Cloud Service Broker – Assessing Provider Attributes in a Governmental Cloud

Luís Monteiro, André Vasconcelos

Instituto Superior Técnico, University Of Lisbon, Tagus Park Campus, Oeiras, Portugal
{luis.f.monteiro, andre.vasconcelos}@tecnico.ulisboa.pt

Abstract. Cloud Service Brokerage is one of the newest trends in the Cloud Computing Paradigm. New Cloud Service Providers emerge in the business at a fast rate. Yet, the lack of standards in this area is still problematic. Adding to this, there are also several concerns of data security and privacy, as well as integration with existing systems in enterprises, which are delaying the adoption of "computing as a commodity", which will bring great cost reductions and added flexibility to organizations worldwide, and will also provide new opportunities in mobile computing to their employees. Cloud Service Brokers are now being implemented in organizations to address these issues, providing enhanced security and privacy to the data in the Cloud, and also by creating an extra abstraction layer in the known Cloud architecture, which aids in the integration of legacy systems with the ones in the Cloud. Also, Cloud Service Brokers can be of great help in Cloud adoption strategies by providing an easy way to select which Cloud Provider is the best to meet one's objectives (which can be cost reduction, greater reliability, etc.). This research presents a working Cloud Service Broker prototype, based on open source technologies, applied to a Case Study Scenario for the Portuguese Public Administration. This Prototype is further enhanced by the adoption, testing and analysis of a still under development Cloud Service Provider Ranking Framework, the Service Measurement Index, which aims to ease the process of Provider selection.

Keywords: Cloud Service Brokerage, Cloud Service Providers, Service Measurement Index, SMICloud, Aeolus Project.

1 Introduction

A new era for enterprise computing has finally arrived. Computing as a commodity has now become a reality, thanks to the Cloud Computing paradigm. Enterpris-

es can benefit greatly from this. Just like water, electricity and other services, Computing can be used and only pay for what you use. This new paradigm came to completely revolutionize the way companies and organizations use their Information Technology (IT) Infrastructure in helping their business achieve more profits, becoming more agile, responsive to the environmental changes and accelerating their time to market. But, on the contrary of most of new technology trends, the Cloud Computing paradigm wasn't first adopted by the companies and organizations, but by the consumers. This is due to some fear that companies felt of the Cloud and the possible loss of security and sovereignty of data. Though many of these concerns have been proven wrong, some may persist and, thus, delaying Cloud adoption. Governments are also considering this new paradigm, since it lowers overall costs with IT Departments, and providing greater integration of Services between the different government departments.
This Service Integration can be achieved by focusing on the task of the Cloud Service Broker, which enables the use of multiple Cloud Providers (Public, Private, or others). This is the focus of this work, in which we will implement a Cloud Service Broker in a simulated scenario for the Portuguese Public Administration.

1.1 Motivation

According to the research in [3], like in many other countries, the Portuguese Public Administration Departments have been fairly autonomous in the selection process for their IT infrastructure, software, systems and communication infrastructures. This also applied to their IT teams, which were independent and self-managed by their department. Today, where data integration and sharing is essential between different organisms inside one organization (in this case the Public Administration of Portugal), this decentralization inherited by the previous IT management model made this task very difficult, requiring even more systems to mediate data sharing and system integration, which require more staff to code and maintain those systems. This leads to more public spending on IT resources and personnel. To solve this and other problems, [3] mentions many strategies and changes that have to be made in order to achieve a much more efficient and less costly Government IT. Among those strategies, migration of systems to the Cloud is suggested as a potential for cost reduction and, at the same time, enhancing flexibility and adaptability of IT infrastructure. The adoption of Cloud Computing has a savings prediction around 4€ million Euros in IT expenditure, having a cost of around 2€ to 2.5€ million Euros. It also has benefits in the standardization of IT among the many departments and impact on economic growth.

To apply a Cloud solution in an efficient way and with cost reduction, risk reduction/mitigation and trust in mind, a Cloud Service Broker is a central piece on this architecture, by providing a way to standardize data used by the applications to work with the broker, which then translates that data to the different Cloud Service Providers. This reduces risk of vendor lock-in, as well as providing greater data redundancy, by using many different providers to store data, assuring that data is backed up and available at all times, even if one provider has some kind of failure. The broker is also important in the selection of the best provider for each service request made by an application, and can make that selection based on many criteria, which can vary for each application and/or user group.

