continuously administration. Therefore it is not a surprise that consumers and SME are not attracted by such offers. On the other hand this flexibility is as already indicated one reason why bigger companies may develop a tendency towards such solutions, because they also have the financial and human resource capabilities to afford it.

Within the different segments of Cloud services all forecasts are seeing a clear trend towards more diversity regarding the type of services offered as well as the distribution between the different sub segments. The growing number of services, which will be also outlined in the following overview on existing services, is a result of the growing number of bigger and smaller suppliers that started in the recent years to migrate their offers also into Cloud solutions. Additionally the growing experience also led to the trend to migrate more and more complex applications like enterprise resource planning (ERP) as well as complete business process into Cloud services. Finally there is also a growing number of completely new offers that are enabled by the existence of other Cloud services, i.e. this services

[12] Please note the difference to the overall forecasts of Gartner results from the additional category Cloud Management and Security services (2011: 2,39; 2016: 7,94), which was not included in this overview.

combine different Cloud services to new offers. As a consequence of this development the distribution of revenues also starts to change. While in the early phase few applications like customer relationship management in the SaaS segment were dominating, the existence of more and more advanced services lead together with more experienced users to a trend towards other services like ERP or BI solutions. Other examples are the earl dominance of computing and storage services in the IaaS segment, which are now complemented by more advanced backup services, or the tendency of offering more types of PaaS services for specific purposes beyond development platforms that can be adjusted to user needs.

Regional development of Cloud Computing

Regarding the regional development it is not surprisingly that North America, in particular the U.S., are the biggest market for Cloud Computing at the moment. According to all forecasts it will show in terms of absolute value the greatest growth. However in terms of growth rate emerging markets like China or India are seen as the coming markets. Europe is at the moment the second biggest market behind the US and followed by Japan and the other more mature Asian markets (Gartner 2012, IDC (cited after Bloomberg 2012). Consequently Gartner (2012) as well as IDC (Bloomberg 2012) indicate the possibility that this fast growth of the merging markets can lead to outpace Europe in the long run.

The strong growth in emerging countries is not really surprisingly. One prominent reason is that most companies and organisations in these countries do not have a strong and long time grown IT infrastructure. As a consequence the migration to new approaches with clear benefits does not require the same efforts as in other areas. As reasons for the slow growth in Europe at least two points were named: firstly, the lower adoption rate in general caused by a greater reluctance against Cloud Computing, and secondly, by the economic crisis of the Euro zone. The first argument clearly relates to the development of adoption and usage patterns (see 4.3). There it is clearly shown that in the US consumers as well as businesses, in particular also SME, adopt Cloud Computing earlier and faster than in Europe.

One positive development is that the adoption/usage and as a consequence the market in Europe gained a stronger momentum in the recent time. This is underlined by the regional forecasts of PAC for Europe (Fielder et al. 2012, 20). Nevertheless this forecasts also shows a surprisingly strong position of the IaaS segment in Europe (including storage solutions), which is bigger then the SaaS segment. This could be an indication that European companies have a stronger tendency towards solutions with a better control of the whole system. This could also imply that there is a stronger tendency towards private Cloud solutions in Europe as in the US. Based on the available data it is not possible to conclude this and it remains an open question.

4.2. Overview on existing services and suppliers

4.2.1. Overview on existing Cloud Computing services

Due to the fact that Cloud Computing is an evolving technology and market it is not possible to deliver an exhaustive overview on offered services or providers. Nevertheless in the following we will provide an overview on the main services in the different market segments of Cloud technology, IaaS, PaaS, SaaS and Cloud related IT services, which we will try to illustrate with some examples

Cloud technology

Databases: enabling the required scalability of Cloud services. Typically different types of NonSQL databases are in use like key-value database or columnar, document-oriented databases. In some cases solutions are used enabling the use of or connection to relational databases. Examples are:

- Apache Accumolo
- CouchDB
- dbShards
- MongoDB

Virtualisation: enabling the provision of scalable virtual machines that can be used for all kind of build upon services. Examples are:

- VM Ware
- Citrix

Infrastructure Management: provison of tools for the management of flexible Cloud systems, which can be used to built and manage all modes of Cloud (public, private, hybrid as well as IaaS, PaaS, SaaS). Examples are:

- Open Nebula
- Open Stack
- CA Turn-key Cloud

Distributed caching: enables the dynamic caching for scalable Cloud systems. Examples are:

- IBM Websphere eXtreme Scale
- Oracle Coherence

Cloud Integration Solutions: enable the integration of public Cloud services into the existing IT landscape of a company. Examples are:

- Cloudswitch
- Nimbus Platform

Other suggested categories are configuration automation as well as abstraction software preventing lock-in effects. Additionally categories for tools providing specific type of services like PaaS or SaaS could be also differentiated. Nevertheless there is growing number of Cloud technology, in particular software solutions for the management of Cloud

systems in different variations. Underneath there is tendency to use Open Source solutions like Open Stack or open Nebula, which are supported by main suppliers like IBM or Google.

However there is also a growing market for underlying hardware, which is not listed separately. This is most likely a sub segment of the data centre hardware market, which is dominated by companies like IBM, Dell, HP, Huawei, Cisco and others. As some of them are also suppliers of the Cloud Computing technology and services they are able to offer fully integrated services to their customers. Another trend supporting this development is the growing number of solutions for modular data centre server platform combining server hardware, switches, management and virtualisation software in a bundle. One example for this is the Unified Computing System from Cisco. Due to the fact that

Infrastructure as a Service (IaaS)

Compute infrastructure: providing server resources for Cloud Computing, which can be dynamically provisioned and configured as needed. Examples are:

- Amazon EC2
- Cloud Sigma
- Rackspace Cloud Servers
- Terremark Enterprise Cloud
- Google Compute Engine
- Google Azure Virtual Machine

Storage infrastructure: provision of massively scalable storage capacity that can be used for all kinds of applications, backups, archiving, file storage, and other purposes.

- Amazon S3
- Rackspace Cloud Files

Backup infrastructure: provision of easy to use solutions for the backup and recovery of files and raw data. Sometimes they are also considered as part of storage infrastructure. Examples are:

- IBM Smart Cloud Managed Backup
- Jungle Disk

Brokerage infrastructure: provision of tools that enable to use different Cloud configurations (public, private, hybrid) and services without problems. Examples are:

- enStartus
- Gravitant

Other categories that are often listed within this segment are Load Balancing infrastructure (sometimes also Content delivery infrastructure) such as Amazon CloudFront, which enables to improve the efficiency (cost and performance) of delivering content and data to customers, or service management infrastructure like Amazon Cloud Watch, which enables to monitor and control other cloud resources. Some also differentiate more detailed for example in the segment of compute infrastructure between solutions for provisioning physical hardware (servers) and virtual machines. Another point is that in all categories

solutions can be found that in principle can be used for the provision of public or private IaaS services, which are often less known as the offers of the big public service providers like Amazon or Google. Finally there is a tendency to comprise several IaaS services into packages and sell them under a specific label like Amazon Cloud Formation, HP Cloud or Rackspace Cloud.

Platform as a Service (PaaS)

General purpose platforms: enabling the provision of runtime environments for all kind of applications. Examples are:

- Amazon AWS Beanstalk
- Microsoft Azure Platform
- Google App Engine
- IBM Smart Cloud Application Services

Development platforms: enabling the provision of of scalable environments for the development and testing of new applications. Examples are:

- IBM Rational Software Services
- Skytap

Database platforms: enabling the provision of easy to use and scale databases of all kind, including SQL and NonSQL databases. Examples are:

- Amazon Dynamo DB
- Microsoft SQL Azure

Integration platforms: enabling the integration of all kind of applications ranging from custom applications to cloud application. Examples are:
Amazon Simple Queue Storage

- IBM Iron Cast
- Informatica Cloud

One recent trend in this segment are Business Intelligence Platforms that provide collections of tools for analysing different types of data from normal business data to big data collections. The classification of this service refers to the earlier mentioned problem of using only three segments (SaaS, PaaS, and IaaS), because the level of service can be also seen as a SaaS offer due to the fact that nearly all suppliers provide ready to use solutions, but also offer custom made analysis. Consequently we decided to list them as SaaS. It should be also remarked that like in the case of IaaS some of the named examples are suitable to be used for both, public or private Clouds.

Software as a Service (SaaS)

CRM: applications and services enabling customer relationship management solutions via web access. The offers itself cover a broad range from full scale CRM solutions to specialized solutions for different purposes or industries. Examples are:

- Salesforce CRM

- Oracle CRM on demand
- IntouchCRM

ERP: software and services enabling integrated solutions for the management of nearly all aspects of business, including assets, matrials, financial resources etc. Examples are:

- SAP by Design
- Netsuite

Business Intelligence: applications and services enabling the analysis of data for better decision making using different technologies like dashbords, reporting. Currently Big Data is the newest topic. Examples are:

- Cloud9 Analytics
- Datameer
- Netsuite Analytics

Collaboration: applications enabling collaboration within a company, but also with other companies or customers. The variety ranges from Conferencing, teamworking or similar software that enable sharing and editing of documents to Social Software Suites. Examples are:

- Jive Social business Software
- Microsoft Office Live
- Social text
- Dropbox

Content management: applications and services enabling the management, production and storage of documents. Examples are:

- Astoria On Demand
- NetDocuments

Project and portfolio management: software and services enabling the management of projects and project portfolios. The spectrum covers simple managment tools up to integrated management and collaboration offers. Examples are:

- Huddle
- Basecamp

Supply Chain Management: application or services enabling the management of logistic flows within a company, but also relations to suppliers and customers. Examples are:

- Aravo
- Deltion

Human Resources: services and applications enabling the management of human resources including payments, data, talent management etc. within a company. Examples are:

- Taleo
- Workday

As already indicated in the review of the market situation there is growing trend to more and in particular to more complex applications, which led to the tendency to create a new segment called Business process as a Service (BPaaS). Most often these services are enriched versions of SaaS offersAgainst this background it is obvious that this list is more a selection than an exhaustive view. Many others categories like Cloud Advertising and Payments, e-Commerce services or industry operations could be easily added. Obvious is the fact that most market researchers strongly focus on the business market and neglect markets for private applications based on Cloud Computing. one reason might be that in many cases of cloud based solutions for consumers the borderline to the other markets, in particular the one for mobile apps, is hard to draw. Therefore it is hard to decide what can be counted as Cloud Computing. Another one might be that this market is less driven by direct purchases, but by revenue models based on advertising or other methods like the in-app purchases of extra goods. Finally there is also an uncertainty if applications like Cloud gaming will succeed at all. Therefore this remains an unsolved challenge for the future years.

Cloud related IT services

Within this segment all services related to introduction and use of Cloud Computing services, mainly for businesses as users. Therefore a great variety of services and packages of services are possible. typical examples are:

Selection&Decision, i.e. support to decide on the use of Cloud Computing in a company and in case of a positive decision support to identify and select the suitable provider;

Training, i.e. training of end-users and management of the company in the right and efficient use of Cloud services;

Implementation, i.e. support for the factual installation and operation of a Cloud service, either public, private or hybrid models;

Integration, i.e. support for the integration of a Cloud service into the existing IT landsacpe of a company.

However there are other services possible dependent on the demand of the customers as well as different combinations of these services. Similar to this situation of suppliers of such services also offers a great variety. One group are big Cloud suppliers like IBM, HP or others, which have their own service business units offering these services for their own, but partly also other suppliers. Another group are the big IT services companies like Accenture, CapGemini, Atos that offer the full range of services from implementation and operation of private and public Clouds to all other services related to Cloud Computing. Finally there is the great majority of small and medium sized IT services companies, which also offer depended on their capabilities different types of services related to Cloud Computing. Consequently we will not try to present a further detailed overview.

4.2.2. Main suppliers of Cloud Computing services

The number of suppliers for different kind of services is increasing with a high rate. Therefore it seems nearly impossible to provide an exhaustive overview, but with regard to size and impact on the Cloud Computing business the list starts to shrink drastically. Moreover the remaining companies sound somehow familiar to the IT and Internet community (see the detailed profiles in the Appendix). An easy way to order them is to look when and in which way they entered the market.

The first group encompass companies like Amazon and Google or Salesforce. The entered the market early, some even say that Amazon has created this market. Therefore they can be seen as the early movers. Although Amazon main business is e-Commerce, it was an obvious move for them to improve the use of their existing, massive resource all over the world, which were needed for their main business. Google on the other hand is primarily a search engine, but with its move into advertising it already started to use technologies, which are now considered to be typical for Cloud Computing. In opposite to this Salesforce, founded in 1999, started as a company for Application Service Providing (ASP). ASP is one of the predecessors of Cloud Computing, in particular SaaS, but failed after the dotcom-crash. Therefore Salesforce had a long phase of suffering before in particular its CRM offer became more and more a success in the middle of the 2000s. Later on Salesforce managed to access new fields and keep pace with offers of other competitors.

The second group, which consist of companies like VMWare, Citrix or Terremark and Rackspace, started as specialists for technologies or infrastructures building the foundations of Cloud Computing such as virtualisation in case of VMWare and Citrix or data center operations in case of Terremark. Not surprisingly they soon started to move into the Cloud Business, because they had they necessary resources already at their disposal. Nowadays they deliver important parts of the Cloud technologies and software like OpenStack, virtualisation tools like Zen and similar. Additionally the also started their own public Cloud offers. Beside this, this segment is also an example of the high dynamic in Cloud Computing in terms of mergers and acquisitions. Citrix and Rackspace bought in recent years many small providers and technology specialists like Xen (Citrix) or Slicehost and JungleDisk (Rackspace). In opposite to this VMWare and Terremark became themselves targets. EMC bought VMWare already in 2004 and recently Terremark was taken over by Verizon, one of the large telecommunication providers in the US.

A third group consist mainly of the great worldwide active IT services provider and hardware producers like IBM, HP, Dell or Cisco. They were soon followed by more regional IT service providers and national telecommunications providers like T-Systems/Deutsche Telekom, BT, Fujitsu Technology Solutions or Atos. On the one hand nearly all were capable to develop or purchase solutions and on the other hand the also had a strong customer base and many alliances with existing other IT companies. Consequently many of them became full service providers from Infrastructure to specific services, most likely they offered it in a first step to their customer base as private Cloud solutions, but some soon started also to offer massive public Cloud offers like HP or Dell. Their advantages are formed by their strong market position in terms of own resources (financial and human),

own capabilities (technology and services), strong customer base and finally networks and alliances, which enabled them altogether to deploy own services within a short term.

A kind of subgroup of them are the in particular some of the software product companies like Microsoft, SAP or Oracle. Their common characteristic was that the started to talk about Cloud Computing, but that their own offers appeared quite late at the market for different reasons. While SAP had many problems to start up Business by Design for SME, oracle was for a longtime not clear if and to what extent they really wanted to enter the Cloud. Finally Microsoft was fighting with many problems in their core business and therefore it was not a surprise that the announced Azure platform only in small steps. Therefore they can considered to be the markets latecomer. However all of them have strong competitiveness situation due to their customer base, resources and capabilities. Consequently it is expected that they will also gain relevant market shares in their fields.

This trail is nowadays followed by many smaller and medium sized companies like IT service providers or specialised software product suppliers, which now also move their business into the Cloud Thereby they often rely on services of one or more of the big suppliers.

Finally there is the group of "Cloud born" companies, i.e. companies with service offers only created for Cloud use and based on Cloud Computing services of other suppliers. These appeared soon after the start of Amazon Web Services. they started to gain attention with the boom of mobile platforms enabling different kind of apps as well as the need for synchronisation and similar features. In difference to the afore mentioned groups they also targeted consumers as customers and thereby spread the concept of Cloud Computing beyond the specialists discussions. Although this market is smaller it also led to a push for Cloud Computing in business. Because of the trend that many consumer started to use their smart phones and tablets also at work (bring/buy your own device BYOD) and thereby introducing Cloud Computing solutions into their companies, many companies were forced to deal with it. the most prominent example for this is Dropbox, which started in 2008 as a synchronisation and file sharing service based on freemium revenue model. In a short term the service became very popular and attracted millions of user. Moreover their use led to the fact that Dropbox grew beyond a file storage service and became more and more a collaboration service (Barret 2011). Although most users only use the space freely available, Dropbox generated 240 Mio. of revenues in 2011 and is now one of the most valuable start-ups in the Silicon Valley. While Dropbox is at least at the moment a very successful example, there is still the challenge to turn the revenues in the long rung into stable earnings. As the example of Facebook has recently shown this can be quite challenging in a market, where so many things are still in the flux as it is in Cloud Computing. However it could be argued that some few points are already clear. One example is that only a number of companies like Google, Amazon or IBM will be able to act as full-scale providers, in particular with regard to the provision of Cloud Computing infrastructure in terms of data centres, network capabilities etc. Because on the one hand the required investments for it are enormous and on the other hand the current price development underlines that it will take a long time until the return will equal them. But new models like the brokerage approach of Zymory and others like Spotcloud enable

smaller data centres to offer there unused capacities. If successful this could create a counterpart to the big players mainly offering their own resources. At the moment this would mainly lead to a further fall of prices, because more and more resources could be offered. If enough companies migrate to the Cloud and close own smaller data centres this could in the long run to development of prices in the other direction if only a few data centres remain. However this is only one example for the fluid state of the technology and market and shows what kind of consequences could evolve from the different developments of them and how difficult it can be to assess them. It clearly refers to the open questions posed already before like for example: what are the dominant revenue models; which new services will evolve after the transformation of the existing ones into the cloud, and finally which new business model will result out of it. Nevertheless there are also some points that seem already clear. Only a few companies will be able to act as full-scale providers, in particular the provision of Cloud Computing infrastructure in terms of data centres, network capabilities etc. require a high level of investments.

