Document name	Code	Segment	Created by
Ahmad2020-Cloud_Computing_Trends_and_Cloud_Migration_Tuple	MULTI-CLOUD ARCHITECTURE > Private cloud	This section will illustrate upon basics of cloud computing, container technology, fog computing, and edge computing. Cloud computing is deployed through public clouds, private clouds, community clouds, and hybrid clouds. It is offered through majorly one of the service deliv-ery models such as infrastructure as a service (IaaS), platform as a service (PaaS), and software as a service (SaaS).	Ivon Miranda Santos
Ahmad2020-Cloud_Computing_Trends_and_Cloud_Migration_Tuple	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	Cloud computing is deployed through public clouds, private clouds, community clouds, and hybrid clouds. It is offered through majorly one of the service deliv-ery models such as infrastructure as a service (IaaS), platform as a service (PaaS), and software as a service (SaaS).	Ivon Miranda Santos
Ahmad2020-Cloud_Computing_Trends_and_Cloud_Migration_Tuple	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Multi: Multi-term has many-faceted implication in cloud computing. Most com-mon of all is multi-tenant environment. Multi-agent system (system of multiple interacting intelligent system) [25] has also become significant in the perspective of cloud computing. This term is also associated with replication and redundancy such as multicast, multi-cloud, and multi-gateway system.	Ivon Miranda Santos
Alouffi2021-A_systematic_literature_review_on_cloud_computing_s	MULTI-CLOUD ARCHITECTURE > Multiple clouds	One of the limitations of the proposed research is its simulation, which could be near a realistic one but cannot be 100 percent applicable to real-world case studies. Therefore, researchers can consider realistic scenarios with different cloud clusters and cloud technologies to develop a multi-cloud system in future works. Given the increased number of published works, we cannot	Ivon Miranda Santos
Ardagna2015-Cloud_and_multi-cloud_computing_Current_challenges_	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Also networks are frequently the Cloud bottleneck and data center energy management is very critical [7]. To cope with such challenges the adoption of multi-Clouds [8], has been advocated by many researchers, since deploying software on multiple Clouds overcomes single provider un-availability and allows to build cost efficient follow the sun applications. Moreover, Cloud computing is also becoming a	Ivon Miranda Santos
Ardagna2015-Cloud_and_multi-cloud_computing_Current_challenges_	MULTI-CLOUD ARCHITECTURE > Cost reduction	To cope with such challenges the adoption of multi-Clouds [8], has been advocated by many researchers, since deploying software on multiple Clouds overcomes single provider un-availability and allows to build cost efficient follow the sun	Ivon Miranda Santos
Asthana2021-Multi-cloud_Solution_Design_for_Migrating_a_Portfol	MULTI-CLOUD ARCHITECTURE > Multiple clouds	486 S. Asthana et al. enterprises operate in a multi-cloud environment. That is why different cloud vendors nowadays are enabling mix and match of cloud services across	Ivon Miranda Santos
Asthana2021-Multi-cloud_Solution_Design_for_Migrating_a_Portfol	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Determining the cloud migration solution that agrees to all these requirements while still be applicable, is not trivial and cannot be achieved by non-analytical/manual ways. To overcome these drawbacks and challenges, we propose a methodology that rec-ommends the optimal set of cloud providers and creates a multi-cloud solution for the client. We evaluate the optimal set of cloud providers based on best the fit between recommendations from historical data as well as a decision optimization solution frame-	Ivon Miranda Santos
Asthana2021-Multi-cloud_Solution_Design_for_Migrating_a_Portfol	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	Yang [12] shows a hybrid cloud solution design for genomics Next Generation Sequencing (NGS) service, which is streamlined for this particular service. Megahed et al. proposes an optimal approach for cloud solution design that satisfies client requirements and cloud offering constraints for an application in [13, 14], though they do not account for the different constraints of choosing	Ivon Miranda Santos
Asthana2021-Multi-cloud_Solution_Design_for_Migrating_a_Portfol	MULTI-CLOUD ARCHITECTURE > Multiple clouds	[27] and Iyoob et al. [28] provide analytical works that have solved problems in the cloud, including multi-cloud. However, they do not include any works that involve multi-cloud solutions. In the aforementioned existing state of the art, we observe a few drawbacks.	Ivon Miranda Santos

Asthana2021-Multi-cloud_Solution_Design_for_Migrating_a_Portfol	MULTI-CLOUD ARCHITECTURE > Multiple clouds	First, the time taken to gather all the features of the applications is quite inefficient, as it takes a lot of time and resources. Second, there is no analytical automated way of efficiently recommending a multi-cloud solution, where the current solutions rely on manual, inefficient evaluation of possible available cloud providers and thus requires a lot of back and forth with the client. That is, the prior art discussed above, as well as other works not reviewed above, focus on different aspects of cloud computing optimization and analytics, rather than multi-cloud solutions.	Ivon Miranda Santos
Asthana2021-Multi-cloud_Solution_Design_for_Migrating_a_Portfol	MULTI-CLOUD ARCHITECTURE > Multiple clouds	3.1 Overview of Our Approach Our methodology is a four-step approach that aims at preparing a multi-cloud solution for a client portfolio of applications. We start with collecting meta data for each application that the	Ivon Miranda Santos
Asthana2021-Multi-cloud_Solution_Design_for_Migrating	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and	is 1 if provider j ∈ J is selected and zero, otherwise.	Ivon Miranda Santos
Asthana2021-Multi-cloud_Solution_Design_for_Migrating_a_Portfol	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	The objective function minimizes the capacity of cloud provider selections and cost of application portfolio assignments.	Ivon Miranda Santos
Asthana2021-Multi-cloud_Solution_Design_for_Migrating_a_Portfol	MULTI-CLOUD ARCHITECTURE > Multiple clouds	4. Then, the optimization algorithm helped to optimize the recommended set of cloud providers which prepared the multi-cloud solution for the client. Providers	Ivon Miranda Santos
Asthana2021-Multi-cloud_Solution_Design_for_Migrating_a_Portfol	MULTI-CLOUD ARCHITECTURE > Multiple clouds	5 Conclusion and Future Work In this work-in-progress paper, we presented a novel method to prepare a multi-cloud solution for a client portfolio of applications. We showed a method that used text mining, dependency graph, and optimization to create that multi-cloud solution. We showed a use case for applying our	Ivon Miranda Santos
Aydin2021-A_Study_of_Cloud_Computing_Adoption_in_Universities_a	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	The purpose of this research was to determine the position of universities in Turkey within the context of cloud computing and to present an abstract hybrid cloud framework for these universities. Descriptive method and survey technique were used in the research. SPSS	Ivon Miranda Santos
Aydin2021-A_Study_of_Cloud_Computing_Adoption_in_Universities_a	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	In this context, a hybrid framework for adopting cloud computing in universities for them to overcome their identified challenges was proposed. The results are primarily intended to provide a guideline to universities in cloud	Ivon Miranda Santos
Aydin2021-A_Study_of_Cloud_Computing_Adoption_in_Universities_a	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	The purpose of this research is to determine the position of universities in Turkey within the context of cloud comput-ing and to present an abstract hybrid cloud framework for adopting cloud computing into universities to overcome the	Ivon Miranda Santos
Aydin2021-A_Study_of_Cloud_Computing_Adoption_in_Universities_a	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	In the study, section "Literature Review" presents a literature review regarding the theoretical and conceptual background, and section "Purpose, Scope and Method of the Study" introduces the research model in detail. In section "Findings and Evaluation," the findings of the study are evaluated. Section "An Abstract Hybrid Cloud Framework for Universities" describes the presented framework, while in the last section,	Ivon Miranda Santos
Aydin2021-A_Study_of_Cloud_Computing_Adoption_in_Universities_a	MULTI-CLOUD ARCHITECTURE > Multiple clouds	• Resource Pooling: The ability to share information resources, such as computer network, server, operat-ing system, database, and computer software, between multiple cloud users.	Ivon Miranda Santos
Aydin2021-A_Study_of_Cloud_Computing_Adoption_in_Universities_a	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	The cloud conceptual reference model created by NIST contains elements that must be included in a cloud structure; these are "Cloud User," "Cloud Controller," "Cloud Service Provider," "Cloud Agent," and "Cloud Carrier" (Sevli, 2011). Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS) are the service models. Public, private, community, and hybrid clouds are four	Ivon Miranda Santos
Aydin2021-A_Study_of_Cloud_Computing_Adoption_in_Universities_a	MULTI-CLOUD ARCHITECTURE > Private cloud	Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS) are the service models. Public, private, community, and hybrid clouds are four deployment models of cloud computing (Goyal, 2014).	Ivon Miranda Santos

Aydin2021-A_Study_of_Cloud_Computing_Adoption_in_Universities_a	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	The main contributions of this study are as follows: • Determination and evaluation of the current situation of universities and their opinions through the research questions determined within the scope of this study; • Presentation of an abstract hybrid cloud framework for the delivery of university information services	Ivon Miranda Santos
Aydin2021-A_Study_of_Cloud_Computing_Adoption_in_Universities_a	MULTI-CLOUD ARCHITECTURE > Private cloud	If "Very good" and "Good" knowledge levels are considered as sufficient levels, it is seen that approximately half of the universities (50.5%) do not have enough knowledge about cloud computing. In the chi-square test performed, no significant difference ($\chi 2 = 0.180$) was found between the state and private univer-sities in terms of knowledge level of cloud computing.	Ivon Miranda Santos
Aydin2021-A_Study_of_Cloud_Computing_Adoption_in_Universities_a	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	Cloud architecture status. Nearly half of the universities (43.5%) stated that they did not have a cloud architecture (Figure 5). Results showed that 21.2% of the participants had a private cloud architecture, 12.9% had a hybrid cloud archi-tecture, 11.8% had a community cloud architecture, and 10.6% had a public cloud architecture. In addition, the data obtained from the survey revealed that most of the respon-dents	Ivon Miranda Santos
Aydin2021-A_Study_of_Cloud_Computing_Adoption_in_Universities_a	MULTI-CLOUD ARCHITECTURE > Private cloud	Nearly half of the universities (43.5%) stated that they did not have a cloud architecture (Figure 5). Results showed that 21.2% of the participants had a private cloud architecture, 12.9% had a hybrid cloud archi-tecture, 11.8% had a community cloud architecture, and 10.6% had a public cloud architecture. In addition, the data obtained from the survey revealed that most of the respon-dents	Ivon Miranda Santos
Aydin2021-A_Study_of_Cloud_Computing_Adoption_in_Universities_a	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	An Abstract Hybrid Cloud Framework for Universities Within the scope of the study, a literature review was made on how to create the conceptualization process of the model. There	Ivon Miranda Santos
Aydin2021-A_Study_of_Cloud_Computing_Adoption_in_Universities_a	MULTI-CLOUD ARCHITECTURE > Private cloud	8 SAGE Open "Public Cloud Model," "Private Cloud Model," "Hybrid Cloud Model," and "Community Cloud Model" (Goyal, 2014). Academicians and researchers have proposed different models for different cloud computing categories for the adop-	Ivon Miranda Santos
Aydin2021-A_Study_of_Cloud_Computing_Adoption_in_Universities_a	MULTI-CLOUD ARCHITECTURE > Private cloud	Some of the critical success factors (CSFs) for the effective implementation of cloud-based e-learning at universities and institutes of higher education are Cloud Data Security, Availability and Reliability, Customizable Service Level Agreement, Network Bandwidth, Compatibility, Technical Support, Management Support, Human and Resource Readiness, Complexity, Cost Flexibility, Ease of Use, and Relative Advantage (Naveed & Ahmad, 2019). Hybrid clouds contain a combination of two or more pri-vate, community, or public cloud structures and therefore have a more complex	Ivon Miranda Santos
Aydin2021-A_Study_of_Cloud_Computing_Adoption_in_Universities_a	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	Hybrid clouds contain a combination of two or more pri-vate, community, or public cloud structures and therefore have a more complex structure (Goyal, 2014). In the study of K. E	Ivon Miranda Santos
Aydin2021-A_Study_of_Cloud_Computing_Adoption_in_Universities_a	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	(2018), an abstract hybrid model for adopting cloud computing in e-government to overcome the e-government's challenges was proposed.	Ivon Miranda Santos

Aydin2021-A_Study_of_Cloud_Computing_Adoption_in_Universities_a	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	In the study of Monsalve et al. (Alonso-Monsalve et al., 2018), the orchestration between the volunteer platform and the public, private, or hybrid clouds was described in the proposed hybrid cloud model. Juma and Tjahyanto (2019) proposed the ITOETAM model, which was the combination of the Technological, Organizational, Environmental (TOE), Technological Acceptance Model (TAM), and Internal, External (I-E) methods, to find challenges and suggest the solution to overcome those challenges (Juma & Tjahyanto, 2019). ITOETAM (the proposed model for cloud computing adoption challenges in Zanzibar's Universities), TOE (the model used previously in cloud challenges), TAM (the model used to solve the challenges of cloud computing), and I-E (the model used to solve challenges in cloud comput-ing) are examples for some different models used in the litera-ture (Juma & Tjahyanto, 2019; Tashkandi & Al-Jabri, 2015). These studies show that cloud-based learning models are becoming widespread and their use is gradually increasing. Elhoseny et al. (2018)	Ivon Miranda Santos
Aydin2021-A_Study_of_Cloud_Computing_Adoption_in_Universities_a	MULTI-CLOUD ARCHITECTURE > Private cloud	(Alonso-Monsalve et al., 2018), the orchestration between the volunteer platform and the public, private, or hybrid clouds was described in the proposed hybrid cloud model. Juma and Tjahyanto (2019) proposed the ITOETAM model, which was the combination of the Technological, Organizational, Environmental (TOE), Technological Acceptance Model (TAM), and Internal, External (I-E) methods, to find challenges and suggest the solution to overcome those	Ivon Miranda Santos
Aydin2021-A_Study_of_Cloud_Computing_Adoption_in_Universities_a	MULTI-CLOUD ARCHITECTURE > Private cloud	cloud broker, and network administrator. A proposed architec-ture based on the hybrid cloud model which uses both the pub-lic and private clouds is simulated using CloudSim. It consists of two main parts, that is, the Cloud Management System and the Hybrid Cloud (Sqalli et al.,	Ivon Miranda Santos
Aydin2021-A_Study_of_Cloud_Computing_Adoption_in_Universities_a	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	A proposed architec-ture based on the hybrid cloud model which uses both the pub-lic and private clouds is simulated using CloudSim.	Ivon Miranda Santos
Aydin2021-A_Study_of_Cloud_Computing_Adoption_in_Universities_a	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	It consists of two main parts, that is, the Cloud Management System and the Hybrid Cloud (Sqalli et al., 2012). In the cloud computing adoption model proposed by Okai et al. (2014), a roadmap for cloud computing adoption is proposed by universities to over-come the	Ivon Miranda Santos
Aydin2021-A_Study_of_Cloud_Computing_Adoption_in_Universities_a	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	In this study, an abstract hybrid cloud framework was pre-sented (Figure 11). The framework consists of Private University Cloud ("PUC") and Community University Cloud ("CUC"). The structure is a hybrid cloud because it includes both PUC and CUC. The purpose of the framework is to meet the expectations of universities in a cloud environ-ment in a cost-effective manner. The stakeholders of the framework are educational institutions, instructors, students, IT personnel, researchers, IT staff and administrators, learn-ers, educational practitioners, and so on. In the creation of the framework, existing studies in the literature on the sub-ject were examined. In the conceptualization process, both the information obtained from the	Ivon Miranda Santos
Aydin2021-A_Study_of_Cloud_Computing_Adoption_in_Universities_a	MULTI-CLOUD ARCHITECTURE > Private cloud	PUC Implementation PUC is a private cloud that can be established by each uni-versity through their own IT resources. Thanks to PUC, data and processes will be managed within each university. This structure will belong to each university itself because it will deliver private cloud services. By PUC, each university will be able to deliver SaaS, PaaS, and	Ivon Miranda Santos
Aydin2021-A_Study_of_Cloud_Computing_Adoption_in_Universities_a	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	There is a portal structure under the proposed model. Services/applications in PUC or CUC will be delivered via this portal structure. Information services in the model will be put into service through a single hybrid cloud platform. Information services to be provided through this	Ivon Miranda Santos

Aydin2021-A_Study_of_Cloud_Computing_Adoption_in_Universities_a	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	Services/Applications of the Proposed Hybrid Cloud Model The architecture of the proposed hybrid cloud includes SaaS, IaaS, and PaaS platform as shown in Figure 12. By combin-ing PUC and CUC environments, the model, which is a com-puting environment, allows data to move and to be shared seamlessly between these environments.	Ivon Miranda Santos
Aydin2021-A_Study_of_Cloud_Computing_Adoption_in_Universities_a	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	These services can be catego-rized as secret services, dynamic services, and so on. When computing and processing demand fluctuates, hybrid cloud computing gives universities the ability to seamlessly scale their on-premises infrastructure. In the survey, 71.4% of IT departments stated that	Ivon Miranda Santos
Aydin2021-A_Study_of_Cloud_Computing_Adoption_in_Universities_a	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	Universities can gain the flexibility and computing power of the CUC cloud for their basic and non-sensitive computing tasks, while they can keep their criti-cal applications and data safely behind a university firewall via CUC. Each of the PUC and CUC environments that make up this hybrid cloud architecture has its own benefits and uses. By combining PUC and CUC into a single hybrid cloud, universi-ties can gain greater control over data safety, accessibility, Aydin 11 privacy, authenticity, and security for both their IT infrastruc-ture and their users' data, applications, and systems. The cloud users of the framework will be able to	Ivon Miranda Santos
Aydin2021-A_Study_of_Cloud_Computing_Adoption_in_Universities_a	MULTI-CLOUD ARCHITECTURE > Private cloud	The cloud users of the framework will be able to use both PUC and CUC services anytime from anywhere. As PUC is a private cloud and offers the most control over security parameters, the services/applications delivered in this struc-ture will be chosen by each university administration. By adopting PUC and CUC, universities will establish a pool of shared services and	Ivon Miranda Santos
Aydin2021-A_Study_of_Cloud_Computing_Adoption_in_Universities_a	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	In this study, literature studies focusing on cloud comput-ing in universities were reviewed based on the research ques-tions, and the position of universities in Turkey was determined. In the study, an abstract hybrid cloud framework that contains guidelines to overcome the major challenges identified was presented. Within this context, the existing conditions and problems in the use of the cloud service model in universities were tried to be identified and some	Ivon Miranda Santos
Aydin2021-A_Study_of_Cloud_Computing_Adoption_in_Universities_a	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	This can be interpreted as an indicator of the need for cloud comput-ing in universities. Therefore, based on this result, an abstract hybrid cloud framework was presented. The fact that the vast majority of IT departments are seeing soft-ware costs as the highest expenditure item of their budget suggests that SaaS cloud services	Ivon Miranda Santos
Aydin2021-A_Study_of_Cloud_Computing_Adoption_in_Universities_a	MULTI-CLOUD ARCHITECTURE > Private cloud	Behind the desire of universi-ties to benefit from cloud computing lies mainly their willingness to use their financial resources cost-effec-tively and efficiently. In the chi-square test done in the study, no significant dif-ference was found between the state and private universi-ties in terms of knowledge level related to cloud computing ($\chi2$ = 0.180). Also, no significant difference was found between the perceptions about operating ($\chi2$ = 0.349), electricity ($\chi2$ = 0.117), software ($\chi2$ =	Ivon Miranda Santos
Aydin2021-A_Study_of_Cloud_Computing_Adoption_in_Universities_a	MULTI-CLOUD ARCHITECTURE > Private cloud	The proposed model consists of two different cloud computing patterns, PUC and CUC. PUC is a private cloud to be structured and managed by each uni-versity. CUC is a community cloud that covers the informa-tion services of PUC cloud	Ivon Miranda Santos

Baby2015-Multicloud_architecture_for_augmenting_security_in_clo	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	As cloud computing service is a pay as you use service, it promises to reduce the initial capital investment as well as operational expenditures for hardware's and software's used in an organization [1]. Clouds can be classified based on the physical distance between the client and the cloud provider into public clouds, private clouds and hybrid clouds. If the cloud vendor is located far away from client it is termed as public cloud and if cloud vendor and client are in nearby premises it is termed as private cloud and if clients make use of both private and public clouds together are termed as hybrid clouds. There are three main service models for cloud	Ivon Miranda Santos
Baby2015-Multicloud_architecture_for_augmenting_security_in_clo	MULTI-CLOUD ARCHITECTURE > Private cloud	As cloud computing service is a pay as you use service, it promises to reduce the initial capital investment as well as operational expenditures for hardware's and software's used in an organization [1]. Clouds can be classified based on the physical distance between the client and the cloud provider into public clouds, private clouds and hybrid clouds. If the cloud vendor is located far away from client it is termed as public cloud and if cloud vendor and client are in nearby premises it is termed as private cloud and if clients make use of both private and public clouds together are termed as hybrid clouds. There are three main service models for cloud	Ivon Miranda Santos
Baby2015-Multicloud_architecture_for_augmenting_security_in_clo	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Many countries have strict regulation on security policies in case of storage of data; especially government data in clouds [3], even though there are service level agreements between cloud users and vendors, data once lost or mishandled cannot be compromised with any penalties or punishments, hence all this have given way to many measures to ensure the integrity and confidentiality of data stored in clouds. One huge discovery in this scenario was to make use of multiple clouds simultaneously for storage and processing; this is termed as Multicloud Architecture [1]. There are several approaches been proposed using this paradigm and each of	Ivon Miranda Santos
Baby2015-Multicloud_architecture_for_augmenting_security_in_clo	MULTI-CLOUD ARCHITECTURE > Multiple clouds	There is no technical means by which the user can be sure about the operation performed in a cloud is not tampered or compromised by an attacker [1]. To overcome this problem of data getting compromised one solution is executing same copies of data on multiple distinct clouds as shown in figure1 [1].The same tasks are performed on multiple clouds and their results are compared thereby the user can be assured on the	Ivon Miranda Santos
Baby2015-Multicloud_architecture_for_augmenting_security_in_clo	MULTI-CLOUD ARCHITECTURE > Multiple clouds	1. The main advantage here is, since multiple distinct clouds execute multiple copies of the same data the cloud user doesn't have to trust one cloud service provider completely. Fig.	Ivon Miranda Santos
Baby2015-Multicloud_architecture_for_augmenting_security_in_clo	MULTI-CLOUD ARCHITECTURE > Private cloud	3.Two approaches are common in this method, first method involves a trusted private cloud taking a small share of critical computation and un-trusted public cloud takes most of the computational load [3]. The second method distributes computation among several un-trusted public clouds with the assumption that	Ivon Miranda Santos
Baby2015-Multicloud_architecture_for_augmenting_security_in_clo	MULTI-CLOUD ARCHITECTURE > Private cloud	Block Level Diagram of Homomorphic Encryption Small trusted private clouds manage the keys and perform the encryption and decryption and massive computations on encrypted data are done by the un-trusted public clouds. A fully homomorphic encryption scheme allows for both additive and multiplicative operations while a partial homomorphic encryption supports either	Ivon Miranda Santos

Bainomugisha2022-Crane_cloud_A_resilient_multicloud_service_abs	MULTI-CLOUD ARCHITECTURE > Multiple clouds	In this paper, we discuss key challenges for developing for and accessing cloud services in resource constrained settings, namely, (1) Frequent Internet partitions and bandwidth constraints, (2) Data jurisdiction restrictions, (3) Vendor lock-in, and (4) Poor quality of service. Inspired by these challenges, we propose a set of important design considerations and properties for a resilient multi-cloud service layer, that includes: (1) Containerization and orchestration of applications, (2) Application placement and replication, (3) Portability and multi-cloud migration, (4) Resilience to network partitions and bandwidth constraints, (5) Automated service discovery and load balancing, (6) Localized image registry, and (7) Support for platform monitoring and management. We present an implementation and validation case study, Crane Cloud, an open source multi-cloud service abstraction layer built on-top of Kubernetes that is designed with inherent support for resilience to network partitions, microservice orchestration (deployment, scaling and management of containerized applications), a localized image registry, support for migration of services between private and public clouds to avoid vendor lock-in issues and platform monitoring. We	Ivon Miranda Santos
Bainomugisha2022-Crane_cloud_A_resilient_multicloud_service_abs	MULTI-CLOUD ARCHITECTURE > Private cloud	(1) Containerization and orchestration of applications, (2) Application placement and replication, (3) Portability and multi-cloud migration, (4) Resilience to network partitions and bandwidth constraints, (5) Automated service discovery and load balancing, (6) Localized image registry, and (7) Support for platform monitoring and management. We present an implementation and validation case study, Crane Cloud, an open source multi-cloud service abstraction layer built on-top of Kubernetes that is designed with inherent support for resilience to network partitions, microservice orchestration (deployment, scaling and management of containerized applications), a localized image registry, support for migration of services between private and public clouds to avoid vendor lock-in issues and platform monitoring. We evaluate the performance and user experience of	Ivon Miranda Santos
Bainomugisha2022-Crane_cloud_A_resilient_multicloud_service_abs	MULTI-CLOUD ARCHITECTURE > Multiple clouds	1. Challenges and requirements for designing and operating a re-silient multi-cloud model for low resource settings. 2. The design considerations and properties for implementing a resilient multi-cloud and bare-metal application cluster such as application state, networking, loadbalancing, monitoring and service exposure for external user access. 3. A prototype implementation of a resilient multi-cloud and bare-metal application cluster (Crane Cloud) which is a subset instan-tiation of the design and implementation options available. This will provide researchers and practitioners with a	Ivon Miranda Santos
Bainomugisha2022-Crane_cloud_A_resilient_multicloud_service_abs	MULTI-CLOUD ARCHITECTURE > Multiple clouds	For instance, the data storage and management microservice needs to be enforced to remain within the boundaries of the country while the plant disease prediction service can run in a public cloud without restrictions and benefit from the rich machine learning libraries and tools. Such a setup would require a multi-cloud environment that spawns boundaries with support for data jurisdiction policies specific to a microservice and use case. The popularity of cloud computing solutions has introduced gaps in key processes of the data management cycle (collection, storage, analysis	Ivon Miranda Santos
Bainomugisha2022-Crane_cloud_A_resilient_multicloud_service_abs	MULTI-CLOUD ARCHITECTURE > Private cloud	New platforms and architectures such as Kubernetes (Burns et al., 2016) offer new possibilities to implement a vendor neutral layer on top of public and private clouds. However, the current offerings of managed Kubernetes layers assume migration of services in situations where there is stable connectivity and infrastructure and are not de-signed for data centers that may be	Ivon Miranda Santos

Bainomugisha2022-Crane_cloud_A_resilient_multicloud_service_abs	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Unfortunately this is not always the case for users located in regions where public cloud data centers are sparse. In the next section, we present the design options that need to be considered when developing a multi-cloud service abstraction layer to address the above challenges particularly in low resource settings. In the subsequent sections, we demonstrated the instantiation of the design	Ivon Miranda Santos
Bainomugisha2022-Crane_cloud_A_resilient_multicloud_service_abs	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Design considerations for a resilient multi-cloud service In this section, we present the design considerations and properties for a resilient multi-cloud service layer that is envisioned to meet the above requirements, namely, (1) Frequent Internet partitions and band-width constraints, (2) Data jurisdiction restrictions, (3) Vendor lock-in, and (4) Poor quality of service. In Section 4, we	Ivon Miranda Santos
Bainomugisha2022-Crane_cloud_A_resilient_multicloud_service_abs	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Sur-veys, pest identification, rapid plant disease diagnosis and predic-tion. A resilient multi-cloud service should provide an adaptive service replication approach that considers the following attributes:	Ivon Miranda Santos
Bainomugisha2022-Crane_cloud_A_resilient_multicloud_service_abs	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Location-aware systems should strive to achieve fairness in cost vis-a-vis performance (Shi et al., 2020) in multi-cloud setups. The design of a location aware system requires request tracking based on the Internet Protocol (IP) address, monitoring components, location sensing and prediction technologies and assorted geolocation APIs so that user requests take advantage of	Ivon Miranda Santos
Bainomugisha2022-Crane_cloud_A_resilient_multicloud_service_abs	MULTI-CLOUD ARCHITECTURE > Multiple clouds	DC 3: Portability and multi-cloud migration Portability in cloud computing can be defined as the ability for movement of applications, workloads, processes and data from one cloud environment to another with least disruption, whether manu-ally or automatically.	Ivon Miranda Santos
Bainomugisha2022-Crane_cloud_A_resilient_multicloud_service_abs	MULTI-CLOUD ARCHITECTURE > Multiple clouds	E. Bainomugisha and A. Mwotil Most of the research work geared to support portability across different cloud environments such as mOSAIC16 (Open-Source API and Platform for Multiple Clouds), Open Cloud Computing Interface (OCCI) have focused on abstraction layers and management tools and container-centric solutions. Containerization allows an application to be built once, placed inside a container image or series of images for a multi-service application and running it on any host operating system that supports the	Ivon Miranda Santos
Bainomugisha2022-Crane_cloud_A_resilient_multicloud_service_abs	MULTI-CLOUD ARCHITECTURE > Multiple clouds	, 2018). A stateful application is a data-driven application that requires persistent storage across a set of multi-cloud clusters with strict data consistency demands. To allow for this, there is a need for consensus algorithms to ensure that cluster states are globally consistent thus providing for dynamic leader election approach (the cloud cluster to act as the leader and handle writes), replication for cluster consistency and safety in ensuring that client requests are served with the correct results (Ongaro and Ousterhout, 2014) in	Ivon Miranda Santos
Bainomugisha2022-Crane_cloud_A_resilient_multicloud_service_abs	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Service discovery and load balancing In a multi-cloud environment, applications may need to be scaled up by increasing application instances for improved user experience or scaled down by destroying excess instances to limit compute costs. In certain scenarios, an application may need to be moved from one cloud provider to another and rescheduled on a	Ivon Miranda Santos
Bainomugisha2022-Crane_cloud_A_resilient_multicloud_service_abs	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Crane Cloud: an implementation of a resilient multi-cloud ser-vice layer This section presents Crane Cloud, a first-cut prototype instantia-tion of design properties and considerations for a multi-cloud service layer presented in Section 3 and summarized in Table 1. Motivated by the unique requirements for low-resource settings in Section 2.2, Crane Cloud is an open source project that attempts to encapsulate the intricacies of operating heterogeneous application clusters into a highly available unified platform for management and	Ivon Miranda Santos

