Literature Review on Multi Cloud Management

Seminar paper

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Abstract

Multi-cloud computing plays a very big role in the current world of IT. Nearly 90% of all companies use cloud services from different providers and thus operate multi-cloud architectures, but only 25% of companies use management tools to coordinate these cloud landscapes.

This literature review addresses the question of what multi-cloud management is and why it can help companies successfully manage their cloud infrastructures today. The aim is to provide companies and managers with a general overview of the topic and a basis for possible further research in the field.

Keywords: Multi-cloud, Multi-Cloud Management, Cloud computing, Literature Review.

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1 Introduction

Cloud computing is defined by the National Institute of Standards and Technology (NIST) as "model for granting users access to a shared pool of configurable computational resources including networks, servers, storage, applications, and services that can be rapidly provisioned with little management or service provider interaction" (P. Mell 2011). It is used by many businesses, because it allows them to focus on core business elements instead having to deal with computer infrastructures and maintenance (J. Hong et al. 2019). The cloud technology is giving on demand delivery of infrastructure and many other services and benefits to the clients. But the initial cloud computing is often susceptible to vendor lock-in. As a solution for that issue many organizations started multiple cloud environments from different Cloud-Service-Providers (CSPs) (K. Kritikos et al. 2020). Nowadays, the use of multiple CSPs or in other words multi-cloud computing is becoming more and more attractive to organisations as it enables cost benefits and better quality of services (D. Petcu 2013).
The aim of this paper is to give a general overview about multi-cloud computing and especially multi-cloud management. In addition, this literature review shows why multi-cloud computing is an important part of many organisations' IT infrastructures today. With the given overview organisations and/or managers have a basic knowledge about the topic and can start individual researches on special types and use-cases of multi-cloud computing.
In the following chapters I am going to focus on the following two research questions:

- What is multi-cloud computing?
- What is multi-cloud management and how can multi-cloud environments be managed?

This literature review is structured in six chapters. After this introduction there will be some background information on multi-cloud and some explanation of terms. In the next step there will be a description of the literature review process where I describe how I did identify relevant literature in the single steps. Fourth I will present the key findings of my research. Thereupon I will discuss the results and the state of the current literature also I will give an outlook on future research. Finally, this literature review will be closed by a conclusion.

2 Background

The term multi-cloud describes a cloud-computing architecture which uses more than one cloud service by independent cloud-service-providers (CSP's) (P. Alpar et al. 2017 & H. A. Imran et al. 2020). In the literature concerning multi-cloud computing one encounters some ambiguities regarding the term multi-cloud, as until today no real standardization exists. For example, in some texts the authors speak of cross-cloud computing or define multi-cloud computing as a "umbrella term" for other frameworks which will be described in this paragraph (J. Hong et al. 2019). There are three popular architectures that contain multiple clouds, some of which can be combined and some of which differ only in detail:

- Multi-Cloud: The multi-cloud framework describes cloud systems which contains more than one cloud deployment and each deployment has to be by a different CSP. Those different cloud networks have their own roles in the system. This leads to the advantage that the trust requirements for CSP's can be reduced (J. Hong et al. 2019 & D. Petcu 2013).
- Hybrid-Cloud: This framework is the most common multi-cloud framework. It describes an environment where a private cloud gets combined with one or more public clouds. Different to multi-cloud there is no need that these clouds have to be from different CSP's (J. Hong et al. 2019 & D. Petcu 2013).
- Federated Cloud Computing: This term describes a cloud network in which the different CSP's share resources which each other which is making the migration of data between the different clouds a lot easier for the client. This approach is mainly used by smaller cloud providers to cover each other's weaknesses (J. Hong et al. 2019 & D. Petcu 2013).

In the following sections, only the multi-cloud architecture is considered.

3 Literature Review

The aim of this literature review is to give the reader an overview about the current approaches and about the current state of research on the management of multi-cloud environments.

3.1 Search String

Finding a fitting search string for this literature review I started gathering some information about multi-cloud-management on "Google" and "Google Scholar" to get a general overview on the topic. Quickly I realized that there are many similar cloud architectures that are very similar to multi-cloud as mentioned in the background section before. That means I had to be very carefully doing my research for not mixing these architectures.