One point nearly all of these companies have in common is the fact that most of them do not publish the revenues of their Cloud services. In case of companies like Amazon, Google, Microsoft or IBM it is therefore nearly impossible to specify the percentage of their overall revenue origin from Cloud. In some cases estimations by market researchers are available, which clearly shows that the percentage of the overall revenues in case of these companies is little (below few percent). Nevertheless these few percent still amount for a total value of round about 2 bn. $ in the case of Amazon and more or less all of these companies announced plans or strategic visions that in the next few years Cloud services will become an important part of their business. In opposite to this the revenues of specialist companies like Rackspace or Salesforce give a more detailed insight, but due to their size their revenues do not reach the total level of Amazon. Finally most of the cloud born start-ups do not name details on their revenues, but in some cases like Dropbox informsations are available, but they do not specify how these revenues are composed, i.e. how big the shares of user payments or advertisement revenues are.

While this description is mainly based on an overall positive view, there are also critics who state that Cloud Computing will soon pass the peak. Some of them even state that Cloud Computing will start to decline due to many unsolved questions and broken promises, others state that Cloud will stay, but only as one market beside the others covering aspects like outsourcing, in particular Business Process Outsourcing (BPO) that was a hype some years ago, or consumer services, but that it will not revolutionize the market as a whole. Typically the truth might be found somewhere in the middle, but based on the current position of development it seems hard to predict where it will be.

From a European point of view one point is that at the moment most of these companies have their headquarters in the US, while only a few European players appear as global players in this field offering their services outside of Europe. Even most of the big European IT Service providers or telecommunication providers seem to be focused on their national markets or only focused at the European market at all. Another point is that not all of the American companies have located data centres in Europe, although Europe is for now the second biggest market. In case they have data centres located in Europe, there is a clear

tendency towards a small set of countries for several reasons. Most prominent example is Ireland, where beside the low level of data protection rules in an European comparison also other reasons such as taxation regulations play a prominent role for the question where to place the European headquarter. Overall this situation is a mirror picture of the past decades, where mostly us-based companies dominate the markets and using a set of specific locations for the entry of the European Market. If this will change in the future depends strongly on both, the overall development of Cloud Computing as well as the development of the legal, social and economic environment and is therefore as hard to predict as the rest.

4.3. Adoption and usage patterns in Cloud Computing

Similar to the numbers on the market development many studies dealing with adoption and usage patterns of different types of user exist. But there you also face some difficulties, because many of the studies are made by consultants and market researcher for a specific purpose. Consequently the methodological quality of these surveys differs strongly. Another point analogue to the market numbers is that they often exist only for a very specific target group and/or for one country. Moreover the number of respondents is also often low, in many cases lower than 100. Both, the low degree of representativeness as well as the quality differences, limits the usability of their analysis. One exception is a study commissioned by DG Connect, which was carried out by IDC between 2011 and 2012. In this case representative samples of round about 1000 companies and the same number of consumers in Europe were asked about their patterns. Therefore we will base our analysis mainly on this study and compare it with available data from the US. For other major regions like Japan, South Korea, China or India data were in only in few cases available. As far as possible we will reflect them as well.

4.3.1. Adoption and usage by business users

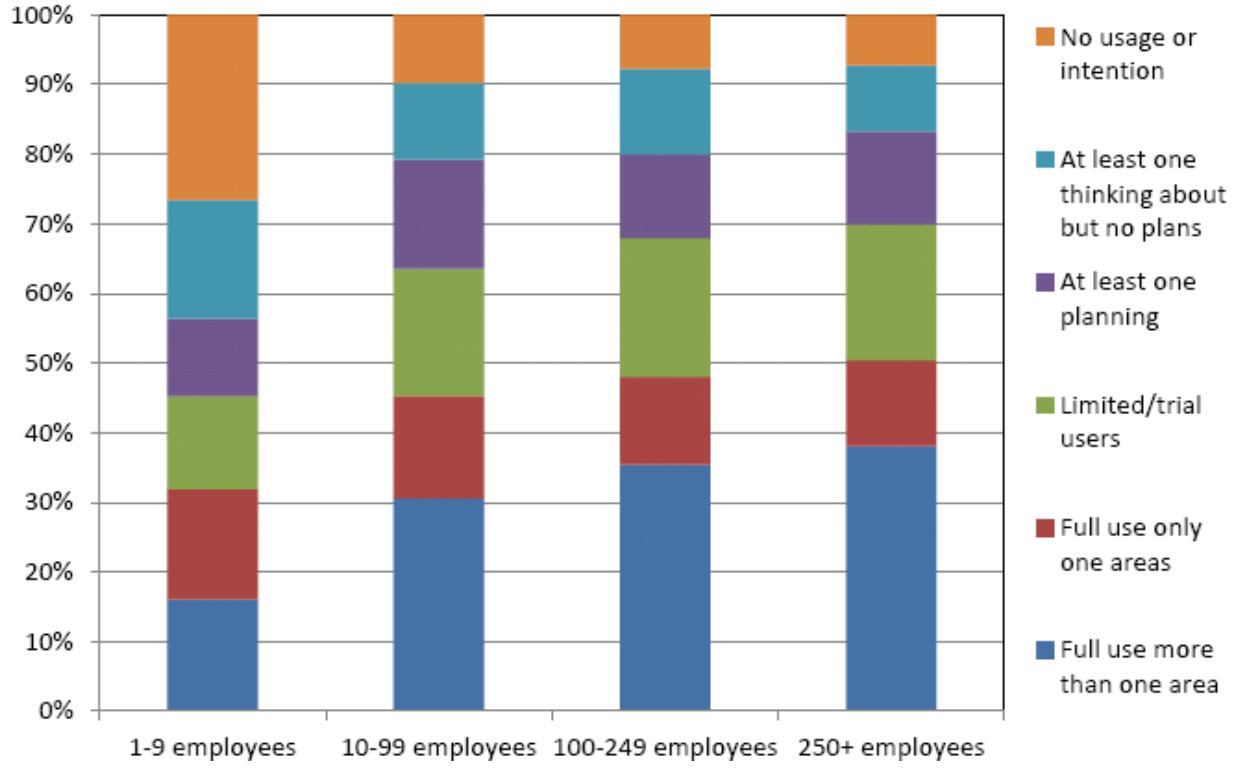
The survey for companies addressed companies of seven main sectors (finance, manufacturing, distribution, healthcare/education, government, telecoms, ad other services) in nine countries of the European Union (Czech, Republic, France, Germany, Italy, Poland, Hungary, Spain, Sweden, UK). In total 1056 companies responded. In a first overview 64% of respondents used Cloud Computing and only 36% do not use Cloud Computing. A more differentiated look shows the details:

Table: Adoption of Cloud Computing by European business users, Source: Cattaneo et al. 2012b, 16

	Type	**Description**
11%	No usage	No usage/intention at all
12%	Thinking	Considering the usage, but no actual plans
13%	Planning	Evaluating or planning to use one or more areas
19%	Limited use	Limited or trial use of one or more areas
13%	Full use one area	Full use of Cloud services in one area
32%	Full use more areas	Full use of Cloud services in more than one area

Overall the results shows that there is already strong group of companies (45%, dark-grey) currently using Cloud services (users in the following), i.e. they already adopted Cloud services and use it in one or more areas. The second group, which either evaluate/plan or make trial/limited use (tester in the following), also amounts for 32% of the companies. Finally the group of companies, who only thinks about or has no plans/intentions (latecomer in the following), amounts for 23%. Moreover further results of the study show that most enterprises (more than 50%) started the adoption in the last two years before the survey (Cattaneo et al. 2012b, 20). Overall it seems that Cloud Computing is already present in some forms in European companies, but that the situation varies. In comparison to that the situation in the US shows some differences. According to a study of the Cloud Industry Forum with 400 respondents from in all sectors (including public sectors as in the IDC study) already 76% of the American companies use at least one or more Cloud services. Since the there were no big time legs between both surveys (November/December 2011 and January 2012) this is no explanation for the differences in the adoption patterns. One point of uncertainty is the question to which extent limited/trial usages were counted in the survey for the US, but however also if this is fully counted as well in Europe there remains a difference of 12%. This is also reflected in the fact that the market in the US is bigger and faster growing than in Europe as shown in the section before.

Picture: Adoption of Cloud services in Europe by business size, Source: Cattaneo et al. 2012b, 21

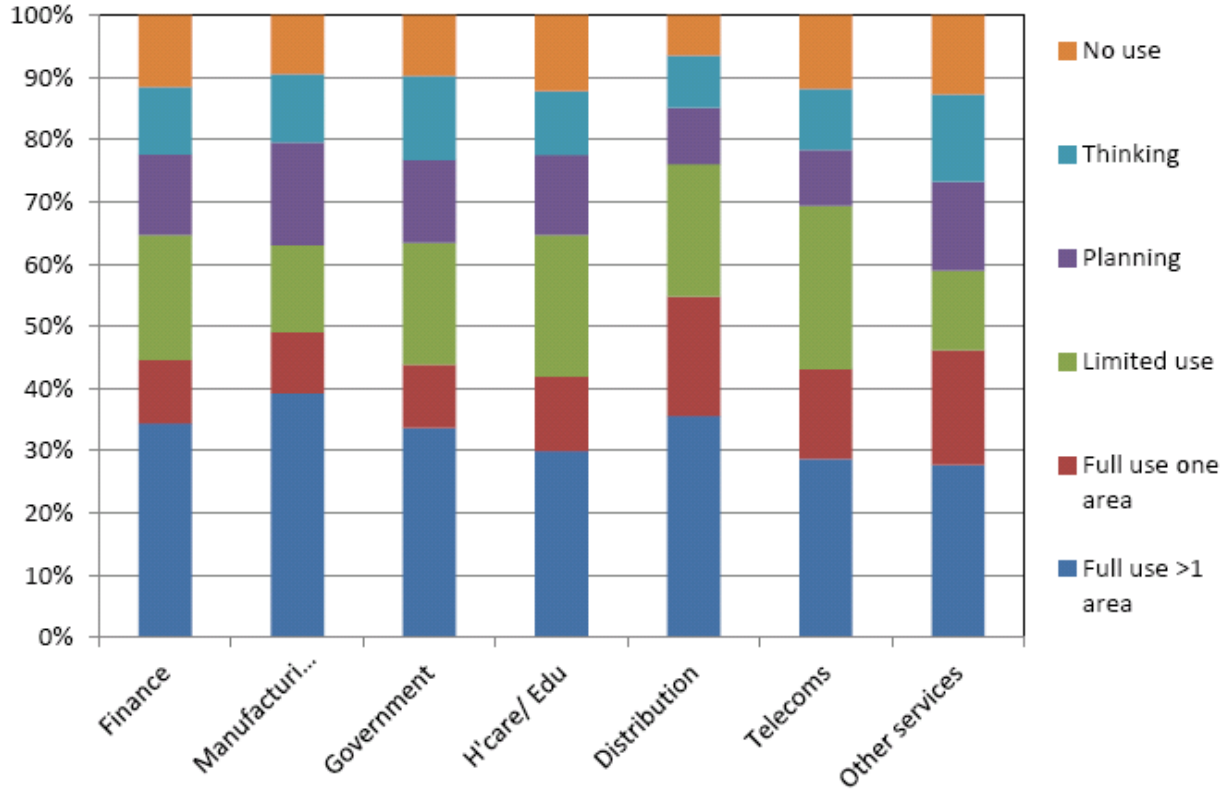


Looking at the adoption patterns by the size classes of European enterprises reveals a clear picture. The bigger companies are the more likely it is that they already use or test Cloud services. Although this result is no surprise, there are some differences to the US. According to the study of the Cloud Industry Forum (2012), but also others like SpiceWorks

(2012), the adoption in the class of enterprises up to 100 employees seems higher than in Europe. Additionally the adoption in this class in the US seems also to be higher than the one in the next class with up to 1000 employees, which would be different as trend than in Europe. However, due to the different size classes it is hard to derive further differences, but it seems that in difference to Europe in particular also SME embrace Cloud services in the US.

Comparing the adoption patterns in the different industry sectors does not reveal big differences. On the level of users lowest (~41% in healthcare/education) and the highest value (~54% in distribution) does not show extreme difference that could not be explained by the different nature of the sectors. Also on the level of testers the differences between lowest and highest vary in the same extent. Due to the lack of data it is not possible to compare to the US.

Picture: Adoption of Cloud services in Europe by business sectors, Source: Cattaneo et al. 2012b, 19

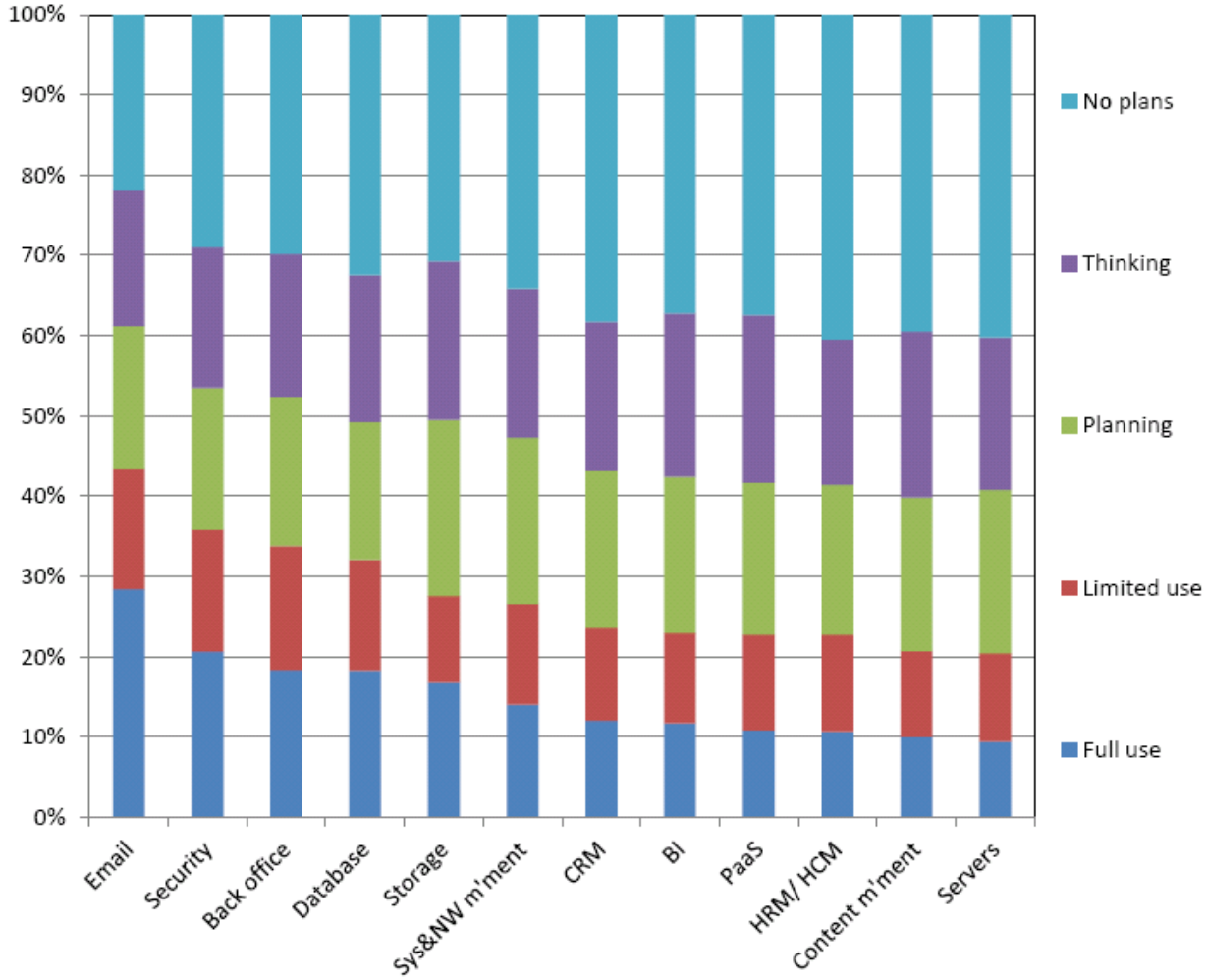


Regarding the different countries there is no clear statement possible. The results show that the level of companies currently using Cloud services vary between 30% (Czech Republic) to 60% (Poland). It is neither possible to differentiate them along geographical location (east, west, north, south) nor size (big, medium, small) (Cattaneo et al 2012b, 18). Therefore it suggests itself that there are other reasons for this difference in Europe, which can not be clearly resolved from the study.[13]

[13] The survey of ENISA among European companies, in particular SME, unfortunately also does not reveal more insights (ENISA 2009)

At a first glance the results regarding usages patterns does not provide any big surprises. Most companies using Cloud services for mostly simple purposes like email, which encompasses according to IDC mail services like Gmail or MS Exchange, or security, which encompasses here services to secure and protect like Google Postini or Symantec MessageLab. A little surprise is that these are already followed by the section of BackOffice, which encompasses a broad range of services ranging from procurement platforms and accounting solutions to full-scale ERP solutions. This is followed by the segments of database and storage also encompassing a great variety of services. However it is no surprise that HR (Human rssources) and servers are at the bottom of the group. While the direct use of computing capacities requires some technical knowledge, the HR is very critical due to its personal data (Cattaneo 2012b, 14).