Bainomugisha2022-Crane_cloud_A_resilient_multicloud_service_abs	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Architecture and overview Crane Cloud is an open source multi-cloud service layer designed to enable developers, organizations and researchers to set up reli-able cloud-services in low resource setting. The Crane Cloud software layer was conceived to address the key hurdles of operating a cloud-service platform in resource constrained environments	Ivon Miranda Santos
Bainomugisha2022-Crane_cloud_A_resilient_multicloud_service_abs	MULTI-CLOUD ARCHITECTURE > Private cloud	The Crane Cloud software layer was conceived to address the key hurdles of operating a cloud-service platform in resource constrained environments characterized by challenges identified in Section 2.2. Its main ingredients include resilience to network partitions, support for microservice orchestration, support for migration of services between private and public clouds to avoid vendor lock-in issues, seamless downtime and network traf-fic load distribution, monitoring metrics, and tools for transforming existing non-cloud compliant services into compliant cloud services. The multi-cloud service layer has five components (managed portal, authentication and authorization, monitoring and billing, local registry and the backend service)	Ivon Miranda Santos
Bainomugisha2022-Crane_cloud_A_resilient_multicloud_service_abs	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Its main ingredients include resilience to network partitions, support for microservice orchestration, support for migration of services between private and public clouds to avoid vendor lock-in issues, seamless downtime and network traf-fic load distribution, monitoring metrics, and tools for transforming existing non-cloud compliant services into compliant cloud services. The multi-cloud service layer has five components (managed portal, authentication and authorization, monitoring and billing, local registry and the backend service) purposely designed	Ivon Miranda Santos
Bainomugisha2022-Crane_cloud_A_resilient_multicloud_service_abs	MULTI-CLOUD ARCHITECTURE > Multiple clouds	4.1.1. Multi-cloud cluster support Crane Cloud enables harmonization of clusters from different cloud providers (public or private) and bare metal environments. It is de-signed to provide for easy migration, replication and loadbalancing of services across different clusters and cloud providers to ensure high availability and improve	Ivon Miranda Santos
Bainomugisha2022-Crane_cloud_A_resilient_multicloud_service_abs	MULTI-CLOUD ARCHITECTURE > Multiple clouds	4.1.2. Managed portal The managed portal provides an interface for access to the rest of the abstracted Crane Cloud multi-cloud components. Developers can deploy and access their application services, monitor resources and running services, manage users and access the	Ivon Miranda Santos
Bainomugisha2022-Crane_cloud_A_resilient_multicloud_service_abs	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Harbor35 perfectly fitted into the picture, providing an extensible API that the backend service would easily consume. Harbor delivers a consistent experience across multiple clouds and works best for environments that may not want to rely on public registries but rather a private one packaged as an add-on. Harbor additionally provides features such as access control on registry images, image vulnerability scanners, image storage and replication using a clustering mechanism. Crane Cloud a is multi-cloud service layer that can work with cloud providers in different regions and availability zones and a zonal scalable registry with a replication service	Ivon Miranda Santos
Bainomugisha2022-Crane_cloud_A_resilient_multicloud_service_abs	MULTI-CLOUD ARCHITECTURE > Hight availability	This enables organizations to work with data-driven and legacy applications while leveraging the portability, scalability and highly available features of containers. Traditionally, Kubernetes used to provide support for manual attachment of cloud-backed storage to applications limiting usage outside the cloud provider but cloud native	Ivon Miranda Santos
Bainomugisha2022-Crane_cloud_A_resilient_multicloud_service_abs	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Distributed, monolithic or streaming, OpenEBS allows deployment of storage technologies and optimizations appropriate to an application type using different storage engines. Additionally, OpenEBS is a multi-cloud storage solution that shares the same philosophy of Crane Cloud borderless computing.	Ivon Miranda Santos

Bainomugisha2022-Crane_cloud_A_resilient_multicloud_service_abs	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	IaaS (virtual machines) hybrid clouds using custom heuristics. Proper-ties such as high availability, scalability, fault-tolerance and monitoring are not discussed and the use of virtual machines may not be the most cost-effective approach to running application workloads. Filip et al. (2018) proposed a solution that considers a finite catalog of primitive microservices and designs a hybrid scheduling algorithm that matches tasks to resources based on task history and availability of resources. In addition to benefits of using a microservice architecture, the paper asserted that costs can further be reduced by placing data	Ivon Miranda Santos
Bainomugisha2022-Crane_cloud_A_resilient_multicloud_service_abs	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Guerrero et al. (2018) presented an optimization approach to reduce service cost, microservices repair time, and microservices network latency overhead in the orchestration process of containers in multi-cloud envi-ronments using the scale level of the microservices and their allocation in the virtual machines, the provider and virtual machine type selection and the number of virtual machines. Sousa et al. (2016) developed a framework for automated deployment of microservice applications in multi-cloud environments with containers. The application's multi-cloud requirements are defined and a systematic method for obtainingDevelopment Engineering 7 (2022)	Ivon Miranda Santos
Bainomugisha2022-Crane_cloud_A_resilient_multicloud_service_abs	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	(2018) presented an optimization approach to reduce service cost, microservices repair time, and microservices network latency overhead in the orchestration process of containers in multi-cloud envi-ronments using the scale level of the microservices and their allocation in the virtual machines, the provider and virtual machine type selection and the number of virtual machines.	Ivon Miranda Santos
Bainomugisha2022-Crane_cloud_A_resilient_multicloud_service_abs	MULTI-CLOUD ARCHITECTURE > Multiple clouds	As more established cloud providers such as Microsoft, Google, Oracle and Ama-zon move towards hosted cloud-native platforms such as Kubernetes for easier configuration and management, the vendor-lockin issues are expected to exacerbate especially with no plans of integration tools or APIs. In summary, there is no standardized solution for implementation and operation of a multi-cloud service layer but rather blocks that independently address the design considerations in Section 3.	Ivon Miranda Santos
Bainomugisha2022-Crane_cloud_A_resilient_multicloud_service_abs	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Conclusion and future work In this paper, we presented Crane Cloud - a resilient multi-cloud service layer for resource constrained environments using Kubernetes and assorted management tools. We highlighted the	Ivon Miranda Santos
Bainomugisha2022-Crane_cloud_A_resilient_multicloud_service_abs	MULTI-CLOUD ARCHITECTURE > Multiple clouds	of a resource constrained environment that includes poor Internet connectivity, frequent Internet partitions and data center power cuts ultimately resulting in poor user experience or even service unavail-ability. Based on these challenges, we enumerated a number of design considerations and properties for a resilient multi-cloud service layer that would form the foundation for Crane Cloud. From easing terminal complexities of operating a cloud service, desirable scaling, availabil-ity, migration and loadbalancing to platform monitoring, Crane Cloud	Ivon Miranda Santos
Belafia2021-From_monolithic_to_microservice_architecture_The_ca	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Such a diversity of services often means a diversity of services implementations, but also of deployments. B. Complexity of Deployment The question of microservices deployment and more gen-erally of cloud deployment is complex due to the multiple factors taken into account in addition to the response time [23]. Elements such as availability, free storage, CPU usage or memory usage are constraints that are imposed to	Ivon Miranda Santos

Brogi2014-Seaclouds_Seamless_adaptive_multi-cloud_management_of	MULTI-CLOUD ARCHITECTURE > Multiple clouds	How to deploy and manage, in an efficient and adaptive way, complex applications over multiple heterogeneous PaaS platforms is one of the problems that have emerged with the cloud revolution. The recently started EU research project SeaClouds aims at enabling a seamless adaptive multi-cloud management of complex applications by supporting the distribution, monitoring and migration of application modules over multiple heterogeneous PaaS platforms. In this paper, after presenting context, motivations	Ivon Miranda Santos
Brogi2014-Seaclouds_Seamless_adaptive_multi-cloud_management_of	MULTI-CLOUD ARCHITECTURE > Private cloud	Due to its prospective benefits and potential, cloud computing is a hot research area. Many private and public clouds have emerged during the last years, offering a range of different services at SaaS, PaaS and IaaS levels aimed at matching different user requirements. To take full benefit of the flexibility provided by the cloud, modules of a complex application should be deployed on multiple clouds depending on their	Ivon Miranda Santos
Brogi2014-Seaclouds_Seamless_adaptive_multi-cloud_management_of	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Many private and public clouds have emerged during the last years, offering a range of different services at SaaS, PaaS and IaaS levels aimed at matching different user requirements. To take full benefit of the flexibility provided by the cloud, modules of a complex application should be deployed on multiple clouds depending on their characteristics and strong points. Current cloud technologies suffer from a lack of standardization, with different providers offering	Ivon Miranda Santos
Brogi2014-Seaclouds_Seamless_adaptive_multi-cloud_management_of	MULTI-CLOUD ARCHITECTURE > Multiple clouds	applications from one platform to another [3]. Since migrating a single applica-tion is a cumbersome and manual process, the deployment, management and reconfiguration of complex applications over multiple clouds is even harder. There is a need for integrating multiple heterogeneous clouds and to solve the problem of distributing services over several providers [4]. Thus, in a scenario where a complex application is distributed on different cloud service providers, a solution is needed in order to manage and	Ivon Miranda Santos
Brogi2014-Seaclouds_Seamless_adaptive_multi-cloud_management_of	MULTI-CLOUD ARCHITECTURE > Multiple clouds	, A → γ, B → γ, C → δ). This implies that, to manage multi-cloud applications, the developer must have knowledge of the different employed PaaS platforms and has to continuously monitor the application. This is a costly and cumbersome process and it would be much more efficient to have some framework doing all the work automatically. In this paper, we discuss the ongoing project SeaClouds (Seamless adaptive multi-cloud management of service-based applications) which focuses on the problem of deploying and managing complex multi-component application over heterogeneous clouds in an efficient and adaptive way. SeaClouds works towards giving organizations	Ivon Miranda Santos
Brogi2014-Seaclouds_Seamless_adaptive_multi-cloud_management_of	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Applications will be dynamically reconfigured by changing the orchestration of the services when the monitoring detects that such properties are not respected. So, SeaClouds' main objective is the development of a novel platform which per-forms a seamless adaptive multi-cloud management of service-based applications. More specifically:	Ivon Miranda Santos
Brogi2014-Seaclouds_Seamless_adaptive_multi-cloud_management_of	MULTI-CLOUD ARCHITECTURE > Multiple clouds	SeaClouds aims at providing the assisted design, synthesis, and simulation of service orchestrations on cloud providers, distributing mod-ules from a cloud-based application over multiple and heterogeneous cloud offerings. O2) The monitoring and run-time reconfiguration operations of services dis-tributed over multiple heterogeneous cloud providers. Monitoring will be in charge of detecting the need of redistributing	Ivon Miranda Santos
Brogi2014-Seaclouds_Seamless_adaptive_multi-cloud_management_of	MULTI-CLOUD ARCHITECTURE > Multiple clouds	The latter two challenges (addressed by O2 and O3) are discussed in the following sections. 2.2 Monitoring of multi-cloud services The ongoing EU FP7 Cloud4SOA project (http:/	Ivon Miranda Santos
Brogi2014-Seaclouds_Seamless_adaptive_multi-cloud_management_of	MULTI-CLOUD ARCHITECTURE > Private cloud	//www.rightscale.com) sup-ports monitoring several public (e.g. Amazon Web Services, Rackspace) and private IaaS clouds (e.g.	Ivon Miranda Santos

Brogi2014-Seaclouds_Seamless_adaptive_multi-cloud_management_of	MULTI-CLOUD ARCHITECTURE > Multiple clouds	On the other hand, it forces providers to invest quite some resources in order to implement the monitoring.Challenges in monitoring of services on multiple clouds. In order to address O2, SeaClouds' monitoring will use and enhance existing monitoring functionalities for the PaaS and IaaS levels.	Ivon Miranda Santos
Brogi2014-Seaclouds_Seamless_adaptive_multi-cloud_management_of	MULTI-CLOUD ARCHITECTURE > Multiple clouds	– Combining and aggregating the above mentioned data to highlight perfor-mance problems and their impact. 2.3 Unified management of multi-cloud	Ivon Miranda Santos
Brogi2014-Seaclouds_Seamless_adaptive_multi-cloud_management_of	MULTI-CLOUD ARCHITECTURE > Multiple clouds	The main aim of TOSCA is to enable the interoperable description of application and infrastructure cloud services, the relationships between parts of the service, and the operational behaviour of these services, independently from the cloud provider. By increasing service and application portability in a vendor-neutral ecosystem, TOSCA aims at enabling portable deployment to any compliant cloud, smoother migration of existing applications to the cloud, as well as dynamic, multi-cloud provider applications.	Ivon Miranda Santos
Brogi2014-Seaclouds_Seamless_adaptive_multi-cloud_management_of	MULTI-CLOUD ARCHITECTURE > Multiple clouds	On the other hand, SeaClouds will also focus on developing functionalities that are deliberately out of scope of TOSCA [13] to solve the issues about policies for the dynamic management of service orchestrations. Although current implementations of TOSCA and CAMP do not support the management of complex application over multiple clouds, SeaClouds will work towards building such	Ivon Miranda Santos
Brogi2014-Seaclouds_Seamless_adaptive_multi-cloud_management_of	MULTI-CLOUD ARCHITECTURE > Multiple clouds	The MODAClouds project (http://www.modaclouds.eu/) also aims at pro-viding quality assurance during the application life-cycle, support migration from cloud to cloud when needed, and techniques for data mapping and synchroniza-tion among multiple clouds. In order	Ivon Miranda Santos
Brogi2014-Seaclouds_Seamless_adaptive_multi-cloud_management_of	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Figure 2 shows the cloud architecture situation currently before SeaClouds (top), and after SeaClouds (bottom). Without SeaClouds, services can only be deployed, managed and monitored on multiple clouds as standalone applications, and not as part of a composite application. This has the consequence that there is no support for synchronized deployment and unified monitoring, which implies that QoS of the entire application is	Ivon Miranda Santos
Brogi2014-Seaclouds_Seamless_adaptive_multi-cloud_management_of	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Management and monitoring of underlying providers. Using standardized and unified metrics and automated auditing, properties over application and services can be ensured (on multiple clouds in a unified and	Ivon Miranda Santos
Brogi2014-Seaclouds_Seamless_adaptive_multi-cloud_management_of	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Increased availability and higher security. The usage of formal models to support the management of service-based applications over multi-clouds environments gives more flexibility to reconfigure the distribution as a SLA violation occurs.	Ivon Miranda Santos

Brogi2014-Seaclouds_Seamless_adaptive_multi-cloud_management_of	MULTI-CLOUD ARCHITECTURE > Multiple clouds	The arrow's coding in Figure 3 is the following: normal and dashed lines are the inputs and outputs to/from the components, respectively; dashed-dotted lines refer to internal executions between components; and dotted lines are the connection between the components and the corresponding APIs. The Planner module will implement SeaClouds planning policy to orchestrate the multi-cloud deployment of the application modules. The Planner will take the input data provided by the SeaClouds users, which will specify which are the application modules to be deployed on multiple clouds, as well as the desired QoS properties for the SLA of the whole application and/or the desired QoS properties and technology requirements needed for individual application modules. The Planner will exploit the Discovery API to discover the capabilities and add-ons featured by available clouds, and it will generate as output an orchestration specification of the application modules over the chosen clouds. The Controller module will implement the multi-cloud deployment of the application modules and SeaClouds monitoring policy. In particular, the Multi-Cloud Deployer component will input the orchestration specification generated by the Planner, and it will deploy (by exploiting the Multi-Cloud Deployment API) the application modules on the specified clouds. The Monitor component of the Controller will be in charge of monitoring (by exploiting the Monitoring	Ivon Miranda Santos
Brogi2014-Seaclouds_Seamless_adaptive_multi-cloud_management_of	MULTI-CLOUD ARCHITECTURE > Multiple clouds	, application modules, or QoS properties and technology requirements). The GUI will also contain a Dashboard component to provide users with a friendly management and visualization of the state of the multi-cloud deployed applications, by providing a unified access to the Discovery, Deployment and Monitoring APIs (Unified Management API). As regards the alignment and promotion of SeaClouds with standards, solu-tions, libraries, or projects, the figure shows (on the right side) the	Ivon Miranda Santos
Brogi2014-Seaclouds_Seamless_adaptive_multi-cloud_management_of	MULTI-CLOUD ARCHITECTURE > Multiple clouds	, Brooklyn). To sum up, SeaClouds platform will provide a set of services, components, and /modules which ease the design and implementation of service orchestra-tors to perform a seamless adaptive multi-cloud management of service-based applications, with added-value, which can be deployed, monitored, dynamically migrated, elastically scaled and distributed among several different PaaSs. But also the idea behind SeaClouds is to look for the non-dependence with the SeaClouds platform, so the applications deployment with SeaClouds will not require SeaClouds services throughout their entire life cycle, and thus will be inherently independent both from their underlying	Ivon Miranda Santos
Brogi2014-Seaclouds_Seamless_adaptive_multi-cloud_management_of	MULTI-CLOUD ARCHITECTURE > Multiple clouds	This means that once the SeaClouds components have helped the user to the decision of distributing and deploying the modules of his/her application, that application can run without using SeaClouds services. Then, apart from the regular way of working of SeaClouds, previously described, it may also offer the user the possibility of (i) simply getting a plan from SeaClouds using the SeaClouds Planner module (without letting SeaClouds performing the deployment), or of (ii) going ahead without SeaClouds after the first deployment, in which case the Multi-Cloud Deployer simply performs the deployment, (without triggering the Monitoring	Ivon Miranda Santos
Brogi2014-Seaclouds_Seamless_adaptive_multi-cloud_management_of	MULTI-CLOUD ARCHITECTURE > Multiple clouds	– Unified management API for clouds. SeaClouds facilitates the access and the administration of both public and private cloud providers providing multi-cloud management tools as well as offering cloud providers and consumers a REST-based approach to cloud-based	Ivon Miranda Santos

Brogi2014-Seaclouds_Seamless_adaptive_multi-cloud_management_of	MULTI-CLOUD ARCHITECTURE > Private cloud	– Unified management API for clouds. SeaClouds facilitates the access and the administration of both public and private cloud providers providing multi-cloud management tools as well as offering cloud providers and consumers a REST-based approach to cloud-based	Ivon Miranda Santos
Brogi2015-Adaptive_management_of_applications_across_multiple_c	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Abstract How to deploy and manage, in an efficient and adaptive way, complex applications across multiple heterogeneous cloud platforms is one of the problems that have emerged with the cloud revolution. In this paper we present context, motivations and objectives of the EU research project SeaClouds, which aims at enabling a seamless adaptive multi-cloud management of complex applications by supporting the distribution, monitoring and migration of application modules over multiple heterogeneous cloud platforms. After positioning SeaClouds with respect to related cloud initiatives, we present the SeaClouds architecture and discuss some of its aspect, such as the use of the OASIS standard	Ivon Miranda Santos
Brogi2015-Adaptive_management_of_applications_across_multiple_c	MULTI-CLOUD ARCHITECTURE > Private cloud	Cloud computing is a model for enabling convenient and on-demand network access to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort or service provider interaction [1]. The cloud assists to reduce time-to-market and provides on-demand scalability at a low cost for the users. Due to its prospective benefits and potential, cloud computing is a hot research area. Many private and public clouds have emerged during the last years, offering a range of different services at SaaS, PaaS and IaaS levels aimed at matching different user requirements. To take full benefit of the flexibility provided by different clouds that offer different services, the modules of a complex application	Ivon Miranda Santos
Brogi2015-Adaptive_management_of_applications_across_multiple_c	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Many private and public clouds have emerged during the last years, offering a range of different services at SaaS, PaaS and IaaS levels aimed at matching different user requirements. To take full benefit of the flexibility provided by different clouds that offer different services, the modules of a complex application should be deployed on multiple clouds depending on their characteristics and strong points.	Ivon Miranda Santos
Brogi2015-Adaptive_management_of_applications_across_multiple_c	MULTI-CLOUD ARCHITECTURE > Multiple clouds	As a result, cloud developers are often locked in a specific platform environment because it is practically unfeasible for them, due to high complexity and cost, to move their applications from one platform to another [3]. Since migrating a single application is a cumbersome and manual process, the deployment, management and reconfiguration of complex applications over multiple clouds is even harder. To overcome the vendor lock-in problem, various standardisation efforts are currently ongoing, such as OASIS Cloud Application Management for Platforms (CAMP, [4]), DMTF Cloud Infrastructure Management Interface (CIMI, [5]), Virtualization Management (VMAN, [6]), or OASIS Topology	Ivon Miranda Santos
Brogi2015-Adaptive_management_of_applications_across_multiple_c	MULTI-CLOUD ARCHITECTURE > Private cloud	, Dell,1 BMC,2 Abiquo,3) are currently commercialising tools for the provisioning, management and automation of applications in leading public and private clouds. A promising perspective, opened by the availability of different cloud providers, is the possibility of distributing	Ivon Miranda Santos
Brogi2015-Adaptive_management_of_applications_across_multiple_c	MULTI-CLOUD ARCHITECTURE > Multiple clouds	) are currently commercialising tools for the provisioning, management and automation of applications in leading public and private clouds. A promising perspective, opened by the availability of different cloud providers, is the possibility of distributing cloud applications over multiple heterogeneous clouds. Indeed, as pointed out by [8], cloud adoption will be hampered if there will be no suitable way of managing data and applications across multiple clouds. In a scenario where a complex application is distributed on different cloud service providers, a solution is needed in order to manage and	Ivon Miranda Santos

Brogi2015-Adaptive_management_of_applications_across_multiple_c	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Once the distribution has been decided, the solution should support operations such as managing the relationships between the different modules, maintaining all the specified properties and requirements, and monitoring and reconfiguring the distribution in case any problem occurs during operation. In this paper, we present the ongoing project SeaClouds (Seamless adaptive multi-cloud management of service-based applications) which focuses on the problem of deploying and managing complex multi-component applications over heterogeneous clouds in an efficient and	Ivon Miranda Santos
Brogi2015-Adaptive_management_of_applications_across_multiple_c	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Applications will be dynamically reconfigured by changing the orchestration of the services they use when the monitoring will detect that such properties are not expected. So, SeaClouds' main objective is the development of a novel platform which performs a seamless adaptive multi-cloud management of service-based applications. More	Ivon Miranda Santos
Brogi2015-Adaptive_management_of_applications_across_multiple_c	MULTI-CLOUD ARCHITECTURE > Multiple clouds	O1) Orchestration and adaptation of services distributed over different cloud providers. SeaClouds aims at providing the assisted design, synthesis, and simulation of service orchestrations on cloud providers, distributing modules from a cloud-based application over multiple and heterogeneous cloud offerings. O2) Monitoring and run-time reconfiguration	Ivon Miranda Santos
Brogi2015-Adaptive_management_of_applications_across_multiple_c	MULTI-CLOUD ARCHITECTURE > Multiple clouds	The rest of the paper is organized as follows. Section 2 will introduce a motivating example to illustrate the problems occurring when deploying an application on multiple cloud providers. Section 3 will position SeaClouds with respect to current cloud initiatives and single out the main	Ivon Miranda Santos
Brogi2015-Adaptive_management_of_applications_across_multiple_c	MULTI-CLOUD ARCHITECTURE > Multiple clouds	In order to motivate our proposal, we introduce an example where a multi-component application is going to be deployed on (potentially) different cloud providers, according to a number of requirements on each of the modules composing the application. After the (multi-cloud) deployment is performed, and components are being executed in different cloud platforms, a monitoring process is in charge of detecting possible requirements violations, which could eventually trigger a reconfiguration. Figure 1 shows the architecture of an online retailing application	Ivon Miranda Santos
Brogi2015-Adaptive_management_of_applications_across_multiple_c	MULTI-CLOUD ARCHITECTURE > Multiple clouds	The latter two challenges (addressed by O2 and O3) are discussed further in the following sections. 3.2 Monitoring of multi-cloud services	Ivon Miranda Santos
Brogi2015-Adaptive_management_of_applications_across_multiple_c	MULTI-CLOUD ARCHITECTURE > Private cloud	//www.rightscale.com) supports monitoring several public (e.g. Amazon Web Services, Rackspace) and private IaaS clouds (e.g.	Ivon Miranda Santos
Brogi2015-Adaptive_management_of_applications_across_multiple_c	MULTI-CLOUD ARCHITECTURE > Multiple clouds	• Combining and aggregating the above mentioned data to highlight performance problems and their impact. 3.3 Unified management of multi-cloud	Ivon Miranda Santos
Brogi2015-Adaptive_management_of_applications_across_multiple_c	MULTI-CLOUD ARCHITECTURE > Multiple clouds	The main aim of TOSCA is to enable the interoperable description of application and infrastructure cloud services, the relationships between parts of the service, and the operational behaviour of these services, independently from the cloud provider [17]. By increasing service and application portability in a vendor-neutral ecosystem, TOSCA aims at enabling portable deployment to any compliant cloud, smoother migration of existing applications to the cloud, as well as dynamic, multi-cloud provider applications.	Ivon Miranda Santos
Brogi2015-Adaptive_management_of_applications_across_multiple_c	MULTI-CLOUD ARCHITECTURE > Multiple clouds	In doing so, SeaClouds might actively contribute to the standardization effort of TOSCA, by contributing review proposals that will emerge while trying to devise a TOSCA-compliant instances of the SeaClouds service orchestration model. Although current implementations of TOSCA and CAMP do not support the management of complex application over multiple clouds, SeaClouds will work towards building	Ivon Miranda Santos

Brogi2015-Adaptive_management_of_applications_across_multiple_c	MULTI-CLOUD ARCHITECTURE > Multiple clouds	The MODAClouds project (http://www.modaclouds.eu/) also aims at providing quality assurance during the application life-cycle, supporting migration from cloud to cloud when needed, and techniques for data mapping and synchronization among multiple clouds. To do so, MODAClouds requires software developers to adopt a Model-Driven Development approach. The monitoring platform developed in MODAClouds overcomes the limitation of the one offered by Cloud4SOA by gathering data of various kinds from components, containers and cloud resources distributed and replicated on multiple clouds. Although this approach has differently from SeaClouds, an impact on the code that needs to be deployed on the cloud, we are	Ivon Miranda Santos
Brogi2015-Adaptive_management_of_applications_across_multiple_c	MULTI-CLOUD ARCHITECTURE > Multiple clouds	One example is The Open Cloudware project (http://www.opencloudware.org/), which aims at building an open software engineering platform for the collaborative development of distributed applications to be deployed across multiple Cloud Infrastructures. In the last years, the term Open Cloud is becoming more popular, with projects like Cloudify, CloudStack, OpenStack, OpenShift,	Ivon Miranda Santos
Brogi2015-Adaptive_management_of_applications_across_multiple_c	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Figure 4 shows the cloud architecture situation currently before SeaClouds (top), and after SeaClouds (bottom). Without SeaClouds, services can only be deployed, managed and monitored across multiple clouds as standalone applications, and not as part of a composite application. This has the consequence that there is no support for synchronized deployment and unified monitoring, which implies that QoS of the	Ivon Miranda Santos
Brogi2015-Adaptive_management_of_applications_across_multiple_c	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Management and monitoring of underlying providers. Using standardized and unified metrics and automated auditing, properties over application and services can be ensured (on multiple clouds	Ivon Miranda Santos
Brogi2015-Adaptive_management_of_applications_across_multiple_c	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Increased availability and higher security. The usage of formal models to support the management of service-based applications over multi-clouds environments gives more flexibility to reconfigure the distribution as a SLA violation occurs.	Ivon Miranda Santos
Brogi2015-Adaptive_management_of_applications_across_multiple_c	MULTI-CLOUD ARCHITECTURE > Flexibility and choice	The usage of formal models to support the management of service-based applications over multi-clouds environments gives more flexibility to reconfigure	Ivon Miranda Santos
Brogi2015-Adaptive_management_of_applications_across_multiple_c	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Deployment plans generated because of replanning triggers are actually reconfiguration plans that include both undeployment and deployment operations. Coming back to the example of Section 2, Figure 6 shows a possible multi-cloud deployment of the different modules of the online retailing system as performed by SeaClouds. It applies the main concepts (modelling, planning and controlling) of the SeaClouds platform to achieve a seamless	Ivon Miranda Santos
Brogi2015-Adaptive_management_of_applications_across_multiple_c	MULTI-CLOUD ARCHITECTURE > Multiple clouds	There are some novel aspects for the proposed SeaClouds platform compared to the previous initiatives and efforts, and we would like to discuss some of them in the following. Multi-cloud orientation. As described previously, cloud computing has proven a major commercial success in the last years, with the appearance of many different vendors. What followed is a need for integrating multiple heterogeneous clouds and to solve the problem of distributing the services over several providers. In particular, the need of orchestration is more evident when complex applications move to cloud environments. With the current cloud technologies, services can only be deployed, managed and monitored on multiple clouds as stand-alone applications, and not as	Ivon Miranda Santos

Brogi2015-Adaptive_management_of_applications_across_multiple_c	MULTI-CLOUD ARCHITECTURE > Multiple clouds	complex application is distributed on different cloud service providers, a solution is needed to manage and orchestrate the distribution of modules in a sound and adaptive way. The SeaClouds platform is proposed to solve these problems and advance the field by supporting the orchestration and deployment to multiple clouds and management thereon, including resilience and migration of modules that compose cloud-based applications over multiple and technologically diverse clouds offerings. Based on the concept of cloud-based services orchestration, SeaClouds can realise the automated arrangement, coordination, deployment and management of multiple services	Ivon Miranda Santos
Brogi2015-Adaptive_management_of_applications_across_multiple_c	MULTI-CLOUD ARCHITECTURE > Multiple clouds	This scalability and flexibility can also help SeaClouds to avoid the risks resulting from the possible delay or even failure of CAMP and TOSCA standardisation activities, or the case that they are not widely accepted by the industry. In addition, by this separation, the planner and deployer components can be more easily reused, respectively, by other developers or initiatives that need them in multi-cloud scenarios. Use of	Ivon Miranda Santos
Brogi2015-Adaptive_management_of_applications_across_multiple_c	MULTI-CLOUD ARCHITECTURE > Multiple clouds	TOSCA enables the interoperable description of application and infrastructure cloud services, the relationships between parts of the services, and the operational behavior of these services, independently from the supplier creating the services, and any particular cloud provider or hosting technology. In line with the main goals of TOSCA [17], the use of this standard will ease automated deployment and management, and will enhance the portability and reusability of multi-cloud applications and their components. In addition, it will also allow the SeaClouds platform to generate TOSCA-compliant orchestration specifications, which will ease the matching and	Ivon Miranda Santos
Brogi2015-Adaptive_management_of_applications_across_multiple_c	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Its objective is to define standardised artefacts and APIs that a PaaS should offer to allow the management, building, administration, monitoring and patching of cloud-based applications. Obviously, the availability of CAMP results can simplify the development of the Discovery API, Monitoring API, and part of the Multi-Cloud	Ivon Miranda Santos
Brogi2015-Adaptive_management_of_applications_across_multiple_c	MULTI-CLOUD ARCHITECTURE > Multiple clouds	CLEI ELECTRONIC JOURNAL VOLUME 18 NUMBER 1 PAPER 1 APRIL 2015 extending and incorporating CAMP, we can cover all future CAMP-compliant providers or tools, allowing application developers to manage applications hosted on multiple clouds environments. Furthermore, by leveraging CAMP, SeaClouds will attract a significant user base (as this standard has a lot of interest but no reference implementations, so far) and advance the	Ivon Miranda Santos
Brogi2015-Adaptive_management_of_applications_across_multiple_c	MULTI-CLOUD ARCHITECTURE > Multiple clouds	In this paper we have presented our ongoing research in the SeaClouds project. The project aims at providing an open source framework to address the problem of deploying, managing and reconfiguring complex applications over multiple and heterogeneous clouds. The SeaClouds approach works towards achieving “Agility After Deployment” by tackling	Ivon Miranda Santos
Caceres2022-State-of-the-art_architectures_for_interoperability	MULTI-CLOUD ARCHITECTURE > Multiple clouds	The absence of common standards and interfaces makes it difficult to connect services of different clouds, migrate between them, or to distribute tasks across various providers. Extensive research in industry and academia has partially addressed the problem of vendor lock-in for cloud migration, however, no solutions are known to enable running applications in a dynamic multi-cloud infrastructure on a permanent basis. This paper describes state-of-the art of cloud infrastructure and considers the combined usage of multiple providers. It analyses approaches of multi-cloud usage that takes advantage of combining platform-specific features of different cloud providers.	Ivon Miranda Santos