Afterwards, I have tried some search strings like "multi cloud architecture", "multi cloud computing" or "multi cloud environment". After analysing the results of these named search strings, I learned that the papers I had found were way to specific about special types of multi-clouds and use cases of multi-cloud-computing.

For this reason, I decided to use "multi cloud management" as my search string, because that way I found way more results regarding the management of multi-cloud architectures. Next, I have tried to narrow my search by filtering the results by date and tried to just use literature that is released after 2018. Due to the fact that I didn't find enough relevant literature which was released after 2018, I needed to remove this filter from my search.

3.2 Literature search

After finding my search string I have continued to search for literature on several databases. The used databases for my research where Google Scholar, EBSCO Host, IEEE Explore and ScienceDirect. In the following table you can see the number of results for the search string "multi cloud management". As you can see the number of results differs a lot on the different databases.

	"Multi Cloud Management"
EBSCO Host	211
Google Scholar	359
IEEE Xplore	6
ScienceDirect	18
∑	594

Table 1. Number of results by database

3.3 Literature Selection

The next step was to filter the results for the relevant literature. First, I read only the titles of the results and deleted those that did not fit the overall theme. I also removed the results that focused only on specific application areas or variations. Through this step I had 63 results left. So, I continued the selection process by reading the abstracts of the remaining results and delete every result that was not fitting into the topic. Once again, I have made sure that not only specific research directions are considered. In the next step I read the full texts of the 21 remaining results and removed the ones which were not fitting as in the step before. In the further process I did the backward and forward search as described by Webster & Watson 2002 to find literature which had some more fundamental information and didn't

appear in the selection process before. In the following graphic the steps and results of the described steps are shown.

Filter	Number of results
Unfiltered	594
Relevance by title	63
Relevance by abstract	21
Relevance by full text	6

Table 2. Process of filtering the results

4 Results

4.1 A definition of Multi Cloud Management

Multi-cloud management is the process of managing multiple cloud computing services in a coordinated way. This typically involves using specialized tools and strategies to ensure that the various cloud services being used are integrated and working together effectively, and that the organization using them can maintain control over its data and applications.

Management tools for multi-cloud environments are needed, because beside all the benefits of multi-clouds (which will be analysed later in this literature review) they add an extra layer of complexity to the cloud architecture. This is related to platform heterogeneity, management control and automated application deployment (F. Samreen et al. 2014).

Multi-cloud management can help organizations take advantage of the benefits of different cloud services without becoming overwhelmed by the complexity of managing multiple different platforms (P. Raj et al. 2018). Multi-cloud management also creates transparency, as the tools usually provide the ability to monitor workloads and many other metrics. Another benefit is that multi-cloud management tools can help IT departments implement security policies and proactively assist them in finding potential security vulnerabilities. In addition, such tools can also support cost management, which can quickly become very complex in the case of larger architectures (VMware 2022).

4.2 Types of Multi Cloud Management

Management of multi-cloud-environments can be achieved directly or through a mediator. The mediator method or volunteer federation can be described as follows: an external organisation gets involved as a centralized entity which is not offering a cloud service itself, but combines different cloud services and manages their communication, to make it available for the customer. Often the mediator is also monitoring the involved services by the customers and can additionally support the customer in various related tasks (N. Grozev et al. 2012 / Petcu 2013). Beside that, the mediator is often not just responsible for operating the multi-cloud, but also for planning the multi-cloud-environment. This can save a lot of time and cost for the customer. Due to that this method is a fast, but more expensive method, where not much know how is needed by the customer (Alpar et al. 2019).

Another form of the volunteer federation is the peer-to-peer architecture. In this case there is no centralised mediator which is responsible for the management of the different providers or any other task. Instead, the cloud providers themselves are responsible for communicating with each other to connect their services and make them available for the customer (N. Grozev et al. 2012).