1.2 Questions, Research Problem and Hypothesis

The main questions to be answered by this project are as follows:
Q. 1: Which attributes for the selection of Cloud Services are the most relevant in a Governmental Cloud?
With this question we pretend to achieve a standardized group of attributes to evaluate Cloud Service Providers.
Q. 2: Is it possible to automate the selection of Providers using some of those attributes?
Q. 3: Do different departments in the same organization have different evaluation attributes for Cloud Service Providers?
After reading this questions that will be addressed with this thesis, we can arrive at the Thesis's problem, which can be formulated in the following question:
Can a Cloud Service Broker be used to select the best Cloud Service Provider for a given Service Request, whilst assuring interoperability between different Providers?
What is pretended in this research project is to achieve a possible reference group of attributes based on the strong points existent on those frameworks.
The set of hypotheses to be researched during the course of this project and tested are as follows:
H. 1: It is possible to achieve an accurate way of selecting the best provider for each Service and User Group for Governmental Clouds based on a Framework of Service Provider attributes;
H. 2: It is possible to automate to some degree the choice of Cloud Service Provider using Cloud Service Broker Solutions existent in the market using based on a Framework of Service Provider attributes.

2 Related Work

This section presents the state of the various areas of interest for this research. First, a brief introduction of the concept of Cloud Computing is presented, followed by an introduction to the main topic for this work, Cloud Service Brokerage, and the existing technologies related to this area.
All the information presented in this section is the result of extensive research through specialized research papers, informative whitepapers and specialized literature in Cloud Computing and Networking.

2.1 Cloud Computing

Due to the fact that Cloud Computing is a recent area of study and research by the scientific community, there still is no clear definition of the concept. Many definitions have been proposed by several authors on many publications. In Annex 1, we can find a table of definitions from several authors. The definition that will be considered for this document is the NIST definition, which says: "Cloud computing is a model for enabling ubiquitous, 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."
The Cloud follows a model called the SPI Model (SaaS, PaaS, and IaaS). This model goes from the less complexity of implementation (SaaS) and more optimized service to a more complex to implement service (IaaS), but more flexible on its uses. PaaS is the middle term, providing more flexibility than the first, but being less complex than the second. As defined in [5]:

- Infrastructure as a Service (IaaS) – The capability provided to the consumer is to provision processing, storage, networks, and other fundamental computing resources where the consumer is able to deploy and run arbitrary software, which can include operating systems and applications.
- Platform as a Service (PaaS) – The capability provided to the consumer is to deploy onto the cloud infrastructure consumer-created or acquired applications created using programming languages, libraries, services, and tools supported by the provider.
- Software as a Service (SaaS) – The capability provided to the consumer is to use the provider's applications running on a cloud infrastructure. The applica-

tions are accessible from various client devices through either a thin client interface, such as a web browser (e.g., web-based email), or a program interface.

It's also important to mention the different types of Clouds that exist [5]:

- Public Cloud – The cloud infrastructure is provisioned for open use by the general public. It may be owned, managed, and operated by a business, academic, or government organization, or some combination of them. It exists on the premises of the cloud provider.
- Private Cloud – The cloud infrastructure is provisioned for exclusive use by a single organization comprising multiple consumers (e.g., business units). It may be owned, managed, and operated by the organization, a third party, or some combination of them, and it may exist on or off premises.
- Hybrid Cloud – The cloud infrastructure is a composition of two or more distinct cloud infrastructures (private, community, or public) that remain unique entities, but are bound together by standardized or proprietary technology that enables data and application portability (e.g., cloud bursting for load balancing between clouds).

2.2 Cloud Service Brokerage and SMI Framework

The architecture of a Cloud Service Broker varies between the different developers and integrator companies. Generally though, most brokers do follow a generic architecture, as follows (based on [7]).

- Cloud Service Requesters/Consumers - This group represents the many Requesters/Consumers of Cloud Service that are in use in enterprises today. This group works by making a request to the Cloud Service Broker for a given service;
- Cloud Service Broker – This is the component responsible for integrating the various Cloud Service Providers and abstracting all this complexity to the users of Requesters/Consumers. It is composed by:
  - Cloud Service Consumer Interface;
  - Cloud Service Publish Interface;
  - Cloud Service Process;
  - Cloud Service Adapter;
- Cloud Service Providers – Group representing the many types of Cloud Service Providers existent nowadays in the Cloud Computing Paradigm.

Please consult [7] for further details on the Cloud Service Broker technology architecture.