Caceres2022-State-of-the-art_architectures_for_interoperability	MULTI-CLOUD ARCHITECTURE > Multiple clouds	This article describes emerging architectures of cloud infrastructure that give customers flexibility to use more services than a single cloud provider offers. Each architecture allows a certain degree of multi-cloud integrations, and each comes with own benefits and caveats. We will discuss limitations of emerging cloud architectures, and present existing solutions to	Ivon Miranda Santos
Caceres2022-State-of-the-art_architectures_for_interoperability	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	Previously, an application developer would select one cloud provider and make use of its integrated set of services and APIs, combining it with on-premises legacy systems, if business had	Ivon Miranda Santos
Caceres2022-State-of-the-art_architectures_for_interoperability	MULTI-CLOUD ARCHITECTURE > Multiple clouds	More and more often, application developers try to improve cloud infrastructure by using resources of heterogeneous cloud from multiple providers [3]. Due to the absence of standard interfaces between clouds, such an integration of multiple providers must be manually developed every time.	Ivon Miranda Santos
Caceres2022-State-of-the-art_architectures_for_interoperability	MULTI-CLOUD ARCHITECTURE > Multiple clouds	III. DEFINITION OF MULTI-CLOUD Multi-Cloud is characterised by "serial or simultaneous use of services from diverse providers to execute an application" [4]. In this article, we consider system multi-cloud if it is using two or more cloud computing services from any number of different cloud vendors in a single network architecture. This refers to the distribution of cloud assets, software,	Ivon Miranda Santos
Caceres2022-State-of-the-art_architectures_for_interoperability	MULTI-CLOUD ARCHITECTURE > Multiple clouds	On a lower level, heterogeneity means that different types of processors are combined to provide virtualized heterogeneous hardware within a single cloud provider. On a higher level, heterogeneity is meant in the context of multi-clouds by combining services from multiple vendors. Heterogeneity is therefore achieved by	Ivon Miranda Santos
Caceres2022-State-of-the-art_architectures_for_interoperability	MULTI-CLOUD ARCHITECTURE > Multiple clouds	There are several cloud architectures presented in scientific works, in particular in [3]. In this research, we will pay attention specifically to architectures which involve multi-cloud integration: Hybrid Cloud, Federated Cloud, Multi-Cloud, Ad-hoc Cloud and Micro Cloud. IV. EMERGING MULTI-CLOUD ARCHITECTURES Most common approaches for building modern fault-tolerant cloud infrastructures propose using redundant resources in multiple data centers and availability zones. As of today, alternative models which use multiple clouds are getting more popular [5]. In the current article, we will go over new multi-cloud architectures to showcase the need in changing the infrastructure of cloud systems. The usefulness of those was pointed	Ivon Miranda Santos
Caceres2022-State-of-the-art_architectures_for_interoperability	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	In this research, we will pay attention specifically to architectures which involve multi-cloud integration: Hybrid Cloud, Federated Cloud, Multi-Cloud, Ad-hoc Cloud and Micro Cloud. IV.	Ivon Miranda Santos
Caceres2022-State-of-the-art_architectures_for_interoperability	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	Following subsections will describe emerging architecture solutions of different layers. A. Hybrid Cloud The simplest form of multi-cloud architecture is a Hybrid Cloud, which represents a consolidation of private and public clouds or a composition of private and public IT infrastructure [7]. Hybrid clouds are especially useful for handling spiking resource demands known in advance, and for working with sensitive data [8]. Most common problems arising for running a hybrid cloud system are related to network, such as problems with latency and connection bandwidth. Also, to access a public cloud from a private cloud there is a need in more complicated network topologies [9]. Limited network capabilities may result in a less effective hybrid cloud setup. A dedicated network linking clouds could power more productive infrastructure, however, this brings an overhead of additional private resources management. Hybrid clouds are typically connected on level	Ivon Miranda Santos

Caceres2022-State-of-the-art_architectures_for_interoperability	MULTI-CLOUD ARCHITECTURE > Multiple clouds	A. Hybrid Cloud The simplest form of multi-cloud architecture is a Hybrid Cloud, which represents a consolidation of private and public clouds or a composition of private and public IT infrastructure [7].	Ivon Miranda Santos
Caceres2022-State-of-the-art_architectures_for_interoperability	MULTI-CLOUD ARCHITECTURE > Private cloud	A. Hybrid Cloud The simplest form of multi-cloud architecture is a Hybrid Cloud, which represents a consolidation of private and public clouds or a composition of private and public IT infrastructure [7].	Ivon Miranda Santos
Caceres2022-State-of-the-art_architectures_for_interoperability	MULTI-CLOUD ARCHITECTURE > Private cloud	Most common problems arising for running a hybrid cloud system are related to network, such as problems with latency and connection bandwidth. Also, to access a public cloud from a private cloud there is a need in more complicated network topologies [9]. Limited network capabilities may result in a less effective	Ivon Miranda Santos
Caceres2022-State-of-the-art_architectures_for_interoperability	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	Cloud federation enables end users to integrate segregated resources from different cloud systems [10]. The difference of this approach with Hybrid cloud is that Hybrid cloud is formed by different cloud models (private and public clouds), while Federated cloud is formed by different cloud models (private and public clouds) as well as the same clouds (joint private clouds). Both hybrid and federated cloud share the same concept. Federated cloud would	Ivon Miranda Santos
Caceres2022-State-of-the-art_architectures_for_interoperability	MULTI-CLOUD ARCHITECTURE > Private cloud	Cloud federation enables end users to integrate segregated resources from different cloud systems [10]. The difference of this approach with Hybrid cloud is that Hybrid cloud is formed by different cloud models (private and public clouds), while Federated cloud is formed by different cloud models (private and public clouds) as well as the same clouds (joint private	Ivon Miranda Santos
Caceres2022-State-of-the-art_architectures_for_interoperability	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	By using cloud provider APIs, organizations can adjust their cloud plan using different service vendors, according to their needs. Federated clouds are connected on same layers as Hybrid clouds, having same difficulty of networking between private and public clouds. In addition, since Federated cloud can connect multiple services, another limiting factor is a need to manually implement APIs of every service of	Ivon Miranda Santos
Caceres2022-State-of-the-art_architectures_for_interoperability	MULTI-CLOUD ARCHITECTURE > Private cloud	By using cloud provider APIs, organizations can adjust their cloud plan using different service vendors, according to their needs. Federated clouds are connected on same layers as Hybrid clouds, having same difficulty of networking between private and public clouds. In addition, since Federated cloud can connect multiple services, another limiting factor is a need to manually implement APIs of every service of	Ivon Miranda Santos
Caceres2022-State-of-the-art_architectures_for_interoperability	MULTI-CLOUD ARCHITECTURE > Multiple clouds	However, even assuming that such an infrastructure would be limited and unreliable, it could be used in together with existing data centers to improve connectivity. V. CHALLENGES OF MULTI-CLOUD INTEROPERABILITY After we presented an overview of most common architectures that involve multi-cloud integrations, we can summarize their common problems from the interoperability point of view. For a more focused review, the challenges will be split into organizational and technical.	Ivon Miranda Santos
Caceres2022-State-of-the-art_architectures_for_interoperability	MULTI-CLOUD ARCHITECTURE > Multiple clouds	A. Organizational problems Even successful cases of multi-cloud deployments in the industry have hit multiple limitations along the way as they try to integrate diverse platforms into a single, secure stack. According to the Forbes survey [19], respondents in the study pointed following challenges related to multi-cloud integration:	Ivon Miranda Santos

Caceres2022-State-of-the-art_architectures_for_interoperability	MULTI-CLOUD ARCHITECTURE > Multiple clouds	From the perspective of technology, following limiting factors can be considered: • Missing API standards: common APIs to run multi-cloud systems need to expect different kinds of resources provided by different clouds. It is a complicated issue since new resources are frequently added to the cloud marketplace, while there are no UDDI-like catalogues which report all resources available for usage. • Different abstractions: all common abstractions, which includes storage and network architectures would vary across cloud providers, which makes the use of multi-cloud a specific task for each application rather than using a generic platform or service. • Different billing: models for user billing differ significantly across cloud providers, making it close to impossible to dynamically estimate cost of the same task running on one cloud or another. These factors result in big programming efforts required every time a multi-cloud application is	Ivon Miranda Santos
Caceres2022-State-of-the-art_architectures_for_interoperability	MULTI-CLOUD ARCHITECTURE > Private cloud	However, there are products available that offer limited integration on IaaS level, like OpenStack, OpenNebula and Nimbus. OpenStack is a collection of open-source software packages designed for building public and private clouds, implemented as a set of Python services that communicate with each other via message queue and database. OpenStack implements two Cloud APIs: the Amazon Elastic Compute Cloud (EC2) API, and its own	Ivon Miranda Santos
Caceres2022-State-of-the-art_architectures_for_interoperability	MULTI-CLOUD ARCHITECTURE > Private cloud	OpenNebula is a similar open-source project, aiming to a greater level of centralization and customizability. Specifically, the idea of OpenNebula is a pure private cloud, 707	Ivon Miranda Santos
Caceres2022-State-of-the-art_architectures_for_interoperability	MULTI-CLOUD ARCHITECTURE > Multiple clouds	CONCLUSION We have reviewed modern cloud architectures involving more than one cloud and analyzed their up- and downsides in terms of multi-cloud integration possibilities. The main problem discovered was a lack of standards that would enable automated discovery and integration of	Ivon Miranda Santos
Caceres2022-State-of-the-art_architectures_for_interoperability	MULTI-CLOUD ARCHITECTURE > Multiple clouds	The article has also reviewed integration solutions available on IaaS level, such as OpenStack. While partially covering management of multi-cloud virtual machines, the integration only covers lower levels of the cloud stack, while most of new services reside on higher levels. Statistics proves that the vast majority of cloud integrations in the industry is still developed	Ivon Miranda Santos
Caceres2022-State-of-the-art_architectures_for_interoperability	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Application and Data levels. The integration should be accomplished by using a single integration protocol - HTTP APIs, and while implementation details would still often differ and require manual implementation, common parts can be formulated in domain-specific ontology models and extracted into a set of patterns, reusable by developers of multi-cloud systems. This idea also has downsides, such as still comparably high amount of manual work, lack of out-of-the-box platform-specific authentication	Ivon Miranda Santos
daSilva2013-From_the_desktop_to_the_multi-clouds_The_case_of_mo	MULTI-CLOUD ARCHITECTURE > Multiple clouds	This server controls the provisioning of other services and allows our clients to manage their services independently. We hope this is going to allow SOFTEAM to de-couple the runtime aspects of multi-cloud applications from the services that need to take profit from them. This paper is organized as follows.	Ivon Miranda Santos
daSilva2013-From_the_desktop_to_the_multi-clouds_The_case_of_mo	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Collaboration in the TeamWork Manager C. MODAClouds: A Model-driven Approach for the Design and Execution of Applications on Multiple Clouds	Ivon Miranda Santos
daSilva2013-From_the_desktop_to_the_multi-clouds_The_case_of_mo	MULTI-CLOUD ARCHITECTURE > Multiple clouds	ModelioSaaS. The main objective of MODAClouds is to offer a set of tools to the Application developers and Operators that help them in dealing with the challenges of designing and deploying cloud applications into multiple clouds. The main	Ivon Miranda Santos

daSilva2013-From_the_desktop_to_the_multi-clouds_The_case_of_mo	MULTI-CLOUD ARCHITECTURE > Private cloud	Our approach therefore relies on standard deployment artefacts and frameworks that can easily be moved from one provider to another. 3) Compatibility with public and private clouds We should be able to deploy the Project Management Server in public and private clouds to address specific client requirements. Rationale:	Ivon Miranda Santos
daSilva2013-From_the_desktop_to_the_multi-clouds_The_case_of_mo	MULTI-CLOUD ARCHITECTURE > Private cloud	Our current prototype is able to deploy and manage instances of the Team Work Manager on private and public clouds. Up to now, we support providers based on the Amazon AWS API only, i.e. the Amazon EC2 IaaS service and the Eucalyptus[3] private cloud. The Model Fragments and Collaboration services	Ivon Miranda Santos
daSilva2013-From_the_desktop_to_the_multi-clouds_The_case_of_mo	MULTI-CLOUD ARCHITECTURE > Private cloud	During this project we also intend to make its implementation cloud provider independent. Even though our current prototype uses the Amazon AWS API that allows it to run either on the public Amazon EC2 cloud and on our private Eucalyptus based cloud, it only supports one cloud at a time, namely, the one on which the Administration Service has been installed. Our plans include supporting migration and monitoring	Ivon Miranda Santos
daSilva2013-From_the_desktop_to_the_multi-clouds_The_case_of_mo	MULTI-CLOUD ARCHITECTURE > Multiple clouds	These questions do not necessarily represent functionalities we intend to implement in our offering, but challenges we, as designers, need to overcome. First of all, the Administration Service needs to be extended with the support monitoring QoS on multiple clouds. We intend to work on the monitoring resource status information such as	Ivon Miranda Santos
deCarvalho2018-Pacificclouds_A_flexible_microservices_based_arc	MULTI-CLOUD ARCHITECTURE > Multiple clouds	One such problem is the so-called vendor lock-in since different cloud providers offer peculiar and often incompatible services, which results in the automatic migration impossibility of the application between cloud providers. This issue becomes even more problematic when thinking of future applications composed of services or components hosted by different cloud providers in a multi-cloud environment. Dealing with ven-dor lock-in in multiple clouds requires addressing two important challenges: interoperability and portability. Some solutions have been proposed to deal with both problems, but most of them fail to provide flexibility. Therefore, we propose PacificClouds, a novel architecture based on microservices for addressing interopera-bility in a multi-cloud environment. PacificClouds differs	Ivon Miranda Santos
deCarvalho2018-Pacificclouds_A_flexible_microservices_based_arc	MULTI-CLOUD ARCHITECTURE > Vendor lock-in avoidance	Dealing with ven-dor lock-in in multiple clouds requires addressing two important challenges: interoperability and portability.	Ivon Miranda Santos
deCarvalho2018-Pacificclouds_A_flexible_microservices_based_arc	MULTI-CLOUD ARCHITECTURE > Multiple clouds	The research further points out that organizations' desire to adopt the cloud for their benefit is primarily related to capacity, scalability, and speed, but they consider urgent the vendor lock-in treatment. One method for treating vendor lock-in is the use of multiple clouds, although a small number of en-terprises adopt this approach, their popularity is in-creasing. One reason for the low adoption of multi-ple clouds is cloud providers interest lack to promote interoperability and portability (Grozev and Buyya, 2014). According to this context, (Opara-Martins et al., 2015) observes the need for dealing with in-teroperability and portability in order to mitigate the problem of vendor lock-in.	Ivon Miranda Santos
deCarvalho2018-Pacificclouds_A_flexible_microservices_based_arc	MULTI-CLOUD ARCHITECTURE > Vendor lock-in avoidance	In addition, (Opara-Martins et al., 2015) still notes that no approach exists that meets the needs of enter-prises. Some of the reasons there is no proposed so-lution widely adopted to mitigate vendor lock-in are: most solutions are inflexible; software architects must adopt specific technologies for the application deve-lopment with	Ivon Miranda Santos
deCarvalho2018-Pacificclouds_A_flexible_microservices_based_arc	MULTI-CLOUD ARCHITECTURE > Multiple clouds	For that matter, the applications are built with the focus on integration with the cloud model, to obtain full cloud advantages; it, also ensures other fe-atures labeled as IDEAL (Isolated state, Distribution, Elasticity, Automated management, Loose coupling). In this manner, the native cloud application can faci-litate the application deployment in multiple clouds, hence help treat	Ivon Miranda Santos

deCarvalho2018-Pacificclouds_A_flexible_microservices_based_arc	MULTI-CLOUD ARCHITECTURE > Multiple clouds	In Section 3, we describe, present challenges and propose a definition for microservices. In this work, we propose a novel architecture ba-sed on microservices to address interoperability for a multi-cloud environment, called PacificClouds, in or-der to mitigate vendor lock-in and aid to obtain full cloud advantages. PacificClouds promotes flexibility for user's decisions related to requirements and ap-plication architecture, and for choosing the clouds to execute each	Ivon Miranda Santos
deCarvalho2018-Pacificclouds_A_flexible_microservices_based_arc	MULTI-CLOUD ARCHITECTURE > Vendor lock-in avoidance	In this work, we propose a novel architecture ba-sed on microservices to address interoperability for a multi-cloud environment, called PacificClouds, in or-der to mitigate vendor lock-in	Ivon Miranda Santos
deCarvalho2018-Pacificclouds_A_flexible_microservices_based_arc	MULTI-CLOUD ARCHITECTURE > Multiple clouds	According to the context aforementioned, the con-tributions of this article are given below: • The proposition and description of PacificClouds, a novel architecture, which provides greater ease in the development of native cloud application, and more flexibility in the deployment and exe-cution of an application in multiple clouds envi-ronment because of microservice use.	Ivon Miranda Santos
deCarvalho2018-Pacificclouds_A_flexible_microservices_based_arc	MULTI-CLOUD ARCHITECTURE > Flexibility and choice	• The proposition and description of PacificClouds, a novel architecture, which provides greater ease in the development of native cloud application, and more flexibility in the deployment and exe-cution of an application in multiple clouds envi-ronment because of	Ivon Miranda Santos
deCarvalho2018-Pacificclouds_A_flexible_microservices_based_arc	MULTI-CLOUD ARCHITECTURE > Multiple clouds	In this work, we adopt the definitions used by (Pe-tcu, 2014b), who classifies different multiple cloud application scenarios as delivery models and presents three main proposals for these models. The first, cal-led multi-cloud, is a delivery model that does not in-clude a prior agreement among the cloud providers, a third party assumes the role of intermediary. In a cloud federation, the second delivery model exists as an established collaboration arrangement among cloud providers to share their resources. The third delivery model, called inter-cloud, can be on both a cloud federation and multi-cloud, but the scalable and opportunistic services must be dynamic, and inter-cloud must possess the cloud broker, which is an in-termediary actor in the relationship between the pro-vider and the consumer. The use of multiple clouds brings several advanta-ges, and through them, we can achieve the full bene-fits of cloud properties such as elasticity and pay-as-you-go (Mezg´ar and Rauschecker, 2014), (Silva et al., 2013). However, the multiple clouds bring several challenges, as well, e.g., interoperability and portabi-lity related to mitigating vendor lock-in. We consider portability the ability	Ivon Miranda Santos
deCarvalho2018-Pacificclouds_A_flexible_microservices_based_arc	MULTI-CLOUD ARCHITECTURE > Benefits of Multi-Cloud	The use of multiple clouds brings several advanta-ges, and through them, we can achieve the full bene-fits of cloud properties such as elasticity and pay-as-you-go (Mezg´ar and Rauschecker, 2014),	Ivon Miranda Santos
deCarvalho2018-Pacificclouds_A_flexible_microservices_based_arc	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Therefore, microservice is a cohesive, inde-pendent process interacting via messages, and micro-service architecture is a distributed application where all its modules are microservices. We propose a definition for microservices based on the definitions cited in this work, because we un-derstand that our definition of microservices shows the meaning of microservices in the context of multi-clouds and more specifically in a scenario which the application is distributed over multiple clouds. Definition (Microservices): are a set of autonomous, independent, self-contained	Ivon Miranda Santos
deCarvalho2018-Pacificclouds_A_flexible_microservices_based_arc	MULTI-CLOUD ARCHITECTURE > Multiple clouds	lock-in. PacificClouds is a novel architecture that addresses the interoperability of distributed applica-tion in multiple clouds via microservices. Thus, Pa-cificClouds intends to provide flexibility for the soft-ware architect both in making decisions related to ap-plication requirements and	Ivon Miranda Santos

deCarvalho2018-Pacificclouds_A_flexible_microservices_based_arc	MULTI-CLOUD ARCHITECTURE > Multiple clouds	4.2 PacificClouds Architecture According to the PacificClouds goals described in section 1, we adopt the multi-cloud delivery model, for it brings greater flexibility. In relation to porta-bility, we assume the three categories used	Ivon Miranda Santos
deCarvalho2018-Pacificclouds_A_flexible_microservices_based_arc	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Finally, associated with the end-user level, we adopted user-centric interoperability. PacificClouds intends to address interoperability in the multi-cloud that focuses on the user's per-spective through microservices and native cloud ap-plications. In this manner, it also addresses an impor-tant issue related to the adoption of cloud	Ivon Miranda Santos
deCarvalho2018-Pacificclouds_A_flexible_microservices_based_arc	MULTI-CLOUD ARCHITECTURE > Multiple clouds	The PacificClouds Core provides information, for the software architect via PacificClouds API, both about resources used by an application and about ap-plication and user's requirements. Adapter is the communication interface between the multiple available clouds and the PacificClouds Core. The adapter sends the capabilities and informa-tion about the cloud resources used by the application to PacificClouds Core. it also sends the	Ivon Miranda Santos
deCarvalho2018-Pacificclouds_A_flexible_microservices_based_arc	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Next, De-ployment Service identifies the cloud for each micro-service according to deploy plan via Microservice As-sociation Service (MAS); after, it deploys the micro-services via Microservice Deployment Service (MD-plS). We can observe that PacificClouds intends to ma-nage the deployment and execution process of the dis-tributed application in multiple clouds to better meet the needs of the application and consequently im-prove end-user satisfaction with the application per-formance. Thus, the PacificClouds will be able to help the software architecture in the process of de-CLOSER 2018 -	Ivon Miranda Santos
deCarvalho2018-Pacificclouds_A_flexible_microservices_based_arc	MULTI-CLOUD ARCHITECTURE > Multiple clouds	5 RELATED WORK In this section, we describe an overview of the six most relevant works related to PacificClouds in regars to treating the interoperability in multiple clouds, in which each of them proposes a different solution to mitigate vendor lock-in. Cloud4SOA introduces a broker-based architec-ture whose primary goal is to address semantic in-teroperability challenges at the PaaS layer, based on SOA architecture (Dandria et al., 2012). The mO-SAIC aims at offering access to heterogeneous re-sources from multiple clouds. Under a high-level perspective, an API and a PaaS compose the mO-SAIC, which PaaS allows us to deploy, configure and manage applications	Ivon Miranda Santos
deCarvalho2018-Pacificclouds_A_flexible_microservices_based_arc	MULTI-CLOUD ARCHITECTURE > Multiple clouds	2013). MODAClouds offers a set of techniques for deve-lopment and runtime operation management of mul-tiple clouds applications. It delivers an open-source IDE for the high-level design, cloud service selection, early prototyping, QoS assessments, semi-automatic code generation, and multiple cloud applications au-	Ivon Miranda Santos
deCarvalho2018-Pacificclouds_A_flexible_microservices_based_arc	MULTI-CLOUD ARCHITECTURE > Multiple clouds	, 2010). Automated Setup of Multi-Cloud Environments for Microservices Applications proposes an automa-ted approach for the selection and configuration of cloud providers for microservices based applications. But it does not deal directly with applications deploy-ment and does not consider costs and quality of ser-vice for optimizing the selection as these depend he-avily on application	Ivon Miranda Santos
deCarvalho2018-Pacificclouds_A_flexible_microservices_based_arc	MULTI-CLOUD ARCHITECTURE > Multiple clouds	In this section, we present an analysis of the works described in Section 5 and the PacificClouds. For this, we offer a summary of the features of all the soluti-ons described in this article, including PacificClouds, related to promoting interoperability in a multi-cloud environment. We consider 10 aspects described in this article, because through them we can	Ivon Miranda Santos
deCarvalho2018-Pacificclouds_A_flexible_microservices_based_arc	MULTI-CLOUD ARCHITECTURE > Multiple clouds	In Table 1, there is the only aspect that all soluti-ons promote the semantic interoperability. Some so-lutions use the semantic interoperability in the appli-cations portability, while others use it in the interope-rability between application modules distributed over multiple clouds, and it includes solutions that use it to treat vertical interoperability between service models. One of the characteristics described in Table 1 refers to	Ivon Miranda Santos

deCarvalho2018-Pacificclouds_A_flexible_microservices_based_arc	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Despite addressing the three levels, MODA-Clouds only addresses horizontal interoperability for cloud federation. ASMEMA does not address any of the vertical and horizontal interoperability levels for the multi-cloud delivery model. Two other solutions, Cloud4SOA and RASIC, address interoperability in only one of the service models.	Ivon Miranda Santos
deCarvalho2018-Pacificclouds_A_flexible_microservices_based_arc	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	Two other solutions, Cloud4SOA and RASIC, address interoperability in only one of the service models. Cloud4SOA addres-ses interoperability at the PaaS level; it does not ad-dress any vertical and horizontal interoperability le-vels, and it uses the hybrid delivery model, which is a cloud federation that has a private cloud and at least one public cloud (Petcu, 2014a). RASIC treats inter-operability in the IaaS service model for multi-	Ivon Miranda Santos
deCarvalho2018-Pacificclouds_A_flexible_microservices_based_arc	MULTI-CLOUD ARCHITECTURE > Private cloud	Two other solutions, Cloud4SOA and RASIC, address interoperability in only one of the service models. Cloud4SOA addres-ses interoperability at the PaaS level; it does not ad-dress any vertical and horizontal interoperability le-vels, and it uses the hybrid delivery model, which is a cloud federation that has a private cloud and at least one public cloud (Petcu, 2014a). RASIC treats inter-operability in the IaaS service model for multi-	Ivon Miranda Santos
deCarvalho2018-Pacificclouds_A_flexible_microservices_based_arc	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Cloud4SOA addres-ses interoperability at the PaaS level; it does not ad-dress any vertical and horizontal interoperability le-vels, and it uses the hybrid delivery model, which is a cloud federation that has a private cloud and at least one public cloud (Petcu, 2014a). RASIC treats inter-operability in the IaaS service model for multi-cloud	Ivon Miranda Santos
deCarvalho2018-Pacificclouds_A_flexible_microservices_based_arc	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Finally, mOSAIC, SeaClouds, and PacificClouds treat interoperability in the IaaS and PaaS service mo-dels. mOSAIC uses the hybrid delivery model; it de-als with vertical interoperability as it makes applica-tion portability. SeaClouds and PacificClouds address vertical and horizontal interoperability levels for the multi-cloud delivery model as well as promote appli-cation portability. RASIC, ASMEMA, SeaClouds, and Paci-ficClouds address interoperability for distributed applications in multiple clouds geographically dispersed, while the other solutions address only ap-plication portability between clouds. In relation to the background technologies in clouds, just Cloud4SOA and SeaClouds do not use clouds that have different background technologies, that is, all clouds involved in the portability or	Ivon Miranda Santos
deCarvalho2018-Pacificclouds_A_flexible_microservices_based_arc	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Therefore, Paci-ficClouds is the only proposed solution that promo-tes the decentralized governance of the applications, to the best of our knowledge, allowing the applica-tion modules to have a loosely coupled, in addition to generating less traffic in the network and therefore allowing greater flexibility. According to the analysis performed in this sub-section, we can observe that PacificClouds allows gre-ater flexibility regarding interoperability in a multi-cloud environment. Because of allowing an applica-tion to be distributed over several clouds according to the requirements of the application and the user re-gardless of the technology used,	Ivon Miranda Santos
deCarvalho2018-Pacificclouds_A_flexible_microservices_based_arc	MULTI-CLOUD ARCHITECTURE > Flexibility and choice	According to the analysis performed in this sub-section, we can observe that PacificClouds allows gre-ater flexibility regarding interoperability in a multi-cloud environment.	Ivon Miranda Santos
deCarvalho2018-Pacificclouds_A_flexible_microservices_based_arc	MULTI-CLOUD ARCHITECTURE > Multiple clouds	7 CONCLUSION We show in this work a novel architecture, called Pa-cificClouds, that supports the interoperability across multiple clouds, allowing the software architect to choose the application requirements and architecture with no need to worry about the application de-ployment in the clouds. The architecture also al-lows the use of several independent clouds and diffe-rent technologies	Ivon Miranda Santos
dePaula2016-A_systematic_literature_review_on_cloud_computing_a	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	The results in this systematic literature review can help the development of guidelines to support newcomers companies to adopt and migrate to the cloud, how the cost-benefit relationship can be evaluated as well as the selection of providers.	Ivon Miranda Santos