The other option of managing a multi-cloud-environment is the direct management of multi-clouds which can be achieved through software solutions (Alpar et al. 2019), but also from libraries (N. Grozev

et al. 2012 / Petcu 2013). Due to the fact that software solutions are usually off-the-shelf tools with unified interfaced to several cloud providers, they give high flexibility and reliability to the customer because that makes the different cloud instances easily interchangeable. These kind of standard software solutions are often advertised that they can be used without profound IT knowledge (P. Alpar et al. 2019).

Otherwise, companies that need customized solutions for specific cloud services or use cases, or even want to integrate a solution into existing software, can work with libraries (N. Grozev et al. 2012).

In some cases, mixed models are used in practice to outsource only individual tasks or interfaces. This is often the case in larger companies (P. Alpar et al. 2019 / Samreen et al. 2014).

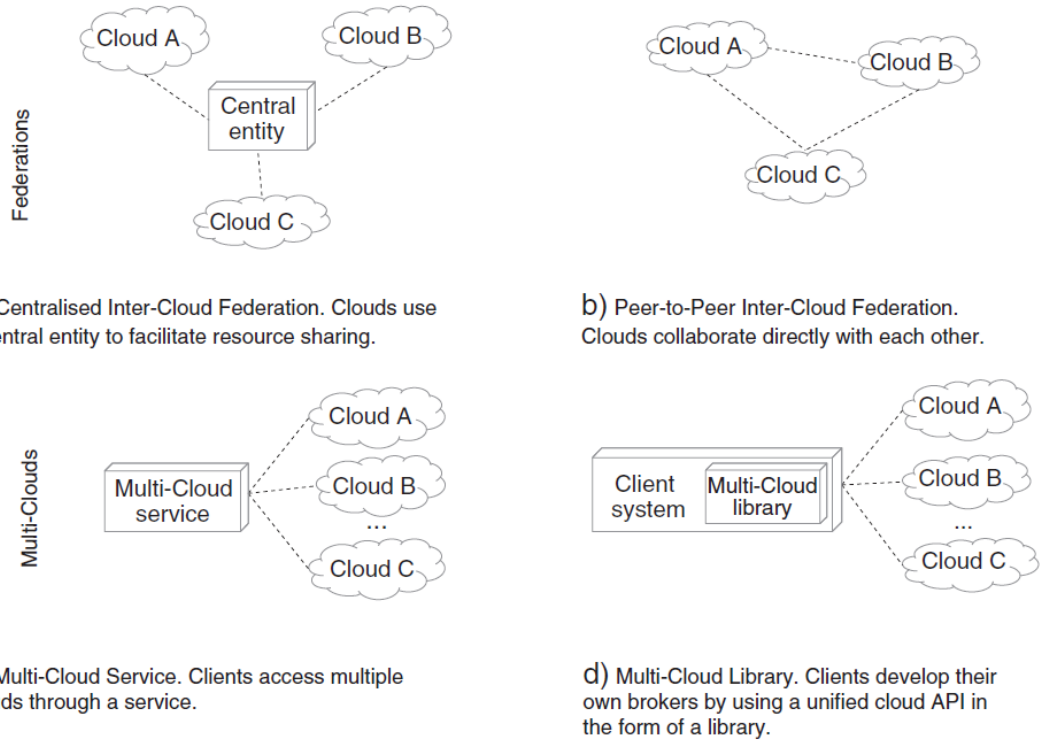

Figure 1. Inter-Cloud developments' architectures ("Inter-Cloud architectures and application brokering: taxonomy and survey" Nikolay Grozev et al. 2012)

4.3 Benefits and challenges of Multi-Cloud-Computing

Multi-cloud-computing is becoming more and more attractive for many companies due to its various benefits which are summarised by Petcu (2013) and J. Hong et al. (2019) in 10 key points:

- Dealing with peaks in service
- Cost optimisation or improvement of service quality
- Reaction to changes of the offers by the providers
- Following constraints (new locations or laws)
- High availability of services and resources
- Avoiding vendor lock-in
- Backups for catastrophes or planned downtimes

- Acting as intermediary
- Enhance own cloud service/resources offers, based on agreements with others
- Using different services for their particularities not provided elsewhere

Beside all those benefits, there are also some challenges about multi-cloud-computing such as access management and authorizations, because the operator needs to manage authorisations and accesses for multiple cloud instances. Another challenge is that as different providers are involved in a multi-cloud-environment, the organization holds more responsibility in term of security for the data on the clouds and the exchange of information between the providers. Additionally, the combination of different providers can create additional overhead, specially in terms of integration and data exchange mechanisms. Support is another challenge, because the user should not need to care which provider is delivering a service, so a client-support or even a self-service feature is needed (P. Alpar et al. 2017).