The Service Measurement Index Framework, abbreviated SMI, is recent development by the Cloud Services Measurement Initiative Consortium (CSMIC) and is now on version 1.0, presented to the public around September 2011. This framework is being developed in an attempt to create a standard for measuring the quality of Cloud Services in general, allowing for a better choice by their potential clients. It's a hierarchical framework, constituted by seven categories and with each category having three or more attributes. Each attribute will have also a set of Key Performance Indicators (KPIs), which are currently under development for a next version of the SMI Framework. The categories on this framework are Accountability, Agility, Assurance, Financial, Performance, Security and Privacy and Usability. For further information on this framework and a description of the attributes, please refer to [1]. One gets the ranking of a given Provider by choosing the attributes that most resemble one's necessities, and by giving weights to each attribute. Then the overall ranking for that Provider is given by calculating the individual scores for each attribute and calculating those rankings with basis on their weights.

3 Solution Architecture

Below in Annex 2 we represent the final solution architecture adopted in this research. This architecture schematic shows the various components at work inside the prototype broker and the Providers chosen for testing, as well as some other information, in order to further clarify how all these components will play together.

3.1 KPIs and Weights for Measurement

The proposed KPIs and Weights on this work are summarized in the table below. This table constitutes a list of the SMI Framework attributes chosen for Provider measurement on the prototype, and upon which works they were based, or if they constitute new proposals for testing within this research's scope.

Category/Attribute	Measure Suggestions
(1)Accountability/Auditability	Four levels of classification, proposal below.
(2)Accountability/Provider Certifications	Based on [1].

Category/Attribute	Measure Suggestions
(3)Agility/Adaptability	Based on SMI Cloud [1].
(4)Agility/Capacity	Three levels of classification, proposal below.
(5)Agility/Extensibility	Three levels of classification, proposal below.
(6)Agility/Portability	Three levels of classification, proposal below.
(7)Agility/Scalability	Based on [1].
(8)Assurance/Availability	Managed automatically by Aeolus.
(9)Assurance/Recoverability	Managed automatically by Aeolus.
(10)Assurance/Reliability	Managed automatically by Aeolus.
(11)Financial/Acquisition & Transaction Cost	Based on SMI Cloud [1].
(12)Financial/On-going Cost	Managed automatically by Aeolus.
(13)Financial/Profit or Cost Sharing	Three levels of classification, proposal below.
(14)Performance/Functionality	1 point for each functionality, until a maximum score of 10 points.
(15)Performance/Interoperability	Based on SMI Cloud [1].
(16)Security and Privacy/Access Control & Privilege Management	Based on [1].
(17)Security and Privacy/Data Geographic/Political	Three levels of classification, proposal below.
(18)Security and Privacy/Data Privacy & Data Loss	Three levels of classification, proposal below.
(19)Security and Privacy/Physical & Environmental Security	Three levels of classification, proposal below.
(20)Security and Privacy/Proactive Threat & Vulnerability Management	Three levels of classification, proposal below
(21)Usability/Client Personnel Requirements	Three levels of classification, proposal below.
(22)Usability/Installability	The score will be given by estimating the average time required for the installation to be ready and available for use by the Client.
(23)Usability/Transparency	Based on SMI Cloud [1].
(24)Usability/Operability	Based on SMI [1].

Table 1. Categories, Attributes and KPIs selected for evaluation of Cloud Service Providers using the SMI Framework.

In order to assess the weights to be applied in each attribute of the framework, a survey was realized through electronic mediums to Computer Engineering Students, Cloud Specialists, Consultants and others. The results acquired are represented in the following graphic. These weights were then applied to the Provider evaluation table when testing the research's resulting solution.