dePaula2016-A_systematic_literature_review_on_cl	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and	Cloud computing · Cloud migration · Provider selection · Cost-benefit relationship · Systematic	Ivon Miranda Santos
dePaula2016-A_systematic_literature_review_on_cloud_computing_a	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	However, the identification of opportunities for migration, the reasoning of an attractive cost-benefit relation-ship and the selection of service providers that best fit their needs are not trivial	Ivon Miranda Santos
dePaula2016-A_systematic_literature_review_on_cloud_computing_a	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	The selection of commercial cloud providers is a challenging task and depends on several variables and indicators.	Ivon Miranda Santos
dePaula2016-A_systematic_literature_review_on_cloud_computing_a	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	Studies have shown that successful migration to the cloud are usually driven by a set of criteria to select providers that best fit their needs	Ivon Miranda Santos
dePaula2016-A_systematic_literature_review_on_cl	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and	Moreover, companies should be able to select a provider according to their needs and profile.	Ivon Miranda Santos
dePaula2016-A_systematic_literature_review_on_cloud_computing_a	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	(i) the identification of strategies and issues that companies have considered to migrate to the cloud; (ii) factors that should be considered in the cost-benefits relationship while adopting and migrating to the cloud; (iii) and finally aspects related to the selection of cloud computing service	Ivon Miranda Santos
dePaula2016-A_systematic_literature_review_on_cloud_computing_a	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	These three services described above are deployed following four different models: (i) Public cloud is available from a third party service provider via web and is a very cost effective option to deploy IT solutions [20]; (ii) Private cloud is managed within an organization and is suitable for large enterprises (managed within the walls of the enterprises). Private clouds provide the advantages of public clouds, but still incur capital expenditures [20]; (iii) Community cloud is used and controlled by a group of enterprises, which have shared interests [20]; (iv) Hybrid cloud is a combination of public and private cloud [20]. This	Ivon Miranda Santos
dePaula2016-A_systematic_literature_review_on_cloud_computing_a	MULTI-CLOUD ARCHITECTURE > Private cloud	These three services described above are deployed following four different models: (i) Public cloud is available from a third party service provider via web and is a very cost effective option to deploy IT solutions [20]; (ii) Private cloud is managed within an organization and is suitable for large enterprises (managed within the walls of the enterprises). Private clouds provide the advantages of public clouds, but still incur capital expenditures [20]; (iii) Community cloud is used and controlled by a group of enterprises, which have shared interests [20]; (iv) Hybrid cloud is a combination of public and private cloud [20]. This	Ivon Miranda Santos
dePaula2016-A_systematic_literature_review_on_cloud_computing_a	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	For this end, the study present different approaches, techniques and tools to overcome diffi-culties and challenges in the context of CC. The scope of this review is specific to identify strategies that can help organizations to migrate and adopt CC, their perception of the cost-benefit relationship of this adoption and how com-panies can select service providers that best fit their	Ivon Miranda Santos
dePaula2016-A_systematic_literature_review_on_cloud_computing_a	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	(i) strategies to identify migration opportunities to the cloud, (ii) relevant fac-tors for the assessment of the cost-benefit of this adoption of cloud and finally (iii) the selection of providers according to	Ivon Miranda Santos
dePaula2016-A_systematic_literature_review_on_cl	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and	How companies select cloud computing service providers according to their needs and profile?	Ivon Miranda Santos
dePaula2016-A_systematic_literature_review_on_cloud_computing_a	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	The knowledge of successful strategies and problems raised by inappropriate selection of CC providers allow organizations to be more confident to identify providers that best fit their	Ivon Miranda Santos
dePaula2016-A_systematic_literature_review_on_cloud_computing_a	MULTI-CLOUD ARCHITECTURE > Private cloud	The [S11] summarized potential benefits and risks to migrate traditional appli-cations to the cloud using CloudFTP on Windows Azure along with the auto-scaling feature. [S18] discussed the motivation, requirements, feasibility of migrating CiteSeerX digital library to provide an IaaS model in a private cloud. In [S24] the authors combine legacy system migration solutions and virtualiza-tion technology with the application of cloudstack to build an enterprise private cloud platform. [S25] presents an overview of major requirements	Ivon Miranda Santos
dePaula2016-A_systematic_literature_review_on_cloud_computing_a	MULTI-CLOUD ARCHITECTURE > Private cloud	[S66] examine CC adoption preparation and reasons for non adoption among Small and Medium Enterprises (SMEs) in Ireland. [S71] proposed a design of a private IaaS Cloud adopted for a university IT infrastructure. The authors proposed two solutions to improve its security; especially the isolation of data in the IaaS Cloud, and the isolation of networks within	Ivon Miranda Santos

dePaula2016-A_systematic_literature_review_on_cloud_computing_a	MULTI-CLOUD ARCHITECTURE > Hight availability	S36] proposed the use of a real option model to help companies think and decide when to switch to cloud based on the expected benefits, uncertainties and the value a company puts on money. [S37] investigated different approaches to reduce both cost and task completion time of computations using Amazon EC2's spot instances for resource provisioning. In the case of [S38], the authors focused on the following factors: availability, portability, integration, migration236 A.C.M. de Paula and G.d.F. de	Ivon Miranda Santos
dePaula2016-A_systematic_literature_review_on_cl	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and	4.3 Selecting Cloud Computing Service Providers (RQ3)	Ivon Miranda Santos
dePaula2016-A_systematic_literature_review_on_cl	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and	How companies select cloud computing service providers according to their needs and profile?	Ivon Miranda Santos
dePaula2016-A_systematic_literature_review_on_cloud_computing_a	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	The goal was to select a cloud provider based on the suitabil-ity of the service provider to the relevant security and privacy requirements.	Ivon Miranda Santos
dePaula2016-A_systematic_literature_review_on_cloud_computing_a	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	Paper [S49] presented the FAGI model, whose goal was to identify the security controls needed by an orga-nization and guided the organization in the selection of a trusted service provider.	Ivon Miranda Santos
dePaula2016-A_systematic_literature_review_on_cloud_computing_a	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	This sys-tematic review provided evidences of strategies used by companies to identify opportunities to migrate and adopt cloud computing, how they assess the cost-benefit relationship and strategies behind the rationale to	Ivon Miranda Santos
dePaula2016-A_systematic_literature_review_on_cloud_computing_a	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	4, it is possible to conclude about the importance of the process to select the strategy to be adopted by a company (RQ1), the cost-benefit relation-ship (RQ2) and in the selection of	Ivon Miranda Santos
dePaula2016-A_systematic_literature_review_on_cloud_computing_a	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	One of the main contribution of this paper was also the discussion of a list of approaches published in the lit-erature that deal with the cost-benefit relationship and the rationale behind the selection of providers and their respective	Ivon Miranda Santos
Elgedawy2015-Sultan_A_composite_data_consistency_approach_for_s	MULTI-CLOUD ARCHITECTURE > Multiple clouds	, Software as a Service) services. Unfortunately, such SaaS multi-cloud deployment approach faces many technical obstacles such as clouds heterogeneity and ensur-ing data consistency across different clouds. Cloud heterogeneity could be easily resolved using service adapters, but ensuring data consistency remains a major obstacle, as existing approaches offer a trade-off	Ivon Miranda Santos
Elgedawy2015-Sultan_A_composite_data_consistency_approach_for_s	MULTI-CLOUD ARCHITECTURE > Multiple clouds	This approach limits the agility and evolution of business services, as it tightly couples them to the chosen data consistency approaches. To overcome such problem, this paper proposes SULTAN, a composite data consistency approach for SaaS multi-cloud deployment. It enables SaaS providers to dynamically define different data consistency requirements for the same SaaS	Ivon Miranda Santos
Elgedawy2015-Sultan_A_composite_data_consistency_approach_for_s	MULTI-CLOUD ARCHITECTURE > Multiple clouds	One approach for preventing such risk is to deploy business services on different clouds. SaaS multi-cloud deployment provides better performance and lower costs compared to the usage of a single cloud, as it provides better availability, responsiveness, and resources utilization [1]. However, SaaS multi-cloud deployment approach faces many technical chal-lenges such as cloud heterogeneity, ensuring data	Ivon Miranda Santos
Elgedawy2015-Sultan_A_composite_data_consistency_approach_for_s	MULTI-CLOUD ARCHITECTURE > Multiple clouds	As we can see every approach has its pros and cons, and requires different handling from the SaaS services. Currently SaaS multi-cloud deployment could be easily achieved by using service adapters to communicate with different storage services, and by choosing storage services that support one or more of the preferred data correctness approaches. Then design the SaaS service according to the	Ivon Miranda Santos
Elgedawy2015-Sultan_A_composite_data_consistency_approach_for_s	MULTI-CLOUD ARCHITECTURE > Multiple clouds	For example, the spanner system enables business service providers to choose from two options: a pessimistic option with bad performance during contention periods, or an optimistic option with a possibility of data inconsistency. We argue that such approach for realizing SaaS multi-cloud deployment is limiting and inflexible for the following reasons: • First, it tightly couples the SaaS service design	Ivon Miranda Santos

Elgedawy2015-Sultan_A_composite_data_consistency_approach_for_s	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Hence, we need to have different consistency requirements for different data items of the same SaaS service. To overcome these limitations, we propose SULTAN, a composite data consistency approach for SaaS multi-cloud deployment. It enables SaaS providers to have different consis-	Ivon Miranda Santos
Elgedawy2015-Sultan_A_composite_data_consistency_approach_for_s	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	SaaS service providers should select a consistency level for each of their services' data objects, by defining a Data Consistency Plan (DCP) for each SaaS service, then submit the	Ivon Miranda Santos
Elgedawy2015-Sultan_A_composite_data_consistency_approach_for_s	MULTI-CLOUD ARCHITECTURE > Multiple clouds	From results, we can see that the strong-escrow consistency is the best option for SaaS services, if they can tolerate data unfreshness, as it provides the best performance with data correctness assurance. Otherwise, a composite data consistency approach should be adopted in SaaS multi-cloud deployments to ensure the correctness of the crucial data. For consistency requirements change evaluation, we con-ducted another set of experiments to measure the time taken (in msec) by SULTAN to	Ivon Miranda Santos
Elgedawy2015-Sultan_A_composite_data_consistency_approach_for_s	MULTI-CLOUD ARCHITECTURE > Multiple clouds	CONCLUSION This paper proposed SULTAN, a composite data consis-tency approach for SaaS multi-cloud deployment. It enables SaaS providers to dynamically define different data consis-tency requirements for the same SaaS service at run-time; by defining different Data Consistency Plans (DCPs), which are executed by coordinating data requests among different cloud	Ivon Miranda Santos
Elmroth2011-Self-management_challenges_for_multi-cloud_architec	MULTI-CLOUD ARCHITECTURE > Multiple clouds	In par-ticular, following Ferrer et.al. [14], we address bursted private clouds (a service provider having a private cloud infrastructured with possibility to expand using external clouds), federated clouds (infrastructure providers using partners to en-sure the capacity needed to serve the service providers that are their customers), and multi-clouds (service providers working directly with multiple external in-frastructure providers). The management challenges in focus are not specific to any of the scenarios, but are rather derived from a single cloud deployment ab-	Ivon Miranda Santos
Elmroth2011-Self-management_challenges_for_multi-cloud_architec	MULTI-CLOUD ARCHITECTURE > Private cloud	In par-ticular, following Ferrer et.al. [14], we address bursted private clouds (a service provider having a private cloud infrastructured with possibility to expand using external clouds), federated clouds (infrastructure providers using partners to en-sure the capacity needed to serve the service providers that are their customers), and multi-clouds (service providers working directly with multiple external in-frastructure providers). The management challenges in focus are not specific to any of the scenarios, but are rather derived from a single cloud deployment ab-	Ivon Miranda Santos
Elmroth2011-Self-management_challenges_for_multi-cloud_architec	MULTI-CLOUD ARCHITECTURE > Hight availability	We propose that this problem is handled with two approaches ideally to be used in combination. The first approach, extending on results from statistical multiplexing of network bandwidth, is to make each admission control decision based on an elasticity analysis for the currently admitted services over a relevant set of time periods, in order to predict the future resource availability. The elasticity analysis includes calculation of probability distributions of load for each service over short to medium time and for the aggregated service workload per cloud over long term. An admission control decision will be made by combining these predictions with very short term ones obtained from elasticity and applying the overall provisioning (governance) policies with	Ivon Miranda Santos
Fowley2018-Cloud_migration_architecture_and_pricing_–_Mapping_a	MULTI-CLOUD ARCHITECTURE > Cost reduction	This is assumed to have better scalability characteristics. It also, as already said, allows better licensing and cost management.	Ivon Miranda Santos
Gholami2016-Cloud_migration_process—a_survey__evaluation_framew	MULTI-CLOUD ARCHITECTURE > Multiple clouds	, 2009), we identified six cloud intrinsic key concerns as follow: (i) resource elasticity, (ii) multi-tenancy, (iii) interoperability and migration over multiple-clouds, (iv) application licensing, (v) dynamicity and unpredictability, and (vi) legal issues. These concerns trigger considerations that an application owner should consider them in the migration process, though they might have	Ivon Miranda Santos

Gholami2016-Cloud_migration_process—a_survey __evaluation_framew	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Tenant isolation for QoS satisfaction (e.g. performance, security, availability and customizability) should be carefully addressed in a cloud application. (iii) Interoperability and migration over multiple-clouds. The cloud environment is proliferated with numerous services which bring a wide range of	Ivon Miranda Santos
Gholami2016-Cloud_migration_process—a_survey __evaluation_framew	MULTI-CLOUD ARCHITECTURE > Multiple clouds	For example, assume an organisation that has contracted for K number of application licenses and pays a fixed annual fee. Once encapsulated into a virtual machine and run in the cloud, multiple instances of it are created by a server based on the workload. In such, the restriction on	Ivon Miranda Santos
Gholami2016-Cloud_migration_process—a_survey __evaluation_framew	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Applied in cloud migration, it meant to transform the legacy application models (e.g. codes and architecture) into platform-independent models, configure them and then generate platform-specific cloud applications using model transformation techniques. As an example, REMICS [S26] is a model-driven methodology with a special emphasis on cloud-enabled legacy applications that can be run on multiple clouds.	Ivon Miranda Santos
Gholami2016-Cloud_migration_process—a_survey __evaluation_framew	MULTI-CLOUD ARCHITECTURE > Multiple clouds	13 artefacts are developed based on cloud variability models and transformed to multiple cloud platforms.	Ivon Miranda Santos
Gholami2016-Cloud_migration_process—a_survey __evaluation_framew	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	5.4.7 Cloud Service/Platform Selection Approaches can be assessed based on the extent to which they properly define activities to identify, evaluate, and select a set of cloud providers that might suit organization and application	Ivon Miranda Santos
Gholami2016-Cloud_migration_process—a_survey __evaluation_framew	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	In general, from 43 reviewed approaches the following important factors were identified for investigation when conducting the activity cloud provider selection: variety of service models offered by provider, price model, the form of SLA, additional services such as backup, monitoring, auto-scaling, security mechanisms, implementation technologies which are supported by provider such as programming languages, development platforms, allowing access to internal operational logs, physical location of application data [S2], sustainability [S4], commitment durability with cloud provider, business objectives [S8], degree of automation, storage encryption mechanisms, storage format and exchange, developer SDKs [S9] and [S10],	Ivon Miranda Santos
Gholami2016-Cloud_migration_process—a_survey __evaluation_framew	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	Once a provider(s) is selected, a contract between the legacy application owner and the cloud service provider is signed.	Ivon Miranda Santos
Gholami2016-Cloud_migration_process—a_survey __evaluation_framew	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	Given the above aspects of multi-tenancy, only the approach proposed by Maenhaut et. al. [S29] incorporates explicit activities to add customisability and security isolation to legacy applications are to move to a hybrid or public cloud environments. That is, enabling multi-tenancy requires the following steps: (i) decoupling databases, (ii) adding tenant configuration databases, (iii) providing tenant configuration interface, (iv) dynamic feature	Ivon Miranda Santos
Gholami2016-Cloud_migration_process—a_survey __evaluation_framew	MULTI-CLOUD ARCHITECTURE > Multiple clouds	To support dynamic deployment and independent component scalability, components should be stateless and minimise storing contextual data. Moreover, the coexistence of multiple running instances of the same components in the cloud environment requires a new session management mechanisms in order to track tenant's behaviors and ensure their security when a number of instances is increased or decreased based on the server workload.	Ivon Miranda Santos
Gourisaria2020-An_Extensive_Review_on_Cloud_Computing	MULTI-CLOUD ARCHITECTURE > Private cloud	are mentioned as following in Table 1. Mobile computing is vastly relied on cloud to make its features work by storing the user data in a public or private cloud. Mobile Cloud Computing (MCC) brings mobile and cloud computing together with wireless networks to give rise to pow-erful	Ivon Miranda Santos
Gourisaria2020-An_Extensive_Review_on_Cloud_Computing	MULTI-CLOUD ARCHITECTURE > Private cloud	4.2 Private Cloud Private cloud is a protected cloud base providing access to specific users. Information is stored in an organization's privatized servers.	Ivon Miranda Santos

Gourisaria2020-An_Extensive_Review_on_Cloud_Computing	MULTI-CLOUD ARCHITECTURE > Private cloud	NET. Users can collaborate with information from such private clouds with their data. 4.3 Hybrid Cloud Hybrid cloud uses the integrated facilities present in both public and private clouds [10, 14]. It is valued in places of fluctuating workloads.	Ivon Miranda Santos
Gourisaria2020-An_Extensive_Review_on_Cloud_Computing	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	4.3 Hybrid Cloud Hybrid cloud uses the integrated facilities present in both public and private clouds [10, 14]. It is valued in places of fluctuating workloads. The scalability that hybrid cloud brings to the company workforce poses a significant reduction in its infras-tructural and managemental expenditure	Ivon Miranda Santos
Gourisaria2020-An_Extensive_Review_on_Cloud_Computing	MULTI-CLOUD ARCHITECTURE > Multiple clouds	A database is a collection of sorted data. The cloud database comprises of multiple components interacting with each other. The basic architecture comprises of a front and a back end.	Ivon Miranda Santos
Gourisaria2020-An_Extensive_Review_on_Cloud_Computing	MULTI-CLOUD ARCHITECTURE > Multiple clouds	7.1 The Hypervisor The hypervisor is a firmware of low-level program which manages the sharing of a unit physical entity of cloud resources among multiple tenants [23]. Unlike other applications that need the operating system to function, the hypervisor bypasses the connection between the operating	Ivon Miranda Santos
Gourisaria2020-An_Extensive_Review_on_Cloud_Computing	MULTI-CLOUD ARCHITECTURE > Private cloud	• Procuring the machine in a public cloud service such as Amazon EC2. • Usage of private cloud management or a VM management present in the local data centre in order to procure the organization’s virtual machine.	Ivon Miranda Santos
Gourisaria2020-An_Extensive_Review_on_Cloud_Computing	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Homomorphic Encryption—It is a particular type of encryption where cipher-text computation is allowed [61]. Distributive Storage—A promising way to value data integrity is to store the data in multiple cloud storage. Deletion Confirmation—Deletion confirmation refers to the non-availability of data after a user has deleted his data after the deletion confirmation. However, data is stored in multiple copies in a server or multiple servers in the cloud.	Ivon Miranda Santos
Hajjat2010-Cloudward_bound_Planning_for_beneficial_migration_of	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	ABSTRACT In this paper, we tackle challenges in migrating enterprise services into hybrid cloud-based deployments, where enterprise operations are partly hosted on-premise and partly in the cloud. Such hy-brid architectures enable enterprises to benefit from cloud-based ar-chitectures, while honoring application performance requirements, and privacy restrictions on what services may be	Ivon Miranda Santos
Hajjat2010-Cloudward_bound_Planning_for_beneficial_migration_of	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	Users ex-ternal to the enterprise could be handled through servers deployed in the cloud, while internal users could be handled through servers located on premise. In this paper, we take a first step towards articulating and ad-dressing two challenges involved in enabling enterprises to move to such a hybrid cloud model, as we discuss below: Component placement:	Ivon Miranda Santos
Hajjat2010-Cloudward_bound_Planning_for_beneficial_migration_of	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	The data center has over 40 firewall contexts, each context associated with a pair of ACLs, and with each ACL having several tens and sometimes hundreds of ACL rules. 2.3 Issues in migrating enterprise applications In this paper, we focus on hybrid cloud architectures, where in-dividual application components may be placed locally or in the cloud. Further, we allow for placement strategies where only a sub-set of servers in a component	Ivon Miranda Santos
Hajjat2010-Cloudward_bound_Planning_for_beneficial_migration_of	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	In particular, servers may be instantiated in the cloud when needed, while requests are in general served from the local data-center. In this paper, we address two key challenges associated with re-alizing hybrid cloud architectures: Planning which servers to migrate: Planning a hybrid cloud lay-out is a complex problem, where an application architect must take several factors into account. The key factors are (i) honoring pol-icy constraints regarding which components must be migrated; (ii) ensuring application response times continue to meet desired tar-gets; and (iii) ensuring the cost	Ivon Miranda Santos

Hajjat2010-Cloudward_bound_Planning_for_beneficial_migration_of	MULTI-CLOUD ARCHITECTURE > Multiple clouds	R,I respectively denote the traffic from the lo-cal data center and the cloud to the Internet after (before) migration. We believe a linear cost model for Internet transfers is a reasonable starting point, and it matches the business model of multiple cloud providers (e.g., Amazon, Azure).	Ivon Miranda Santos
Hajjat2010-Cloudward_bound_Planning_for_ben	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	For example, Fig. 6 shows the hy-brid cloud topology based on the migration scenario in Fig. 4.	Ivon Miranda Santos
Hajjat2010-Cloudward_bound_Planning_for_beneficial_migration_of	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	5 Evaluation This section presents results evaluating the importance and effec-tiveness of our model in planning hybrid cloud layouts. Our eval-uations were conducted using (i) a real application made available as part of the Windows Azure SDK (§5.1), and (ii) a real Enterprise Resource Planning (ERP) application deployed in a large	Ivon Miranda Santos
Hajjat2010-Cloudward_bound_Planning_for_beneficial_migration_of	MULTI-CLOUD ARCHITECTURE > Multiple clouds	The service time of FE and BE is negligibly small. We also mea-sured the transfer delays of the original images and the thumbnails between the clouds over multiple runs. The mean (stddev) trans-fer time of the original images and thumbnails between the two data centers was	Ivon Miranda Santos
Hajjat2010-Cloudward_bound_Planning_for_beneficial_migration_of	MULTI-CLOUD ARCHITECTURE > Multiple clouds	In this paper, we have framed the problem as one of deciding how many servers to migrate to the cloud, and focused on a two location model (lo-cal and cloud data-center). In the future, it would be interesting to generalize this to models that allow any number of servers to be instantiated in the local and cloud data-centers, and allow for multiple cloud locations. Finally, it may be interesting to extend our cost and latency models	Ivon Miranda Santos
Hajjat2010-Cloudward_bound_Planning_for_beneficial_migration_of	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	In this paper, we have made two contributions. First, we have shown (i) the potential benefits of hybrid cloud deployments of en-terprise applications compared to “all or nothing” migrations; and (ii) the importance and feasibility of a planned approach to making migration decisions. Second, we have shown the feasibility of au-tomatic and assurable reconfiguration of reachability policies as en-terprise applications are migrated to hybrid cloud models. We have validated our algorithms using a campus ERP application, Azure-based cloud deployments, and	Ivon Miranda Santos
Hwang2015-Computing_resource_transformation__consolidation_and_	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	ABSTRACT With the promise of providing flexible and elastic comput-ing resources on demand, the cloud computing has been at-tracting enterprises and individuals to migrate workloads in the legacy environment to the public/private/hybrid clouds. Also, cloud customers want to migrate between cloud providers with different requirements such as cost, performance, and manage-ability.	Ivon Miranda Santos
Hwang2015-Computing_resource_transformation__consolidation_and_	MULTI-CLOUD ARCHITECTURE > Private cloud	ABSTRACT With the promise of providing flexible and elastic comput-ing resources on demand, the cloud computing has been at-tracting enterprises and individuals to migrate workloads in the legacy environment to the public/private/hybrid clouds. Also, cloud customers want to migrate between cloud providers with different requirements such as cost, performance, and manage-ability.	Ivon Miranda Santos
Hwang2015-Computing_resource_transformation__consolidation_and_	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	Therefore, although the expectation has risen with various requirements on the target cloud platforms and environments, the cloud migration techniques have not provided enough options that can satisfy the various requirements. In this paper we propose a model to tackle the migration challenges that transform one resource into same or another resource in hybrid clouds. We formulate the problem as a constraint satisfaction problem, and iteratively decompose the server components and consolidate the	Ivon Miranda Santos

Hwang2015-Computing_resource_transformation__consolidation_and_	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	Enterprises are increasingly migrating their existing IT infrastructure to the cloud, driven by the promise of low-cost access to elastic resources [1, 2]. Depending on the compliance and security requirements, as well as the business criticality of the business applications (often referred to as workloads), enterprises may choose one or more cloud environments, such as private cloud, 3rd party public cloud, traditional data center, resulting in hybrid cloud environments. Because the target environments are diversified and enterprises have a large num-	Ivon Miranda Santos
Hwang2015-Computing_resource_transformation__consolidation_and_	MULTI-CLOUD ARCHITECTURE > Private cloud	Enterprises are increasingly migrating their existing IT infrastructure to the cloud, driven by the promise of low-cost access to elastic resources [1, 2]. Depending on the compliance and security requirements, as well as the business criticality of the business applications (often referred to as workloads), enterprises may choose one or more cloud environments, such as private cloud, 3rd party public cloud, traditional data center, resulting in hybrid cloud environments. Because the target environments are diversified and enterprises have a large num-	Ivon Miranda Santos
Hwang2015-Computing_resource_transformation__consolidation_and_	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	It is the most of importance that many of these processes can be smoothly executed with well planned resource mappings between the source and the target upfront. In this paper, we propose a model to tackle the migration challenges that transform one resource into same or another resource in hybrid clouds based on source requirements and target availability. We investigate the tranformation metrics that need to be taken into consideration for the migration resource planning, server	Ivon Miranda Santos
Hwang2015-Computing_resource_transformation__consolidation_and_	MULTI-CLOUD ARCHITECTURE > Multiple clouds	ENTERPRISE-SCALE MIGRATION Cloud transformation for an enterprise IT environment entails the processes that migrate an enterprise's data, appli-cations, and services from on-premise data centers to a cloud environment, or to multiple cloud environments respectively	Ivon Miranda Santos
Hwang2015-Computing_resource_transformation__consolidation_and_	MULTI-CLOUD ARCHITECTURE > Private cloud	As the target environment becomes more diversified, the complexity on deciding where to move rather than how to move renders migration analytics a harder problem. The pos-sible choices for target environments include container, (pub-lic/private) virtual machine, baremetal, POD (Performance Op-timized Data Center), datacenter, geo-location, cloud provider, service model. As shown in Figure 1 that illustrates	Ivon Miranda Santos
Hwang2015-Computing_resource_transformation__consolidation_and_	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Not only the performance issues, the scalability is an another issue because, for example, the database can not easily be scaled out when it is running in the localhost, together with a consumer application. When an administrator wants to redesign application de-ployment to increase performance and support an elastic scalability in the target cloud, a server that runs multiple networked applications needs to be decomposed into separate components. For example, a high-end physical server that runs many applications can be decomposed into many virtual machines, each	Ivon Miranda Santos
Hwang2015-Computing_resource_transformation__consolidation_and_	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	Hajjat et al. [2] analyze the potential benefits of hybrid cloud deployments of enterprise applications, and the importance and feasibility of a planned approach to making migration decisions. Also, authors have shown the feasibility of automatic and assurable reconfiguration of reachability policies as enterprise applications are	Ivon Miranda Santos
Hwang2015-Computing_resource_transformation__consolidation_and_	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	CONCLUSION The enterprise-scale migration analytics provides an ef-fective migration planning capability that can transform re-sources from on-premise data centers to target clouds. We have described a model to tackle the migration challenges that transform one resource type into same or another resource type in hybrid clouds. We formulate the problem as a constraint satisfaction problem, and iteratively decompose the server components	Ivon Miranda Santos

Jambunathan2018-Architecture_decision_on_using_microservices_or	MULTI-CLOUD ARCHITECTURE > Private cloud	There are many containers available but docker is the most accepted one and are open source, have its own ecosystem to manage. Like VM, container also has its own life cycle to manage and every cloud service provider, be it a public cloud like AWS, Azure, Google or private cloud like OpenStack, VMware supports Docker containers. For example – AWS has elastic container service (ECS)[4] and Azure provides	Ivon Miranda Santos
Jambunathan2018-Architecture_decision_on_using_microservices_or	MULTI-CLOUD ARCHITECTURE > Private cloud	It can run anywhere within the runtime environment. Because of its modular in nature, one can easily containerize the application, dockerize, and deploy it in both public and private cloud environment. With help of the native cloud services, one can avail the scalability, security, fault tolerant features and that makes microservices more appropriate	Ivon Miranda Santos
Jamshidi2013-Cloud_migration_research_A_systematic_review	MULTI-CLOUD ARCHITECTURE > Multiple clouds	The needs for self-adaptive cloud-enabled systems. Multi-tenancy refers to a design principle of cloud architecture, where a single instance of the application running on a computing facility on the cloud serves multiple tenants that reside in different organizations. Since cloud applications are designed to support multitenancy, they face more different contexts in comparison with on-	Ivon Miranda Santos
Jamshidi2015-Cloud_migration_patterns_A_multi-cloud_service_arc	MULTI-CLOUD ARCHITECTURE > Multiple clouds	This paper suggests a catalogue of fine-grained service-based cloud architecture migration patterns that target multi-cloud settings and are specified with architectural notations. The proposed migration patterns are based on empirical evidence from a number of migration projects, best practices for cloud architectures	Ivon Miranda Santos
Jamshidi2015-Cloud_migration_patterns_A_multi-cloud_service_arc	MULTI-CLOUD ARCHITECTURE > Private cloud	Cloud migration [1] benefits from the cloud promise of converting capital expenditure to operational cost [2]. Mixing cloud architecture with private data centers adds operational efficiency for workload bursts while legacy systems [3] on-premise still support core business services. Instead of re-architecting applications, they can be re-hosted from on-premise to possibly multiple cloud architectures, either private or public ones. We are concerned with the migration of legacy on-	Ivon Miranda Santos
Jamshidi2015-Cloud_migration_patterns_A_multi-cloud_service_arc	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Instead of re-architecting applications, they can be re-hosted from on-premise to possibly multiple cloud architectures, either private or public ones. We are concerned with the migration of legacy on-premise software to multi-cloud architectures. Multi-cloud deployment [4] is particularly effective in dealing with the following challenges: • Users are widely distributed where they are located around multiple data centers.	Ivon Miranda Santos
Jamshidi2015-Cloud_migration_patterns_A_multi-cloud_service_arc	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Our main contribution is a set of fine-grained service-oriented migration fragments that allows application developers and architects to plan the migration and communicate the plan and the decision with non-technical stakeholders. The patterns define architectural change in the application re-engineering and deployment setting, through which an application is gradually modernized and deployed in a multi-cloud. A migration plan is defined as a composition of	Ivon Miranda Santos
Jamshidi2015-Cloud_migration_patterns_A_multi-cloud_service_arc	MULTI-CLOUD ARCHITECTURE > Multiple clouds	2 Background We first introduce architecture migration patterns and the multi-cloud deployment setting. Migration Patterns.	Ivon Miranda Santos