4.4 Current state and trends

According to Flexeras "State of the Cloud" report from 2022, 89% of the surveyed organizations are using multi-cloud computing, while just 25% of those organisations are using multi-cloud management tools. In comparison to Flexeras "State of the Coud" report from 2020 the use of multi-cloud computing went down by 4% and the use of multi-cloud management tools by 1%. The most used types of multi-cloud tools are cost management tools and security tools (State of the Cloud 2022, Flexera).

In the next years there will be properly more organizations which will be using multi-cloud management tools, because of the growing state of complexity in these architectures (K. Kritikos et al. 2020).

5 Discussion

5.1 Commonalities and differences among the literature

While doing my research on multi-cloud computing, I noticed that all the relevant sources are speaking about the same reasons for using multi-cloud computing, also every source enumerates the same benefits and challenges for it (as mentioned in paragraph 4.3). In the literature used, the definition for multi-cloud and other similar frameworks are always nearly the same, but around other sources the definitions for multi-cloud management were slightly different, which is justified by the non-existence of standardizations. Which leads me to one of the biggest problems around multi-cloud sourcing/management and cloud computing in general: the lack of current standardizations. For example, one of the most important standardizations for cloud computing "The NIST Definition of Cloud Computing" by the National Institute of Standards and Technology (NIST) is not updated since 2011. By that time multi-cloud computing was such a new technology that it wasn't even mentioned in that definition by the NIST. A proper standardization of multi-cloud and also an update on cloud computing in general would properly make the management of multi-cloud platforms a lot easier.

5.2 Practical implications

A big part of the available literature about multi-cloud computing and management is focused on special use-cases of multi-cloud like for example: "blockchain-based data storage" or "disaster recovery solutions". Other papers focus on describing to market situation and compare multi-cloud management solutions and providers.

This paper focuses on a general overview about multi-cloud computing, the importance of multi-cloud management and the different forms of management solutions. Which can be used as a fundament for further research on more specific use-cases and topics around multi-clouds.

5.3 Future research

Future research on multi-clouds should focus on setting and updating standards. Beside the fact that there should be more literature on multi-cloud in general, next research directions should focus on combining multi-cloud with other technologies like machine-learning or big data as these technologies can be used solving current challenges regarding multi-cloud computing.

5.4 Limitations in actual literature

This review is limited by a few factors. There is currently not a lot of literature regarding multi-cloud and especially multi-cloud management. There are several papers about use cases and market comparisons, but just very few papers that give an overview about these topics. Also, the most sources that I have found are from between 2011 – 2019, which clearly can't give a meaningful summary of the current state of the art regarding the topic.

6 Conclusion

Multi-cloud computing is an already widely used technology that compensates for many of the disadvantages of traditional cloud computing. Due to numerous positive characteristics such as the prevention of vendor lock-in and better availability of services (see chapter 4.3), it will continue to gain acceptance.

However, the use of multi-cloud management tools is not yet widespread, as many companies prefer to outsource the management of these infrastructures due to the high complexity. However, technologies such as machine-learning could make management tools much easier to use in the future and offer even more possibilities for the optimal control of multi-cloud environments.

Source	Intro/Backround/ Definition	Types of MCM	Benefits / Challenges	State and Trends
Jiangshui Hong et al. 2019	X		X	
Kyriakos Kritikos et al. 2020	X			X
Dana Petcu 2013	X	X	X	
Paul Alpar et al. 2017	X	X	X	
P. Raj et al. 2018	X			
Nikolay Grozev et al. 2012		X		
Samreen et al. 2014	X	X		X
H. A. Imran et al. 2020	X			

Appendix 1. Literature Matrix

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