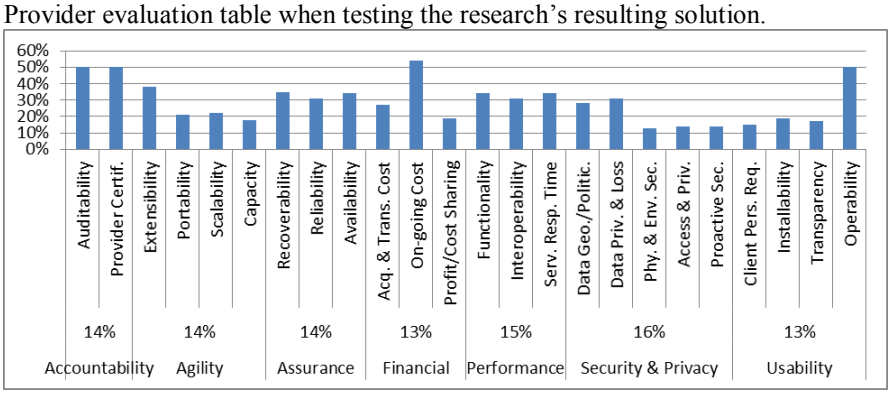

Fig. 1. Survey results

4 Testing the Solution

The prototype described above was then tested through the realization of a Case Study Scenario based on the Public Administration of the Portuguese Government. This scenario had two main components to be tested: first, we selected two major Providers, compatible with Aeolus, and created a spreadsheet to evaluate their scores using the SMI Framework methodology with the results from the development phase. Afterwards, these results were then configured into the prototype and some functionality and usability tests were done in order to assess how the Aeolus-based Cloud Service Broker is capable of supporting the Case Study Scenario at hand.

4.1 KPIs Results

The KPIs used and measured within this scenario have been studied and tested when evaluating the Providers chosen for testing. On Annex 3, you can find a summarized table with the conclusions drawn from this attribute testing phase.

4.2 Functionality Results

The following table summarizes the functionality and usability tests of the proposed prototype Cloud Service Broker, and some conclusions on those tests.

Test Case	Significance	Success	Procedure
Deploy on Best Rank Provider	Normal	Yes	Easy
Deploy on Specific Provider	High	Yes	Medium (needs single realm configuration)
Obtain SSH Credentials	Normal	Yes	Easy
Interacting With Instance	High	Yes	Easy
Access Control Lists	High	Yes	Medium (needs a high number of steps)
Migration between Instances or Providers	Normal	Partial (errors on restoration)	Hard (has to install several packages, some migration tool errors need debug)
Distributed Broker	Low	Yes	Hard (needs to install and configure a Provider, a VM and all the Aeolus server software).
Priorities' Change	Normal	Yes	Easy

Table 2. Analysis of the Cloud Service Broker Prototype Testing Procedure.

5 Conclusion

We can conclude there is still a big need for Cloud Service Brokerage as a service, and as a tool as well, because even though Cloud Computing is slowly evolving into standards such as OpenStack, there are still too many different proposals for standards, and many proprietary, non-compliant APIs. The Aeolus-based prototype proposed in this research is a possible and promising solution, and a possible way for future improvements in this area. The prototype created, together with the SMI Framework, constituted a good solution to manage mid-to-big sized hybrid Cloud architectures, enabling an Administrator to easy deploy, undeploy, monitor, limit and manage all its instances. Also a great advantage is the template language used in Conductor. This language eases the creation of system images and its consequent deployment in any number of servers. Aeolus 0.14.0 even adds the possibility to extend their built in selection algorithms. The Broker tool can also be a great ally in mitigating some of the existing barriers nowadays, and even other in the future. The Broker can be successfully used to reduce the risk of vendor lock-

in when choosing Cloud Providers, by providing a unique interface to interact with several different ones. In a short note about the SMI Framework, we think, that this Framework, though it is in its early stages of development, is a strong tool to aid companies in choosing the best Providers according to their needs. Despite some difficulties it may pose because of the choice between many attributes, we think this is also its strength, covering almost any type of decision, information or problem that any Client could have. SMI Framework is an on-going work that deserves the full attention of the scientific community that could help greatly on advancing Cloud Computing. Finally we can conclude that the Broker prototype suggested constitutes a viable, strong and working solution that can, even today, help any company and/or government to manage its Cloud infrastructure, in a first phase of adoption, being almost an indispensable tool in any Cloud transition arsenal, for any kind of organization.

References

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[2] S. K. Garg, S. Versteeg e R. Buyya, "SMICloud: A Framework for Comparing and Ranking Cloud Services," em *2011 Fourth IEEE International Conference on Utility and Cloud Computing*, 2011.

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[5] P. Mell e T. Grance, "The NIST Definition of Cloud Computing - Recommendations of the National Institute of Standards and Technology," NIST, Gaithersburg, MD 20899-8930, 2011.