Jamshidi2015-Cloud_migration_patterns_A_multi-cloud_service_arc	MULTI-CLOUD ARCHITECTURE > Multiple clouds	, the architecture does not allow the database to be updated by multiple instances. Multi-cloud. In order to build highly scalable and reliable applications, a multi-cloud deployment is appropriate. Our objective is to provide architectural guidance for migrating cloud-based systems that run on multiple independent clouds. Multi-cloud denotes the usage of multiple, independent clouds by a client or a service. A multi-cloud environment is capable of distributing work to resources deployed across multiple clouds [10]. A multi-cloud is different from federation where, a set of cloud providers voluntarily interconnect their infrastructures to allow sharing of resources [10]. Hybrid deployment can be considered as a special case of multi-cloud where an application is deployed in both on-premise as well as cloud platforms. This deployment model is essential in cases where critical data needs to be kept in house in corporate data centers. We reviewed different	Ivon Miranda Santos
Jamshidi2015-Cloud_migration_patterns_A_multi-cloud_service_arc	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	A multi-cloud is different from federation where, a set of cloud providers voluntarily interconnect their infrastructures to allow sharing of resources [10]. Hybrid deployment can be considered as a special case of multi-cloud where an application is deployed in both on-premise as well as cloud platforms. This deployment model is essential in cases where critical data needs to be kept in	Ivon Miranda Santos
Jamshidi2015-Cloud_migration_patterns_A_multi-cloud_service_arc	MULTI-CLOUD ARCHITECTURE > Multiple clouds	A Multi-cloud Service Architecture 9(2) modernization performed primarily for technical reasons resulting in sub-optimal response to business change, (3) architectures determined bottom-up from existing APIs and transactions may need re-evaluation for multi-clouds.	Ivon Miranda Santos
Jamshidi2015-Cloud_migration_patterns_A_multi-cloud_service_arc	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	• MP5 Multi-Cloud Refactoring: MP6 (hybrid refactoring), MP7 (hybrid refactor-ing with on-premise adaptation), MP8 (hybrid refactoring with cloud adaptation), MP9 (hybrid refactoring with hybrid adaptation)	Ivon Miranda Santos
Jamshidi2015-Cloud_migration_patterns_A_multi-cloud_service_arc	MULTI-CLOUD ARCHITECTURE > Private cloud	A third goal is portability, i.e., it can be moved between a cloud and a private data Table 1.	Ivon Miranda Santos
Jamshidi2015-Cloud_migration_patterns_A_multi-cloud_service_arc	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Pattern MP6 was selected because there was no need for any interface adaptation (as in MP7-MP9) or multi-cloud deployment (as in MP10 and	Ivon Miranda Santos
Jamshidi2015-Cloud_migration_patterns_A_multi-cloud_service_arc	MULTI-CLOUD ARCHITECTURE > Multiple clouds	A number of migration strategies and best practices have been suggested in terms of patterns in [18–20]. These are rather informal and do not consider a multi-cloud setting. The objective there was mainly classification of existing best practice into migration strategies. The key advantage and novelty of our work, more than a set of patterns, is the notion of assembly-based situational migration at the architecture level, specifically towards pattern-based migration planning for multi-cloud deployment. It enhances the state-of-the-art by a tractable	Ivon Miranda Santos
Jamshidi2015-Cloud_migration_patterns_A_multi-cloud_service_arc	MULTI-CLOUD ARCHITECTURE > Multiple clouds	8 Conclusion and Outlook We identified cloud migration patterns, which in combination allow planning the migration of applications for multiple cloud platform deployment. The introduction of migration patterns complements existing migration practices and allows for an engi-neering approach towards	Ivon Miranda Santos
Jamshidi2017-Pattern-based_multicloud_architecture_migration	MULTI-CLOUD ARCHITECTURE > Multiple clouds	This paper presents Variability-based, Pattern-driven Architecture Migration .V-PAM), a migration method based on (i) a catalogue of fine-grained service-based cloud architecture migration patterns that target multi-cloud, (ii) a situational migration process framework to guide pattern selection and composi-tion, and (iii) a variability model to structure system migration into a coherent framework. The proposed migration patterns are based on empirical evidence from several migration projects, best practice for cloud	Ivon Miranda Santos

Jamshidi2017-Pattern-based_multicloud_architecture_migration	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Mixing cloud architecture with private data centers adds operational efficiency for workload bursts while legacy systems on-premise still support core business services [3]. Instead of re-architecting applications, they can be re-hosted from on-premise to possibly multiple cloud offerings, either private or public ones. We are con-cerned with the migration of legacy on-	Ivon Miranda Santos
Jamshidi2017-Pattern-based_multicloud_architecture_migration	MULTI-CLOUD ARCHITECTURE > Private cloud	Mixing cloud architecture with private data centers adds operational efficiency for workload bursts while legacy systems on-premise still support core business services [3]. Instead of re-architecting applications, they can be re-hosted from on-premise to possibly multiple cloud offerings, either private or public ones. We are con-cerned with the migration of legacy on-	Ivon Miranda Santos
Jamshidi2017-Pattern-based_multicloud_architecture_migration	MULTI-CLOUD ARCHITECTURE > Multiple clouds	According to a Gartner report [4], multicloud strategies will become common for 70 percent of organizations by 2019.	Ivon Miranda Santos
Jamshidi2017-Pattern-based_multicloud_architecture_migration	MULTI-CLOUD ARCHITECTURE > Multiple clouds	The patterns define architectural changes in the application re-engineering and deployment setting, through which an application is gradually modernized and deployed in a multi-cloud environment. In this context, a migration plan is defined as a composition of selected patterns for addressing specific architectural situations and	Ivon Miranda Santos
Jamshidi2017-Pattern-based_multicloud_architecture_migration	MULTI-CLOUD ARCHITECTURE > Multiple clouds	However, challenges remain: (i) on-premise application modernized in isolation, not part of a consistent architecture; (ii) modernization performed primarily for technical reasons resulting in sub-optimal response to business change; (iii) architectures determined bottom-up from existing APIs and transactions may need re-evaluation for multi-clouds. Their combination aims to provide a systematic, unbiased and comprehensive process and pattern	Ivon Miranda Santos
Jamshidi2017-Pattern-based_multicloud_architecture_migration	MULTI-CLOUD ARCHITECTURE > Multiple clouds	3.3. Define cloud platform profiles Profiles of one or more cloud platforms (including multi-cloud scenarios) should also be created. Each candidate cloud platform and its provider can be captured in terms of whether they satisfy the organisational and technical constraints.	Ivon Miranda Santos
Jamshidi2017-Pattern-based_multicloud_architecture_migration	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Constraints need to be addressed by either find-ing solutions or by circumventing them. At the core of the method, which we detail over the next three sections for a multi-cloud setting, is a collection of architecture-oriented migrations patterns that help to manage and find solutions for the technical constraints in particular. Using a	Ivon Miranda Santos
Jamshidi2017-Pattern-based_multicloud_architecture_migration	MULTI-CLOUD ARCHITECTURE > Multiple clouds	VARIABILITY APPROACH TO MIGRATION DEFINITION In order to build manageable and scalable cloud applications that meet the communication, avail-ability or performance constraints just discussed in previous section, a multi-cloud deployment is often appropriate [23, 24]. The V-PAM method proposed in this work aims at facilitating migration pattern selection and customization for applications that run on multiple independent clouds. 4.1. Motivation of multi-cloud and variability Multi-cloud denotes the usage of multiple, independent clouds by a client or a service. A multi-cloud environment is capable of processing user demand and distributing work to resources deployed across multiple clouds [25]. A multi-cloud is different from a federation where a set of cloud providers voluntarily interconnect their infrastructures to allow sharing of resources among each other [25]. Hybrid deployments can be considered as a special case of multi-cloud where an applica-tion is deployed in both on premise infrastructure as well as on cloud platform(s). Such a deployment model is essential in cases where critical data needs to be kept in-house in corporate data cen-ters. Different application types and requirements may benefit from and even demand a multi-cloud deployment – see [23] for supplementary materials. In a multi-cloud configuration perspective, parts of the application can be deployed on PaaS, IaaS or	Ivon Miranda Santos

Jamshidi2017-Pattern-based_multicloud_architecture_migration	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	A multi-cloud is different from a federation where a set of cloud providers voluntarily interconnect their infrastructures to allow sharing of resources among each other [25]. Hybrid deployments can be considered as a special case of multi-cloud where an applica-tion is deployed in both on premise infrastructure as well as on cloud platform(s). Such a deployment model is essential in cases where critical data needs to be	Ivon Miranda Santos
Jamshidi2017-Pattern-based_multicloud_architecture_migration	MULTI-CLOUD ARCHITECTURE > Benefits of Multi-Cloud	Different application types and requirements may benefit from and even demand a multi-cloud deployment – see [23] for supplementary	Ivon Miranda Santos
Jamshidi2017-Pattern-based_multicloud_architecture_migration	MULTI-CLOUD ARCHITECTURE > Multiple clouds	To match these requirements and dimensions, we identified 15 suitable patterns, reported in [23]. The key reasons behind a multi-cloud migration are already indicated in the situational description and process model captured in the organization, application and platform profiles: Location.	Ivon Miranda Santos
Jamshidi2017-Pattern-based_multicloud_architecture_migration	MULTI-CLOUD ARCHITECTURE > Multiple clouds	VMaccess /. Therefore, our joint model consists of three individual variability models at different levels addressing different concerns of multi-cloud application deployments. VMf unc is a fully fledged variability model that represents both functional commonalities and variabilities of the	Ivon Miranda Santos
Jamshidi2017-Pattern-based_multicloud_architecture_migration	MULTI-CLOUD ARCHITECTURE > Multiple clouds	The reason behind this choice for VMplatf orm is that the OVMs are smaller and less complex because they only model variability and not the commonalities. This is useful in the context of multi-cloud environments because for modeling, the deployment space, we only need to consider different variability that each platform may offer and not thinking about their commonalities. The faceted variability model distinguishes different roles: application developers (Dev),	Ivon Miranda Santos
Jamshidi2017-Pattern-based_multicloud_architecture_migration	MULTI-CLOUD ARCHITECTURE > Multiple clouds	The variability model helps to map the profiles and constraints from the process model onto the patterns. We first introduce the structure and content of architecture migration patterns and the multi-cloud deployment setting before providing a more comprehensive catalogue of patterns in the next section. 5.1. Migration patterns in multi-cloud setting Our migration patterns are sequences of architectural changes (refactoring) in the application deployment setting, through which the	Ivon Miranda Santos
Jamshidi2017-Pattern-based_multicloud_architecture_migration	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Thus, the application component is re-deployed as-is on a cloud platform. The current architecture is mirrored in the cloud, but can take advantage of vir-tualization to not only reduce operational expenditure, but also to create multiple instances of the application to improve scalability and failover without increasing capital expenditure. The key risk is that underlying	Ivon Miranda Santos
Jamshidi2017-Pattern-based_multicloud_architecture_migration	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Scalability is coarse-grained and can-not easily be achieved if, for example, the architecture does not allow the database to be updated by multiple instances. In order to build highly scalable and reliable applications, a multi-cloud deployment is often appropriate. Our objective is to provide	Ivon Miranda Santos
Jamshidi2017-Pattern-based_multicloud_architecture_migration	MULTI-CLOUD ARCHITECTURE > Multiple clouds	1170 P. JAMSHIDI, C. PAHL AND N. C. MENDONÇA that run on multiple independent clouds. Multi-cloud denotes the usage of multiple, independent clouds by a client or a service. A multi-cloud environment is capable of distributing work to resources deployed across multiple clouds [29]. A multi-cloud is different from a cloud federation – for the latter a set of cloud providers voluntarily interconnect their services to allow sharing of resources [29]. Hybrid deployment is a special case of multi-cloud where an application is deployed in both on-premise as well as cloud platforms.	Ivon Miranda Santos

Jamshidi2017-Pattern-based_multicloud_architecture_migration	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	A multi-cloud is different from a cloud federation – for the latter a set of cloud providers voluntarily interconnect their services to allow sharing of resources [29]. Hybrid deployment is a special case of multi-cloud where an application is deployed in both on-premise as well as cloud platforms. Note that we primarily target Platform-as-a-Service (PaaS) clouds that provide middleware	Ivon Miranda Santos
Jamshidi2017-Pattern-based_multicloud_architecture_migration	MULTI-CLOUD ARCHITECTURE > Multiple clouds	PATTERN-BASED MULTI-CLOUD ARCHITECTURE MIGRATION 1171 Relocation (core pattern MP3): variant pattern MP4 (relocation for multi-clouds) Multi-Cloud Refactoring (core pattern MP5): variant patterns MP6 (hybrid refactoring), MP7 (hybrid refactoring with on-premise adaptation), MP8 (hybrid refactoring with cloud adaptation), MP9 (hybrid refactoring with hybrid adaptation) Multi-Cloud Rebinding (core pattern MP10): variant pattern MP11 (rebinding with cloud brokerage) Replacement (core pattern MP12): variant patterns MP13 (replacement with on-premise adaptation), MP14 (replacement with cloud adaptation) Further variants can be added, but we will show the sufficient completeness of the given set to	Ivon Miranda Santos
Jamshidi2017-Pattern-based_multicloud_architecture_migration	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	Relocation (core pattern MP3): variant pattern MP4 (relocation for multi-clouds) Multi-Cloud Refactoring (core pattern MP5): variant patterns MP6 (hybrid refactoring), MP7 (hybrid refactoring with on-premise adaptation), MP8 (hybrid refactoring with cloud adaptation), MP9 (hybrid refactoring with hybrid adaptation) Multi-Cloud Rebinding (core pattern MP10): variant pattern	Ivon Miranda Santos
Jamshidi2017-Pattern-based_multicloud_architecture_migration	MULTI-CLOUD ARCHITECTURE > Multiple clouds	each of which corresponds to a migration step to achieve the target configuration from a specific configuration following a particular pattern. Note that one path from the source configuration (current on-premise application architecture) to the target (multi-cloud application architecture)	Ivon Miranda Santos
Jamshidi2017-Pattern-based_multicloud_architecture_migration	MULTI-CLOUD ARCHITECTURE > Private cloud	Applications located in the public cloud are available over the Internet, but authentication concerns exist. Another goal is portability, that is, it can be moved between a public cloud platform and a private data center without modification to application code or operations. Furthermore, a tractable migration plan to the cloud platform is	Ivon Miranda Santos
Jamshidi2017-Pattern-based_multicloud_architecture_migration	MULTI-CLOUD ARCHITECTURE > Multiple clouds	MP11 can be selected, because the user profiles were to be kept on-premise. Pattern MP6 was selected because there was no need for any interface adaptation (as in MP7–MP9) or multi-cloud deployment (as in MP10 and MP11). 3.	Ivon Miranda Santos
Jamshidi2017-Pattern-based_multicloud_architecture_migration	MULTI-CLOUD ARCHITECTURE > Multiple clouds	an e-commerce application with high availability and performance needs, a document processing system that needs a multi-cloud integration with ERP system compo-nents, a financial services application with a hybrid on-premise/cloud architecture and the need for	Ivon Miranda Santos
Jamshidi2017-Pattern-based_multicloud_architecture_migration	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	a document processing system that needs a multi-cloud integration with ERP system compo-nents, a financial services application with a hybrid on-premise/cloud architecture and the need for integrated security management, components of an ERP system with the need for mobile access,	Ivon Miranda Santos
Jamshidi2017-Pattern-based_multicloud_architecture_migration	MULTI-CLOUD ARCHITECTURE > Multiple clouds	These migration projects cover a range of application types, giving us certainty that a variety of application areas can be successfully covered through the proposed patterns. Distribution: we considered single public cloud, hybrid on-premise/public cloud and heteroge-neous multi-cloud settings. Complexity: from cloud-based storage to multi-tier applications with 10 subsystems with more than 50 individual	Ivon Miranda Santos
Jamshidi2017-Pattern-based_multicloud_architecture_migration	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	These migration projects cover a range of application types, giving us certainty that a variety of application areas can be successfully covered through the proposed patterns. Distribution: we considered single public cloud, hybrid on-premise/public cloud and heteroge-neous multi-cloud settings. Complexity: from cloud-based storage to multi-tier applications with 10 subsystems with more than 50 individual	Ivon Miranda Santos

Jamshidi2017-Pattern-based_multicloud_architecture_migration	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Sectors: from software vendors to larger financial services and food sector. Common to many of these is the need to integrate with different components of a distributed business process across heterogeneous multi-cloud settings, which highlights the need for multi-cloud pattern support. The V-PAM method has been employed in these projects particularly in the early stage, supporting feasibility studies and	Ivon Miranda Santos
Jamshidi2017-Pattern-based_multicloud_architecture_migration	MULTI-CLOUD ARCHITECTURE > Multiple clouds	, [16, 24, 41]) — providing empirical evidence for further cloud migration research. Our work is complementary to those approaches, as none of them provides a variability-driven planning solution based on a constructive pattern cat-alogue, and which is particularly suited to support migration decisions targeting multi-cloud	Ivon Miranda Santos
Jamshidi2017-Pattern-based_multicloud_architecture_migration	MULTI-CLOUD ARCHITECTURE > Decision Models for Multi-Cloud Adoption	Our work is complementary to those approaches, as none of them provides a variability-driven planning solution based on a constructive pattern cat-alogue, and which is particularly suited to support migration decisions targeting multi-cloud	Ivon Miranda Santos
Jamshidi2017-Pattern-based_multicloud_architecture_migration	MULTI-CLOUD ARCHITECTURE > Multiple clouds	A number of migration strategies and best practices have been sug-gested in terms of patterns in [15, 25, 26]. These are rather informal and do not consider a multi-cloud setting. The objective there was mainly classification of existing best practice into migration strategies. The key advantage and novelty of our work, more than a set of patterns, is the notion of assembly-based situational migration at the architecture level, specifically towards pattern-based migration planning for multi-cloud deployment. It enhances the state-of-the-art by proposing a	Ivon Miranda Santos
Jamshidi2017-Pattern-based_multicloud_architecture_migration	MULTI-CLOUD ARCHITECTURE > Multiple clouds	CONCLUSION AND OUTLOOK We have presented a cloud migration method – V-PAM for Variability-based, Pattern-driven Archi-tecture Migration – built around architecture change patterns, which allows planning the migration of applications for multiple cloud platform deployment. The introduction of migration patterns com-plements existing migration practices and allows for an engineering approach	Ivon Miranda Santos
Jamshidi2017-Pattern-based_multicloud_architecture_migration	MULTI-CLOUD ARCHITECTURE > Multiple clouds	The variability models act as a link to manage migration variability through a product-line style approach. Architecture-oriented patterns for multi-cloud settings are important for two reasons. Firstly, architectures are often refactored to adapt an application to the cloud platform, to benefit more	Ivon Miranda Santos
Jamshidi2017-Pattern-based_multicloud_architecture_migration	MULTI-CLOUD ARCHITECTURE > Multiple clouds	1182 P. JAMSHIDI, C. PAHL AND N. C. MENDONÇA often multi-cloud environments. Our implicit assumptions here included the possibility to	Ivon Miranda Santos
Kratzke2017-Understanding_cloud-native_applications_after_10_ye	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	All these cloud providers and their services forming nowadays our understanding of the term cloud computing. Al-though terms like public/private/hybrid cloud computing and acronyms like IaaS (Infrastructure as a Service), PaaS (Platform as a Service) or SaaS (Software as a Service) are frequently used, these terms are often understood in differing ways. Gladfully, the mentioned terms are defined precisely by the	Ivon Miranda Santos
Kratzke2017-Understanding_cloud-native_applications_after_10_ye	MULTI-CLOUD ARCHITECTURE > Private cloud	All these cloud providers and their services forming nowadays our understanding of the term cloud computing. Al-though terms like public/private/hybrid cloud computing and acronyms like IaaS (Infrastructure as a Service), PaaS (Platform as a Service) or SaaS (Software as a Service) are frequently used, these terms are often understood in differing ways. Gladfully, the mentioned terms are defined precisely by the	Ivon Miranda Santos
Kratzke2017-Understanding_cloud-native_applications_after_10_ye	MULTI-CLOUD ARCHITECTURE > Multiple clouds	, 2014). But interop-erability or portability in hybrid or multi-cloud scenarios (PRINC-2) seems to be only considered by single case or survey studies so far (Ben Belgacem et al.,	Ivon Miranda Santos
Kratzke2017-Understanding_cloud-native_applications_after_10_ye	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	, 2014). But interop-erability or portability in hybrid or multi-cloud scenarios (PRINC-2) seems to be only considered by single case or survey studies so far (Ben Belgacem et al.,	Ivon Miranda Santos

Lahmar2018-Multicloud_service_composition_A_survey_of_current_a	MULTI-CLOUD ARCHITECTURE > Multiple clouds	This approach is unrealistic since other existing clouds may host more suitable services. Extensive surveys have been presented for Web service composition13 and service composition in single clouds.14 However, few approaches have been proposed to deal with service composition across multiple clouds. The collected works from the	Ivon Miranda Santos
Lahmar2018-Multicloud_service_composition_A_survey_of_current_a	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	This model is beneficial in reducing the interactions' cost between service providers and the management effort.1 To cope with the heterogeneity of cloud users' profiles and requirements, 4 main types of cloud deployment models have emerged: public, private, hybrid, and community cloud.1 Figure 1 illustrates the layered model of cloud computing, as well as its corresponding service models. Among the existing cloud service–delivery models, we mention “software as a service” (SaaS) such as online word processing and spreadsheet tools, customer relationship management services and web content delivery services Salesforce customer relationship management, and Google Docs16; “platform as a service” (PaaS) such as Microsoft Azure and Google App engine16; and “infrastructure as a service” (IaaS) such as Amazon	Ivon Miranda Santos
Lahmar2018-Multicloud_service_composition_A_survey_of_current_a	MULTI-CLOUD ARCHITECTURE > Private cloud	This model is beneficial in reducing the interactions' cost between service providers and the management effort.1 To cope with the heterogeneity of cloud users' profiles and requirements, 4 main types of cloud deployment models have emerged: public, private, hybrid, and community cloud.1 Figure 1 illustrates the layered model of cloud computing, as well as its corresponding service models. Among the existing cloud service–delivery models, we mention “software as a service” (SaaS) such as online word processing and spreadsheet tools, customer relationship management services and web content delivery services Salesforce customer relationship management, and Google Docs16; “platform as a service” (PaaS) such as Microsoft Azure and Google App engine16; and “infrastructure as a service” (IaaS) such as Amazon	Ivon Miranda Santos
Lahmar2018-Multicloud_service_composition_A_survey_of_current_a	MULTI-CLOUD ARCHITECTURE > Benefits of Multi-Cloud	The next section summarizes the techniques and methods adopted by researchers to compose services in a traditional single-cloud environment. Then, the benefits and the taxonomy of multicloud approach are presented in Section 5.	Ivon Miranda Santos
Lahmar2018-Multicloud_service_composition_A_survey_of_current_a	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Furthermore, some selected services from a single cloud cannot totally satisfy the user requirements, such as security and compliance or business and technical needs.50 This is why services used in the composition process must be combined from several clouds. The migration from a single-cloud service composition to the MCSC has multiple reasons, among which we can quote especially the limited utility in the single cloud and the improved QoS levels when composing services from multiple clouds. The latter allow better satisfying the users' QoS	Ivon Miranda Santos
Lahmar2018-Multicloud_service_composition_A_survey_of_current_a	MULTI-CLOUD ARCHITECTURE > Private cloud	The cloud computing paradigm, as it was defined by the National Institute of Standards and Technology for the first time, consists in offering services deployed by 1 provider (eg, Nirvanix, Google Apps, and Amazon AWS), in a single datacenter. Therefore, only 1 availability zone hosts the services offered by either public or private clouds. The hybrid cloud could be also considered as a single-cloud environment if both the used public and private clouds are served by the same provider. In	Ivon Miranda Santos

Lahmar2018-Multicloud_service_composition_A_survey_of_current_a	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	Therefore, only 1 availability zone hosts the services offered by either public or private clouds. The hybrid cloud could be also considered as a single-cloud environment if both the used public and private clouds are served by the same provider. In contrast, the multicloud is a distributed	Ivon Miranda Santos
Lahmar2018-Multicloud_service_composition_A_survey_of_current_a	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Furthermore, using several clouds is also successful in avoiding downtime and data waste, enhancing the enterprise performance and eschewing vendor lock-in.22 The classification of the multiple cloud environments (MCEs) differs from one article to another. Therefore, different cloud taxonomies have	Ivon Miranda Santos
Lahmar2018-Multicloud_service_composition_A_survey_of_current_a	MULTI-CLOUD ARCHITECTURE > Multiple clouds	• Intracloud, also called cloud of clouds, is the case where 2 different services or more, collaborating together, are provided by the same vendor, which is the case of the internal collaboration. The intracloud environment is classified in some literature references as a cloud networking rather than multiple clouds.51 • Hybrid cloud is the composition of public and	Ivon Miranda Santos
Lahmar2018-Multicloud_service_composition_A_survey_of_current_a	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	The intracloud environment is classified in some literature references as a cloud networking rather than multiple clouds.51 • Hybrid cloud is the composition of public and private cloud resources or capabilities for a certain period. The problem that exists, when using the hybrid cloud, is the possibility of disclosing of the private capabilities and exposing of the private resources to danger.51 • Crossclouds, in such environment, a series of steps consisting of matchmaking, resource discovery, and authentication, is followed by a federation of several cloud suppliers in order to	Ivon Miranda Santos
Lahmar2018-Multicloud_service_composition_A_survey_of_current_a	MULTI-CLOUD ARCHITECTURE > Private cloud	The intracloud environment is classified in some literature references as a cloud networking rather than multiple clouds.51 • Hybrid cloud is the composition of public and private cloud resources or capabilities for a certain period. The problem that exists, when using the hybrid cloud, is the possibility of disclosing of the private capabilities and exposing of the private resources to danger.51 • Crossclouds, in such environment, a series of steps consisting of matchmaking, resource discovery, and authentication, is followed by a federation of several cloud suppliers in order to	Ivon Miranda Santos
Lahmar2018-Multicloud_service_composition_A_survey_of_current_a	MULTI-CLOUD ARCHITECTURE > Multiple clouds	The latter are filtered using some strategies, and, at the end, the most optimal one is chosen. In metaheuristic-based approaches, service composition has been realized by combining services from multiple clouds such as in Rostami et al,54 Yu et al,55 and Zhang et al.65 A genetic algorithm (GA) has been adopted inWang et al.63 In this work, the service composition is realized in a distributed environment, in order	Ivon Miranda Santos
Lahmar2018-Multicloud_service_composition_A_survey_of_current_a	MULTI-CLOUD ARCHITECTURE > Multiple clouds	In Baker et al,69 the pivotal objective is reducing the number of composed services and their providers in order to meet the user requirements of energy consumption. For this reason, an energy-efficient multiple cloud-computing service composition algorithm called E2C2 is proposed. The latter aims at generating an energy composition plan, in which each service has a variable that indicates	Ivon Miranda Santos

Lahmar2018-Multicloud_service_composition_A_survey_of_current_a	MULTI-CLOUD ARCHITECTURE > Multiple clouds	10 of 24 LAHMAR AND MEZNI environment in general.26 Agents can also negotiate with cloud providers on behalf of users to reach an agreement on the offered QoS and select the optimal service composition that comes from multiple clouds. The first agent-based approach that deals with cloud service composition was presented in Gutierrez-Garcia and Sim.26 It considers differ-ent types of cloud service composition (1-time,	Ivon Miranda Santos
Lahmar2018-Multicloud_service_composition_A_survey_of_current_a	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	environment in general.26 Agents can also negotiate with cloud providers on behalf of users to reach an agreement on the offered QoS and select the optimal service composition that comes from	Ivon Miranda Santos
Lahmar2018-Multicloud_service_composition_A_survey_of_current_a	MULTI-CLOUD ARCHITECTURE > Flexibility and choice	For most researchers, the main objective behind composing services in a multicloud environment was ensuring a high QoS, reliability, flexibility, etc.	Ivon Miranda Santos
Lahmar2018-Multicloud_service_composition_A_survey_of_current_a	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Therefore, responding to the user requirements will be impossible. However, in case where the data are stored on multiple clouds and one of them is affected by the attacks, we could simply move toward another cloud provider. • Data intrusion.	Ivon Miranda Santos
Lahmar2018-Multicloud_service_composition_A_survey_of_current_a	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Also, the rise of big data on cloud computing environments has led to the emergence of Big services. The latter are collections of collaborating, interrelated services for handling and dealing with big data, across multiple clouds. Big service is an interdisciplinary field that requires the support of many technologies, such as cloud computing, business process management, big data, Internet of things, software engineering, service	Ivon Miranda Santos
Lahmar2018-Multicloud_service_composition_A_survey_of_current_a	MULTI-CLOUD ARCHITECTURE > Multiple clouds	9.3 SLA issues The advantages of using services from multiple clouds and the heterogeneity of the QoS requirements are the reasons behind investigating the SLA in a multicloud environment, in order to maximize the user's profit. SLA interoperability and issues	Ivon Miranda Santos
Lahmar2018-Multicloud_service_composition_A_survey_of_current_a	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	To guarantee an efficient selection, a semantic description of the providers require-ments and offers is used.	Ivon Miranda Santos
Lahmar2018-Multicloud_service_composition_A_survey_of_current_a	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	The presented framework is realized in order to help SaaS providers, not only in selecting the appropriate IaaSs but also in allocating them while considering the existing SLA	Ivon Miranda Santos
Lahmar2018-Multicloud_service_composition_A_survey_of_current_a	MULTI-CLOUD ARCHITECTURE > Multiple clouds	The restrictions of a single-cloud service deployment have resulted the emergence of the multicloud as a deployment environment. For example, Nacer et al19 considered that scattering the business activities and deploying them in multiple clouds will enhance their security. Brogi et al82 presented an approach to deal with the deployment, management, and	Ivon Miranda Santos
Lahmar2018-Multicloud_service_composition_A_survey_of_current_a	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	It concerns the SaaS that could be selected by moving from one IaaS provider to another, searching for the provider that has appropriate properties.	Ivon Miranda Santos
Lahmar2018-Multicloud_service_composition_A_survey_of_current_a	MULTI-CLOUD ARCHITECTURE > Multiple clouds	11 REQUIREMENTS FOR MCSC By studying the existing cloud service composition approaches, several limits have been extricated and should be taken into account when combining services with different granularities from multiple clouds. Thus, an efficient MCSC approach must	Ivon Miranda Santos
Lahmar2018-Multicloud_service_composition_A_survey_of_current_a	MULTI-CLOUD ARCHITECTURE > Private cloud	Given that the communication between providers in the cloud environments mentioned above is costly and time consuming, minimizing the number of the used clouds is a basic objective during the composition process. • the accuracy and the protection of the private data during the composition, given the uncertainty and dynamicity of the cloud environment. When organizations intend to use services from the diverse clouds, it is necessary to offer to them sufficient guarantee concerning privacy	Ivon Miranda Santos