Picture: Usage patterns of Cloud services in Europe by different types of services, Source: Cattaneo et al. 2012b, 14



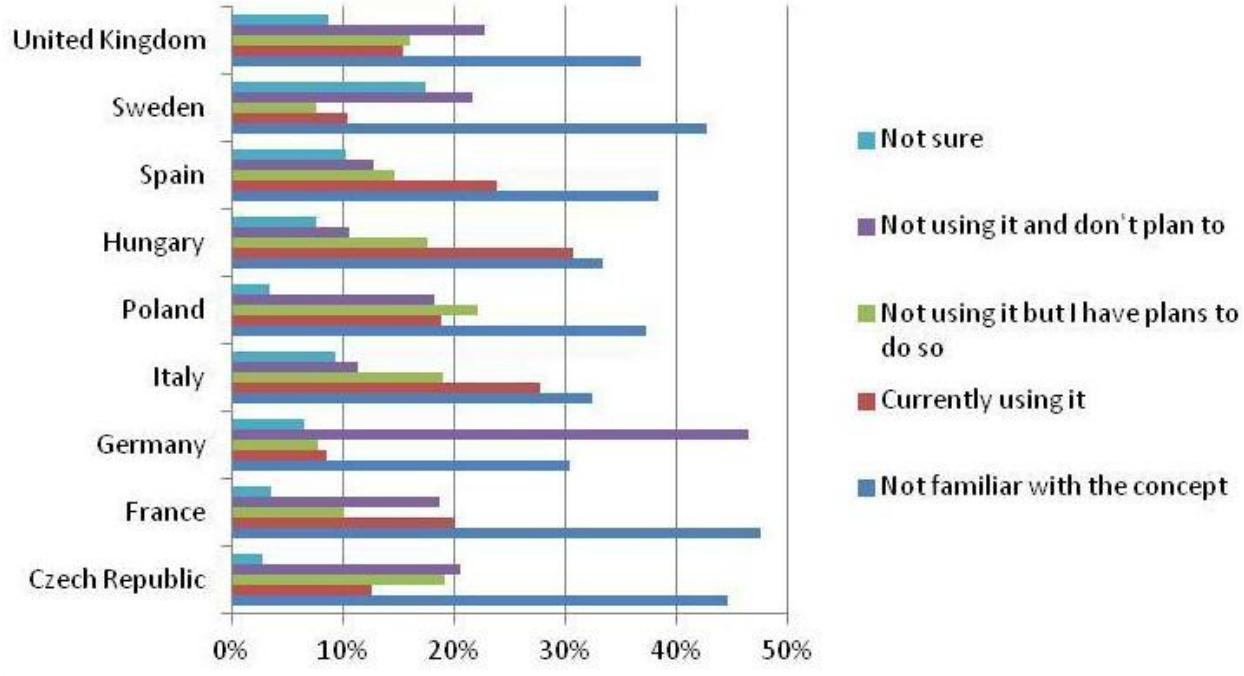
Based on that we can conclude that in particular simple services are already used as Cloud services, but that there is tendency to move on now towards more complex and partly critical services. In general the same statement seems to be valid for the adoption in the US. Although the definitions are not the some the study of SpiceWorks (2012) indicates same trends, in particular the fact that applications are now grow faster, for the US, but in ttl at a higher level of adoption at al.

These results confirm what was already outlined in the section on markets in different regions, in particular that Europe is lagging behind in the adoption of Cloud services. One surprise is that particular SME in the US adopting faster than their European counterparts, which is also one explanation for the big differences in terms of market size, because SME are the majority of European enterprises. In terms of maturity, i.e. the extent of usage of more complex Cloud services, it is hard to say how big this difference is at all. Gartner (2012) claims that Europe is lagging behind the US at least for two years, but others fear that this lag is even bigger (Borja 2012).

4.3.2. Adoption and usage by consumers

Comparing different studies on the adoption and usage of Cloud services by consumers reveals that the already discussed problem of defining Cloud Computing is even more problematic in this environment. In opposite to the business segment, where things are more settled, the answer to the question what consumer Cloud services are varies strongly. Examples for this problem are question if activities like usage of online portal like online search or social networks are already Cloud services for consumers. From the studies it seems like that in particular in European surveys the definition is broader then the one in US surveys, which focus more strongly on Cloud services in a narrow sense. Therefore a direct comparison of data is only possible to a very limited extent and requires a reflection of this problem during the analysis.

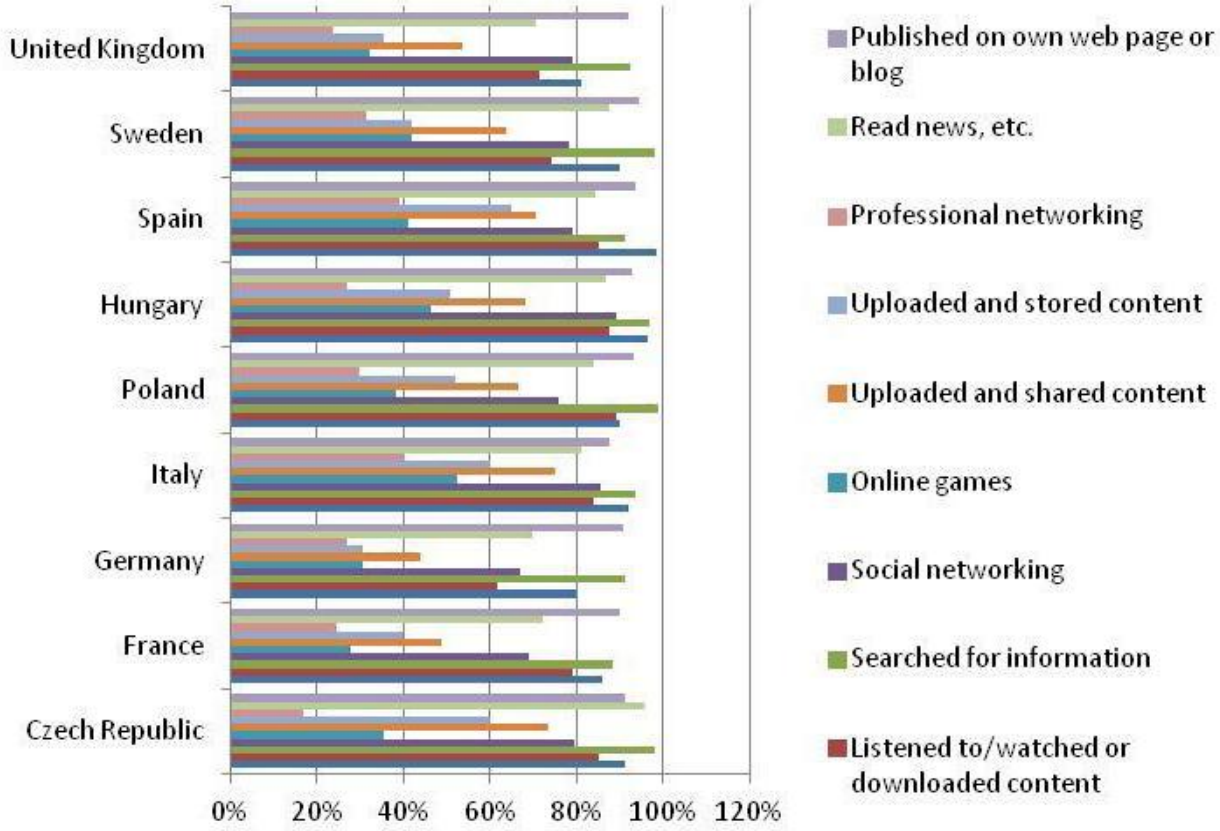
Picture: Familiarity of consumers with the concept of Cloud Computing in selected European countries, Source: Cattaneo et al. 2012b, 55



The survey of IDC, which is based on nearly 1000 consumer respondents from nine EU Member states, clearly shows that there is some variation regarding the usage of Cloud services in between these countries. While in Germany less than 10% of the respondents stated that they are currently using it, the number in Hungary is above 30%. At a first look

this variation can not be explained by the typical patterns like the geographical location of country, its size or its level of economic performance. Therefore other factors seem to be more helpful to explain this variety. One possible explanation might be the attitude towards privacy and data protection. The latest Eurobarometer on this topic (TNS 2011) shows that this can only explain a little bit, but not all results. For example the level of trust in case of data protection to Internet companies is in both countries, Czech Republic (25%) and Hungary (23%) above the European average (22%(), but the adoption varies strongly between them. Moreover in Sweden already 26% trust internet companies, but the adoption is the second lowest behind Germany (TNS 2011, 137-145). Also we can vary this with other results from the Eurobarometer, but overall it shows that there are some helpful indications, but no full explanation. One reason might be that number of respondents per countries is at the lower limit of representativeness. Another point is that parts of the respondents were maybe not aware that they in fact used Cloud services, because a look at the number of persons who used online storage (upload and store of content) in the picture below it shows that more people used such services, which are most likely Cloud based services. Consequently the results should not be taken as fixed statements.

Picture: Usage of free consumer Cloud services by types of services in selected European countries, Source: Cattaneo et al. 2012b, 51

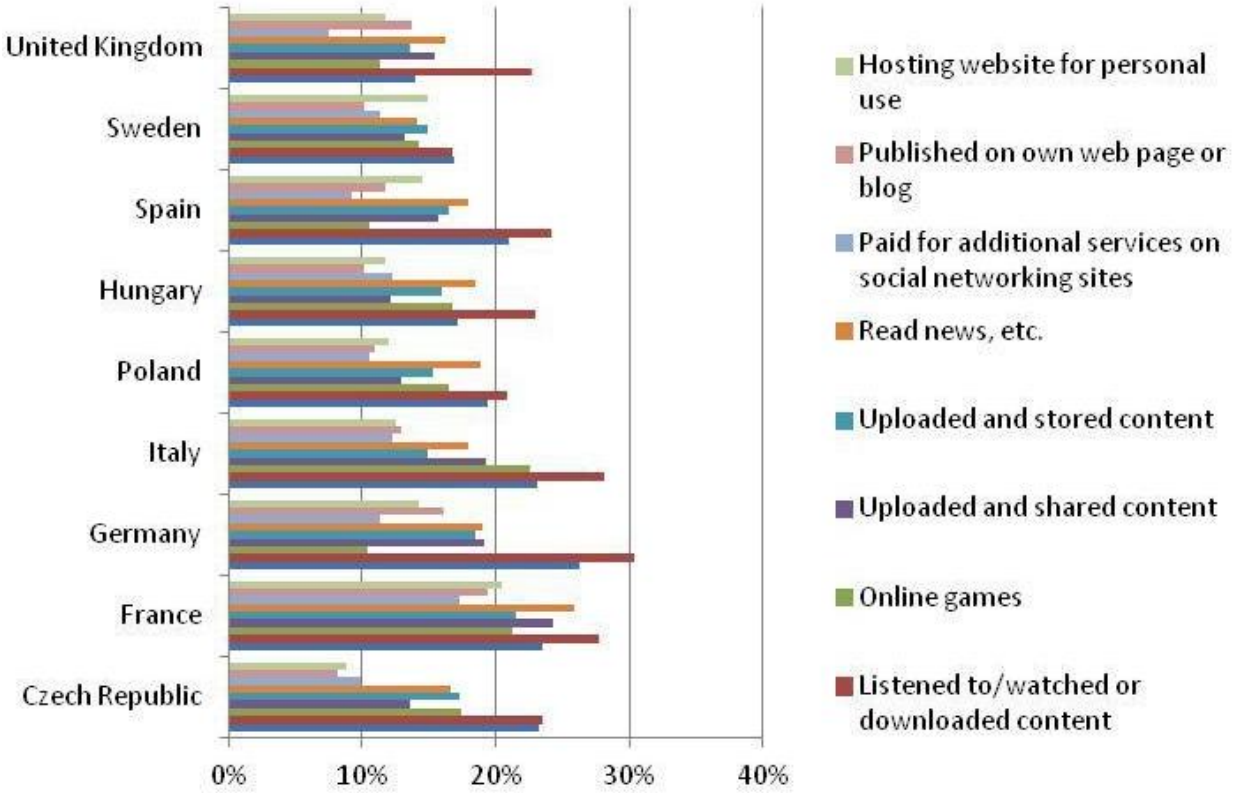


With regard to the usage patterns the IDC report shows two main points. the first point is that services like information search, streaming or blogging, where people only disclosure some information as they like are used by nearly all respondents. Moreover there are also no big differences between the different countries. In opposite to that people are less willing to store their content/data online. Only one exception from this trend is the use of

social networks, but as stated before there is question if some of these activities are really Cloud services. However some of the numbers for services like online storage, which is as indicated before a Cloud service, suggest that in Europe more people then shown by the first picture are using some kind of Cloud services. Nevertheless it is not possible to conclude final numbers out of the information available.

The second point is that it is obvious that people are less willing to pay for the same services. As shown the by the different results for nearly all services only few people are willing to pay for services as long as these are also freely available. Nevertheless this is an interesting result, because also the services are free of charge people pay a different price because these services are financed by advertising. Even in some case individual usage patterns are used to target advertising, which means that much more personal information are disclosed then maybe in case of a paid services. The difference is smallest in particular in the segments of streaming offers for music, videos or other multimedia content. Overall these results are not really surprisingly and confirm at least in parts existing perceptions of adoption and usage patterns.

Picture: Usage of paid consumer Cloud services by types of services in selected European countries, Source: Cattaneo et al. 2012b, 52

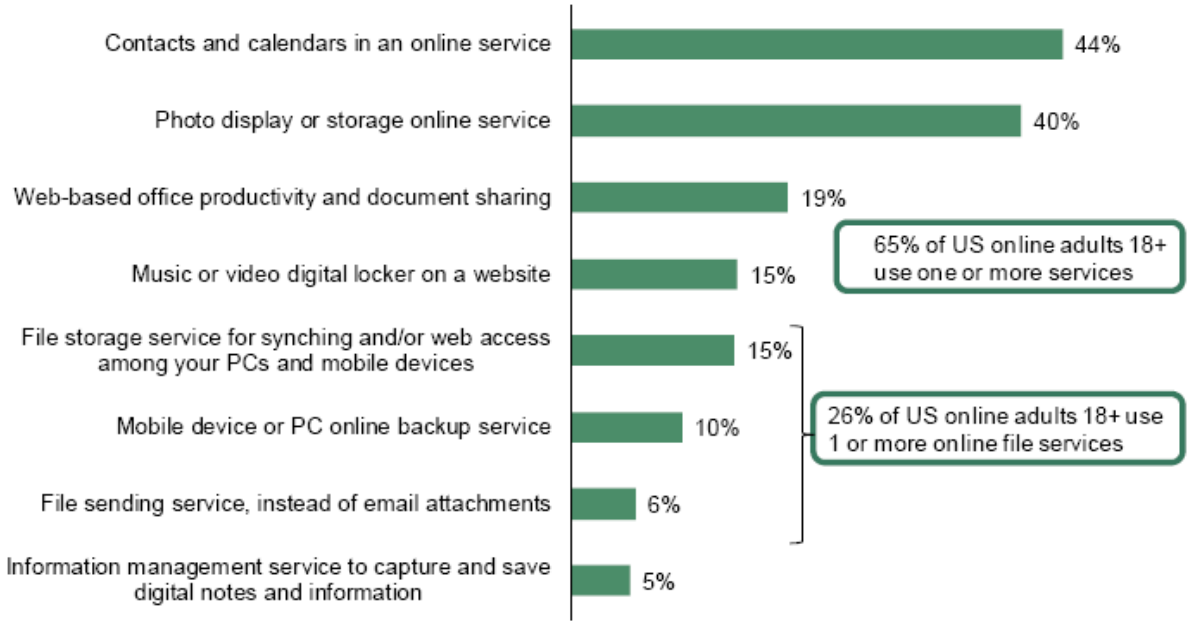


Also not surprisingly studies for the US seem to indicate the same pattern regarding payment as in Europe. A study carried out by PwC in 2012 showed that any types of fees would clearly affect the usage of Cloud services, in case of the study the usage of a digital locker for multimedia content (PwC 2012, 12). Regarding the overall adoption and usage it is hard to make comparisons, due to the fact that the question and therefore types of services in focus are not comparable. In recent studies like the one by Forrester (2012),

which was commissioned by Cloud service provider, the focus is in a narrow sense much mare focused on typical Cloud services like online calendars, storage or streaming.

Overall this study of Forrester among more then 2000 consumers concludes that nearly two-third of the US consumers use one or more Cloud services. According to the study services like online schedules, storage of photos and with a clear distinction collaboration tools are the services mostly used. Based on that it is not possible to judge on the degree of personal information involved, but it seems also obvious that at least the online storage of data and personal documents is also not as widespread as other services (Forrester 2012, 6-8).

Picture: Usage of consumer Cloud services by types of services in the United States, Source: Forrester 2012, 7



Overall the results show that the adoption and usage by consumer does not really lag behind the adoption in business. Some articles even state that the number of early adopters in the consumer segment was higher than in business (Schofield 2012; Layo 2012). Consequently they were responsible that through the use of personal devices like smart phones or tablets Cloud services like Dropbox entered companies. This trend, called consumerization of IT, is expected to continue as the recent hype around the BYOD (Bring/buy your device) shows (Trend Micro 2012). The underlying belief is that people do not wnat to limit themselves to classical desktops PC, but instead want to use the full scale of devices like notebooks, smart phones or tablets. Moreover the borders between private use and use for for business is more and more becoming blurred, which is maybe a side effect of the blurred borders of working private life in modern times. Consequently Gartner already forecasts that the personal Cloud, which will consist of mix of private and business devices using different kinds of Cloud services for work and life purposes, will replace the old PC in the coming years. Although it might be not in such a short term, it is obvious that new mobility will strongly impact usage patterns in the next decade. Beside the more optimistic views on benefits and cost reductions, there are also critics stating that this

development will cost companies at least in the next years much more money then they can expect to save by the use of Cloud computing due to challenges klike upgrade of existing systems, security solutions and hardware costs (Scholfiel 2012; Layo 2012).