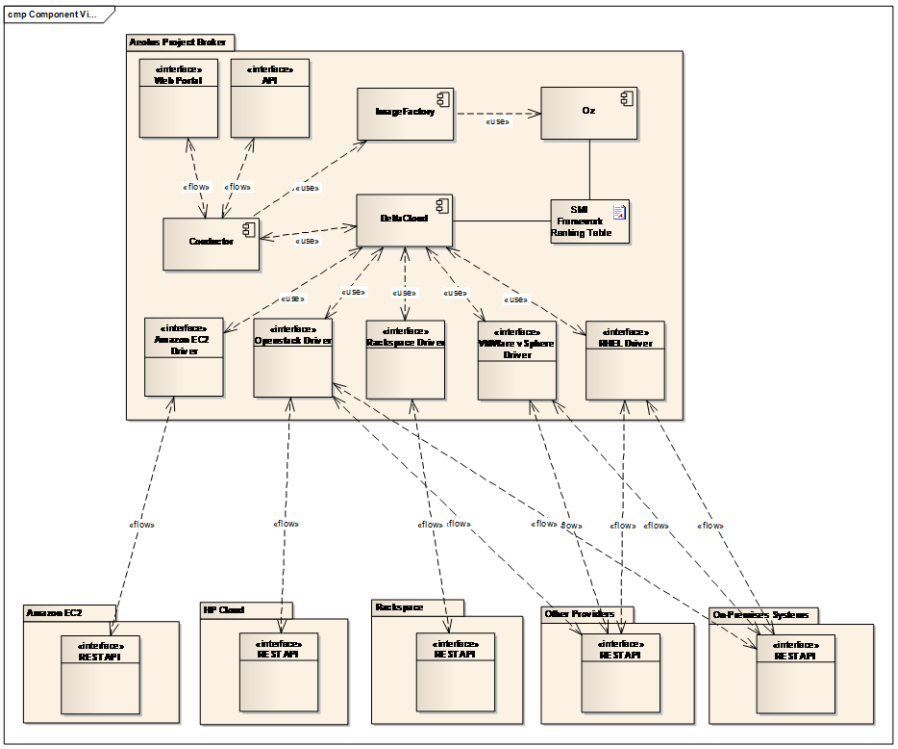
[6] CSMIC Carnegie Mellon University Silicon Valley, "Service Measurement Index - Version 1.0," Moffet Field, CA USA, 2011.

[7] S. Weixiang, H. Jie e K. Bhumip, "Cloud Service Broker," 2011.