Lahmar2018-Multicloud_service_composition_A_survey_of_current_a	MULTI-CLOUD ARCHITECTURE > Multiple clouds	• the satisfaction of the user's requirements by selecting services that meet at best what is mentioned in the SLA. Investigating the SLA in the cloud computing facilitates the selection of the appropriated services from the multiple clouds environment. It offers an acceptable degree of service quality, which allows to avoid composing useless services.	Ivon Miranda Santos
Lahmar2018-Multicloud_service_composition_A_survey_of_current_a	MULTI-CLOUD ARCHITECTURE > Multiple clouds	However, most of them deal with only particular service models in a traditional cloud environment. The proliferation of multicloud environments has raised the need for effective multicloud management tools, to allow enterprises spread their services across multiple clouds.Mul-ticloud tools are expected to accelerate services deployment and scaling and to automate monitoring, governance, and configuration tasks.	Ivon Miranda Santos
Lahmar2018-Multicloud_service_composition_A_survey_of_current_a	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Cloud4SOA95 is a broker-like multicloud platform that, in addition to the deployment, governance and monitoring tasks, it allows to semantically orchestrate heterogeneous PaaS services. SeaClouds project96 aims to provide an open source framework for the adaptive management of complex applications over multiple heterogeneous Clouds (PaaS platforms). SeaClouds relies on a discovery APIs and a planning policy to determine the best offer for each application module and to	Ivon Miranda Santos
Lahmar2018-Multicloud_service_composition_A_survey_of_current_a	MULTI-CLOUD ARCHITECTURE > Multiple clouds	These add more complexity to the already unsolved cloud computing issues. Some of the future topics that need to be addressed aremainly related to the service composition under privacy and security constraints, the management of available services in a multicloud setting, and the composition of emerging types of services such as BPaaS across multiple clouds. In what follows, we discuss the	Ivon Miranda Santos
Lahmar2018-Multicloud_service_composition_A_survey_of_current_a	MULTI-CLOUD ARCHITECTURE > Cost reduction	Effectively reusing arbitrary granularities of BPaaS fragments has not been solved yet.19 Reusing BPaaS fragments rather than reusing atomic services from the multicloud can not only decrease the composition time, but also improve the reliability of the whole composition process.58 Seen that a multicloud deployment is costly, but at the same time it is more secure than a single one, it will be interesting to equilibrate these 2 criteria.	Ivon Miranda Santos
Lichtenthaler2019-Requirements_for_a_model-driven_cloud-native_	MULTI-CLOUD ARCHITECTURE > Private cloud	In the PSM, a concrete decision has to be made on where the system should be deployed, e.g., at which cloud provider or in a private cloud. There are various options for deploying applications in the evolving cloud services landscape and	Ivon Miranda Santos
Mahmood2020-Erp_issues_and_challenges_a_research_synthesis	MULTI-CLOUD ARCHITECTURE > Private cloud	(2016) say that managing security-related issues in cloud ERP is a complex and challenging process. So, to tackle this problem cloud vendors offer service of private cloud, which is more secure as compare to the public cloud. This study supports the earlier findings in relevant research.	Ivon Miranda Santos
Maniah2022-A_systematic_literature_review_Risk_analysis_in_clou	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	Based on the type of service, the Cloud is divided into 4 (four), namely: Private Cloud, which is a Cloud service that is aimed at a group or group and limits access only to that group; Public Cloud, which is a Cloud service that can be accessed by any customer with an internet connection; Community Cloud, which is a Cloud service aimed at the commu-nity which can consist of two or more organizations that have sim-ilar Cloud requirements; and Hybrid Cloud, which is a Cloud service that combines at least two types of Cloud services from Pri-vate Cloud, Public Cloud or Community Cloud (Huth and Cebula, 2011). According to The National Institute of Standards and Tech-nology (NIST) - Reference Architecture, there are 5 (five) main actors in the Cloud ecosystem that describe their functions and roles,	Ivon Miranda Santos

Maniah2022-A_systematic_literature_review_Risk_analysis_in_clou	MULTI-CLOUD ARCHITECTURE > Private cloud	Based on the type of service, the Cloud is divided into 4 (four), namely: Private Cloud, which is a Cloud service that is aimed at a group or group and limits access only to that group; Public Cloud, which is a Cloud service that can be accessed by any customer with an internet connection; Community Cloud, which is a Cloud service aimed at the commu-nity which can consist of two or more organizations that have sim-ilar Cloud requirements; and Hybrid Cloud, which is a Cloud service that combines at least two types of Cloud services from Pri-vate Cloud, Public Cloud or Community Cloud (Huth and Cebula, 2011). According to The National Institute of Standards and Tech-nology (NIST) - Reference Architecture, there are 5 (five) main actors in the Cloud ecosystem that describe their functions and roles,	Ivon Miranda Santos
Maniah2022-A_systematic_literature_review_Risk_analysis_in_clou	MULTI-CLOUD ARCHITECTURE > Low security risks	Table 5 shows the number of articles that review issues of risk types and risk components that often appear in cloud environ-ments. There are types of risk that most often arise are information security risk (weight = 7), risk of losing access to data (weight = 6), financial risk (weight = 2), risk of compliance with various regula-tions and laws (weight = 3) , risk of using virtual machines (weight = 5), Error in choosing CSP (weight = 4), and Failure man-agement (weight = 1). So that the percentage of the most dominant type of risk is the risk of information security by 25%, followed by the risk of losing access to data by 21%. Meanwhile, the possible risk components that often arise are threat (weight = 5), impact (weight = 4), risk factors (weight = 3), vulnerability (weight = 2), and damage (weight = 1). So that the percentage of risk compo-nents that most often arose was threat of 33%, followed by an impact	Ivon Miranda Santos
Maniah2022-A_systematic_literature_review_Risk_analysis_in_clou	MULTI-CLOUD ARCHITECTURE > Private cloud	Choosing the right cloud service provider is also an important thing to pay attention to before migrating to the cloud. To ensure security on cloud migration, it is a shared responsibil-ity for related parties, for example government, private organiza-tions, education sector and researchers. Research in the field of cloud computing still opens up great opportunities for researchers in the future, but the challenges will certainly increase, for this rea-son, it is necessary for similar studies to be developed	Ivon Miranda Santos
Maniah2022-A_systematic_literature_review_Risk	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and	A risk assessment model for selecting cloud service providers.	Ivon Miranda Santos
Mateen2021-A_dynamic_decision_support_system_for_selection_of_c	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	; Hanan, A. A Dynamic Decision Support System for Selection of Cloud Storage Provider.	Ivon Miranda Santos
Mateen2021-A_dynamic_decision_support_system_for_selection_of_c	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	In recent years, the cloud computing model has gained increasing attention and popularity in the field of information technology. For this reason, people are migrating their applications to public, private, or hybrid cloud environments. Many cloud vendors offer similar features with varying costs, so an appropriate choice will be the key to guaranteeing comparatively low operational	Ivon Miranda Santos
Mateen2021-A_dynamic_decision_support_system_for_selection_of_c	MULTI-CLOUD ARCHITECTURE > Private cloud	In recent years, the cloud computing model has gained increasing attention and popularity in the field of information technology. For this reason, people are migrating their applications to public, private, or hybrid cloud environments. Many cloud vendors offer similar features with varying costs, so an appropriate choice will be the key to guaranteeing comparatively low operational	Ivon Miranda Santos
Mateen2021-A_dynamic_decision_support_system_for_selection_of_c	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	However, the selection of a suitable cloud storage provider is a complex problem that entails various technical and organizational aspects.	Ivon Miranda Santos
Mateen2021-A_dynamic_decision_support_system_for_selection_of_c	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	In this research, a dynamic Decision Support System (DSS) for selection of an appropriate cloud storage provider is proposed.	Ivon Miranda Santos
Mateen2021-A_dynamic_decision_support_system_for_selection_of_c	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	The examples for IAAS include Microsoft Azure and Amazon Web Service (AWS) [2]. Cloud computing has three main types (public, private, and hybrid) with different benefits for each type. The public cloud is a standard cloud computing model in which resources, such as CPU, memory, a repository, and APIs, are available to	Ivon Miranda Santos

Mateen2021-A_dynamic_decision_support_system_for_selection_of_c	MULTI-CLOUD ARCHITECTURE > Private cloud	The examples for IAAS include Microsoft Azure and Amazon Web Service (AWS) [2]. Cloud computing has three main types (public, private, and hybrid) with different benefits for each type. The public cloud is a standard cloud computing model in which resources, such as CPU, memory, a repository, and APIs, are available to	Ivon Miranda Santos
Mateen2021-A_dynamic_decision_support_system_for_selection_of_c	MULTI-CLOUD ARCHITECTURE > Private cloud	These services can be public websites like Daraz, or storage space like Dropbox and OneDrive. A private cloud has a restricted environment where services are available through autho-rization (e.g., government ministry websites). In order to get the flavor of both public and private environments, there is a hybrid cloud. This type is not commonly used owing to some security concerns. Similarly, public users do not easily accept private cloud re-strictions. A	Ivon Miranda Santos
Mateen2021-A_dynamic_decision_support_system_for_selection_of_c	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	, government ministry websites). In order to get the flavor of both public and private environments, there is a hybrid cloud. This type is not commonly used owing to some security	Ivon Miranda Santos
Mateen2021-A_dynamic_decision_support_system_for_selection_of_c	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	Similarly, public users do not easily accept private cloud re-strictions. A community cloud is a variant of hybrid cloud that provides services within a community [3]. Figure 1 clearly shows that cloud services are dependent on the user's capability requirement and the openness of the membership.	Ivon Miranda Santos
Mateen2021-A_dynamic_decision_support_system_for_selection_of_c	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	[14] has identified the criteria for the selection of cloud storage providers and analyzed several cloud storage providers on the identified	Ivon Miranda Santos
Mateen2021-A_dynamic_decision_support_system_for_selection_of_c	MULTI-CLOUD ARCHITECTURE > Decision Models for Multi-Cloud Adoption	Cloud-Genius equally under-stands the selection steps of multi-criteria decision-making issues in resolving the main grouping of the cloud virtual	Ivon Miranda Santos
Mateen2021-A_dynamic_decision_support_system_for_selection_of_c	MULTI-CLOUD ARCHITECTURE > Hight availability	The decision to shift data to the cloud environment is not a simple task as it involves multiple contradictory aspects. Some of these complex factors include performance, pri-vacy, data security, legal concerns, scalability, service availability, quality of service, and mainly the cost	Ivon Miranda Santos
Mateen2021-A_dynamic_decision_support_system_for_selection_of_c	MULTI-CLOUD ARCHITECTURE > Multiple clouds	The important function is a comparison of providers and rank-ings that works based on the user's selected parameters. A database is created to store information about multiple cloud providers. Different operations are performed on	Ivon Miranda Santos
Mateen2021-A_dynamic_decision_support_system_for_selection_of_c	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	The important function is a comparison of providers and rank-ings that works based on the user's selected parameters.	Ivon Miranda Santos
Mateen2021-A_dynamic_decision_support_system	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and	Moreover, users can select different parameters in order to see the best provider for their	Ivon Miranda Santos
Mateen2021-A_dynamic_decision_support_system	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and	Besides basic tasks like registering, users can select parameters for ranking providers [25].	Ivon Miranda Santos
Mateen2021-A_dynamic_decision_support_system_for_selection_of_c	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	The data extractor fetches the specific data against the selected parameters of the cloud providers from their websites and sends it to DSS	Ivon Miranda Santos
Mateen2021-A_dynamic_decision_support_system	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and	In the cloud service comparison, users can select parameters to obtain a list of cloud	Ivon Miranda Santos
Mateen2021-A_dynamic_decision_support_system_for_selection_of_c	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	Then, users can choose any cloud provider according to their needs by selecting parameters like number of CPU cores, amount of storage, and availability of synchronization and/or file	Ivon Miranda Santos
Mateen2021-A_dynamic_decision_support_system_for_selection_of_c	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	For ranking, the user can select the ranking type based on the cloud storage provider list and ranked on the basis of user selection type.	Ivon Miranda Santos
Mateen2021-A_dynamic_decision_support_system	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and	Twenty cloud storage providers are selected to test the proposed DSS:	Ivon Miranda Santos
Mateen2021-A_dynamic_decision_support_system	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and	Twenty cloud storage providers are selected to test the proposed DSS:	Ivon Miranda Santos
Mateen2021-A_dynamic_decision_support_system_for_selection_of_c	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	We have selected the "number of CPU cores" as a parameter for the selection of cloud provider as it affects the retrieval of data as well as	Ivon Miranda Santos
Mateen2021-A_dynamic_decision_support_system_for_selection_of_c	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	We have selected the "number of CPU cores" as a parameter for the selection of cloud provider as it affects the retrieval of data as well as	Ivon Miranda Santos
Mateen2021-A_dynamic_decision_support_system_for_selection_of_c	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	After the login page, control shifts to the ranking page where a user can rank cloud storage providers by selecting either minimum cost or	Ivon Miranda Santos
Mateen2021-A_dynamic_decision_support_system_for_selection_of_c	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	After the login page, control shifts to the ranking page where a user can rank cloud storage providers by selecting either minimum cost or	Ivon Miranda Santos
Mateen2021-A_dynamic_decision_support_system_for_selection_of_c	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	After the login page, control shifts to the ranking page where a user can rank cloud storage providers by selecting either minimum cost or	Ivon Miranda Santos

Mateen2021-A_dynamic_decision_support_system_for_selection_of_c	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	After the login page, control shifts to the ranking page where a user can rank cloud storage providers by selecting either minimum cost or	Ivon Miranda Santos
Mateen2021-A_dynamic_decision_support_system_for_selection_of_c	MULTI-CLOUD ARCHITECTURE > Multiple clouds	After getting user requirements, all potential pairs of parameters are calculated. All frameworks use multiple criteria, but the proposed system considers fewer parameters than SMICloud as well as Cloud Genius and focuses on the critical parameters like performance and cost because of major impact on the ranking. Accuracy and Dynamic database functionality are the other	Ivon Miranda Santos
Mateen2021-A_dynamic_decision_support_system_for_selection_of_c	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	Therefore, selection of a cloud storage provider is a very important task; otherwise, organizations have to pay a huge amount of money.	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_fo	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and	A multicriteria optimization model for cloud service provider selection in multicloud environments	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_fo	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and	The value of such strategy increases with proper selection of qualified service providers.	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_fo	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and	In this paper, a constrained multicriteria multicloud provider selection mathemat-ical model	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_for_cloud_servic	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	For the sake of comparison, Taguchi's robust design method was used to select the algorithms' parameters values, an initial feasible solution was generated using analytic hierarchy process (AHP)—as the most used method to solve the cloud provider selection problem in the literature, all three algorithms used that solution and, in order to avoid AHP limitations, another initial solution was generated randomly and used by	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_for_cloud_servic	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	) in terms of service level agreement; a contract between customers and cloud service providers where cloud service providers (the latter) guarantee a satisfactory level of quality of service (QoS) requirements.2 Cloud service provider selection is one of the most significant challenges for cloud customers.3,4 Due to the growing number of	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_for_cloud_servic	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	Prices and performance levels of the similar offered services are varied, and, consequently, selecting an appropriate provider that can fulfill QoS requirements becomes increasingly difficult.	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_for_cloud_servic	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	Conse-quently, some research papers, from customer perspective, tried to answer the question of what are the most important criteria for cloud provider selection?12,14,15 But, measuring the identified criteria was not a simple task because of lack of standard to various providers.16 Therefore, the Cloud Service Measurement Index Consortium has developed service measurement index (SMI),17 a standard measurement framework which helps decision-	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_for_cloud_servic	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	Despite the fact that measuring SMI KPIs is an important step in provider selection process which enables researchers to build accurate models, the proposed methods to solve the selection problem in the literature depended on	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_for_cloud_servic	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	The previous research papers proposed frameworks and models to tackle the provider selection problem by ranking different providers based on different criteria in order to select a single cloud provider to satisfy customer's	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_for_cloud_servic	MULTI-CLOUD ARCHITECTURE > Multiple clouds	For example, an enterprise may favor Amazon or Google to analyze big data, but to run Microsoft-centric applications it may prefer Azure. Multicloud is a strategy that uses services and resources from multi-ple cloud provider,23 therefore the application can be run on different IaaS platforms based on those applications' unique needs. So, it is a strategy that helps customers to avoid vendor lock-in problem and improve QoS or minimize	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_for_cloud_servic	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Cloud provider selection plays a significant role in increasing multicloud value. Despite of multiclouds challenges, its usage is increasing and, thus, it became the focus of recent research papers.21 References 34-37 focused on VMs and pro-posed models/schemes for VMs placement across multiple cloud providers. While References 38-40 proposed multicloud storage models in	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_fo	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and	Cloud provider selection plays a significant role in increasing multicloud value.	Ivon Miranda Santos

Mohamed2020-A_multicriteria_optimization_model_for_cloud_servic	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	The gap in the literature was this research motivation to propose a general model for selecting providers in multicloud environment considering any number of infrastructure services based on different criteria in addition to considering customer's acceptable level for each	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_for_cloud_servic	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	Therefore, in this paper, the cloud provider selection problem is formulated as a constrained multicriteria multicloud provider selection problem.	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_for_cloud_servic	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	• proposing a general model for selecting cloud providers in a multicloud environment considering any number of IaaS services;	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_for_cloud_servic	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	• formulating the proposed model based on multicriteria that includes cloud services evaluation's criteria and cloud providers evaluation's criteria; • considering the customer's acceptable level of each criterion; and • proposing three metaheuristic algorithms for	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_fo	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and	The multicriteria multicloud provider selection problem can be addressed using either a static or	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_fo	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and	In this scenario, the multicloud provider selection can be done offline only once.	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_for_cloud_servic	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	In this case, the optimization algorithm should run periodically to adapt providers' selection to the variable requirements of IaaS services and cloud providers' conditions.	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_for_cloud_servic	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	In this paper, we focus on the static approach whereas dynamic multicloud provider selection will be investigated in the future work.	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_for_cloud_servic	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	The proposed multicloud provider selection model is compared to the sin-gle cloud provider selection model based on cost criterion.	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_for_cloud_servic	MULTI-CLOUD ARCHITECTURE > Cost reduction	The proposed multicloud provider selection model is compared to the sin-gle cloud provider selection model based on cost criterion.	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_for_cloud_servic	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	Section 2 deals with multicloud provider selection problem; it starts with problem description and proceeds with the model formulation.	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_fo	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and	2 MULTICLOUD PROVIDER SELECTION PROBLEM	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_fo	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and	The cloud provider selection model has three major stakeholders: customer, cloud broker, and	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_for_cloud_servic	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	In the provider selection process, cloud broker plays the main role because it acts as an intermediary between the customer and providers in order to satisfy customer's requirements.	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_for_cloud_servic	MULTI-CLOUD ARCHITECTURE > Multiple clouds	B } denote set of parameters that defined the ki provided service k that offered by provider j, and |S( ) | = B . Thus, in the context of multicloud $P\ P$ provider ki ki selection, the cloud broker is responsible for selecting multiple providers that satisfies the customer's requirements in order to minimize the cost and maximize the benefits subject to a set of constraints. The multicloud provider selection model was formulated as integer programming	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_for_cloud_servic	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	Thus, in the context of multicloud provider selection, the cloud broker is responsible for selecting multiple providers that satisfies the customer's requirements in order to minimize the cost and maximize the benefits subject to a set of	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_fo	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and	The multicloud provider selection model was formulated as integer programming and was built	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_fo	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and	FIGURE 1 A high level conceptual model of multicriteria multicloud provider selection	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_fo	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and	The multicloud provider selection model is formulated as:	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_for_cloud_servic	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	While the integration cost is assumed to be fixed and it is incurred regardless of the number of services that are rented from the selected	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_fo	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and	Suitability measure is customer focused and needs to be performed at the initial selection of	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_fo	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and	Reference44 proposed an agent to select cloud service provider based on the RFV.	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_for_cloud_servic	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	Multicloud provider selection problem is proved to be NP-complete problem based on the similarity between it and the multi-item vendor selection (MIVS) problem that discussed in Reference.51 MIVS is a special type of procurement problem; it is the problem of procuring a number of different items from different vendors, with no	Ivon Miranda Santos

Mohamed2020-A_multicriteria_optimization_model_for_cloud_servic	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	They can find the optimum solutions because they can avoid being trapped in a local optimum and can search very large spaces of candidate solutions.52-54 Besides, from the literature, the selected algorithms are the most used algorithms to solve the provider selection problem especially	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_fo	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and	randomly; for each required service, a random cloud provider is selected.	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_for_cloud_servic	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	(a) the most popular IaaS providers were selected like Amazon AWS,45 DigitalOcean,46 Microsoft Azure,47 and Google Compute Engine,48 (b) for each provider, IaaS services were scanned and three common services were cho-sen (VM, blob storage, and file storage), (c) for each service, the strategy for collecting the value of each parameter in Section 2.2.2 was to select the absolute minimum and the absolute maximum of each	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_for_cloud_servic	MULTI-CLOUD ARCHITECTURE > Multiple clouds	This section is dedicated to answer two main questions: (a) how much the cost is improved when using the multi-cloud selection model instead of single cloud selection model? and (2) what is robust solution algorithm for solving the proposed model? In order to answer the first question, the proposed multicloud provider selection model is compared to the single cloud	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_for_cloud_servic	MULTI-CLOUD ARCHITECTURE > Cost reduction	(a) how much the cost is improved when using the multi-cloud selection model instead of single cloud selection model? and (2) what is robust solution algorithm for solving the proposed model?	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_for_cloud_servic	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	In order to answer the first question, the proposed multicloud provider selection model is compared to the single cloud provider selection model based on cost criterion.	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_for_cloud_servic	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	In the second phase, AHP method was used to generate a candidate solution; from the literature, AHP was the most used method to tackle the selection problem of cloud providers.	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_for_cloud_servic	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	But using AHP method, only one provider can be chosen, so for each requirement AHP is applied to select the candidate provider and it was applied through the following steps:	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_fo	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and	The overall goal of “Cloud Service Provider Selection” is demonstrated in the first level.	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_fo	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and	This paper considered the constrained multicriteria multicloud provider selection problem.	Ivon Miranda Santos
Mohamed2020-A_multicriteria_optimization_model_for_cloud_servic	MULTI-CLOUD ARCHITECTURE > Multiple clouds	36. Chaisiri S, Lee BS, Niyato D. Optimal virtual machine placement across multiple cloud providers. Paper presented at:	Ivon Miranda Santos
Naik2021-Performance_evaluation_of_distributed_systems_in_multi	MULTI-CLOUD ARCHITECTURE > Multiple clouds	9447123 Performance Evaluation of Distributed Systems in Multiple Clouds using Docker Swarm Nitin Naik	Ivon Miranda Santos
Naik2021-Performance_evaluation_of_distributed_systems_in_multi	MULTI-CLOUD ARCHITECTURE > Multiple clouds	School of Informatics and Digital Engineering, Aston University, United Kingdom Email: n.naik1@aston.ac.uk Abstract—The design of distributed systems in multiple clouds have been gaining popularity due to various benefits of the multi-cloud infrastructure such as minimizing vendor lock-in, data loss and downtime. Nonetheless, this multi-cloud infrastructure also poses several challenges such as compatibility, interoperability, complex provisioning and configuration due to the variation in technologies and services of each cloud	Ivon Miranda Santos
Naik2021-Performance_evaluation_of_distributed_systems_in_multi	MULTI-CLOUD ARCHITECTURE > Benefits of Multi-Cloud	Abstract—The design of distributed systems in multiple clouds have been gaining popularity due to various benefits of the multi-cloud infrastructure such as minimizing vendor lock-in, data loss and	Ivon Miranda Santos
Naik2021-Performance_evaluation_of_distributed_systems_in_multi	MULTI-CLOUD ARCHITECTURE > Vendor lock-in avoidance	Abstract—The design of distributed systems in multiple clouds have been gaining popularity due to various benefits of the multi-cloud infrastructure such as minimizing vendor lock-in, data loss and	Ivon Miranda Santos

Naik2021-Performance_evaluation_of_distributed_systems_in_multi	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Virtualization is regarded as the base technology of the cloud and therefore, most cloud-based distributed systems are based on it. Nevertheless, virtual machines require substantial resources and cause several issues across multiple clouds such as provisioning, configuration management, load balancing and migration. Docker Swarm is a container-based clustering tool that resolves some of these issues and supports the design of distributed systems in multiple clouds. It has also incorporated several inbuilt attributes of the distributed system, however, it is still evolving. This paper initially presents the simulated development of a Docker Swarm-based distributed system which can be easily replicated in multiple clouds. Subsequently, based on the simulated Docker Swarm-based distributed system, it performs an evaluation of several attributes of this distributed system such as high availability and fault tolerance; automatic	Ivon Miranda Santos
Naik2021-Performance_evaluation_of_distributed_systems_in_multi	MULTI-CLOUD ARCHITECTURE > Multiple clouds	The designing of distributed systems has many challenges such as successful handling of failure of machines, disks, networks, and software. Distributed systems can be made more effective if they are designed in multiple clouds by leveraging several benefits of the multi-cloud in-frastructure such as minimizing vendor lock-in, data loss and downtime [3], [4]. Nonetheless, this multi-cloud infrastructure also poses several challenges such as compatibility, interop-erability, complex provisioning and configuration due to the variation in technologies and services of each cloud provider [5]. Inevitably, it increases the complexity of design process of distributed systems and operations across multiple clouds [4]. Virtualization is regarded as the base technology of the cloud and therefore, most cloud-based distributed systems are based on it. Nevertheless, virtual machines demand substantial resources and cause several issues across multiple clouds such as provisioning, configuration management, load balancing and	Ivon Miranda Santos
Naik2021-Performance_evaluation_of_distributed_systems_in_multi	MULTI-CLOUD ARCHITECTURE > Benefits of Multi-Cloud	Distributed systems can be made more effective if they are designed in multiple clouds by leveraging several benefits of the multi-cloud in-frastructure such as minimizing vendor lock-in, data loss and downtime [3], [4].	Ivon Miranda Santos
Naik2021-Performance_evaluation_of_distributed_systems_in_multi	MULTI-CLOUD ARCHITECTURE > Vendor lock-in avoidance	Distributed systems can be made more effective if they are designed in multiple clouds by leveraging several benefits of the multi-cloud in-frastructure such as minimizing vendor lock-in, data loss and downtime [3], [4].	Ivon Miranda Santos
Naik2021-Performance_evaluation_of_distributed_systems_in_multi	MULTI-CLOUD ARCHITECTURE > Multiple clouds	an OS-level virtualization and it requires fewer resources than a virtual machine, thus, it resolves the speed and performance issues of virtualization for software developers [3]. Docker Swarm is a container-based clustering tool that supports the design of multi-cloud distributed systems in those clouds which are supported by Docker [4]. It has also incorporated several inbuilt attributes of the distributed system, however, it is still evolving. This paper illustrates the design of a distributed system in multiple clouds using a Docker Swarm cluster. Subsequently, it presents the simulated development of a Docker Swarm-based distributed system in VirtualBox, which can be easily replicated in multiple clouds. Finally, based on the simu-lated Docker Swarm-based distributed system, it performs an evaluation of several attributes of the Docker Swarm-based distributed system such as high availability and	Ivon Miranda Santos

Naik2021-Performance_evaluation_of_distributed_systems_in_multi	MULTI-CLOUD ARCHITECTURE > Multiple clouds	This evaluation demonstrates that the Docker Swarm-based distributed system is relatively easy to design and act as a natural distributed systems due to several inbuilt attributes of distributed systems. Additionally, Docker supports many virtual and cloud environ-ments, therefore, this Docker Swarm-based distributed system can also be replicated into multiple clouds. The remainder of this paper is organised as follows: Section II explains about containerization, Docker container and Docker Swarm; Section III illustrates the design of a distributed system in multiple clouds using Docker Swarm; Section IV presents the simulated development of a Docker Swarm-based distributed system which can be easily replicated in multiple clouds. Section V performs an	Ivon Miranda Santos
Naik2021-Performance_evaluation_of_distributed_systems_in_multi	MULTI-CLOUD ARCHITECTURE > Multiple clouds	C. Docker Swarm Docker Swarm is a cluster management and orchestration tool that connects and controls several Docker nodes to form a single virtual system [9], [10]. It is an enhancement of Docker container technology for creating a cluster of nodes across several machines or clouds and designing distributed systems in multiple clouds. Docker Swarm offers several essential attributes of a distributed system to the Swarm cluster such as availability, reliability, fault tolerance, maintainability and scalability, which is an added	Ivon Miranda Santos
Naik2021-Performance_evaluation_of_distributed_systems_in_multi	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Fig. 3 illustrates the design of a distributed system using Docker swarm cluster of three manager and two worker nodes on multiple clouds, which will be simulated later. All five clouds in the illustrated design are supported by Docker [11].	Ivon Miranda Santos
Naik2021-Performance_evaluation_of_distributed_systems_in_multi	MULTI-CLOUD ARCHITECTURE > Multiple clouds	This paper presented the performance evaluation of a distributed system using Docker Swarm. It illustrated the design and simulated development of the distributed system in multiple clouds using Docker Swarm. Subsequently, the paper demonstrated an evaluation of several attributes of the distributed system such as high availability and fault tolerance; automatic scalability, load balancing and maintainability of services; and	Ivon Miranda Santos
Naik2021-Performance_evaluation_of_distributed_systems_in_multi	MULTI-CLOUD ARCHITECTURE > Multiple clouds	is relatively easy to design and act as a natural distributed systems due to several inbuilt attributes of distributed sys-tems. Additionally, Docker supports many virtual and cloud environments, therefore, this Docker Swarm-based distributed system can also be replicated into multiple clouds. However, this simulated distributed system was a small Docker Swarm cluster, therefore, in the future, it will be useful to perform an evaluation on a large Docker Swarm cluster. Moreover, it may be worthwhile to develop and evaluate this distributed system in the multiple clouds to analyse their communication	Ivon Miranda Santos
Opara-Martins2016-Critical_analysis_of_vendor_lock-in_and_its_i	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	Moreover, more than half (50.9 %) of the organisations polled in the study are already using cloud services for at least one application domain within their organisa-tion. The higher majority (69 %) utilise a combination of cloud services and internally owned applications (i.e. hy-	Ivon Miranda Santos
Opara-Martins2016-Critical_analysis_of_vendor_lock-in_and_its_i	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	Adoption of cloud computing by UK businesses The survey affirms that the concept of using cloud com-puting services to address the business IT needs has established a mainstream deployment across organisa-tions of various sizes. To further substantiate this matter, interestingly about 36 % of participants confirmed using a hybrid (public and private) cloud deployment model as opposed to a private cloud. Only 46 % of UK firms par-ticipated in the survey use public cloud services, in spite of the associated security risks (Fig. 4). The rate of adop-tion has been motivated by numerous indicators for effective cloud deployment decision. The most cited rea-sons for adopting cloud computing includes better scal-ability of IT resources (45.9 %), collaboration (40.5 %), cost savings (39.6 %) and increased flexibility (36.9 %). This suggests that organisations are	Ivon Miranda Santos