4.3.3. Adoption and usage by governments

As already indicated in the previous section on adoption and usage patterns in business, the survey of IDC (Cattaneo 2012b, 19) as well as the one of the Cloud Industry Forum (2012, 3-5) both included government and public services in their general survey. In the case of the IDC survey Europe that government as well as healthcare/education as a public service reach average values of adoption and usage (~43% and ~41% of users or respectively ~62% and ~63% if trial/limited use is counted as well). The survey for the US states that also 63% of public services already have adopted and use one or more Cloud services. Although it seems from this first view that with respect to public services and administrations Europe is at the same level, but a report by KMPG (2012) on the adoption in ten countries worldwide including US, UK, Italy, Singapore and some others shows that there considerable differences in the way how it is done. Therefore it seems helpful to review the public activities to determine if there are differences and to what extend. From the point of this study, there two points most relevant:: firstly, which type of Cloud models are used (public, hybrid, private), and secondly for what purpose, i.e. for internal use of services or also for purposes like e-Government/-Administration, communication or other public services like health records etc (KMPG 2012, 21-26).

If you look at the European level the picture is not quite clear, i.e. there is a lack on information about if and how European administrations and organisations use Cloud services. As indicated by the funding of the 7th FP there several activities in the area of scientific organisations including also European organisations in this area. However, there no further information to find about European administrations use of Cloud Computing.

On the level of the member states the picture varies strongly, but it seems hard to detect clear patterns. For example the survey of KMPG (2012) encompassed five member states (Italy, Spain, Denmark, Netherlands, UK) and the comparison of them shows strong difference towards the question to which extend the countries are expected to implement Cloud computing in public services. regarding this Italy and Denmark are leaders towards a full implementation of it, while in the other countries the tendency at the moment is more towards testing or setting up partial implementations. Possible factors influencing this development could be size of the country, degree of centralisation (central vs. federal structures), interest in cost savings, but also many others (KMPG 2012, 21-26).

In the case of Denmark there existed due to the structure of the national identity system (called CPR) already a strong centralised system, where records from the public registration system, national health services or tax system and others were stored centrally (Friedewald et al. 2008). Therefore it seems easier to move into the Cloud, but on the other hand the official documentations of the Agency for Digitisation show that there are many initiatives ongoing on different levels like the transition of the central platform for companies to submit invoices to the state (NemHandel) into a public Cloud service[14] as well as it shows

[14] See http://digitaliser.dk/resource/567373.

the development of a national strategy for Cloud Computing. However, as far as it seems there are no plans for a central Cloud of the public services.[15]

In opposite to that the , but the British National Strategy implemented a national Cloud platform called "G-Cloud" is a platform for all public services in Great Britain. One kex element is to set up a kind of an open marketplace displaying services that can be procured, used, reviewed and reused across the public sector. The major aim of the program is to reduce costs of public services through centralisation of infrastructures and the reuse of programs and apps. However the program steered by the Home office and the Ministry of Justice is the central pillar of the government's Cloud Computing Strategy and supports the overall ICT strategy for Great Britain by inter alia setting standards, creating lead users in order to enable the British ICT industry and supporting the take up of Cloud services in private business.[16]

Comparable, but with a much broader focus the French government announced last year the "Andromedé" Cloud. On a first look it is a combination of a R&D support program and a national Cloud platform enabling the secure and data protection compliant use of Cloud Computing. In opposite to the British program this platform is not only directed at public services, but also at companies. Therefore it is led by a industry consortium, but the French state keeps through the national investment bank CDF and its funds a control stock of more than 30% (Auffray 2012). However after some troubles it was recently announced that the program is now split into two consortia, one led by Orange and Thales and another one led by SFR and Bull. In both projects the French government will invest the same amount of money via the CDF. Since this was only decided in September the directions of the projects called Cloudwatt and Numergy are still shaping their focus (Guegneau 2012). Above that there are only few information about the actual usage of Cloud Computing on different levels of the French public services available.

In opposite the situation in Germany is much more diverse. On the national level the Federal Ministry of Economics and Technology is funding the R&D support program "Trusted Cloud". It is aimed at developing applications for the use in public services or private companies, in particular in small and medium sized enterprises (SME). Consequently the program is organised in four pillars: basis technologies, industrial applications, applications for the health system and applications for the public sector. It will be complemented in 2012 by another technology developing program called "internet based services for business", which will be a follow-up of the "Theseus" program. Together they form the main part of the action program "Cloud Computing", which deals additionally with international cooperation, knowledge transfer and creation of favourable framework conditions.[17] Above that level there is ongoing discussion that the Ministry for Interior plans to implement a national German Cloud that is similar to France directed at the public services as well as companies in Germany (Kalenda/Pößneck 2011) Nevertheless there are also a number of Cloud activities on the state level in Germany, but like in the case of the regional data

[15] See http://www.digst.dk/Arkitektur-og-standarder/Cloud-computing.

[16] See http://www.cabinetoffice.gov.uk/sites/default/files/resources/government-cloud-strategy_0.pdf.

[17] See http://www.trusted-cloud.de/documents/01_Goerdeler_BMWi.pdf.

centre of Stuttgart most of these activities are aimed at private clouds, which should help to reduce costs and improve service quality.[18]

In the US the "Federal Cloud Computing Strategy" was adopted in February 2011. It is based on a long-term process that started already in 2008 when as mentioned before the National Institute of Standards and Technology (NIST) started a process to define Cloud Computing. The strategy outlines that Cloud Computing is not only a paradigm shift for the IT industry, but that it changes the way how public services will work for citizens in terms of possibilities, and also in terms of efficiency and costs. It also describes the necessary framework conditions for the public use and ways to achieve it. Central element is the introduction of a "Cloud first policy" requiring that public services have to give priority to Cloud as the first alternative for new IT systems.[19] This Cloud first policy went into effect in 2012, but already before the US government started several initiatives before. In a first step the General Service Agency (GSA) that provides central services for the federal and local governments in the US moved in 2009 the general information portal for citizens USA.gov into a third party hosted infrastructure. The aim was to improve the service quality (number and length of down times) while reducing the operational costs. Initially it used an public IaaS offer from Terremark, but recently GSA decided to move USA.gov portal and the datat.gov portal, which is the central portal for the Open Data strategy, to the public IaaS environment of CGI. Meanwhile other federal ministries and agencies also started to move their portals into other public Cloud services (Montalbano 2012). The other central project of the GSA was the establishment of apps.gov, which should be a storefront for cloud solutions for all federal and local public services (ministries, agencies, etc.). In principle it is based on a flexible IaaS environment and offers user the chance to search for existing solutions, mainly existing best practices. Moreover user should be also enabled to test these solutions and adjust them if necessary to their own needs. However, the GSA shut down Apps.gov in December 2012. Officially the GSA stated the need to further develop their offers for customers as the reason for this step, but in recent time there was after the first enthusiasm some critics on the platform stating that it was a political project not backed and taken up by its user (Weigelt 2012). Nevertheless it worked well as a flagship and speed up the process of up taking of Cloud Computing in public services in the US. Consequently there are a set of other projects ongoing like the Department of Health and human Services use of Salesforce CRM solution for their regional centres as well as the use of Salesforce at the Census Bureau (Violino 2011; Wyld 2010). Another example is the engagement of NASA in the development of the Nebula project, which turned no into an open source technology for Cloud Computing (Wyld 2010).

Overall this illustrates three points about Cloud Computing for public services in Europe and its differences to the US. Firstly, the situation in Europe is as already guessed quite diverse and foremost driven by national initiatives. Secondly most of these activities are still at an early stage. Finally, the national programs and strategies are more often aimed at great national clouds that are also aimed at companies and not only public services as well as they also often seen as a key stone to enable the national IT industry competitiveness.

[18] See http://www.kommune21.de/meldung_13367_Kommunen+auf+dem+Weg.html.

[19] See http://www.cio.gov/documents/Federal-Cloud-COmputing-Strategy.pdf.

Although the latter point may be no official intention of the current US strategy, it is seen at least as a side effect of it (Higgins 2012). In most other parts the US approach differs clearly from the ones in Europe. One point is that as an early adopter some of the projects of the federal government already achieved a stable status. The second point is that the US tends to use public Cloud services already offered, while some of the EU member states prefer to develop their own Cloud platforms, mostly in cooperation with national IT service providers. In this respect these countries are comparable to Japan, where the Kasumigaseki Cloud represents also an national Cloud platform for public services (Wyld 2010). Due to the fact that this will take time to develop and implement, most states virtualizes their existing data centres into private Clouds in the meantime to profit from cost reductions.

4.4. Conclusions: Current and future directions in the development of the Cloud Computing market and usage

Not surprisingly the result of this review is that Cloud Computing services are one of fast growing segments within the markets for software and IT services. Only Mobile Computing or Big Data seem to have the same growth rates, but their markets sem to e smaller. Moreover they are also drivers for the Cloud market, because they often rely on it.

Taking the markets as a proxy for the overall development, we can state that acordingly to the reports of different market research companies that the share of Cloud Computing in the overall market will grew from a few percent at the moment (~1-2%) to a range of 5-10% (5 years horizon) and 10-20% (10 years horizon) in the next years. Therefore Cloud Computing will become an essential part of the overall market. Parts of this growth result from the overall growth of the software and IT services as well IT hardware market, but it will also replace parts of existing markets, in particular for example the classical segment of software products based on licenses and maintenance contracts as well as IT service segments like Outsourcing. There is a little bit uncertainty to the extent of impact in these segments and especially their time frames. However there is also the fact that Cloud related services like integration consulting will grow and maybe will compensate the loss in the IT service market. In the case of a strong growth of hybrid usage models, which is seen by some researchers, this increase could be even stronger then the loss and lead to further grow. Commonly it is expected that the growth of these concerned segments will slow down and maybe stagnate in next years because of the growth of Cloud Computing, but it seems unclear if and when it will lead to a decline of it.

The common view is that in respect of the different services models the market for the SaaS model (including BPaaS in its different definitions) will stay the biggest one also in future. Nevertheless there is a tendency to believe that IaaS, which is with clear distinction the second biggest market will grow at a higher rate. Moreover some experts also believe that PaaS will also gain of importance. Though this will lead to an increasing share of both models within the Cloud Computing market, SaaS will remain in absolute value the main market in future. One reason are the different adoption and usage patterns. In particular consumers using Cloud services for private purposes as well as for their work life, but also the growing number of SME adopting Cloud services are more used to standardised product offers instead of the more flexible, but also more complicate ones like PaaS and IaaS.

Within the different segments there is a clear trend towards more diversity. More and more complex services are offered as shown by the overview on existing services. In particular in the segment of SaaS the trend towards business process offers is a clear sign for that. This also results more diversity in terms of the revenue distribution between the different services.

Regarding the regional development it is not surprisingly that the US are the biggest market for Cloud Computing at the moment. According to all forecasts it will show in terms of absolute value the greatest growth. However in terms of growth rate emerging markets like China or India are seen as the coming markets. Europe is at the moment the second biggest market behind the US and followed by Japan, but it is characterized by a smaller growth then many other regions. As reasons for this slow growth most of the researchers name at least two points: firstly, the lower adoption rate in general caused by a greater reluctance against Cloud Computing, and secondly, by the economic crisis of the Euro zone. This clearly relates to the development of adoption and usage patterns. However it seems like that in the last two years there is also growing tendency in Europe to explore possibilities of Cloud Computing. Finally, it still needs to be clarified if for example European companies have stronger tendency towards private Clouds in order to at least profit of some of the advantages of Cloud Computing.

Similar to the growing number of offers there is also emerging number of young companies, mostly acting as aggregators that use existing Cloud services as a basis for new services. However, the strongest player in the market are all well known. On the one hand there are early movers like Amazon and Google with a strong background in internet-based services as well as for example Salesforce, which was an early proponent of SaaS and its predecessors. On the other hand there are the IT service providers like IBM, HP or Deutsche Telekom (T-Systems) and others who strongly rely on their technology and customer-base. Another group is formed of specialist like VMWare or Citrix, which were engaged in virtualisation and similar ground lying technologies. They are in a strong competitive position due to the spread of their software and tools. Finally there is the group of more product-oriented companies like Microsoft, Oracle or SAP, which all started at a later stage, but rely on their experiences, strong profile as well as their existing market position. Finally there is the group of "Cloud born" companies like Dropbox or Evernote. A difference is that they often address consumer in the first line. However the question will be which of these companies are able to turn their revenues into profit while growing further. most probably one a few will become global players and many of them will not survive in the long run. Additionally there is also a strong trend towards the acquisition of promising start-ups and medium sized companies. In recent years mostly companies with a focus on business relevant Cloud technology and services got acquired, but this may change soon.

As already indicated is Europe lagging behind in the adoption and usage of Cloud services. European companies are overall less engaged in using Cloud services as there American counterparts. Most obvious is the difference in the SME segment, where American companies are more likely to adopt Cloud services. Another point is that most of the European companies only started in the last two years, which might be one explanation for the differences in the adoption patterns. With regard to the different types of usages, it is

not possible to determine bigger differences between the US and Europe. Most often simple applications are the first ones in both regions, while with more experience the complexity of used services increase. There are also uncertainties to which extent European companies tend more to use private Cloud instead of public Cloud offers. Given this and taking the positive development in recent years into account, it might be that the lagging behind of Europe is not as big as some predictions state or discussants fear.

In case of the consumer adoption and usage patterns the situation is more complicated due to the different definition of consumer Cloud services. Therefore comparisons between the different studies and analysis are only possible to a very limited extent. Overall the results show that the adoption of Cloud services for consumer shows varies between the different European countries. Like in the other cases typical patterns like geographical location, size etc. are not self-evident, but it seems likely that different approaches towards privacy and trust reflected in other studies form a first good indication, but can't explain everything. In regard to what kind of services are used two trends are obvious. First of all, most of the consumers prefer to use free services instead of paid ones. Secondly the studies show not surprisingly that services with less involvement of personal information or personal data are more used than others. Overall these results are not really surprising. Based on the information available to the situation in the US it seems clear that US consumer also clearly prefer free service offers in the case of Cloud. As for the second point, the relation between personal information/data and adoption, it is not possible to find relevant information, but maybe the absence might be also a sign. In total it seems like that the adoption level in the US is higher then the one in Europe. Overall, in both cases, Cloud services are seen as one of the first examples of comsumerization in IT, which will be one important trend together with mobility in the future that impacts our usage patterns. The impacts and benefits are still subject of partly controversial discussions.

At a first glance the adoption level of Cloud services in government and public services does not seem to differ so much between the US and Europe. But there some differences, most obviously with respect to the overall attitude and the resulting course of action. The US federal government already started in 2009 to implement projects and meanwhile adopted a Federal Cloud strategy foreseeing a Cloud first policy, which leads often to the use of existing public Cloud services. In contrast, many European states started to develop plans for a national Cloud platform with varying coverage (only public services or also companies), which will take time to develop and implement. Until these platforms may work, many smaller efforts as short-term solutions are made that led to the introduction of private Clouds within the existing structures. Additionally part of these plans is also often to support the national IT industry through these activities. However, there are also European countries using different patterns, which underline again the diversity of Europe. Finally this situation leads to the question which approach is on the one hand best suited to achieve an increase of efficiency within public services, improved transparency and security for citizens as well as best suited to give a boost for the Cloud take up and industry. It might be that in the there is no clear answer to it, but at the moment it is obvious that the more pragmatically approach gains more attention.

Concluding, we can state that the growing maturity of Cloud Computing will also lead to a transformation in usage and offers. While the last years were shaped by the fact that most services where transferred from existing offers into the Cloud, the future development will enable more services building upon other services creating new value chains etc. One open question is to what this "Cloud innovation" will occur and how it will impact the existing industry, but also users and society. Although it is hard to predict this in detail, it can be expected that it will change both, but it remains open if it will be a revolution or more an evolution. Most likely is that it is somewhere in between.

Nevertheless some trends for the next years are already observable. The first one is that in particular for innovative Cloud offers consumer will play an important role. Many examples like Dropbox were first taken up by consumers and then brought to companies ("Consumerization of IT"). Other examples like Spotify are specifically targeted at consumers and due to the growing spread of smart phones and tablets this entanglement of Cloud services and app services will intensify. In the market for business oriented Cloud services the trend of more and more complex services was already indicated. Most likely the growing adoption of services and in particular the creation of new services connecting different services that were not connected before will result in an increased need for integration and especially governance solutions for it. One reason is that the integration of new services will lead to a growing hybridization of the existing IT landscape in companies. Another reson is that this will result that more and more critical applications and data will be involved. Both requires high levels of integration to enable a meaningful results, but it also requires governance strategies to comply to existing regulations and to assure the security of own data and applications.

5. IDENTIFICATION AND ASSESSMENT OF DRIVING FACTORS AND BARRIERS FOR CLOUD COMPUTING

5.1. Methodology for identifying and assessing of driving factors and barriers

5.1.1. Scope and approach of the identification and assessment

This final section of the report aims at an identification and assessment of driving factors and barriers for Cloud Computing based on a review of studies related to it. The main aim is to provide an initial input for the upcoming phases of the project, which are will deal in detail with the benefits and risks of Cloud Computing for Europe.