Annex 1

Author/Reference	Year	Definition/Excerpt
M. Klems [11]	2008	*you can scale your infrastructure on demand within minutes or even seconds, instead of days or weeks, thereby avoiding under-utilization (idle servers) and over-utilization (blue screen) of in-house resources...*
P. Gaw [11]	2008	*using the internet to allow people to access technology-enabled services. Those services must be 'massively scalable...*
R. Buyya [6]	2008	*A Cloud is a type of parallel and distributed system consisting of a collection of interconnected and virtualized computers that are dynamically provisioned and presented as one or more unified computing resources based on service-level agreements established through negotiation between the service provider and consumers*
R. Cohen [11]	2008	*Cloud computing is one of those catch all buzz words that tries to encompass a variety of aspects ranging from deployment, load balancing, provisioning, business model and architecture (like Web2.0). It's the next logical step in software (software 10.0). For me the simplest explanation for Cloud Computing is describing it as, "internet centric software...*
J. Kaplan [11]	2008	*a broad array of web-based services aimed at allowing users to obtain a wide range of functional capabilities on a 'pay-as-you-go' basis that previously required tremendous hardware/software investments and professional skills to acquire. Cloud computing is the realization of the earlier ideals of utility computing without the technical complexities or complicated deployment worries...*
D. Gourlay [11]	2008	*...the next hype-term...building off of the software models that virtualization enabled*
D. Edwards [11]	2008	*...what is possible when you leverage web-scale infrastructure (application and physical) in an on-demand way...*
B. de Haff [11]	2008	*...There really are only three types of services that are Cloud based: SaaS, PaaS, and Cloud Computing Platforms. I am not sure being massively scalable is a requirement to fit into any one category.*
B. Kepes [11]	2008	*...Put simply Cloud Computing is the infrastructural paradigm shift that enables the ascension of SaaS. ... It is a broad array of web-based services aimed at allowing users to obtain a wide range of functional capabilities on a pay-as-you-go basis that previously required tremendous hardware/software investments and professional skills to acquire*
K. Sheynkman [11]	2008	*Clouds focused on making the hardware layer consumable as on-demand compute and storage capacity. This is an important first step, but for companies to harness the power of the Cloud, complete application infrastructure needs to be easily configured, deployed, dynamically-scaled and managed in these virtualized hardware environments*
O. Sultan [11]	2008	*...In a fully implemented Data Center 3.0 environment, you can decide if an app is run locally (cook at home), in someone elses data center (take-out) and you can change your mind on the fly in case you are short on data center resources (pantry is empty) or you having environmental/facilities issues (too hot to cook). In fact, with automation, a lot of this can can be done with policy and real-time triggers...*
K. Hartig [11]	2008	*..really is accessing resources and services needed to perform functions with dynamically changing needs...is a virtualization of resources that maintains and manages itself.*
J. Pritzker [11]	2008	*Clouds are vast resource pools with on-demand resource allocation...virtualized ...and priced like utilities*
T. Doerksen [11]	2008	*Cloud computing is ... the user-friendly version of Grid computing*
T. von Eicken [11]	2008	*outsourced, pay-as-you-go, on-demand, somewhere in the Internet, etc*
M. Sheedan [11]	2008	*...'Cloud Pyramid' to help differentiate the various Cloud offerings out there...Top: SaaS; Middle: PaaS; Bottom: IaaS*
A. Ricadela [11]	2008	*...Cloud Computing projects are more powerful and crash-proof than Grid systems developed even in recent years*
I. Wladawsky Berger [11]	2008	*...the key thing we want to virtualize or hide from the user is complexity...all that software will be virtualized or hidden from us and taken care of by systems and/or professionals that are somewhere else - out there in The Cloud*
B. Martin [11]	2008	*Cloud computing encompasses any subscription-based or pay-per-use service that, in real time over the Internet, extends IT's existing capabilities*
R. Bragg [5]	2008	*The key concept behind the Cloud is Web application... a more developed and reliable Cloud. Many find it's now cheaper to migrate to the Web Cloud than invest in their own server farm ... it is a desktop for people without a computer*
G. Gruman and E. Knorr [14]	2008	*Cloud is all about: SaaS...utility computing...Web Services... PaaS...Internet integration...commerce platforms....*
P. McFedries [22, 15]	2008	*Cloud Computing, in which not just our data but even our software resides within the Cloud, and we access everything not only through our PCs but also Cloud-friendly devices, such as smart phones, PDAs... the megacomputer enabled by virtualization and software as a service...This is utility computing powered by massive utility data centers.*

Annex 2



Annex 3

Attribute	Applicability	Difficulty	Significance
1	High	Medium (some providers may resist to disclose their business)	High
2	High	Easy (Internet search usually answers	High

3	Medium (this timings may vary from time to time, hard to normalize and measure)	Hard (much variation in these values).	Medium
4	High	Easy (Internet search)	Low (most Providers have similar capacities)
5	High	Hard (might require consulting Provider's commercial staff)	High
6	High	Hard (might require search, consulting or even testing)	Medium (to avoid vendor lock-in)
7	Medium	Medium (requires some calculations and testing)	High
8	High	Hard (manual mode), Easy (automatic)	High
9	High	Hard (manual mode), Easy (automatic)	High
10	High	Hard (manual mode), Easy (automatic)	High
11	High	Medium (requires calculations and details on pricing)	High (financial)
12	High	Medium (if manual), Easy (automatic)	High (financial)
13	Medium	Hard (requires consulting and even some negotiation)	Medium (it's not a common business model)
14	High	Easy (Internet search)	Medium (many Provider's offer similar functionalities)
15	High	Medium (Internet search and calculations)	Medium (only needed if an organization adopts an Hybrid Cloud or switches vendor)

16	Medium (some companies prefer "security by obscurity")	Easy (Internet search)	High (security)
17	Low (requires legal counseling on most matters)	Medium (if well informed about laws and some Internet search)	High (privacy)
18	Medium (some companies prefer "security by obscurity")	Easy (Internet search)	High (security and privacy)
19	Low (requires good auditability levels)	Hard (most Providers prefer not to disclose such details)	High (security)
20	Low (requires good auditability levels)	Medium (Providers don't give details on the technology, but tell which type of security features they possess)	High (security)
21	High	Easy (information available when contracting services)	Medium
22	Medium (might vary in time and due to several factors)	Medium (great variation thanks to different factors)	Medium
23	High	Medium (requires some calculations and disclosure of failure information from Provider to Clients)	High
24	High	Easy (Key-User testing)	High (Clients want easy to assess and learn services)