Opara-Martins2016-Critical_analysis_of_vendor_lock-in_and_its_i	MULTI-CLOUD ARCHITECTURE > Private cloud	The survey affirms that the concept of using cloud com-puting services to address the business IT needs has established a mainstream deployment across organisa-tions of various sizes. To further substantiate this matter, interestingly about 36 % of participants confirmed using a hybrid (public and private) cloud deployment model as opposed to a private cloud. Only 46 % of UK firms par-ticipated in the survey use public cloud services,	Ivon Miranda Santos
Opara-Martins2016-Critical_analysis_of_vendor_lock-in_and_its_i	MULTI-CLOUD ARCHITECTURE > Multiple clouds	10, we believe there are opportunities that exist for the regulatory and standard bodies to take the necessary action. One potential solution would be to standardise the APIs in such a way that businesses (or SaaS developers for example) could deploy services and data across multiple cloud providers. Thus, the failure of a single cloud provider/vendor would not take all copies of	Ivon Miranda Santos
Opara-Martins2016-Critical_analysis_of_vendor_lock-in_and_its_i	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Likewise, cloud vendors can also leverage these in-terfaces to develop new PaaS offerings, or adapt the existing ones, which would be compliant with independ-ent tools. Thus, cloud users save time when deploying applications across multiple cloud platforms. At present, the effort of deploying applications with vendor-specific tools across multiple PaaS cloud plat-forms is a non-trivial task. Developers	Ivon Miranda Santos
Opara-Martins2016-Critical_analysis_of_vendor_lock-in_and_its_i	MULTI-CLOUD ARCHITECTURE > Multiple clouds	However, this can be simplified using the CAMP inter-face common to both source and target platforms. To simplify the deployment efforts and support migration across multiple cloud platforms, CAMP defines the Plat-form Deployment Package (PDP). A PDP is an archive containing a plan file together with application content files such as web archives, database schemas, scripts, source	Ivon Miranda Santos
Opara-Martins2016-Critical_analysis_of_vendor_lock-in_and_its_i	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	Data synchronization is another concern, encountered in cloud interoperability and not in data portability [63]. To further substantiate this argument, we elucidate on the need for a portable hybrid environment by highlight-ing two main categories of portability scenarios encoun-tered in current cloud service market: 1) porting legacy applications or data; and 2) porting cloud	Ivon Miranda Santos
Opara-Martins2016-Critical_analysis_of_vendor_lock-in_and_its_i	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Moreover, modules can be combined into configuration stacks. Juju Juju is a cloud configuration, deployment and mon-itoring environment that deploy services across multiple cloud or physical servers and orchestrate those services [74]. Activities within a service deployed by Juju are or-chestrated by a Juju charm, which is a deployable service or	Ivon Miranda Santos
Perrons2013-Cloud_computing_in_the_upstream_oil_and_gas_industr	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	Private and hybrid cloud solutions have consequently emerged within the industry to yield as much benefit from cloud-based technologies as possible while working within these constraints. This paper argues, however, that the move to private and hybrid clouds will very likely prove only to be a temporary stepping stone in the industry's technological evolution. By presenting evidence from other market sectors that have faced similar challenges in their journey to the cloud, we propose that enabling technologies and conditions will probably fall into place in a way that makes the public cloud a far more attractive	Ivon Miranda Santos
Perrons2013-Cloud_computing_in_the_upstream_oil_and_gas_industr	MULTI-CLOUD ARCHITECTURE > Private cloud	Private and hybrid cloud solutions have consequently emerged within the industry to yield as much benefit from cloud-based technologies as possible while working within these constraints. This paper argues, however, that the move to private and hybrid clouds will very likely prove only to be a temporary stepping stone in the industry's technological evolution. By presenting evidence from other market sectors that have faced similar challenges in their journey to the cloud, we propose that enabling technologies and conditions will probably fall into place in a way that makes the public cloud a far more attractive	Ivon Miranda Santos

Perrons2013-Cloud_computing_in_the_upstream_oil_and_gas_industr	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	The upstream oil & gas industry generally falls into the category of cautious adopters. Although there is considerable evidence that the upstream oil & gas sector has begun to move towards the cloud (Beckwith, 2011), this progress has typically been in the form of private clouds rather than public ones (Feblowitz, 2011), or hybridized solutions that mix cloud and existing non-cloud IT resources (Mathieson and Triplett, 2011). Therein	Ivon Miranda Santos
Perrons2013-Cloud_computing_in_the_upstream_oil_and_gas_industr	MULTI-CLOUD ARCHITECTURE > Private cloud	The upstream oil & gas industry generally falls into the category of cautious adopters. Although there is considerable evidence that the upstream oil & gas sector has begun to move towards the cloud (Beckwith, 2011), this progress has typically been in the form of private clouds rather than public ones (Feblowitz, 2011), or hybridized solutions that mix cloud and existing non-cloud IT resources (Mathieson and Triplett, 2011). Therein	Ivon Miranda Santos
Perrons2013-Cloud_computing_in_the_upstream_oil_and_gas_industr	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	We will then show how many of these challenges have also been encountered in other industries, and use these examples to shine light on how these problems might be overcome in the oil & gas sector. Next, we will consolidate these emerging trends from other industries into a prediction: whereas current cloud strategies in the oil & gas industry tend to be conservatively clustered around the concept of private clouds and hybridized cloud solutions, we believe that enabling technologies and conditions will fall into place in a way that makes the public cloud a far more attractive option for the upstream oil & gas industry in the years ahead. We will then	Ivon Miranda Santos
Perrons2013-Cloud_computing_in_the_upstream_oil_and_gas_industr	MULTI-CLOUD ARCHITECTURE > Private cloud	We will then show how many of these challenges have also been encountered in other industries, and use these examples to shine light on how these problems might be overcome in the oil & gas sector. Next, we will consolidate these emerging trends from other industries into a prediction: whereas current cloud strategies in the oil & gas industry tend to be conservatively clustered around the concept of private clouds and hybridized cloud solutions, we believe that enabling technologies and conditions will fall into place in a way that makes the public cloud a far more attractive option for the upstream oil & gas industry in the years ahead. We will then	Ivon Miranda Santos
Perrons2013-Cloud_computing_in_the_upstream_oil_and_gas_industr	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	These technical realities of the industry bring about an important question: how can the upstream oil & gas sector yield as much benefit as possible from cloud-based technologies while working within these constraints? Private and hybrid clouds have emerged as popular solutions.	Ivon Miranda Santos
Perrons2013-Cloud_computing_in_the_upstream_oil_and_gas_industr	MULTI-CLOUD ARCHITECTURE > Private cloud	These technical realities of the industry bring about an important question: how can the upstream oil & gas sector yield as much benefit as possible from cloud-based technologies while working within these constraints? Private and hybrid clouds have emerged as popular solutions.	Ivon Miranda Santos
Perrons2013-Cloud_computing_in_the_upstream_oil_and_gas_industr	MULTI-CLOUD ARCHITECTURE > Private cloud	At the moment, however, the public cloud model sometimes comes with security risks. Private clouds are one alternative for managing and mitigating these kinds of threats. The objective of private clouds is not ‘‘to sell capacity over the Internet through publicly accessible interfaces, but to give local users a flexible and agile private infrastructure to run service workloads within their	Ivon Miranda Santos
Perrons2013-Cloud_computing_in_the_upstream_oil_and_gas_industr	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	Private clouds can also support a hybrid cloud model by supplementing local infrastructure and computing capacity from an external public cloud’’ (Sotomayor et al., 2009, p. 15). In this way, hybrid clouds offer the best of both worlds insofar as this approach makes it possible to manage security-related threats carefully while creating a secure conduit through which customers can selectively leverage the scalability of the public cloud whenever and however they want. Hybrid cloud solutions are a clever way to reap many of the benefits of the public cloud while maintaining a higher degree of control over data security, and they are therefore a very useful bridging technology that customers can use to	Ivon Miranda Santos

Perrons2013-Cloud_computing_in_the_upstream_oil_and_gas_industr	MULTI-CLOUD ARCHITECTURE > Private cloud	Private clouds can also support a hybrid cloud model by supplementing local infrastructure and computing capacity from an external public cloud'' (Sotomayor et al., 2009, p. 15). In this way, hybrid clouds offer the best of both worlds insofar as this approach makes it possible to manage security-related threats carefully while creating a secure conduit through which customers can selectively leverage the scalability of the public cloud whenever and however they want. Hybrid cloud solutions are a clever way to reap many of the benefits of the public cloud while maintaining a higher degree of control over data security, and they are therefore a very useful bridging technology that customers can use to	Ivon Miranda Santos
Perrons2013-Cloud_computing_in_the_upstream_oil_and_gas_industr	MULTI-CLOUD ARCHITECTURE > Private cloud	The same dynamic forces that re-shaped the retail sector may, with a bit of tweaking, be able to help the oil & gas industry get to the public cloud more quickly, too. Some data security experts even go so far as to suggest that data can be safer in the public cloud than in the privately managed facilities of companies that do not specialize in IT. Jeremy	Ivon Miranda Santos
Perrons2013-Cloud_computing_in_the_upstream_oil_and_gas_industr	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	The evidence presented here therefore makes a strong case in support of highly modular IT architectures that will be relatively easy and inexpensive to change in the future. Although private and hybrid cloud architectures are popular within the industry at the moment because of existing constraints, the examples pre-sented in this paper point to a future that is increasingly predicated on the public cloud. We accordingly believe that companies within the upstream oil & gas industry—including international oil companies, national oil companies, service com-panies, and vendors—would be well advised to build into their systems enough flexibility and modularity to make this change when the time is	Ivon Miranda Santos
Petcu2014-Portability_in_clouds_Approaches_and_research_opportu	MULTI-CLOUD ARCHITECTURE > Multiple clouds	The porting process of services is usually triggered by the operational changes. If the Cloud portability is ensured, third parties are able to be developed, acting as intermediaries between multiple customer and multiple Cloud providers, enabling deployments according the customer requirements to the appropriate Cloud and adaptation to the current status and consumption conditions of the multiple Cloud services. The porting process of data, applications or services is usually triggered at customer	Ivon Miranda Santos
Petcu2014-Portability_in_clouds_Approaches_and_research_opportu	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	Continuity: to ensure continuity in application and service functionality. The portability between Private and Public Clouds is essential in realizing the vision of the Hybrid Cloud that handles the peaks in service and resource requests addressed to a Private Cloud using external resources of a Public Cloud. The porting process	Ivon Miranda Santos
Petcu2014-Portability_in_clouds_Approaches_and_research_opportu	MULTI-CLOUD ARCHITECTURE > Private cloud	Continuity: to ensure continuity in application and service functionality. The portability between Private and Public Clouds is essential in realizing the vision of the Hybrid Cloud that handles the peaks in service and resource requests addressed to a Private Cloud using external resources of a Public Cloud. The porting process	Ivon Miranda Santos
Petcu2014-Portability_in_clouds_Approaches_and_research_opportu	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Porting between Clouds of all or a part of existing services, applications or data is usually done one time. However a third party running services on multiple Clouds and offering unique entry points to various service customers is interested to ensure that the porting process is reversible, fast and semi-automated. The most challenging scenario for portability is that in which the Cloud applications are distributed across several administrative domains of different providers simultaneously, and, moreover, at least data (if not even application and service	Ivon Miranda Santos
Petcu2014-Portability_in_clouds_Approaches_and_research_opportu	MULTI-CLOUD ARCHITECTURE > Private cloud	1. Vertical portability as the capability of an application intended for a Private Cloud to be portable to a Public Cloud. The restriction is that the application runs on the same technology stack	Ivon Miranda Santos

Petcu2014-Portability_in_clouds_Approaches_and_research_opportu	MULTI-CLOUD ARCHITECTURE > Multiple clouds	According Hill and Humphrey [18], the APIs that are allowing Cloud portability are classified in three categories: 1. multiple independent implementations, like Eucalyptus versus EC2, AppEngine versus AppScale; 2. runnable on multiple Clouds, but not through independent implementations, like the several implemen-tations of MapReduce; 3. separators of the application into application-logic layer and Cloud layer (Table 4.3). Representative for the first category, AppScale is an open source	Ivon Miranda Santos
Petcu2014-Portability_in_clouds_Approaches_and_research_opportu	MULTI-CLOUD ARCHITECTURE > Multiple clouds	The jclouds introduces the following abstractions: description of node with metadata such as CPU, RAM, security policy; an abstract representation of a node with parameters such as minCPU, OS type; group of nodes to be managed together; set of command to be executed on nodes; information about the provider. Most of the above enumerated libraries are language-dependent in their attempt to provide a common access to multiple Clouds. Typically they provide provide a code-based model of the infrastructure and do not offer any mechanism for	Ivon Miranda Santos
Petcu2014-Portability_in_clouds_Approaches_and_research_opportu	MULTI-CLOUD ARCHITECTURE > Private cloud	life-cycle of the application components, not on the management of Cloud resources. Adaptors are build for the major Public and Private Cloud technologies. The Personal Testbed Cluster (PTC) allows the development of the applications on a desktop and test on few virtual machines (as much as the desktop allows) and later on the seamless transfer of the applications into Private or Public Clouds. CompatibleOne is based on a platform and a model for the description, aggregation and integration of distributed resources provisioned	Ivon Miranda Santos
Petcu2014-Portability_in_clouds_Approaches_and_research_opportu	MULTI-CLOUD ARCHITECTURE > Multiple clouds	The DSLs allows to the domain experts to create programs having little knowledge in programming. The model-driven approach, often summarized as model once, generate anywhere, is particularly relevant when it comes to provisioning and deployment of applications and services across multiple Clouds, as well as migrating the source code and data from one service provider to another. Through high level models and automatic transformations, the application	Ivon Miranda Santos
Petcu2014-Portability_in_clouds_Approaches_and_research_opportu	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	A roadmap for the Cloud software engineering was proposed by Da Silva and Lucredio [36]. The key-points of their roadmap are: solutions for avoidance of data lock-in; decision making about the migration towards the Cloud; legacy software migration; a re-engineering process for the Cloud migration; mechanisms to facilitate the hybrid Cloud; implementation of Modelling as a Service; Cloud service composition; case studies; open source platforms.	Ivon Miranda Santos
Rai2015-Exploring_the_factors_influencing_the_cloud_computing_a	MULTI-CLOUD ARCHITECTURE > Multiple clouds	2013). Given the multiple benefits of cloud computing, many organizations are keen to adapt to this innovative tech-nology. However, tackling security issues regarding the cloud and the migration process has hampered the cloud	Ivon Miranda Santos
Rai2015-Exploring_the_factors_influencing_the_cloud_computing_a	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Survey on the secure migration process was done, to identify key concerns related to the secure adoption of cloud by both industry and academia and also to seek their expert opinion on the proposed framework. All the participants had considerable understanding of cloud computing, its multiple offerings, related technologies, and many hands-on expertise to Cloud environment. As part of their work, the participants were part of the team, which migrated different types of applications to Cloud	Ivon Miranda Santos
Ranchal2020-Disrupting_healthcare_silos_Addressing_data_volume_	MULTI-CLOUD ARCHITECTURE > Multiple clouds	The HDI service plays a critical role by providing an accurate and efficient data acquisition mechanism in building an end to end healthcare solution. The aim of this paper is to highlight the challenges of large-scale healthcare data acquisition from multiple sources and provide guidance on leveraging cloud for building an HDI service for regulated environments. Thus, we have generalized the requirements, proposed design pat-terns, and provided a reference implementation of the HDI service without making	Ivon Miranda Santos

Ranchal2020-Disrupting_healthcare_silos_Addressing_data_volume_	MULTI-CLOUD ARCHITECTURE > Multiple clouds	An outcome of the work is that IBM contributed its FHIR implementation to open source. The future vision will consider secondary use-cases where de-identified healthcare data from multiple sources are securely linked into a cloud-based global data repository, while satisfying regulatory compliance.	Ivon Miranda Santos
Ravi2019-Emergence_of_middleware_to_mitigate_the_challenges_of_	MULTI-CLOUD ARCHITECTURE > Multiple clouds	In addition, today's cloud users are mobile devices and consuming a cloud service onto mobile device poses another set of risks. One way to handle this complexity is to devise an intermediary which can take care of the heterogeneity at the cloud and mobile level, and ensure a multi-cloud deployment of application by taking advantage of the best features from dif-ferent vendors simultaneously. Thus, this paper is a sincere initiative to understand the problem beneath multi-cloud solutions and their embrace for the mobile world. Hence, the following paper begins with a broad coverage of existing work, gives an outline of a multi-cloud middleware, and discusses existing issues with API heterogeneity which is the prime point of concern in the vendor lock-in issue.	Ivon Miranda Santos
Ravi2019-Emergence_of_middleware_to_mitigate_the_challenges_of_	MULTI-CLOUD ARCHITECTURE > Multiple clouds	So, in writing flexible code for the cloud, there are four key concepts: Portability, Interoperability, Federation, and Multi-Cloud. When two cloud providers can communicate with each other, it is	Ivon Miranda Santos
Ravi2019-Emergence_of_middleware_to_mitigate_the_challenges_of_	MULTI-CLOUD ARCHITECTURE > Multiple clouds	When a cloud app works across heterogeneous cloud providers, it is Portability. When mul-tiple cloud vendors interact coherently to achieve a custom task to achieve either peak performance or cost efficiency, it is Federation and when a third-party tries to ease the communication among multiple cloud providers, it is Multi-Cloud. Gener-ally, to eliminate vendor lock-in, an application needs to be portable and purposely designed to be used across multiple clouds. A kind of reverse lock-in or lock-out is required to utilize the	Ivon Miranda Santos
Ravi2019-Emergence_of_middleware_to_mitigate_the_challenges_of_	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Service invocations from mobile devices differ in various ways due to its diversity in compiler, operating system (OS), and code incompatibil-ity issues.2 Hence, the native mobile application has to necessarily undergo some changes to accommodate a cloud service offering. In this paper, since the core idea revolves around invoking multi-cloud solutions, there is a need to bring about a disciplined approach of invoking cloud solutions from mobile devices without over-loading the mobile resources and ensure that multi-cloud solutions can be utilized onto mobile devices. Thus, the focus of this paper revolves around these two major concerns: "How to consume multiple cloud resources despite the heterogeneity with cloud service offerings"? And "How to ease the development of an mobile appli-cation that requires accessing multiple cloud	Ivon Miranda Santos
Ravi2019-Emergence_of_middleware_to_mitigate_the_challenges_of_	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Thus, the outline of the paper goes this way. Section 2 discusses about the basic motivation behind the development of multiple clouds technical solution, Sec. 3 discusses the "state-of-	Ivon Miranda Santos
Ravi2019-Emergence_of_middleware_to_mitigate_the_challenges_of_	MULTI-CLOUD ARCHITECTURE > Multiple clouds	2. Motivations for Multiple Cloud Solutions The authors in this paper3 explain that multiple cloud solutions can be either sequential or simultaneous. When a consumer sequentially consumes services from multiple clouds, it means that once for all, he wishes to migrate to a different provider for cost benefits, contract ending, location-wise legislation issues, or a provider shutdown itself. During simultaneous consumption of services, the con-sumer dynamically places requirement for additional backup, or fault tolerance. In such a case, invocation from multiple clouds happens at run-time. The two deliv-ery models that offer the sequential and simultaneous mode of services are the Federated and the Multi-cloud.4 Federated cloud is where all cloud providers have an agreement to rent/lease resources to others for	Ivon Miranda Santos

Ravi2019-Emergence_of_middleware_to_mitigate_the_challenges_of_	MULTI-CLOUD ARCHITECTURE > Multiple clouds	He just gets the resources he requested for. In Multi-cloud, the end-consumer relies on a broker or intermediary who dynamically approaches the given set of providers, negotiates the terms of service consumption, programmat-ically provisions the resources and ensures seamless utilization of multiple cloud resources. The broker also takes care of the heterogeneity in the programming envi-ronments of the cloud providers while negotiating the terms of service consumption. Thus, through interoperable APIs and standard protocols, interoperability can be achieved in the case of federated clouds, and by ensuring data and service mobility, portability can be achieved for multiple clouds. Below are the key forces that drive the development of multiple	Ivon Miranda Santos
Ravi2019-Emergence_of_middleware_to_mitigate_the_challenges_of_	MULTI-CLOUD ARCHITECTURE > Multiple clouds	In fact, there are hundreds of location-based services which work on issues such as earthquake or a tsunami, to help victims get first aid from nearby locations. Only by utilizing multiple clouds, one can embrace the widely distributed resources and provide the best time-driven services to consumers.	Ivon Miranda Santos
Ravi2019-Emergence_of_middleware_to_mitigate_the_challenges_of_	MULTI-CLOUD ARCHITECTURE > Multiple clouds	However, these SDKs are heterogeneous. Therefore, many libraries like jclouds,28 Libcloud29 and Fog30 have emerged to allow developers to add abstraction between the cloud SDKs and enable multi-clouds. The multi-cloud libraries are tightly coupled to their programming languages like Java, Python, and Ruby, so the language compiler is able to check the correctness of the developer code but does not know to treat issues that focus on general properties and characteristics. Modeling View — Once the application is deployed and adapted to a certain cloud, in order to move it in another cloud, an inspection of the source code is needed to identify the specific API calls or to build a model or representation of the code. Tools that can do are Cloud4SOA for semantic-based PaaS offering,31 REMICS for combining model-driven approach with agile practices,32 and Multi-Cloud DevOps Alliance (MODAClouds) for model-driven development of multi-cloud operations.33 For this, model-based solutions are becoming increasingly popular in cloud com-puting as they provide domain-specific modeling languages and	Ivon Miranda Santos
Ravi2019-Emergence_of_middleware_to_mitigate_the_challenges_of_	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Model-driven engineering is employed in a new technique called Cloud Blueprinting. Cloud Blueprinting — A Cloud Blueprinting offers a means to rapidly and eas-ily deploy pre-built, pre-configured, pre-optimized application payloads on virtual resource pools on the cloud and helps configure multiple cloud environments to meet application requirements and policies. It also includes a detailed deployment plan and an integration solution description, and abstracts the	Ivon Miranda Santos
Ravi2019-Emergence_of_middleware_to_mitigate_the_challenges_of_	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Meta-data constructs in the form of templates are used for providing a common understanding of the service features; a model-driven approach is employed in order to automatize the app deployment 4CaaSt project34 is an example of Cloud Blueprinting. Semantic View — However, we notice that existing model-based multi-cloud solutions lack for a precise semantics in their specifications. For example, the spec-ifications of Cloud Machine Learning (CloudML) and OASIS35 are informal	Ivon Miranda Santos
Ravi2019-Emergence_of_middleware_to_mitigate_the_challenges_of_	MULTI-CLOUD ARCHITECTURE > Multiple clouds	The lack of for-malization hinders the understanding of the models, thus complicates the inter-operability in multiclouds. Reference Architecture for Semantically Interoperable Clouds (RASIC), Cloud Provider Independent Model (CPIM), Open-source API and Platform for Multiple Clouds (mOSAIC), and UCI enable semantic interoper-ability across clouds for ensuring portability. Service-Oriented Computing View — Web services are well-known Service Oriented Architecture (SOA) implementation models that could successfully inte-grate heterogeneous services from various service providers like	Ivon Miranda Santos

Ravi2019-Emergence_of_middleware_to_mitigate_the_challenges_of_	MULTI-CLOUD ARCHITECTURE > Multiple clouds	And with the added credit of mobility features, it can serve a user anywhere and anytime. For this benefit, it is very essential to ensure that multiple cloud services are utilized by the mobile devices with ease, irrespective of the heterogeneity in the programming environments. Let us progress little by little to understand the developments in the	Ivon Miranda Santos
Ravi2019-Emergence_of_middleware_to_mitigate_the_challenges_of_	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Before laying the middleware, the real challenge lies in creating the unique API set, iden-tifying the complexity of working with distributed cloud services, mapping each service to the middleware API, and an efficient approach to service clients with low bandwidth consumption, lesser energy, and faster and optimized response. The next section gives a generic overview about the API requirements and its expectations to fulfill the multi-cloud scenario for mobile devices.	Ivon Miranda Santos
Ravi2019-Emergence_of_middleware_to_mitigate_the_challenges_of_	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Hence, an API designed should be simple, standard, and complete. Figure 4 gives an outline of the necessary characteristics an API should hold for multi-cloud solutions. Basically, design of an API should simplify the life of the implementer.	Ivon Miranda Santos
Ravi2019-Emergence_of_middleware_to_mitigate_the_challenges_of_	MULTI-CLOUD ARCHITECTURE > Multiple clouds	And completeness means lesser roundtrips. With this understanding of the API, we begin to describe the middleware for handling the multi-cloud operations for mobile devices. 5.	Ivon Miranda Santos
Ravi2019-Emergence_of_middleware_to_mitigate_the_challenges_of_	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Cloud Interoperability is a very challenging task because of the existence of Cloud API propagation74 where each cloud provider provides its own set of Web services and Application programming Interfaces. Next generation mobile applications are focusing in the combination of different cloud capabilities from multiple clouds for the creation of composite services that are not tied to cloud specifications, and for transferring data easily from one cloud to another. To the best of our knowledge, not much	Ivon Miranda Santos
Ravi2019-Emergence_of_middleware_to_mitigate_the_challenges_of_	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Native mobile apps). FUSION aims to fuse multiple cloud vendors with multi-ple handheld devices. From the cloud end, it acts as a solution to solve the cloud interoperability issue, and from the client end, it enables to access hybrid cloud ser-vices from mobile devices with less effort.	Ivon Miranda Santos
Ravi2019-Emergence_of_middleware_to_mitigate_the_challenges_of_	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	FUSION aims to fuse multiple cloud vendors with multi-ple handheld devices. From the cloud end, it acts as a solution to solve the cloud interoperability issue, and from the client end, it enables to access hybrid cloud ser-vices from mobile devices with less effort. This middleware includes its own unique stack of API set, designed with a protocol efficient for mobile or	Ivon Miranda Santos
Ravi2019-Emergence_of_middleware_to_mitigate_the_challenges_of_	MULTI-CLOUD ARCHITECTURE > Multiple clouds	This middleware includes its own unique stack of API set, designed with a protocol efficient for mobile or handheld devices. FUSION abstracts the Web APIs of multiple clouds at a common level, coordinates among different clouds, and acts as a one-stop solution for mobile clients. Figure 5 displays the generic architecture of	Ivon Miranda Santos
Ravi2019-Emergence_of_middleware_to_mitigate_the_challenges_of_	MULTI-CLOUD ARCHITECTURE > Multiple clouds	And from the perspective of middleware, if there are any changes to the middleware with respect to versioning or so, it takes care of pushing these updates to a group of recipients over multicast fashion. Overall, FUSION takes care of performing multi-cloud operation from the mobile end for achieving a common purpose.	Ivon Miranda Santos
Ravi2019-Emergence_of_middleware_to_mitigate_the_challenges_of_	MULTI-CLOUD ARCHITECTURE > Multiple clouds	The FUSION model is built as an open source and portable PaaS platform. It works on top of IaaS and is a deployable service, meaning any client can deploy the FUSION model on their environment, and use it as an agent for supporting dynamic negotiations with multiple cloud providers for assisting mobile cloud applications. The FUSION framework is designed and implemented in a service-oriented fashion where the clients are the mobile devices, and the server is the FUSION PaaS plat-form, which provides a runtime environment for tasks execution in a multi-	Ivon Miranda Santos

Ravi2019-Emergence_of_middleware_to_mitigate_the_challenges_of_	MULTI-CLOUD ARCHITECTURE > Private cloud	It is a cloud computing environment that is required as the first step towards the implementation. The FUSION framework has employed Eucalyptus, a private cloud environment to set up this PaaS platform. The experimental setup has been implemented with Eucalyptus 3.1.2 version	Ivon Miranda Santos
Ravi2019-Emergence_of_middleware_to_mitigate_the_challenges_of_	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Emergence of Middleware platform becomes a brokering system offering a collection of tools to build, control, and establish multi-cloud environment for mobile cloud applications.	Ivon Miranda Santos
Ravi2019-Emergence_of_middleware_to_mitigate_the_challenges_of_	MULTI-CLOUD ARCHITECTURE > Multiple clouds	The load bench-mark signifies the information on the mean inter-arrival time between new clients, respectively. The load testing is simulated with 20 nodes each generating from 500–2000 simultaneous requests to signify a multi-cloud operation. Since FUSION is set up on Eucalyptus, the node	Ivon Miranda Santos
Ravi2019-Emergence_of_middleware_to_mitigate_the_challenges_of_	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Such heterogeneity impedes using cloud services unless they are going to stick to the same provider. Various academic and business forums have taken up this issue seriously and are working to create a unified method of utilizing multiple cloud solutions. This paper takes a step forward in servicing the multiple cloud solutions for mobile devices. To support the above notion, this paper has done an extensive survey of the existing solutions that are offered in the market for both the cloud end and the mobile end, and then briefs about how a generic middleware should work and also outlines about the API	Ivon Miranda Santos
Ravi2019-Emergence_of_middleware_to_mitigate_the_challenges_of_	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	To support the above notion, this paper has done an extensive survey of the existing solutions that are offered in the market for both the cloud end and the mobile end, and then briefs about how a generic middleware should work and also outlines about the API heterogeneity with the existing vendors, and selects the suitable API technology that the middleware could hold. Developing such a framework would certainly decrease the effort and complexity of developing a mobile application that requires accessing distributed hybrid cloud	Ivon Miranda Santos
Raza2019-A_review_on_security_issues_and_their_impact_on_hybrid	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	Faculty of Computer Science and Information Technology University of Gujrat, Gujrat, Pakistan Abstract—The evolution of cloud infrastructures toward hybrid cloud models enables innovative business outcomes, twin turbo drivers by the requirement of greater IT agility and overall cost-containment pressures. Hybrid cloud solutions combine the capabilities of both public clouds along with those of on-premises private cloud environments. In order to key benefit with hybrid cloud model, there are different security issues that have been shown to address. In this paper, we explain security issues in detail such as to maintain trust and authenticity of information, Identity management and compliance which is influencing in enterprises due to migration of IT cloud technologies are increasingly turning to hybrid clouds. Here, work outcomes with comparative study of different existing solution and target the common problems domains and security threads.	Ivon Miranda Santos
Raza2019-A_review_on_security_issues_and_their_impact_on_hybrid	MULTI-CLOUD ARCHITECTURE > Private cloud	Abstract—The evolution of cloud infrastructures toward hybrid cloud models enables innovative business outcomes, twin turbo drivers by the requirement of greater IT agility and overall cost-containment pressures. Hybrid cloud solutions combine the capabilities of both public clouds along with those of on-premises private cloud environments. In order to key benefit with hybrid cloud model, there are different security issues	Ivon Miranda Santos

Raza2019-A_review_on_security_issues_and_their_impact_on_hybrid	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	In the past few years, several business enterprises are go mainstream that by rapid provisioning the cloud resources and to leverage the scale inherent in IT Infrastructure to cut costs and modernize IT operational for service delivery requirements rather than need of purchasing their own expensive IT infrastructure. Today many enterprises for cost savings IT cloud technologies are increasingly turning to hybrid clouds, allowing them to combine the benefits of building private and public clouds as well as to leverage the scale inherent in their existing IT Infra-structure to cut costs and modernize IT operational agility for service delivery requirements. Recently, survey covered that many enterprises	Ivon Miranda Santos
Raza2019-A_review_on_security_issues_and_their_impact_on_hybrid	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Today many enterprises for cost savings IT cloud technologies are increasingly turning to hybrid clouds, allowing them to combine the benefits of building private and public clouds as well as to leverage the scale inherent in their existing IT Infra-structure to cut costs and modernize IT operational agility for service delivery requirements. Recently, survey covered that many enterprises are rapidly adopting a multi-cloud approach using different cloud service vendors to support their IT infrastructure [3]. According to survey respondents, Microsoft Azure use 58%, and	Ivon Miranda Santos
Raza2019-A_review_on_security_issues_and_their_impact_on_hybrid	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	Additionally, Google Cloud use 19%, Oracle Cloud use 9%, and RackSpace use 7.3%. Hybrid cloud computing is about aggregation and integration of computer, networking, applications, storage, security and management into unified, orchestrated management framework which enables enterprise IT and developers to leverage scale, flexibility and cost savings of existing in-house IT investment tools, systems and privacy policies scale to manage in the enterprise data center with their newly adopted cloud services[4], [5]. The IDC report predicts	Ivon Miranda Santos
Raza2019-A_review_on_security_issues_and_their_impact_on_hybrid	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	1. A Hybrid cloud includes a few addition features as discussed below. A. Integration of Infrastructure and the Application Environment Hybrid cloud platform is the capability spinning up workloads or virtual machines for infrastructure as a service same in both private and public clouds. B. Interconnectivity The parallel processes in which two coexisting environments communicate and interact facilitate the exchange of data, VMs and applications	Ivon Miranda Santos
Raza2019-A_review_on_security_issues_and_their_impact_on_hybrid	MULTI-CLOUD ARCHITECTURE > Private cloud	A Hybrid cloud includes a few addition features as discussed below. A. Integration of Infrastructure and the Application Environment Hybrid cloud platform is the capability spinning up workloads or virtual machines for infrastructure as a service same in both private and public clouds. B. Interconnectivity The parallel processes in which two coexisting environments communicate and interact facilitate the exchange of data, VMs and applications	Ivon Miranda Santos
Raza2019-A_review_on_security_issues_and_their_impact_on_hybrid	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	C. Portability of Applications Using cloud aware development builds systems from re-usable components that will work the same across cloud environments. D. Monitoring and Management across Cloud Environments In a Hybrid clouds, monitoring and management is essential for the health of the system, visibility into system health across clouds is crucial In spite of such significant benefits, migration of IT cloud technologies from enterprises have important aspect over privacy, integrity, security concerns and compliance considerations due to reliability on multi cloud vendors such as Microsoft, Amazon and Google [7]. The descriptive study in this paper is summarised with a view to discuss and different security issues	Ivon Miranda Santos