Based upon that premises of the overall project we selected a set of most recent studies and articles dealing with factors, which are driving or impeding the take up of Cloud Computing. Moreover we focused mainly on studies and articles, which deal in general or with a specific European view with such factors. Another point resulting from this approach is that the definition of Cloud Computing varies in the studies. Consequently we restrict our review of factors according to our own definition and scoping in section 2.4, i.e. we focus on public and hybrid Cloud services across all three service models (IaaS, PaaS, SaaS). Regarding the other classification criteria's like revenue/pricing models or type of actors we will not limit ourselves due to the blurred situation, but critically reflect used categories if necessary. In return, we will not address traditional software and IT services, such as outsourcing, with an IT-provider offering computing services on the customer's premises or near-by, using exclusive, non-shared resources.

The review of the studies and articles also implicate some further limitations. First of all most of the studies deal with Cloud Computing from a business point of view, because business use is seen by most studies as the crucial segment for further development of Cloud ComputingConsequently they focus strongly on issues availability or confidentiality related to it. These are considered as important for the question whether businesses will put more and more of their computing into the cloud in the future or not and thereby important for the economy as a whole. However this would be similar true for government and public services as well as for consumer services. But while the first is dealt with in some studies by incorporating public services into surveys etc, the latter are often only mentioned shortly. One reason for that might be that in many cases the definition of consumer Cloud services stays vague and include services like streaming services such as Spotify, which are technically sometimes cloud based, but more often a peer-to-peer based service, or Facebook, which uses a worldwide distributed private Cloud, but which are not a Cloud service per se. Another argument is that issues like availability, confidentiality and integrity are also seen as important for consumers, but that it is more feasible that due to their importance these issues will be solved with business user first. this argument is supported by one figure presented by Cattaneo et al. (2012a, 45) stating that security pribvacy and data location are the most important barriers for consumers. Moreover it is expected that consumers could profit of such solutions. Although this

viewpoint might be true, it bears the risk of overlooking developments like the consumerization of IT that can evolve as one major trend in the next few years.

Similar to the problem of the varying definition of Cloud Computing, the varying terminology for drivers (sometimes enablers) and barriers among the different studies are problematic. One example is that in some cases similar terms relate to different aspects of it like for example flexibility can refer to flexibility of IT through the use of Cloud, but also to the flexibility of an organisation as a whole enabled by Cloud. In return total different terms can relate to the same fact. Therefore one challenge is to sort and bundle or unbundle these different terminologies. Related to it is the empirical basis of the different studies and the methods of data gathering and analysis. Many research articles are based on general opinions and less on empirical evidences such as interviews or surveys. Although all arguments might be true, it increases the challenge of assessing single facts. In case of surveys and interviews the selection of questions and topics is often limited or even worse it might be based on the authors' intention and interests. Given the fact that many of these surveys are carried out by IT companies or related consulting or market research companies, one should be aware of this and reflect the results. Finally all of these research and studies lack of long time empirical evidences like for example longitudinal studies of the impact and benefits of Cloud on organisations. One reason is that Cloud only exist a few years and that there is only a limited number of early adopters, which could deliver such more detailed insights. Another one is clearly the fact that this would also require new approaches in research, which are lacking at the moment due to the uncertainties on definitions, models, etc.

Another point is that many of barriers and drivers are interrelated or even can fulfil both functions depended on their current status (and maybe the point of view of the author). One example for the latter point is the availability of network connections, which can hinder in case it is insufficient, but it can also work as a driver of the development if enough network capacity is available. An example for the first point are the interrelations of trust in Cloud computing and the questions of data location and data security. Consequently the identification and assessment will need to reflect such points.

Finally, another limitation is that these studies deal foremost with the users' point of view. From a overall economic perspective this scope neglects the question if there is similar to the adoption patterns a lower take up of Cloud service by European suppliers and if yes what are possible reasons for it. Regarding the market situation the overview of existing suppliers has already shown that the majority of important players in the emerging Cloud segment are of US origin. This is confirmed by other studies that analyse the European deficits in participating in emerging IT markets (Veugelers et al. 2012, 12). It seems like that the current situation of the emerging market for Cloud services start to reproduce the current situation of the overall software and IT services industry, which is since decades shaped by a dominance of American companies. Consequently we will also have a look at possible barriers for the development of the supply side. But while only a few studies (for example Rossbach/Welz 2011) deal with the situation of European Cloud suppliers, there is a continuous track of studies on the competitive situation of the IT industry as a whole. Consequently we will use the most new research results (for example Aumasson et al.

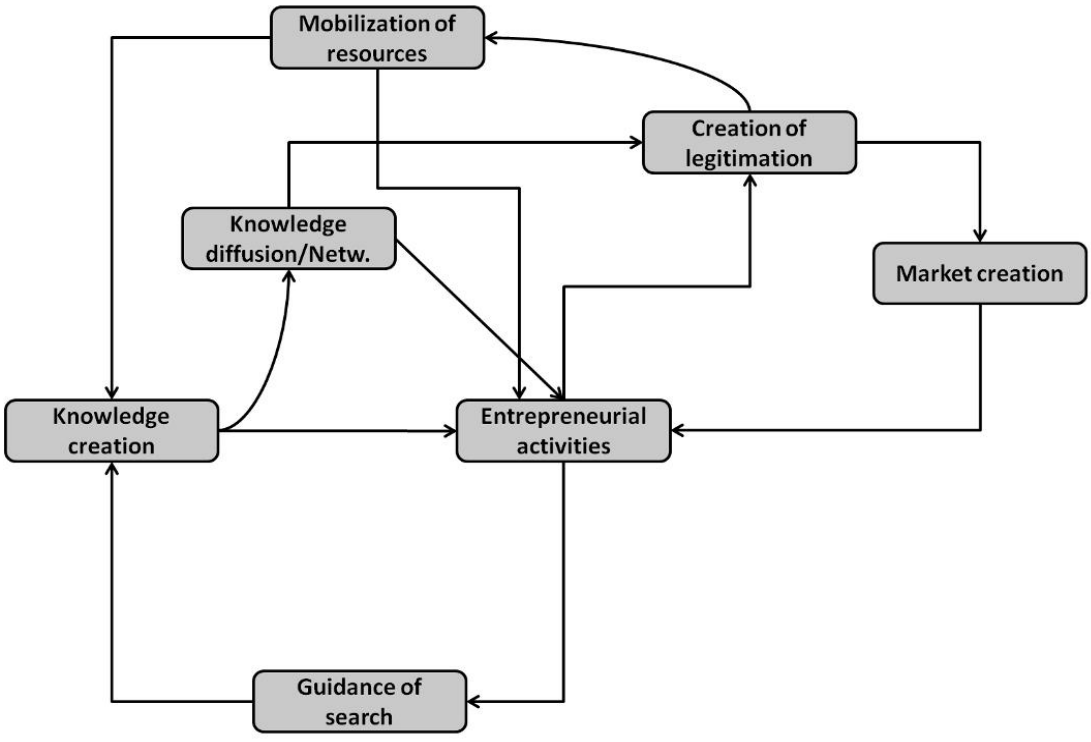
2010, Veugelers et al. 2012) to derive barriers for them. The main challenge here is to determine which of the overall barriers have a specific significance for Cloud suppliers. This is necessary to understand if there are specific needs beyond the existing suggestions and measures. Another point is to reflect the question if there are others with a high significance for the European Cloud industry, which are not covered by existing studies.

5.1.2. Methodological background

Against the background of the given scope and limitations it is necessary to apply a methodology that is able to provide a framework that allows to cover both, demand and supply side, as well as to analyse the interrelations and dependencies of barriers and drivers.

One approach that could fulfil these requirements is an analysis of functional dynamics based on the technical innovation system approach (TIS), in particular it is aimed at the analysis of emerging technologies like Cloud Computing. A TIS can be described as a network of actors, interacting under specific institutional infrastructure to generate, apply and distribute a specific technology (Carlsson/Stankiewicz 1995). Normally, the main processes and activities of a TIS were called functions. They serve the overall goal to invent, use and diffuse innovation. Although there is no consent agreement on which functions are the most important, there seems to be a set of seven functions named by a majority of researchers that are characteristic for emerging technological systems (Hekkert et al. 2007; Bergek et al. 2008): Knowledge production; Knowledge diffusion and Networking; Entrepreneurial activities (founding and experimenting); Guidance of search processes; Market creation; Mobilisation of resources (capital/human); Creation of legitimacy.

Picture: System functions and their interdependencies (adapted from Hekkert et al. 2007)



This approach offers some advantages, but there are also challenges regarding the goal of this study.

First of all the integration of interdependencies is one major advantage of this approach. Moreover it allows to all important areas identified (for example data protection and retention or consumer protection as part of legitimacy, liability and cross-border activities as part of market formation, innovation activities as part of entrepreneurial activities or standards and interoperability as part of the regulatory framework).

Another one is that it explicitly addresses the problematic of emerging technologies as it is the case in cloud computing. It fulfils most of the typical characteristics and signs of emerging technological innovations systems in its formative phase, i. e. high technical uncertainty (f. e. lack of standards); markets are small, and characterized by high uncertainty, but start to grow fast; problems with legitimacy (f. e. lack of trust). Although not all of the listed functions can be fulfilled sufficiently yet due to this, there is an immense structural overlapping and dependency on other systems. In the case of Cloud Computing these systems are Software & IT services, telecommunication services and Internet.

However one criticism is that the analysis is mostly focussed on the supply side, i.e. the demand side in terms of consumer needs and inputs. This point is for example outlined by Dewald and Duffer (2011), which propose to differentiate sub-structures for market formation to countervail the lack of user integration. Another criticism is that the regulatory environment is often seen as part of other functions, but in fact in some cases it requires a individual analysis. Finally there is also the need to integrate functions that are specific and important to the case of Cloud Computing.

Based on this basic understanding we have conducted our research along a model which is derived from the functional dynamics analysis introduced by Bergek et al. (2008). It uses a set of process goals reflecting the functions and elements of the emerging innovation system to enable an analysis based on literature and event analysis. The advantages of using such process goals is that they offer more flexibility and are "closer" to the various instruments used in innovation and partly industrial policy. Consequently they are well-suited to identify and asses barriers and drivers. Given the mentioned constraints we adapted it to our needs in the case of Cloud Computing taking into account existing research and derived nine process goals:

- creation of a knowledge base and support of knowledge diffusion, i.e. support of research and development, but not only limited to technological knowledge, and the diffusion of the resulting knowledge between research, industry and user;
- increasing the human capital basis, i.e. enhance the education of developer and user;
- encouragement of entrepreneurial activities, facilitate training and other support for entrepreneurs;
- provisioning of infrastructures, i.e. ensure the availability of technical infrastructures;
- improvement of regulatory environment, i.e. the adjustment of the legal framework;

- fostering the creation of markets, i.e. support the development and improvement of emerging markets by different means;
- supporting the creation of legitimation, contribute to the acceptance of the technology by increasing trust or etc.;
- improving financial capital situation, i.e. assist start-ups and fast growing companies to access financial capital required.

The analysis itself was split up into three main steps. The first phase was focussed on desk research on the political and regulatory framework as a first review of existing studies and literature on barriers and drivers of Cloud Computing. This step pursued two aims. Firstly, we used the results of it to adjust our framework to the subject of Cloud Computing and its specifics as described above. The second aim was to gain an overview of the existing political and regulatory framework of Cloud Computing, which includes a comprehensive analysis of existing and planned policy actions on the EU level, which can be considered as important for Cloud Computing. Moreover it also included an analysis of actions and activities in other counties, in particular the US, and the developments on a global level like organisations as ITU.

In a second step we undertook an in depth analysis of the existing studies and literature on barriers and drivers. It was aimed at gaining an overview on already identified factors, their definitions and the underlying evidences. Afterwards we consolidated this list of factors in order to reduce the number of duplicities, overlaps and contradictions. As a result a short description of each factor was assembled. Above that the results of it were also used for the identification of affected actors as well of the related areas, which describes if a factor relates to business, legal, cultural or technological developments. Concluding the empirical evidences, as far as available were, integrated into a short overview.

In the third step we undertook an assessment of the identified factors and their current and possible future based on the empirical evidences presented by the studies as well as on additional material related to the topic like for example data from other sources like Eurobarometer, Eurostat and others.

Finally the results of all steps were summarized for each factor, either driving and/or impeding, according to the following scheme and listed along the different categories described above:

Name
Type of factor: barrier, driver (or both);
Affected group: supply side, demand side (or both);
Related area: business, legal, cultural, technological;
Description: short description of the factor reflecting the most important aspects of the factor;
Evidence: short analysis of evidence from existing studies and surveys on the importance of the factor;
Assessment: short evaluation of the factor and its current and future relevance;
Activities: if applicable, a description of recent activities on EU level.

5.2. Identification and assessment of driving factors and barriers

5.2.1. Creation of a knowledge base

Level of R&D

Type of factor: barrier;

Affected group: supply side;

Related area: business

Description: This factor refers to the factor that the low level of R&D investments in IT is one one major factor for the lagging behind of European firms in emerging segments of the ICT market.

Evidence: the yearly IPTS report on R&D in ICT in Europe shows that European ICT spending at company level significantly lags behind the US. in particular the software and IT service as well as the internet sector, which are fundamental for Cloud Computing, are affected by it (see for example Turlea et al. 2010, 75; Turlea et al. 2011, 55).

Assessment: this factor has some relevance, but in many discussions it is pointed out that the findings are maybe more a consequence of the lack of leading IT companies then the cause of the problem, especially since the spending on ICT R&D in other industries are quite high in Europe (fr example automotive industry).

Activities: In recent years the Commission launched several initiatives to raise the company level spending in ICT. One major example is the introduction of public-private partnerships, which are aimed at attracting company to invest additionally in R&D by providing specific state support. Other measure were he increase of the ICT budget in the 7th framework program.

Pre-commercial procurement

Type of factor: barrier

Affected group: supply side

Related area: business

Description: in recent years the lack of usage of pre-commercial procurement was discussed as a fundamental problem of linking public funded R&D with the development of new markets, most notably also in field of ICT (see National ICT Director Forum 2006). In the aftermath the Commision adopted 2007 an Communication on this topic (EC COM (2007) 799), which recommend the implementation of such mechanism in the EU member states. In principle pre commercial procurement means that governmental agencies use some parts of their procurement budget to purchase innovative solutions, which are still under development. Example for it is the Small business Innovation Research (SBIR) in the US, which was established in the 1980s.

Evidence: The importance of pre-commercial procurement is often shown based on the example of the SBIR programme (see for example Wessner 2008). Also in research the demand oriented policies recently gained more attention (Edler 2011, OECD 2011). Therefore some evidence exist for the positive impact, but it is not undisputed.

Assessment: the factor of pre-commercial procurement is overall not of highest priority, because it only gains attention for a small set of companies. Nevertheless in particular in emerging sectors like Cloud it could be of use to drive the development of fast growing SME.

Activities: After the adoption of the Communication in 2007 the EC itself launched several pilots for pre-commercial procurement within the 7th framework program, which is now in its final round. Above that the Commission also announced to continue this path within the coming Horizon2020 program, which was stated as one initiative of the Innovation union (EC COM (2010) 546). Additionally the Commission also launched two new proposals (EC COM (2011) 896 and EC COM (2011) 895) replacing the existing public procurement directives, which are also aimed at easining pre-commercial procurement in the member states. Within all activities ICT is one major field to pilot such procedures. Consequently DG Connect also started to monitor the development of it within the EU.[20]

5.2.2. Increasing the human capital basis

Lack of human capital

Type of factor: barrier

Affected group: both, supply side as well as demand side

Related area: business, technological

Description: this factor refers to shortage of educated labour force. Most of it is connected with a lack of skilled It experts in the software and IT industry, but it also relates to the lack of skilled users. While the former are necessary to ensure that the IT industry itself is capable to develop new solutions in emerging fields, the latter point refers to the fact that such new solutions also require skilled user able to exploit the possibilities of it (see for example Aumasson et al. 2010, 263-272).

Evidence: While shortage of IT developers is a recurring claim of the different industry associations and also well researched by many studies on the member state or EU level (see for example Korte et al. 2009) and also the need of skilled users is widely accepted, there is only a few research regarding the change of requirements caused by Cloud Computing. A first approach was done by study commissioned by the European Commission in 2011, which clearly underlines the changing requirements due to Cloud Computing and the resulting need for for more support in the creation of such skills, in particular for SME using Cloud Computing (Laugesen et al. 2011). Nevertheless there is no further research if and how Cloud Computing will impact the need for skilled labour.

Assessment: Shortages of labour force and a lack of skilled current labour force are always among the top priorities in most studies on the competitiveness of the IT and software industry itself, but there is lack of research of lacking skills as reasons for current adoption patterns. However it can be assumed that it is one important barrier, which will also continue in the future years. On interesting point is that the shortage is also seen in the US as one of the most important barriers (Light 2011).

Activities: Within the DAE the pillar 6 is several actions dedicated to fight computer illiteracy and labour shortage, including increasing the share of women in ICT labour force and consumer education. Additionally to these actions of DG Connect, there is the e-skills program of DG Enterprise, which exists since the mid 2000, addressing the increase of skilled ICT labour force. In recent years some efforts were made to align this program also to the needs of Cloud Computing and related fields like Cybersecurity (Laugesen et al. 2011). Both programs are closely coordinated and address demand as well as supply side.

[20] See http://cordis.europa.eu/fp7/ict/pcp/policy_en.html

5.2.3. Encouragement of entrepreneurial activities,

Public Procurement and the role of the state

Type of factor: barrier

Affected group: supply side

Related area: business

Description: The factor relates to the role of the state as driver for market developments through its purchasing power. Governments and public bodies are responsible for round about 20% of the market volume in IT services and software within the EU member states (Aumasson et al. 2010, 231-240). This resulting power could be used to reinforce technological and economic developments desired. While in the US, where the share of the state is higher especially due to the defence sector, this is used as a measure like for example the existing Cloud first principle, it is often neglected by European governments.

Evidence: few studies focussed now on the topic of the procurement power of the state in Europe like Aumasson et al. (2010, 142-143). The lack of use of it is clearly seen as a barrier, but depended on the type of business its importance varies. Often related points like the technology neutral procurement or procurement for standard setting are more widely discussed.

Assessment: Public procurement is one of the major markets and also if its share will not rise in the next years due to the current economic development, it will still remain a considerable factor. Nevertheless it is not among the leading barriers.

Activities: At the European level the DAE focus on the power of public procurement in particular for the implementation of standards and interoperability, which is reflected in pillar 2 "Standards and interoperability" (EC COM (2010) 245). As part of these activities guidelines for procurement were developed by an study commissioned in 2011.[21] Above that the recent communication on Cloud Computing names as key action 3 the European Cloud Platform, which is aimed at a joint procurement of Cloud Computing solutions in the public Sector (EC COM (2012) 529), which was already announced earlier. Further the Commission also made two proposals aimed at replacing the old public procurement directives from 2004, which are still under negotiation.

5.2.4. Provisioning of infrastructures

Network availability and reliability

Type of factor: barrier, driver (both);

Affected group: supply side, demand side;

Related area: business, legal, technical;

Description: The availability of reliable network connections is a fundamental technological requirement for Cloud Computing (see Section 3.2). Therefore the existence of enough reliable network connections, in particular also mobile connections, is one driving factor for the development of Cloud Computing, because it enables mobile use as one of main advantages of it. On the other hand the lack of such connections will be an impeding factor, because the transfer of data and the use of applications would be so retarded that it would discourage users. However, there is also the challenge that the growing

[21] See http://cordis.europa.eu/fp7/ict/ssai/study-action23_en.html.

adoption of Cloud services will lead to a growth of network traffic, which would require a further extension of cost-intensive bandwidth. Consequently its importance as barrier or driver on the European level is stressed in several points:

- Lack of availability/bandwidth in specific regions (mostly rural) (Fielder et al. 2012, 76; Cattaneo 2012a, 19);
- Increase of connectivity as incentive (f.e. Schubert et al. 2012, 5);
- growth of data can impact availability/reliability negatively (Couturier 2011, Hofman/Woods 2010).

Evidence: The study of Cattaneo et al. (2012c, 32-38) list slow internet connection as one, but only minor relevant barrier for the uptake based on survey of more then 1000 companies across Europe. However due to its fundamental character its importance on the official level is still seen as high as outlined by Fielder et al. (2012, 76) based on interviews with European officials. Finally the future importance is underlined by Cisco's forecast of Cloud based IP traffic, which states that in the next five years the traffic will increase six-fold (Cisco 2012). Although this forecast might be driven by the needs of Cisco, there is still some truth in it that needs to be reflected.

Assessment: Network availability and reliability is an important factor, but due to the progress made in the last years to increase available network capacities by introduction and funding of new technologies like LTE (mobile) or FTTH (flat wired) it has lost of importance. Nevertheless it still needs to be reflected regularly due to its interrelation to the growth of traffic in case of successful adoption of Cloud.

Activities: As already indicated there were several activities undertaken as part of the DAE action plan. Within this eight actions summarized as pillar 4 "Fast and ultra-fast internet connections" several initiatives like a communication on broadband, new financing schemes (Connecting Europe Facility) are introduced, old schemes like structural funds adjusted or the implementation of radio spectrum policy are completed or on track. However in 2012 the EC stated the slowest growth in broadband availability in the last years.[22]

Mobility

Type of factor: driver

Affected group: supply and demand side

Related area: business, cultural, technological

Description: The increased number and types of devices, in particular mobile ones, require a higher flexibility of the IT infrastructure due to its requirements on collaboration, synchronisation and similar. This important to both, business and public services for which it is crucial to ensure their integrity of IT operations, as well as for consumers, which want to use their medias, photos and other contents on different devices at home and on the road. Moreover with trends like BYOD the requirements will also rise. Consequently solutions supporting this are among the fastest growing services in Cloud.

Evidence: Mobility is named as the top benefit (beyond cost savings) by companies according to Cattaneo et al (2012c), where most of the current user also realized benefits until now (Cattaneo et al. 2012c, 23-24). Other study like Fielder et al. (2012, 32) also name it as one driver for the further development of Cloud Computing. This is

[22] See http://ec.europa.eu/digital-agenda/en/pillar-4-fast-and-ultra-fast-internet-access.

underlined by the fact that nearly all market researchers forecast a growth in numbers of sold mobile devices.

Assessment: As shown by the studies it is one of the most important drivers for Cloud Computing. Especially in connection with other drivers like productivity gains, which are partly based on the use of such devices. Due to the growing diffusion of mobile devices and the fact that the types of devices will also further increase it seems likely that mobility stays an important driver for Cloud Computing, especially since the consumer directed app environment heavenly rely on Cloud solutions.

Activities: On the EU level different actions are undertaken to support mobility directly or indirectly. One major action is the radio spectrum policy as part of Pillar 4 of the DAE. Other actions are the control of roaming fees for users of mobile devices.

5.2.5. Improvement of regulatory environment

Lack of interoperability/standards

Type of factor: barrier.

Affected group: supply side, demand side.

Related area: business, technical.

Description: The lack of interoperability refers to the problem describes the possibility that customers either can not integrate their data or applications between different suppliers or that they can not or only under the take of loss (of data/financial resources) migrate their data and applications from one to another supplier due to technical incompatibilities. Therefore it is also closely related to the provider lock-in. As reasons for it two main points are named (Fielder et al. 2012, 74; Cattaneo et al 2012a, 19, 37-38):

- the lack of standards for data hindering transfer;
- the use of proprietary Application programming Interfaces.

Evidence: Fielder et al. (2012) base their judgement on a set of interviews with organisations and companies. Cattaneo et al. (2012 c, 33-40) name it as one part of data availability and portability as one of the top 5 barriers for the adoption of Cloud Computing in a survey of more then 1000 companies in Europe.

Assessment: As outlined by Cattaneo et al. (2012a, 37-38) the problem is less considered as barrier for the initial adoption of Cloud services, but in the long term it could turn into a barrier for a competitive market and therefore reduces or even reverse the benefits for customers in using Cloud Computing. Above that it will may also hinder other , new suppliers to enter the Cloud market successfully. Therefore it is already an existing barrier, but its importance will grow in future if there are no actions to ensure it.

Activities: In the new communication on Cloud (EC COM (2012) 529) the EC names the as the first key action "Cutting through the jungle of standards". Among the several points related to that action one is also to task the existing Cloud group of ETSI to start a stakeholder dialogue to identify required standards including activities related to interoperability, data portability and reversibility. Above that the topic of standards and operability in ICT is the second action pillar of the DAE that names in total seven overall actions to improve the use of standards and interoperability schemes. This includes for example legislation efforts, public procurement, licensing schemes and the

implementation of the European Interoperability Framework. According to the EC own information most actions like the legislation or the adoption and implementation of the EIIF are completed or on track. Only the guidance for public procurement and ICT standardisation is delayed.[23]

Legal jurisdiction and consumer rights

Type of factor: barrier

Affected group: supply side, demand side (or both);

Related area: business and legal

Description: this factor relates to question of the details which jurisdiction is relevant if the provider is based in another country. Currently many smaller and medium sized enterprise, but also consumers are afraid that in such a case they need to go to foreign authorities to set up a complaint or case in case of troubles with a service provider. due to the fact that consumers and SME feel strong uncertainties about their own capabilities as well as the possibilities to claim and obtain justice. this relates for consumer rights as well as for data protection.

Evidence: Cattaneo et al (2012c, 33-41) name this as the top barrier out of their survey of more then 1000 companies in Europe. Also other studies like the survey of Colt (2011, 11) and others (Bradshaw 2011) mention this point.

Assessment: the high ranking of this factor in one survey as well as the existence of it in other studies underline the importance of it as one of the major barriers. moreover it concerns also other points like data protection as well as it is closely related to market fragmentation. Altogether they are an important building block for removing barriers.

Activities: at the European level the underlying challenges and problems are addressed in several ways. One way is the new directive on consumer rights (DIRECTIVE 2011/83/EU), the newly proposed Common European Sales Law (EC COM (2011) 635) and the communication on the coherent framework building trust in eCommerce (EC COM (2011) 942). Since most of the related activities are still ongoing it is not fully clear what the outcome will be. Another example for that is the proposed data protection directive, where the problem of jurisdiction is also one point of arguing.

Terms of contract/service level agreements

Type of factor: barrier

Affected group: both, supply and demand side

Related area: business and legal

Description: this factor relates to the problems of customers to deal with offers of Cloud suppliers. in detail it subsumes several challenges including:

- Lack of transparency of terms of contracts, i.e. unclear formulations in the terms and conditions of many suppliers;
- Lack of clear service level agreements that guarantee specific levels of service and regulate liability and similar points.

Overall it is driven by the feeling that specific terms of contracts and some SLA are misleading and even disadvantageous for customers.

Evidence: Several studies either of existing terms of contracts (Bradshaw 2011, Couturier et al. 2011) or interview based findings (Fielder et al. 2011, 67-71) suggest that these

[23] See http://ec.europa.eu/digital-agenda/en/pillar-2-interoperability-and-standards.

concerns might be true. Especially the lack of standardized SLA and clar contracts is realized as a reason for reluctance. It should be also considered that in particular for start-ups the lack of orientation and the resulting uncertainties can be major factor hindering market entry or further growth.

Assessment: although not all researcher cover this specific topic, it seems to be important especially for small and medium sized companies that are not able to negotiate individual contracts due to their and their capabilities. Moreover it will gain of importance as soon as more practical experiences exist and first experiences may show the difficulty situation that prevails in existing contracts.

Activities: in the recent communication on Cloud Computing (EC COM (2012) 529) this point is highlighted as one of three key areas. Therefore key action 2 of the communication lines out that in the following years experts from industry, civil society organisation and similar should work n recommendations for SLA as well as on best practices for term of contracts. Moreover it is planned to coordinate this work on an international level to ensure that these results will be applied also outside the EU.

Data protection and privacy

Type of factor: barrier

Affected group: demand side

Related area: legal and technological;

Description: this factor relates to question how Cloud providers handle personal information received by customers, in particular if they are using it for different purposes or allow third parties access to it. Underlying are two different points. firstly, in the case of freemium services often terms of conditions foresee the possibility that providers can use data to personalize offers or similar things, and secondly there is the aspect if these and other data are disclosed to third parties. Therefore this factor is closely related to the question of data security as well as to data location and retention.

Evidence: Cattaneo et al (2012a, 45, 2012c, 28) show that privacy and data protection are among the priorities of consumers in Europe for the adoption of Cloud Computing. The importance for business is underlined by the results on data security and integrity as well as data location presented by Cattaneo et al. (2012c, 32-44) and Colt (2011, 7).

Assessment: Data protection and privacy and the related topics of security and location form one important barrier for the adoption of Cloud Computing. Also some aspects treated here are more specific for consumers; the topic also has some relevance for business. moreover the clarification of these issues would also offer more clarity for the supply side. The current situation could prevent that providers enter the market due to the risks related to it.

Activities: Recently the commission proposed a new directive on data protection (EC COM (2012) 09) dealing with many of these points, in particular definition and use of personal data, data location and similar. Due to the ongoing and partly controversial discussions of the proposal, it is not possible to conclude on final solutions especially regarding the issues described here.

Data security and integrity

Type of factor: barrier

Affected group: demand side

Related area: business, legal, and technological;

Description: this factor refers to the question if the data stored in a Cloud is sufficiently protected by the Cloud provider. It contains several aspects including the question of security in terms of the general level of security measures of the Cloud supplier, security issues related to the remote access, in particular with mobile devices as well as the integrity and confidentiality measures of the provider ensuring access restrictions and related issues. Also this is mostly seen as a barrier, some experts argue opposite. they claim that Cloud solutions are more secure then the in-house solutions especially of small and medium sized enterprises.

Evidence: Cattaneo et al. (2012c, 32-444) list as number two barrier for the adoption of Cloud Computing in Europe. The Colt CIO survey even list it as the top concern of the interviewed persons. beside this general evidence there are many studies dealing with detailed problems like the mobile access (Asokan 2011) or state its relevance based on expert interviews (for example Fielder et al. 2012). Additionally other legal analysis (Robinson et al. 2010; Bigo et al. 2012) stress the importance, but also the challenges related to it.

Assessment: together with data location and protection, security and integrity is the main barrier for the adoption of Cloud Computing in Europe and will remain an important factor also in the coming years. Reasons are the need of further legal clarification as well as the need for more technological solutions, which will take time to achieve.

Activities: Regarding the legal aspects the proposed directive on data protection EC COM (2012) 09) is a first step to ensure legal certainty for users as well as providers. Nevertheless the detailed regulations are still a matter of discussions. The technical solutions are primarily a task for user and provider, but the Commission also address this topic broadly in the current ICT research programs of the 7th framework program and it seems clear that this will be continued in Horizon2020.

Data location and data retention

Type of factor: barrier

Affected group: demand side

Related area: business, legal

Description: This factor refers to the problem users to know exactly where their data is stored and which other parties, most likely governmental institutions in the country where the data is stored, may have access to it. In principle it subsumes two points. the first one is the question of data location, which contradicts partly the original intention of Cloud Computing of location independence. Nevertheless the regulatory framework in many countries require that companies in specific areas like person related data are able to ensure the whereabouts of it in a specific jurisdiction (localisation requirements) (Berry/Reisman 2012, 18-20). A further point is the question if and how governmental institutions in third countries can legally gain access to user data. Most often the debate refers to the Patriot Act and other laws in the US like the Foreign Intelligence Surveillance Amendment Act (FISAA), which can enable US governmental service to access such data without information to the data owner. This argument was recently highlighted by a study for the EP (Bigo et al. 2012), but there are also many discussions if and to what extent it is really true or possible to do so

(Gross 2012). One fact driving this debate is that in earlier cases like the 2006 SWIFT scandal it was proven that US authorities did so.

Evidence: Beside the actual public debate the significance of this issue is showed by the study of Cattaneo et al. (2012c, 32-44) state that this point is at the moment among the top barriers for European companies, in particular for SME and public agencies. Also the survey of Colt (2011, 11-12) shows that compliance and geographical location play an important role. other mentions these based either on review of existing practices or interviews (see for example Buchmann 2012, Lynn 29012, Fielder et al. 2012, 60). It is also highlighted by other legal analyses as one of the major challenges from a legal point of view (Robinson et. al 2010)

Assessment: Given both, the public attention as well as the survey results, it is clear that this point is of high significance for the adoption; especially most of the leading suppliers are of US origin. However many of the US providers started to establish specific European services (based in European data centres) to counter this challenge, but many users seem not fully to trust. Regarding the future importance Cattaneo et al. (2012c, 43) underline that it will remain important in the next years, but not as much as other topics. Remarkable might be that European Cloud suppliers sometimes advertise their European offers as a safe haven, but it should be remarked that also in Europe national authorities are allowed to gain access under specific circumstances.

Activities: On the European level no direct actions on data location are ongoing, although the question of data location is one of the most prominent points in the current debates (see for example Bigo et al 2011). However several member states foresee that critical data or data containing personal information require a localization, but there exist several exceptions from this rule. Regarding data retention the debate is strongly focussed on the rules applied in the US and the consequences for European consumers and businesses, but there is also an ongoing discussion on data retention in the EU related to update of the respective directive (Directive 2006/24/EC). Another point are the different regulation that are part of the proposed new directive on data protection (EC COM (2012) 09), which is controversially discussed and still under negotiation.

Data availability and reliability of data access

Type of factor: barrier.

Affected group: demand side.

Related area: legal, technical.

Description: This barrier refers to the fact that customers can be affected if they can not or only badly access their data and applications. This includes temporarily disconnection to the service, permanent loss of services or the termination of the supplier. Reasons for that can be multi folded. Examples:

- outage of a suppliers data centre for technical or other reasons (disaster);
- technical problems in the data centre leading to data loss;
- bankruptcy or acquisition of the supplier.

Evidence: The problem of data availability and reliability is included by Cattaneo et al. (2012c, 33-40) among the topic of Data portability and availability including other aspects. It is ranked as the fifth highest barrier. Additionally it is also named in other studies as one possible barrier like for example Fielder et al. (2012, 48; based on a

review of outages), Bohnert (2012) or Cachin/Schunter (2011), but with no further empirical evidence.

Assessment: The study of Cattaneo et al. (2012c, 33-40) pinpoints the importance of availability, but it may be that the other components like vendor lock-in are considered to be more relevant as this one. Therefore availability and reliability and in particular regulations on compensation and the continuation in case of termination are issues, but not among the top priorities.

Activities: The problem is not addresses by a single action due to fact that technical issues like the operation of data centre are central parts of the daily operations of suppliers. However what can be addressed are the questions of service quality/liability, compensations and transition, which is part on the key action 2 "Safe contract terms and conditions" announced in the new Communication on Cloud Computing (EC Com (2012) 529).

5.2.6. Fostering the creation of markets

Market fragmentation

Type of factor: barrier;

Affected group: both, demand and supply side

Related area: business, legal, cultural

Description: Market fragmentation refers to the challenges of cross-border operations between the different member states. One challenge is that the term refers to many single points and different areas. Moreover the understanding what it all comprises changed over time. Here we understand it in its broadest form, though this bear some overlaps with other points like consumer rights, jurisdiction or similar things. Examples for challenges in cross-order activities are:

- cross-border payments;
- VAT regulations in case of cross-border transactions;
- cross-border application of consumer rights and similar laws;
- IPR in case of cross-border activities.

This list is not exhaustive and could be easily amended with other points related to cross-border activities. Although it is often listed as a particular barrier for the supply side, it also affects the demand side by hindering a stronger inner-European competition of providers.

Evidence: many earlier studies refer to the importance of mitigating or removing these obstacles for cross-border activities in the EU. One example is the study of Aummasson et al. (2010, 224-227) that names market fragmentation and related problems as one priority for increasing the competitiveness of the European software and IT services industry.

Assessment: due to its character as a barrier for both sides market fragmentation will remain as one important factor hindering the development in Cloud Computing, but also in many other areas. Above that is subsumes a broad set of challenges. Consequently some of them have a high significance for Cloud Computing, but are not specific for it. However, given the fact that the priority varies between demand and supply side as well as the fact that many parts are also closely related to other factors

it is hard to make an overall judgement, but finally the single digital market will remain one important priority to increase the competitiveness of Europe.

Activities: within the DAE (EC COM (2011) 245) the digital single market is set up as pillar one including 21 actions covering a broad spectrum from VAT rules, consumer rights, IPR to roaming solutions. Due to its priority it also led to many actives including the new directive on consumer rights (DIRECTIVE 2011/83/EU), the newly proposed Common European Sales Law (EC COM (2011) 635) and the communication on the coherent framework building trust in eCommerce (EC COM (2011) 942), review s on existing rules on payments and actions on the use of open data/public sector information. While some of them are completed, many are also ongoing.

Vendor lock-in

Type of factor: barrier;

Affected group: demand side, but also affects supply-side;

Related area: business, legal, cultural, technological;

Description: Vendor lock-in describes the problem of companies to move their data from one Cloud provider to another or back into their own IT. Underlying is the fear to be bound to one service provider, which can impact the financial negotiations as well as the flexibility and competitiveness of the user company. It is closely related to a set of other barriers, in particular interoperability/standards as well as contractual issues. These are the most named underlying practical concerns named within this topic. Above that a cultural dimension of being reluctant against dependencies plays a role, which can be often found in smaller companies.

Evidence: Cattaneo et al. (2012 c, 33-40), who summarise most of the factors under the label of data availability and portability, see it as one of the top 5 barriers for the adoption of Cloud Computing in a survey of more then 1000 companies in Europe. The study of Cot (2011) shows that the topic in their regular survey of 500 CIO is a rising topic that now concerns nearly half of all respondents. Other studies (f. e. Hofmann/Woods 2010) also name this particular problem.

Assessment: Due to the fact that vendor lock-in is a topic compromising other highly relevant topics like contractual issues or interoperability it is highly important, but it could be treated as separate topics. However the cultural aspect, which is not well researched yet, still remains. It is connected to the lack of trust, but it might be that its full spectrum goes beyond the the trustworthiness of the supplier, which needs to be reflected.

Activities: The lack of interoperability/standards and contractual issues as well as the lack of trust are already addressed on the European level as described in the different sections. Other activities are not known.

5.2.7. Supporting the creation of legitimation

Lack of trust

Type of factor: barrier

Affected group: supply side, demand side (or both);

Related area: business and cultural

Description: This factor refers to a general lack of trust towards Cloud Computing by customers, either in business or as consumers. It is shaped by two main factors: Firstly there is a general uncertainty towards Cloud Computing based on a lack of knowledge and/or general distrust in the underlying basic concepts and the related loose of control; and secondly, uncertainty against individual suppliers and their offers, which seem unclear. Especially the latter point is strongly related with the factors of contractual issues, transparency or vendor lock-in. The former one relates strongly to the points of data security, location and protection.

Evidence: As shown by the study of Cattaneo et al. (2012b, 12,41,55; 2012c, 33-40) and the CIO survey of Colt (2011, 22-23) there are different aspects of the general lack of trust, either based on a lack of knowledge on Cloud Computing and its risks and benefits or a lack of trust in the concept and or its reliability. both are general indicators for further uncertainties on Cloud Computing. The distrust into offers of individual providers is clearly shown by the fear against vendor lock-in and reliability or concerns about contractual issues and other factors like data location.

Assessment: The lack of general trust has a high relevance, because though it is often only an unclear sentiment based on blurry information, it impacts hardly the general perception of all other challenges and barriers in Cloud Computing. Its future importance will rely on a set of factors including the question if there will be major incidents around Cloud Computing in the next years or not.

Activities: the general lack of trust can not be addressed with single measures. As outlined it refers to a set of factors influencing it. Therefore many actions like the key actions of the recent communication (EC COM (2012) 549) addressing problems like the jungle of standards or the different terms of contracts as well as the example of the state as forerunner in Cloud applications can contribute to create and increase trust. Other initiatives increasing consumer rights or creating trust in eCommerce (EC COM (2011) 942) are also suited to support this effort. Nevertheless some factors can not be addressed by policy measures.

Lack of transparency in business practices

Type of factor: barrier;

Affected group: demand side;

Related area: business and legal

Description: this factor refers to the lack of transparency of Cloud suppliers that is perceived by their customers. This lack is seen in three major areas:

- transparency regarding the total costs, i.e. customers fell that they are poorly informed on the overall costs for the introduction and usage of Cloud services;
- transparency regarding the update policy and the ownership of customizations, i.e. the update policy and the consequences for adjustments made by users;
- transparency regarding certifications and audits, i.e. the question what the presence or non-presence of certificates and audits mean for customers.

Evidence: the transparency of costs is underlined by the survey of Colt (2011, 22) stating that it is one, but not one of the most important barriers. Cattaneo et al. (2012a, 60) name the lack of certificates and audits as one barrier based on their in-depth interviews as well as they name ownership and update policy as barriers resulting from their company survey (Cattaneo et al 2012c, 32-40).

Assessment: all studies does not highlight one of these points. Based on that result one can assume that they have some, but not a particular important relevance for the decision on adopting Cloud services. However this may changes if in the course of time incidents occur where the costs of Cloud projects explode or projecs fail because of reliability of providers.

Activities: Currently there are no activities on the European level, but within the consumer rights as well as within possible models for term of contracts such question as cost declarations or update and customizations will or can play a role. Above that the proposal of a specific certificate was several mentioned in the current discussions (see Cattaneo et al. 2012c, 51; Rossbach/Welz 2011, 22), but until now it is not pursued by the Commission.

Cost savings

Type of factor: driver

Affected group: demand side

Related area: business

Description: Saving of costs for IT operations is the main argument for Cloud Computing used to advertise it especially in business. It is expected that the use of Cloud services are likely to reduce costs due to price advantages compared to traditional in-house IT for companies, in particular small and medium sized ones, while at the same time increasing flexibility of IT operations.

Evidence: According to Cattaneo et al (2012b,c) describe that in their survey of more than 1000 European companies more then 78% of the companies that already used Cloud services realized cost savings, of which 36% said it was above 205 compared to traditional IT (Cattaneo et al. 2012c, 22). The CIO survey of Colt also name cost pressures as one of the three top enablers for Cloud Computing (Colt 2011, 7, 19). Above that other studies argue also with cost savings as the main driver for the usage of Cloud services in companies (f.e. Fielder et al. 2012; Armbrust 2010). However, obvious is that similar questions and considerations for consumers do not exist.

Assessment: Cost savings are the main driver for the business use of Cloud services and therefore it is also the main driver. However, beside some surveys, there are only some few examples, most likely more of anecdotic nature, to really prove this in long term perspective.

Activities: The only possible action on EU level related to this is to ensure a competitive market for Cloud services across Europe, which enables customers to take advantage of the cost benefits.

Flexibility of business

Type of factor: driver

Affected group: demand side

Related area: business

Description: Flexibility of business means that Cloud Computing is expected to support companies to act more flexible to changes of the business environment and thereby also to exploit smaller niches in the market. On the one side this refers to the increased capabilities to use advanced analytics to understand market developments, which is with traditional IT architecture not affordable for many companies, in particular for SME. On the other hand it also refers to the fact that Cloud Computing is seen as an enabler to ease the access to new markets or to speed up the time to market, because the scalability and flexibility of solutions also allows the exploitation of smaller market advantages without high entry costs (Cattaneo et al. 2012c, 23).

Evidence: As shown by Cattaneo et al. (2012c, 22-24) round about 20% of the current Cloud user already realized benefits in terms of new locations and more then 80% are expecting it as one benefit. A study of KPMG based on survey of 900 business executives sees the reduction of time to market among the top 3 impacts, also among European executives (KPMG 2011, 7-8). Additionally a survey of IBM Institute for Business Value and the Economist intelligence Unit of more then500 executives worldwide names new markets/delivery channels as number three motivation to implement Cloud Computing (IBM/EUI 2012, 3). Additionally it is also named in various scientific and popular journal articles, but mainly based on authors' opinion. However, as in other, further empirical material proving the reality is missing.

Assessment: Flexibility is closely related to productivity and innovation. Behind cost savings all three together play a major role for driving Cloud Computing. It can be expected that after the initial cost savings are realized they also become the major driver for the further exploitation of Cloud Computing, which would directly to an increase of their importance.

Activities: Due to the clear business nature of this driver no political activities are likely to address the topic.

Productivity

Type of factor: driver

Affected group: demand side

Related area: business

Description: This category relates to the promise of Cloud Computing to lead to productivity gains in organisations. It comprises therefore several aspects that sometimes are summarized as one or split up into several enablers or drivers. Main areas mentioned are the following ones:

- standardisation of processes, i.e. the use of unified IT services and products contributes to improvements in the process organisation and use of resources
- flexibility of the organisation, i.e. transitions and organisational changes are easier to implement
- increased collaboration i.e. increased collaboration through mobile devices beneath employees as well as possibilities to increase collaborations with partners.

- scalability of IT, i.e. the fact that the IT organisation can be easily adjusted to changing needs without lasting investments, which then can be used for other purposes.

Evidence: Due to the broad scope of it evidences can be found in several studies. The survey of Colt (2011, 6-7) names ease of transition (in IT) of as the leading enabler as well as standardisation of process at number 5. Cattaneo et al. (2012c, 22-24) also name productivity and standardisation as realized and expected benefits of current Cloud users. Above that they also list under the term IT to Capex the fact that savings through a more flexible IT could be used for other purposes as a realized and expected benefit. The surveys of KPMG and IBM/EUI name changes or increased collaboration with partners are expected impacts or benefits of Cloud usage (KPMG 2011, 7-8; IBM/EUI 2012, 3). The benefits of an increased mobility of employees are obvious and often described in relation with mobility as a driver.

Assessment: Innovation is closely related to productivity and flexibility. Behind cost savings all three together play a major role for driving Cloud Computing. It can be expected that after the initial cost savings are realized they also become the major driver for the further exploitation of Cloud Computing, which would directly to an increase of their importance.

Activities: Due to the clear business nature of this driver no political activities are likely to address the topic.

Innovation

Type of factor: driver

Affected group: supply and demand side

Related area: business, technological;

Description: Innovations relates to the fact that Cloud Computing is seen as an key enabler to develop and implement new services or products faster and easier with reduced cost. While suppliers, in particular start-ups, are able to use existing Cloud offers to build up and expand their business without high level of fix costs, the demand side also profits from similar effects, i.e. the scalability and flexibility of Cloud services should enable them to implement new ideas and technologies more easily to provide new services and products for their customers (see for example Cattaneo et al. 2012c, 23, Fielder et al. 2012, 37).

Evidence: In several studies innovations based on Cloud Computing and related benefits or impacts are named as major driver, especially as a long-term result. Nevertheless, the study of Cattaneo et al (2012c, 22-23) shows that already now 20% of the current Cloud user have seen benefits in terms of new businesses (services or products). On the supply side new companies like Dropbox, which are based on other Cloud services, are clear examples. Other aspects as a shortening of the time to market (KPMG 2011, 7-8) or the creation of new delivery channels/markets (IBM/EUI 2012, 3) are also partly covering tese aspects. Additionally it is also named in many other studies, either based on experts interviews or authors' opinion (see for example Fielder et al. 2012, 37).

Assessment: Innovation is closely related to productivity and flexibility. Behind cost savings all three together play a major role for driving Cloud Computing. It can be expected that after the initial cost savings are realized they also become the major

driver for the further exploitation of Cloud Computing, which would directly to an increase of their importance.

Activities: Due to the clear business nature of this driver no political activities are likely to address the topic.

5.2.8. Improving financial capital situation

Lack of financial capital

Type of factor: barrier

Affected group: supply side

Related area: business

Description: this factor refers to the problems of financing the founding and growth of companies. In most cases it refers to at least two points: Firstly the restrictions to receive external financing from banks or other sources, and secondly to the lack of venture capital. In particular the low level of venture capital in comparison to the US is one of the most often named reasons in the public discussion for the lagging behind of the European IT and software industry. While in the past the discussion was mainly focused on start-ups and early stage companies, research in the last years paid in particular attention to fast growing companies and there needs to finance growth (for example Cincera/Veugelers 2010). Consequently the scope was broadened ranging now from the financing of founding to growth.

Evidence: Several studies underline the importance of financial capital, in particular venture capital for software and IT companies. Most recently Veugelers et al. (2012, 25-35) showed empirical evidences for the impact of the lack of particular venture capital on the performance in the ICT sector in Europe.

Assessment: The relevance of this topic is highlighted by nearly all existing studies (see for example Veugelers et al. 2012, Aummasson et al. 2010), but it must be noted that this problem is not a particularity for the European Cloud or software and IT services industry, because nearly all high tech industries in Europe suffer from it. Based on that we can conclude that it is of high relevance for Cloud, but it is not particular specific for it.

Activities: Given the fact that the problem is well know since more then a decade the EU already undertook several efforts to boost the European market for venture capital. Recently the Commission addressed the problem in three communications (Small Business Act (EC COM (2008) 349), Innovation Union (EC COM (2010) 546, Single Market(EC COM (2010) 648) announcing activities towards a single European venture capital market, increase the access to finance for innovators or the continuation of the risk-sharing financial facilities. Parts like the RSFF are already implemented or on their way as the proposal for new regulatory regime for venture capital shows, but mostly only in early stages.

5.3. Conclusions: initial analysis of factors and outlook

The initial analysis with a focus on the situation Europe as described above shows some interesting insights regarding the identified drivers and barriers.

Overall results

First of all it is obvious that in the existing studies the number of barriers outnumber the number of drivers. One reason might be that many existing studies in Europe based on the assumption that Europe lags behind focus more on the barriers and risks and less on driver or benefits. As expected there is also a strong focus on the demand or user side, in particular on business use. This latter point seems remarkable given the growing impact of private or use on business use, which is seen as one of the major trends in the coming years. Consequently the number of factors related to the supply side s lower. Due to the high number of barriers and especially due to different naming and differentiations within the different reports we tried to consolidate it for the purposes of this report, i.e. we aggregated some of the barriers and let out some of the very specific ones that only have significance for a low number of users. Another differentiating characteristic is that for most of the barriers related to the demand side more research is done. In contrast the barriers for the supply side are less specific and deal more with general problems of high technology in Europe. Consequently further research would be required to understand their specific impact on Cloud suppliers and to derive eventually specific measures to address these problems.

Another point is that there is set of factors that are ambiguous, either because they are driver or barriers for demand as well as for the supply side or they appear as drivers or barriers dependent on the different viewpoints. One example for the latter point is as indicated the question of security. While many people are afraid of security breaches caused through the storage of their data in premises of Cloud providers, other argues that Cloud providers normally are more serious and professional about security then many companies, in particular small and medium sized companies. An example for the former point is interoperability/standards and the related vendor lock-in. At a first glance it is often seen as a barrier for the adoption by customers, because it would reduce their operational flexibility and lead into dependencies from one supplier. But at a second look, the point also reveals its importance for the supply side, because on the long term such a situation would hinder effective competitiveness and would discriminate especially new firms entering the market. Both example show that the factors and actors are closely interrelated and that in many cases more viewpoints and possible

As for the positioning of factors along the different introduced process goals, it is striking that they cluster around market creation/formation and entrepreneurial activities and their interrelated processes like creation of legitimating or provisioning of resources (human/financial capital for example) as well as clearly refer to the regulatory framework like questions of consumer rights. This suggests that Cloud Computing already left the early stage of emergence. Nevertheless there are also some remarkable, overarching factors with clear relation to earlier stages like interoperability, which is closely connected with knowledge creation and diffusion. It could for example indicate that European companies lack of access to knowledge, although it might be available in Europe due to research done here. Overall this distribution and particular the concentration around these two focal points underline that measures need to be implemented now to ensure a quick response to current challenges.

Analysis of drivers

Overall the analysis of drivers showed that drivers receive less attention as barriers. It is also not surprising that the few studies dealing with it focus strongly on drivers significant for the adoption in business. There are only few studies also dealing with more general aspects like infrastructure or technology, most often labelled as enablers. As a consequence drivers specific for consumers are mostly neglected, which is remarkable in that respect that some studies name consumerization of IT as one driver for business, but neglect the question why this persons use their mobile devices, presumably firstly bought for private use, also for work. In case of the barriers this is not the case due to the fact that many highlighted concerns of business are also highly relevant for consumers like data protection or security.

In principle most of the studies identify cost savings and resulting effects like increased competitiveness as the major driver for the adoption of Cloud Computing. Although this argument is true, it should be noticed that the time horizon of this driver is only short- and mid-term. The reason is that with a growing overall adoption of Cloud Computing in business the cost and all resulting other advantages will decrease. Consequently one can expect that other factors like innovation or flexibility will gain of importance in the future, because in long-term they offer more potential to differentiate in competition for example by niche strategies or new innovation cycles.

Finally it should be also noticed that most of these advantages are subject of decisions on company level. As a consequence it is complicated or impossible to induce incentives to do so. Only more general drivers like for example infrastructure or research can be influenced in different ways. Finally this may be another reason for the low attention on drivers.

Analysis of barriers

As expected the analysis of barriers shows a strong focus on barriers that are in particular related to the business use of Cloud Computing. Nevertheless many of these concerns like data protection and security are also relevant for consumers, but the question if there are consumer-specific barriers remains mostly unresolved.

Not surprisingly it is the fact that the analysis points out that one focal area are all barriers related to data security, data location, trust and privacy. In nearly all studies there among the most important ones and it is obvious that they have a high significance for business as well as for consumers. The detailed view of it also underlines that these barriers located in the regulatory framework and the creation of legitimation are strongly intertwined. Moreover they directly influence the market creation and formation, which is reflected in the lower adoption of Cloud services in Europe and consequently the lagging behind in terms of market growth as shown in sections 4.1 and 4.3. The interrelation and its impact is less astonishingly because they all can be seen as a result of one basic principle of Cloud Computing: the loss of the physical control over IT and data and its consequences. Therefore trust and legitimation will play an important role for the further uptake of Cloud Compunting for business as well as for consumers. This also underlines the need for an

increased knowledge diffusion in case of Cloud or other emerging technologies, which should not only be focussed on the knowledge diffusion between research and industry in terms knowledge transfer, but also knowledge diffusion between research and user (business as well as consumers) require also knowledge diffusion on the demand side, but not focussed on technological questions.

Related to this another cluster of barriers arises around the legal and regulatory framework, particular questions concerning the jurisdiction, consumer rights and contractual issues (terms of contracts/SLA). All points are applicable to both, business as well as consumers, but the importance may differ. While the former point of jurisdiction is especially important for consumers and small and medium sized enterprises, which are prefer access to jurisdiction in their own country, the latter one is more important for companies. In particular the topic of SLA and liability is for many companies, especially small and medium sized ones, of great importance. They reason is that in opposite to others they need to rely on the use of standard contracts and SLA and are not able to negotiate customized contracts and SLA.

The contractual issues also refer to another cluster with a particular high significance for business, i.e. the question of vendor lock-in and related technical and legal issues like interoperability and standards. The reason for its significance is quite obvious given the the problems that can arise from it like a lack of flexibility due to problems with data portability and integration or dependency on single vendors. They directly lever out the related benefits for users or in the worst case flip them into the opposite. Not surprisingly fears regarding this lower the probability of adoption.

While this sketches a quite clear picture for barriers on the demand side, the distribution and significance for barriers on the supply side does not seem to be so clear. Some points like vendor lock-in as well as standards and interoperability are clearly also of importance for Cloud providers. Also contractual issues or questions like data protection might be of indirect importance, in particular for start-ups and smaller and medium sized enterprises, because it would provide clarity necessary to enter the market.

Whereas these points also show a certain degree of specific relation to Cloud Computing, the other points are generally broader and affect not only Cloud service provider. Although it is obvious that most of them direct affect the entrepreneurial activities, they do not cluster as much as they do in case of the demand side barriers, i.e. they are not as closely related as in the case of data protection and the regulatory framework for example. However some of them bear individual points that at least are of a certain significance and particularity for Cloud. One example is the market fragmentation, where points like the VAT regulations or the eCommerce directive have a specific relevance not only, but also for Cloud service provisioning. Another example is the lack of R&D spending, which is also exist in other industries, but which is very distinctive in the European internet industry Other factors like lack of financial capital or the importance of the different types of public procurement refer to general challenges, which are also of relevance for ICT in general as well as for other high tech industries. this poses two questions that can not be answered in

this stage of the project. Firstly the question if there are specific characteristics within for Cloud suppliers, and secondly to which extent these problems really affect them at all.

Finally this underlines again the need for further research in both cases, demand as well as supply side. Moreover it also shows the need to challenge some of the arguments. Either because they show some ambiguity like the case of security or they quite unspecific and part of the recurring complaints of different kinds of associations.

Ongoing activities

As shown by the descriptions there are already many initiatives ongoing at the European level addressing the different factors, in particular barriers. Since most of them were only launched in the last two years or are still ongoing, it is hard to make any further conclusion. Consequently it needs an in depth review of the activities as well as of the barriers as foreseen in the coming phase to allow further judgments regarding the question if they address the underlying problems in a sufficient way as well as there progress is promising or not.

Outlook

Based on this initial analysis and assessment, the coming phase will analyse the economic and social impacts of Cloud Computing, i.e. research selected benefits and risks in detail. In a first step a final validation of factors, which will take place in coordination with STOA, will be performed in order to shape the focus of the future research. Afterwards we will analyse the impacts in two in interrelated strands. A first one will deal with the direct impacts of Cloud Computing on the software and IT industry as well as with its impacts on business, public services/governments and consumers. Based on this work, indirect impacts on the society and economy as a whole will be determined as far as possible. In the second part selected factors like security, privacy, intellectual property rights and other legal issues that influence the impact of Cloud Computing will be analysed in detail. Based on that in-depth understanding we will develop options addressing the different factors. Finally the results of both strands will be intertwined in one concluding report.

Finally we will also start the work on the topics of Social Networks, which itself is separated into two strands: Social network Sites, addressing mostly consumer oriented social networks as for example Facebook or Google+, and secondly Enterprise Social Media services addressing services offered for example by Yammer. Although we treat these topics due to their specific context separately, each of these topics will be oriented towards the main research questions of the project and will be also linked to the work done on Cloud Computing. Only if necessary, adaptations will be made. Consequently both will deliver an overview on the state-of-the-art in these fields. Afterwards major factors influencing the development will be identified, analysed and assessed. Above that impacts on economy and society will be analysed and finally different options will be discussed.

APPENDIX: PROFILES OF SELECTED CLOUD COMPUTING SUPPLIERS

Amazon

Company profile: Known as an e-commerce company, Amazon is also market leader in cloud computing und was one of the first enterprises, which brought IT-infrastructure to the market in the early 2000s and is therefore seen as one of the pioneers of Cloud Computing. In the beginning Amazon most likely offered unused capacities of their own server infrastructure, but now Amazon Web Services has become an own business within the company. Amazon focuses strongly on service offers in the IaaS and PaaS segment.

Service offers: Under the umbrella of Amazon Web Services (AWS) the company offers a broad set of different Cloud services (over 25 at the moment), mainly in the areas of IaaS and PaaS. It includes for example:

Amazon Elastic Compute Cloud (Amazon EC2): offers scalable computing capacities;

Amazon DynamoDB: provides a scalable NoSQL online database service;

Amazon Relational Database Service (RDS): offers a scalable database server based on MySQL or Oracle;

Amazon Simple Storage Service (Amazon S3): offers scalable storage accessible by web servics;

Amazon CloudFront: a Content Delivery Network for improving the delivery quality of content for customers;

Data centre location: The European data centre is located in Dublin/Ireland.

Financial information: Due to the fact that Amazon does not show the revenue of AWS as distinct category in their revenue statistics, only some estimation exists about the annual volume. Based on the assumption that the category "Others" is mainly driven by AWS it is guessed that Amazon made approximately 1,5 bn. $ revenue in 2012 from AWS. Further information about profits are not available, but some doubt that Amazon makes profits at the moment at all due to the ongoing price competition.[24]

Google

Company Profile: Google is the leading search engine provider and one of the most well-known internet companies. As a part of its strategy Google also offers Cloud Computing products ranging from customer offers to specific company offers.

Service offers: As already hinted Google offers a broad variety of Cloud based services as a consequence of their tests in the last years. however, since 2011 it started to consolidate its offers. Now one can distinguish between two cntral pillars: 1. Customers

[24] See http://gigaom.com/cloud/how-big-is-amazon-web-services-bigger-than-a-billion/.

offers; and 2. Business offers. Both offer in core the same services like storage, mail or calendar, but with different quality and revenue models. Customer offers are:
Google Sky Drive: offers scalable storage;
Google G-Mail: offers webmail resources;
Google Docs: offers collaboration services;
Google Calendar: offers online scheduling resources.
Most of these services directed at customers are offered as a kind of freemium services, while other in recent where integrated into other Google services like Google+.
In 2012 Google reordered its business offers under the umbrella of the *Google Cloud platform*. It offers a variety of services including:
Google App Engine: offer resource to develop own apps;
Google Compute Engine: offers scalable computing capacity;
Google Cloud Storage: offers scalable storage resources;
Google BigQuery: offers solutions for Big Data analysis;
Google CloudSQL: offers storage based on SQL data bases (in opposite to Cloud Storage)
Other services include prediction tools and others.

Data centre location: The European data centres are located in Dublin/Ireland, Saint Ghislain/Belgium and Hamina/Finland.

Financial information: There are some difficulties to estimate Googles revnue from Cloud services. The first point is that all customer offers are based on freemium models, where it is hard to guess the value create through advertisement. The other point is that Google like other companies does not distinctive Cloud revenues in their reports. However, Gartner estimated the revenues for the old app engine as central part of the new Cloud Platform on round about 200 Mio. $ in 2011.[25]

IBM

Company profile: IBM is one of the leading IT-enterprises and one of the worldwide largest IT service providers, but offers also hardware solutions in particular in the high class server and mainframe segment. In the last decade it also expand more and more in the software segment, mostly in the business to business software segment, either by own developments or acquisitions.

Service offers: As a full scale IT service provider IBM offer the full range of services including Cloud technology, which enable organisations (companie or public services) to construct their own cloud infrastructure as well as public Cloud services in all segments (IaaS, PaaS and SaaS). Above that it also offer consulting services related to both.

[25] See http://www.zdnet.com/blog/btl/google-apps-for-business-0-5-percent-of-googles-revenue-says-gartner/60880.

Private Cloud: IBM offers under the label of IBM Smart Cloud Fondation offers a set of different tools and process suited to enable organisations installing their own Clouds. It includes tools like IBM Smart Cloud Entry or IBM Pure Application System.

Public Cloud: IBM offers based on their own technologies IBM offers under the umbrella of IBM Smart Cloud services a road variety of public Cloud services in all segments: IaaS – Smart Cloud Enterprise; PaaS – Smart Cloud Apllication; SaaS – several specific solutions from Blueworks (Busines Process Management) up to dedicated services for public agencies using certified IBM data centres.

Consulting: IBM offers consulting for Cloud strategies, services related to the implementation and security services.

Data centre location: According to the latest information IBM operates 35 data centres in at least 15 EU Member states, which are also designed to be used for Cloud Computing services.[26]

Financial information: Like all other companies IBM does not reveal concrete data on their revenues with Cloud Computing in the last years. Only information available was that the revenues doubled in the first quarters of 2012 and that the CEO set the ambitious target of 7 bn. $ revenues in 2015.[27]

Microsoft

Company profile: Microsoft is the leading producer of standardized software mass products, in particular for operating systems and office applications. But it also engaged in other areas like games and games devices or mobile platforms. In recent years the dominating position of Microsoft was challenged through many new developments, so that Microsoft started several iniatives to keep up with the developments of the markets.

Service offers: Although Microsoft announced its Windows Azure platform already in 2008 it took until 2010 before first services started for the general public. Even now there only some services but not all available. In general the Azure platform promises a full featured service stack offering different services on all layers (iaaS, PaaS, SaaS). However it focuses mostly on PaaS and SaaS offers. Examples of existing services are:

Microsoft Azure Virtual machine, which allows the usage of computing and storage capacities of Azure;

Microsoft Azure Web sites, which allows the development of websites and applications;

Microsoft Azure SQL Services, which enable the usage of SQL databases for storage and development;

Microsoft Azure office 365, which offers the classical Windows Office family as a Cloud services including storages and other functionalities.

[26] See http://www-03.ibm.com/press/us/en/pressrelease/36441.wss.

[27] See http://www.ciozone.com/index.php/Cloud-Computing/IBM-Cloud-Computing-to-Contribute-$7-Billion-in-Revenue-By-2015.html.

Additionally Microsoft also offers many other services and software,w hich could be sonsidered as Cloud. Examples are the conumer-oriented offers for webmail or storage or all software products like Exchange enabling communication and collaboration services. Finally Microsoft started with its Windows 8 platform also a market for Windows apps.

Data centre location: At the moment Microsoft has two main European data centres operating in Dublin/Ireland and Amsterdam/The Netherlands (backing up each other). both are also sed for the Azure platform. Additionally uses a content delivery network with eignt nodes distributed over Europe to ensure service qulaity for Azure.

Financial information: Like all other major companies Microsoft does not reveal its Cloud/Azure revenues in details. Due to the fact that Microsoft also hides its revenues in the different existing divisions like Office 365 revenues in the normal PC division no market researcher are likely to guess it, in particular since some products like Exchange also could be seen as Cloud software.

Salesforce

Company profile: Salesforce was founded in 1999 by an former Oracle manager and three software developers aiming at the provisioning of software applications via the internet (ASP) and is one of the pioneers in Cloud Computing. After some initial struggles the company started to succeed with its customer relationship management (CRM) solutions from the mid of the 2000s.

Service offers: From the beginning onb Salesforce focussed on CRM solutions, which are offered in different modules. The modules got expanded by a set of acquisitions of smaller companies and their solutions, which were mainly integrated into the existing Salesforce products, though some of them exist independently. Main offers are:

Sales Cloud, which offers a typical CRM solution for administrate customer data;

Service Cloud, which offers customer services solutions, in particular communications solutions for all means from phone to social media;

In recent years Salesforce started to expand its offer towards other areas. This includes the following:

Force.com, which offers a platform for developers of business software applications based on Salesforce Cloud infrastructure;

AppExchange, which offers a market for business applications from third parties certified and tested by Salesforce and its partners,

Data centre location: At the moment Salesforce operates eight data centre in the US and Asia (Singapore), but there is plan to establish one in London in 2013. However all data centre are only co-locations hosted by Equinix.[28]

[28] See http://www.businesscloud9.com/content/dreamforce-salesforcecom-london-data-centre-confirmed-next-year/11968.

Financial information: According to the latest statements Salesforce revenue in 2012 was round about 2,2 Bn. $, of which most, but not all is related to Cloud Computing.[29] Although the revenue grew fast in the last years, Salesforce closed nearly all years with small or bigger losses.[30]

Rackspace

Company profile: Rackspace is one of the market leaders for hosting services. The company offers services like the allocation of servers, storage and the administration of those things. It started in 1996 in San Antonio as an internet service provider and moved gradually into the hosting business in the following decade. Thereby it became one of the leading independent hosting and data centre operators in the US. In 2008 Rackspace started to offer Cloud services based on a technology by Mosso, a subsidiary of Rackspace founded in 2006. Moreover it together with the NASA and others like IBM brought the underlying technologies into the Open Stack project, which develops open Cloud technologies under the heading of the Apache Foundation.

Service offers: based on the Mosso and Open Stack technologies Rackspace nowadays offer a set of public Cloud services focussing mainly on IaaS and PaaS. Examples are:

Cloud Sites, which offers the hosting of different types of web sites and related development and deployment platforms accesible by web services;

Cloud File, which offers online storage as well as a content delivery network that can be used at different levels including easy access through web services based on the acquired Jungle Disk technology;

Cloud Server, which enables access to scalable computing resources based on the Rackspace infrastructure in different modes.

Data centre location: Rackspace operates at the moment one data centre in London/Great Britain, which is also used for hosting Cloud services.

Financial information: Analysts estimate that Rackspace will reach round about 300 Mio. $ revenues in Cloud services in 2012 based on strong growths in the first two quarters. The total revenue for 2012 is estimated uo to 1,2 bn. $ in total.[31]

Dropbox

Company profile: Dropbox was founded in 2007 by an former MIT student. According to the birth legend he wanted to solve its problems of availability and synchronisation of bigger files while travelling. Until 2011 it received roughly a 25 mio. $ from different venture capital companies incuding Sequoia and other well known ones. Additionally it was already spotted as one of the most promising companies by different market

29 See http://www.salesforce.com/company/news-press/press-releases/2012/02/120223.jsp.
30 See http://www.informationweek.com/software/enterprise-applications/salesforcecom-revenues-surge-but-should/240142626.
31 See http://cloudcomputing.sys-con.com/node/2328228.

researchers in 2009 and 2010. Moreover the number of user grew rapidly up to more then 50 million in the beginning of 2012. All this made Dropbox to one of the most emerging Cloud companies. In 2012 it also started to acquire other companies for streaming and photo storage provision, which are expected to contribute to the service offer of Dropbox.

Service offers: In general Dropbox provides a file hosting service that offers scalable cloud storage and by enabling file synchronization it allows online collaboration. it is gbased on server software, which operates on the infrastructure of other Cloud service providers and a client software, which covers all main operating systems for PC and mobile devices as well as an web access and which is easy to handle.

Data centre location: From beginning on Dropbox used Amazon's S3 as main service for its storage. Consequently it does not operate own data centres (at least until now).

Financial information: According to public information Dropbox reached revenues of 240 Mio. $ in 2011, though its main business model is a freemium service where more then 90% of the user only use the freely available services.[32]

[32] See http://www.forbes.com/sites/victoriabarret/2011/10/18/dropbox-the-inside-story-of-techs-hottest-startup/.

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