Raza2019-A_review_on_security_issues_and_their_impact_on_hybrid	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	RELATED WORK Security in the hybrid cloud is still a major concern for many IT organizations. Undale et al. [10] describes comparison and performance review of AES, Blowfish and RC6 Symmetric cryptographic algorithm in hybrid cloud application with standard cryptographic techniques, such as Proxy encryption, ABE (Attribute based encryption)with its types. To make an efficient solution and to make an NP Complete solution of image encryption problem on hybrid cloud environment.	Ivon Miranda Santos
Raza2019-A_review_on_security_issues_and_their_impact_on_hybrid	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	With the encryption technique we have used steganography for text data storage. In this paper, our aim is to achieve the image and text data privacy using hybrid cloud. Sanjay et al. [13] focused on to identify the security threats in a hybrid cloud architectures for enterprises and suggested control method to access the data in Hybrid cloud approach using multi factor authentication from on-premises Active Directory. Federated Identities between on premises directory solution using Federated	Ivon Miranda Santos
Raza2019-A_review_on_security_issues_and_their_impact_on_hybrid	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	Anukrati and Dubey et al. [14] address some challenges to consider when migrating to hybrid clouds and techniques can addressed in hybrid infrastructure securities can be provide to protect encryption and decryption communication, key based security algorithms which are countered authentication and authorization techniques secured over the intra cloud communication in which an automatic, intelligent migration service in hybrid cloud relay on agent technology. In this research paper major areas of focus on a group of unified Identity & Access Management and privacy frameworks across cloud computing	Ivon Miranda Santos
Raza2019-A_review_on_security_issues_and_their_impact_on_hybrid	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	Hardayal and Shekhawat et al. [15] mainly concern the security risks and solutions in hybrid cloud computing for electronic governance. This study summarizes major security issues based	Ivon Miranda Santos
Raza2019-A_review_on_security_issues_and_their_impact_on_hybrid	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	Patil et al. [16] introduce a secure Hybrid Cloud approach for encrypted deduplication of data using key generation. We propose secure hashing algorithm for avoiding deduplication, which generates a unique key for each file. The generated key is stored in private cloud and Key generation process involves inside the public cloud. For security consideration to encrypt the data before updating data into the cloud becomes necessary. For achieving authorized deduplication along with protect data security, hashing algorithm is used which makes	Ivon Miranda Santos
Raza2019-A_review_on_security_issues_and_their_impact_on_hybrid	MULTI-CLOUD ARCHITECTURE > Private cloud	We propose secure hashing algorithm for avoiding deduplication, which generates a unique key for each file. The generated key is stored in private cloud and Key generation process involves inside the public cloud. For security consideration to encrypt the data before	Ivon Miranda Santos
Raza2019-A_review_on_security_issues_and_their_impact_on_hybrid	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	Following major problems are observed during the study. In the Table I below a comparative study about security issues in Hybrid cloud:(IJACSA) International Journal of Advanced Computer Science and Applications, Vol. 10, No. 3, 2019	Ivon Miranda Santos
Raza2019-A_review_on_security_issues_and_their_impact_on_hybrid	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	Shared technology issues Working with hybrid cloud still requires implementing proper data security and Integrity among these main security issues. In fact, Identity and Access Management involved in	Ivon Miranda Santos
Raza2019-A_review_on_security_issues_and_their_impact_on_hybrid	MULTI-CLOUD ARCHITECTURE > Private cloud	Data security refers to data confidentiality, integrity, authentication (CIA) in cloud [18]. A. Compliance with Regulatory and Policy Requirements Not only you have to compensate public cloud and private cloud provider are in compliance audit practices, but you also must demonstrate coordination of other third parties or open-source tools between both clouds is compliant [19]. B. Poorly Constructed SLAs Many cloud providers such as Amazon, Microsoft, Google and IBM support a large amount of	Ivon Miranda Santos

Raza2019-A_review_on_security_issues_and_their_impact_on_hybrid	MULTI-CLOUD ARCHITECTURE > Private cloud	To make sure that public cloud provider can demonstrate the infrastructure meet those commitments, options and incentives detailed in the service level agreement (SLAs) [20]. To make trusted private cloud lives up to that similar to the SLA.(IJACSA) International Journal of Advanced Computer Science and Applications,	Ivon Miranda Santos
Raza2019-A_review_on_security_issues_and_their_impact_on_hybrid	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	356 | P a g e www.ijacsa.thesai.org C. Reconfiguration Issues Several issues are resulted due to migration of components from the private cloud to the public cloud due to reconfiguring components in hybrid cloud such as addressing, firewall and component placement [21]. D. Shared Technology Issues Virtualization technologies are mostly approach in	Ivon Miranda Santos
Raza2019-A_review_on_security_issues_and_their_impact_on_hybrid	MULTI-CLOUD ARCHITECTURE > Private cloud	356 | P a g e www.ijacsa.thesai.org C. Reconfiguration Issues Several issues are resulted due to migration of components from the private cloud to the public cloud due to reconfiguring components in hybrid cloud such as addressing, firewall and component placement [21]. D. Shared Technology Issues Virtualization technologies are mostly approach in	Ivon Miranda Santos
Raza2019-A_review_on_security_issues_and_their_impact_on_hybrid	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	There is a more prone for accessing data in one virtual machine from another virtual machine on same physical server [23]. Demonstrating threats in hybrid cloud security to introduce a secure authentication framework for hybrid cloud services is required [24]. So we will target numerous threats is shown in Table II and	Ivon Miranda Santos
Raza2019-A_review_on_security_issues_and_their_impact_on_hybrid	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	CONCLUSION Hybrid cloud computing is inexorable paradigm where computing is on demand service of private and public both cloud. Emerging technologies related to any application should consider the several possible security threats. The various security issues presented would definitely useful the cloud users to suitable choice and hybrid cloud vendors to handle such kind of threats efficiently. Also, a study of hybrid model a framework of security and requirement of	Ivon Miranda Santos
Repschlaeger2012-Cloud_requirement_framework_Requirements_and_e	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	The fact that interoperability between providers hasn't been achieved makes a provider selection often irreversible or requires much effort (Hoefer and Karagiannis, 2010; Repschlaeger and	Ivon Miranda Santos
Repschlaeger2012-Cloud_requirement_framework_Requirements_and_e	MULTI-CLOUD ARCHITECTURE > Private cloud	It includes building protection (surveillance by guards or electronic devices), fire safety and physical access control. Connection opportunities focus on dedicated connections to realize separate private Cloud areas, e.g. Virtual Private	Ivon Miranda Santos
Repschlaeger2012-Cloud_requirement_framework_Requirements_and_e	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	On the other hand customers will be guided by means of this framework to adopt and implement Cloud solutions, especially for selection and comparing providers or to advance the	Ivon Miranda Santos
Repschlaeger2012-Cloud_requirement_framework_Requirements_and_e	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	This can be quite different based on the possible use cases (e.g. provider portfolio design, customer Cloud service selection process, provider benchmarking) of this framework.	Ivon Miranda Santos
Saif2022-CSO-ILB_chicken_swarm_optimized_inter-cloud_load_balan	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Generally, most of the existing load balancing techniques sufer from performance degradation due to the communication over-heads among the containers. Moreover, less attention is given to stabilize the load in a multi-cloud environment. Therefore, to overcome this problem, there is a need to develop an elastic load balancing method to improve the performance of cloud systems. This paper proposed an autonomic CSO-ILB load balancer to ensure the elasticity of the cloud system and balance the user workload among the available containers in a multi-cloud environment. The concept of multi-loop has been	Ivon Miranda Santos

Saif2022-CSO-ILB_chicken_swarm_optimized_inter-cloud_load_balan	MULTI-CLOUD ARCHITECTURE > Multiple clouds	When the resources in the cloud cannot process the huge business processes, the cloud elastic-ity is declined, and the solutions become unfeasible [27]. Load balancing in a multi-cloud environment ofers performance improvement and elasticity to process huge business tasks within a minimum time. Also, the auto-scaling mechanisms improve the efciency of the cloud environment, thereby refecting the overall reputation [28, 29].	Ivon Miranda Santos
Saif2022-CSO-ILB_chicken_swarm_optimized_inter-cloud_load_balan	MULTI-CLOUD ARCHITECTURE > Multiple clouds	To achieve both load balancing and auto-scaling simultaneously, efective meth-ods are required. Therefore, we propose a novel technique combining task schedul-ing and load balancing to achieve the abovementioned objectives in a multi-cloud environment.	Ivon Miranda Santos
Saif2022-CSO-ILB_chicken_swarm_optimized_inter-cloud_load_balan	MULTI-CLOUD ARCHITECTURE > Multiple clouds	This task can be addressed with the help of diferent techniques and algorithms where the most popular ones are based on meta-heuristics. Though several works exist on the load balancing in the cloud, most of them cannot completely optimize the process in a multi-cloud and com-plex dynamic scenario. Also, the existing techniques utilized only simple and very few	Ivon Miranda Santos
Saif2022-CSO-ILB_chicken_swarm_optimized_inter-cloud_load_balan	MULTI-CLOUD ARCHITECTURE > Multiple clouds	This article introduces a load balancing algo-rithm to avoid such a research gap in this feld. Also, this article proposes a solu-tion for resource auto-scaling in multi-cloud employing multi-loop in the self-adap-tation system. The major issues include overloading containers, resource wastage	Ivon Miranda Santos
Saif2022-CSO-ILB_chicken_swarm_optimized_inter-cloud_load_balan	MULTI-CLOUD ARCHITECTURE > Multiple clouds	The major contributions of our proposed work include the following: • To extend a dynamic scheduling strategy DCMM-MTS based on task ranking to dynamically schedule the tasks among available containers in multi-cloud. • To apply the autonomic multi-loop control in the self-adaptation system to ef-ciently monitor the load on containers and take decisions accordingly	Ivon Miranda Santos
Saif2022-CSO-ILB_chicken_swarm_optimized_inter-cloud_load_balan	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	Gamal et al. [38] suggested a hybrid bio-inspired algo-rithm to ensure efcient load balancing in the cloud. The method integrated Ant Colony Optimization with an Artifcial Bee Colony algorithm to balance the load between the VMs	Ivon Miranda Santos
Saif2022-CSO-ILB_chicken_swarm_optimized_inter-cloud_load_balan	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Table 1 summarizes the cloud environment's most recent and efcient load balancing techniques. Balancing the load in multi-cloud is challenging; Table 1 shows that the exist-ing load balancing strategies focus on balancing the load in a single cloud, but there is no work mainly focused on load balancing in containerized multi-cloud. Therefore, the proposed article attempts to maintain the load balancing and ensure the vertical and horizontal elasticity in containerized multi-cloud through autonomic computing. The	Ivon Miranda Santos
Saif2022-CSO-ILB_chicken_swarm_optimized_inter-cloud_load_balan	MULTI-CLOUD ARCHITECTURE > Multiple clouds	The artifcial Bee Colony Optimization (BCO) [49] includes the system's reliability problems. The exten-sion of the multi-cloud algorithm might increase the system's complexity and lead to imbalance. The existing Shufed Frog Leaping Algorithm (SFLA) [50] is not convergent and has	Ivon Miranda Santos
Saif2022-CSO-ILB_chicken_swarm_optimized_inter-cloud_load_balan	MULTI-CLOUD ARCHITECTURE > Multiple clouds	3 Proposed methodology The cloud environment constantly receives dynamic workloads from multiple users. Therefore, proper scheduling is required to assign appropriate resources to the incoming workloads.	Ivon Miranda Santos
Saif2022-CSO-ILB_chicken_swarm_optimized_inter-cloud_load_balan	MULTI-CLOUD ARCHITECTURE > Multiple clouds	This bio-inspired algo-rithm efciently balances the load on the overloaded container by migrating the tasks to the appropriate under-loaded container in the datacentre. Moreover, a self-adaptation system based on an autonomic MAPE loop is utilized to deal with the dynamic changes in the multi-cloud environment. Figure 1 shows the	Ivon Miranda Santos
Saif2022-CSO-ILB_chicken_swarm_optimized_inter-cloud_load_balan	MULTI-CLOUD ARCHITECTURE > Multiple clouds	The proposed module efciently balances the container load through the migration of tasks. Using the population-based approach, the load bal-ancer focuses on efciently balancing the load autonomously in multi-cloud.	Ivon Miranda Santos

Saif2022-CSO-ILB_chicken_swarm_optimized_inter-cloud_load_balan	MULTI-CLOUD ARCHITECTURE > Multiple clouds	The cloud system receives tasks from cloud users dynamically. The incoming tasks must be allocated to the available containers throughout the multi-cloud system. These tasks consist of certain requirements and deadlines based on the resources provision for the tasks' execution.	Ivon Miranda Santos
Saif2022-CSO-ILB_chicken_swarm_optimized_inter-cloud_load_balan	MULTI-CLOUD ARCHITECTURE > Multiple clouds	The utilized containers are categorized into three types based on the load (i) over-loaded, (ii) balanced, and (iii) under-loaded containers. The load balancer con-centrates on the over-loaded containers and balances the load equally between all the available containers throughout the multi-cloud environment. It ensures a bal-ance between the containers while assigning resources for task	Ivon Miranda Santos
Saif2022-CSO-ILB_chicken_swarm_optimized_inter-cloud_load_balan	MULTI-CLOUD ARCHITECTURE > Multiple clouds	3.2.1 Automatic adaptation The automatic adaptation or the self-adaptation module is the major module that allows the containers to adapt to the changes recognized in a multi-cloud environ-ment. The user tasks are dynamic in nature; hence cloud containers must	Ivon Miranda Santos
Saif2022-CSO-ILB_chicken_swarm_optimized_inter-cloud_load_balan	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Thus, global information can be obtained regarding the load entering the cloud environment. The components monitor, analyzer, planner and executor remain decentralized to main-tain a balance between multi-cloud containers during the auto-scaling process. The necessary actions are pre-defned in the planner component so that the defned actions are	Ivon Miranda Santos
Saif2022-CSO-ILB_chicken_swarm_optimized_inter-cloud_load_balan	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	The analyzer component is responsible for checking whether there is a need for auto-scaling. The hybrid auto-scaling is carried out to efectively scale the cloud resources to execute any number of tasks entering the cloud. The planner component is installed with a predictor to predict	Ivon Miranda Santos
Saif2022-CSO-ILB_chicken_swarm_optimized_inter-cloud_load_balan	MULTI-CLOUD ARCHITECTURE > Multiple clouds	The managed element incorpo-rates the application logic, which stays as a medium for directing the observed input from the environment to the system. Figure 3 depicts the working of a self-adaptation module with a multi-loop in a multi-cloud environment. The adaptation module obtains information from the environment and decides the actions taken to distribute the load among the available containers in multi-cloud data centers. Multi-loop	Ivon Miranda Santos
Saif2022-CSO-ILB_chicken_swarm_optimized_inter-cloud_load_balan	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Fig. 3 Working of Multi-Cloud Self-Adaptation using multi-Loop1128 M. A. N. Saif et al. 1 3 the resources such as the CPU and bandwidth using (10) and (11) and takes appro-priate actions to balance the load throughout the multi-cloud system. The use of multiple control loops helps in analyzing complex scenarios by using multiple sub-loops along with the main control loop for the	Ivon Miranda Santos
Saif2022-CSO-ILB_chicken_swarm_optimized_inter-cloud_load_balan	MULTI-CLOUD ARCHITECTURE > Multiple clouds	and CMODLB approaches attained 70.28%, 74.88%, 84.19%, 88.23%, 90.76%, 88.56%, 88.94%, 89.24%, 89.59%, 89.99% and 90.26% respectively. This article presents a novel CSO-ILB load balancing technique to balance the load in the containerized multi-cloud environment. The experiments proved that the proposed method could efciently balance the load among the available contain-ers by accurately choosing the	Ivon Miranda Santos
Saif2022-CSO-ILB_chicken_swarm_optimized_inter-cloud_load_balan	MULTI-CLOUD ARCHITECTURE > Multiple clouds	The proposed CSO-ILB technique has been compared with the existing ACO, BCO, ASFLA and CSO algorithms. All the existing algorithms are also imple-mented in the multi-cloud environment to evaluate the performance improvement of the proposed approach. From the conducted simulations, it has been observed that the proposed approach obtained better and	Ivon Miranda Santos
Saif2022-CSO-ILB_chicken_swarm_optimized_inter-cloud_load_balan	MULTI-CLOUD ARCHITECTURE > Multiple clouds	The overall observations show that the improvement rate of the pro-posed model is 61% in terms of response time, 59% in execution cost, 45% in task migration count, 45% in make-span, 38% in energy utilization, 42% in idle time, 35% in reliability, and 30% in CPU utilization. Thus, it can be concluded that the proposed approach outperformed the other approaches in all the considered param-eters, providing efcient load balancing, ensuing the vertical and horizontal elas-ticity in a multi-cloud environment, and satisfying both cloud user and provider objectives.	Ivon Miranda Santos

Saif2022-CSO-ILB_chicken_swarm_optimized_inter-cloud_load_balan	MULTI-CLOUD ARCHITECTURE > Multiple clouds	5 Conclusion and future scopes In this article, an efcient CSO-ILB technique has been proposed for load balanc-ing in multi-cloud. Initially, the tasks are scheduled using the extended DCMM-MTS algorithm to reduce the	Ivon Miranda Santos
Saif2022-CSO-ILB_chicken_swarm_optimized_inter-cloud_load_balan	MULTI-CLOUD ARCHITECTURE > Multiple clouds	CSO-ILB: chicken swarm optimized inter-cloud load balancer… been built for monitoring the dynamic changes in the multi-cloud system to improve the efciency of the scaling decisions. Based on these decisions, vertical or horizontal scaling is performed to ensure the elasticity of the cloud environ-ment. The simulation is performed in the multi-cloud containerized environment using the ContainerCloudsim toolkit to prove the performance and efciency of the proposed approach. The results demonstrated that the proposed approach out-performed the other approaches regarding CPU utilization, make-	Ivon Miranda Santos
Sailer2018-Healthcare_application_migration_in_compliant_hybrid	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	Abstract. Key challenges in managing healthcare applications lie in the area of compliance of the deployment environments and the usage of hybrid clouds. Our approach, as reported in this paper, utilizes two innovative concepts: compliance conformance validation and environment reconstruction supported by a Platform as a Service (PaaS) environment performing healthcare applica-tion automated migrations in hybrid clouds. We show how the migration process is conducted with dynamic	Ivon Miranda Santos
Sailer2018-Healthcare_application_migration_in_compliant_hybrid	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	Section 4 will detail the design of our Health Complaint Cloud services to natively support the HIPAA regulations. There is a rich body of literature that addresses the migration of legacy or enterprise applications to cloud [9–15] and its security and cloud hybrid aspects [12, 16–20]. Because migration to cloud is a major change for a service provider, carefully thought-out decisions factoring in technical,	Ivon Miranda Santos
Sailer2018-Healthcare_application_migration_in_compliant_hybrid	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	A survey on cloud migration decision making methodologies has been conducted in [13]. Migration to hybrid or federated clouds is another aspect addressed by current research. This type of migration requires partitioning of the application.	Ivon Miranda Santos
Sailer2018-Healthcare_application_migration_in_compliant_hybrid	MULTI-CLOUD ARCHITECTURE > Multiple clouds	An analysis of cloud migration methodologies has been conducted [19], and from the security per-spective the authors conclude that there is little research on the migration of the security and compliance aspects. Moving to cloud remains a complex endeavor which requires planning and exe-cution of multiple steps and various vendors such as AWS [22] and Cisco [18] have published guides for the service providers illustrating the required processes on their respective platforms. Our intent in this paper is to contribute to the	Ivon Miranda Santos
Sailer2018-Healthcare_application_migration_in_compliant_hybrid	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	Moving to cloud remains a complex endeavor which requires planning and exe-cution of multiple steps and various vendors such as AWS [22] and Cisco [18] have published guides for the service providers illustrating the required processes on their respective platforms. Our intent in this paper is to contribute to the migration aspects in the context of HIPAA regulated hybrid cloud with a focus on providing or maintaining compliance. On an abstract level, some of the concepts used for this migration are	Ivon Miranda Santos
Sailer2018-Healthcare_application_migration_in_compliant_hybrid	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	6 Conclusion Modern healthcare applications present particular challenges in cloud and hybrid cloud environments. Keeping these applications up-to-date in live cloud environments can be costly and	Ivon Miranda Santos
Shirvani2018-An_iterative_mathematical_decision_model_for_cloud	MULTI-CLOUD ARCHITECTURE > Multiple clouds	On the other hand, multicloud brings several merits such as vendor lock-in avoidance, system fault tolerance, cost reduction, and better quality of service. The biggest challenge is in selecting an optimal web service composition in the ever increasing multi-cloud market in which each provider has its own pricing schemes and delivers variation in the service security level. In this regard, we embed a module in the cloud broker to log service downtime and different attacks to	Ivon Miranda Santos

Shirvani2018-An_iterative_mathematical_decision_model_for_cloud	MULTI-CLOUD ARCHITECTURE > Vendor lock-in avoidance	On the other hand, multicloud brings several merits such as vendor lock-in avoidance, system fault tolerance, cost reduction, and better quality	Ivon Miranda Santos
Shirvani2018-An_iterative_mathematical_decision_model_for_cloud	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	The biggest challenge is in selecting an optimal web service composition in the ever increasing multi-cloud market in which each provider has its own pricing schemes and delivers variation in the service security level.	Ivon Miranda Santos
Shirvani2018-An_iterative_mathematical_decision_model_for_cloud	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	Another challenge is to select appropriate providers along with related services to cover the user's business process in large search space of the ever increasing multicloud market, which has mis-cellaneous competitive providers and handful	Ivon Miranda Santos
Shirvani2018-An_iterative_mathematical_decision_model_for_cloud	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	In the main phase, our biobjective optimization algorithm explores the search space, enlisted in the primary phase or enlisted off-line, to select appropriate providers for web service composition based on cost and security risks derived from the cloud broker's log file, thus integrating reliable	Ivon Miranda Santos
Shirvani2018-An_iterative_mathematical_decision_	MULTI-CLOUD ARCHITECTURE > Low security risks	In our evaluation, each cloud with low service cost is not appropriate unless its security risk is	Ivon Miranda Santos
Shirvani2018-An_iterative_mathematical_decision_model_for_cloud	MULTI-CLOUD ARCHITECTURE > Private cloud	Four service deployment types are private, public, hybrid, and community. Private cloud can be owned and managed by a single organization; public cloud is open for the general public to use at a low fee. It is owned and managed by a third	Ivon Miranda Santos
Shirvani2018-An_iterative_mathematical_decision_model_for_cloud	MULTI-CLOUD ARCHITECTURE > Private cloud	The community cloud is used for individuals and organizations with the same mission, policy, benefit, etc. Moreover, hybrid cloud includes composition of 2 or more clouds (private, commu-nity, or public) that are known unique entities. More generally, enterprises adopt the hybrid architecture in which some services are deployed in on-premises, whereas other services are	Ivon Miranda Santos
Shirvani2018-An_iterative_mathematical_decision_model_for_cloud	MULTI-CLOUD ARCHITECTURE > Vendor lock-in avoidance	The aforementioned features can only be found in MCE. In contrast to a single cloud, multicloud offers choice and flexibility for users in which they can provide services in competitive markets with low price and better QoS, thus preventing long-	Ivon Miranda Santos
Shirvani2018-An_iterative_mathematical_decision_model_for_cloud	MULTI-CLOUD ARCHITECTURE > Benefits of Multi-Cloud	Moreover, using multicloud ser-vices brings several benefits such as lock-in avoidance, a fault-tolerant system, and low security risks in failure, hardware corruption, service disruption, and sanction circumstances.27	Ivon Miranda Santos
Shirvani2018-An_iterative_mathematical_decision_model_for_cloud	MULTI-CLOUD ARCHITECTURE > Low security risks	Moreover, using multicloud ser-vices brings several benefits such as lock-in avoidance, a fault-tolerant system, and low security risks in failure, hardware corruption, service disruption, and sanction circumstances.27 Although the advantages of CC are trivial for everyone, each technology such as CC has its new threats and risks as well as related merits especially for the	Ivon Miranda Santos
Shirvani2018-An_iterative_mathematical_decision_model_for_cloud	MULTI-CLOUD ARCHITECTURE > Low security risks	Finally, a cloud com-poser selects reliable composition with both low cost and security risk inclination to cover BUs' requirements.	Ivon Miranda Santos
Shirvani2018-An_iterative_mathematical_decision_model_for_cloud	MULTI-CLOUD ARCHITECTURE > Low security risks	The final decision is based on cash flows of different deployment options in a determined life cycle along with the security risk measurement.	Ivon Miranda Santos
Shirvani2018-An_iterative_mathematical_decision_	MULTI-CLOUD ARCHITECTURE > Benefits of Multi-Cloud	Multicloud also brings several benefits such as vendor lock-in avoidance and system fault	Ivon Miranda Santos
Shirvani2018-An_iterative_mathematical_decision_model_for_cloud	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	Service deployment is typically available, which depends on the business and security requirement. Several service deployment types are private, public, community, hybrid cloud, and even a federated one. Users can deploy all of their needed services on-premises such as traditional IT or on-premises with cloud technology	Ivon Miranda Santos
Shirvani2018-An_iterative_mathematical_decision_model_for_cloud	MULTI-CLOUD ARCHITECTURE > Private cloud	Service deployment is typically available, which depends on the business and security requirement. Several service deployment types are private, public, community, hybrid cloud, and even a federated one. Users can deploy all of their needed services on-premises such as traditional IT or on-premises with cloud technology or the so-called private cloud. In this case, the term losses as a risk impact can be ignored from	Ivon Miranda Santos

Shirvani2018-An_iterative_mathematical_decision_model_for_cloud	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Finally, the method to quantify the security risks in economic factors is pro-posed. Furthermore, in a multicloud scenario, multiple providers are offering different virtual devices and computing units with different pricing and security levels in the market, which are taken into account as a bioptimization problem in the decision model.HOSSEINI SHIRVANI ET AL. 11 3.3.1 Security tenets According to broad research on security issues,14,38-41,69 the triple-vector feature (availability, integrity, and confidentiality)	Ivon Miranda Santos
Shirvani2018-An_iterative_mathematical_decision_model_for_cloud	MULTI-CLOUD ARCHITECTURE > Benefits of Multi-Cloud	3.4 Cloud decision model By using multicloud as a multisourcing option to cover business functional and nonfunctional requirements, several bene-fits are brought to users (whether individuals or organizations), such as a fault-tolerant system, lock-in avoidance, low risk, etc. As such, web service composition is selected to meet the needs, which is made possible by multicloud SOA reusabil-ity. Figure 5 shows the web service composition in cloud application. There are several cloud applications with different composition patterns, ie, sequence, parallel, and branch and loop,77-79 which are supported by Business Process Execution Language,80 but for the sake of simplicity, we consider the sequence pattern, as can be seen in Figure 7. Consequently, the cloud decision model	Ivon Miranda Santos
Shirvani2018-An_iterative_mathematical_decision_model_for_cloud	MULTI-CLOUD ARCHITECTURE > Multiple clouds	System framework: To take benefit of the multicloud for mission-critical applications, this paper applies combinato-rial optimization concepts for web service composition, which utilizes multiple clouds. Our system framework is similar in system design as those in previous works.33,81,82 It has several modules that are	Ivon Miranda Santos
Shirvani2018-An_iterative_mathematical_decision_model_for_cloud	MULTI-CLOUD ARCHITECTURE > Benefits of Multi-Cloud	To take benefit of the multicloud for mission-critical applications, this paper applies combinato-rial optimization concepts for web service composition, which utilizes multiple clouds.	Ivon Miranda Santos
Shirvani2018-An_iterative_mathematical_decision_	MULTI-CLOUD ARCHITECTURE > Cost reduction	Then, we compare it as an optimal mul-ticloud solution with on-premises cost to make a final	Ivon Miranda Santos
Shirvani2018-An_iterative_mathematical_decision_	MULTI-CLOUD ARCHITECTURE > Decision Models for Multi-Cloud	Then, we compare it as an optimal mul-ticloud solution with on-premises cost to make a final	Ivon Miranda Santos
Shirvani2018-An_iterative_mathematical_decision_	MULTI-CLOUD ARCHITECTURE > Cost reduction	4.3.2 Genetic algorithm to find the Pareto front of COST and RISK in multicloud	Ivon Miranda Santos
Shirvani2018-An_iterative_mathematical_decision_model_for_cloud	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	The second model is a random biobjective model, which casually selects services from different providers to meet the requested web services.	Ivon Miranda Santos
Shirvani2018-An_iterative_mathematical_decision_model_for_cloud	MULTI-CLOUD ARCHITECTURE > Cost reduction	More-over, in this section, Op2 is representative of the multicloud adoption option, and to harness data transfer cost, we use at most 3 clouds per 10 requested web services in MCE.	Ivon Miranda Santos
Shirvani2018-An_iterative_mathematical_decision_model_for_cloud	MULTI-CLOUD ARCHITECTURE > Decision Models for Multi-Cloud Adoption	Finally, we exemplify a real company, an SME, as a case study for multicloud adoption decision with analysis on options Op1 through Op4. Note that the problem of web service composition, as Figure 7 illustrates, is abstractedly known as a bipartite graph. Finding the optimal deterministic solution belongs to an NP-complete problem. For instance, in the simplest scenario, ie, finding deterministic optimal composition of 10 web services through 30 providers takes 3010 μs, which is provided in the 19 days of investigation, for each solution, and takes 1 μs in an examined platform. This is the reason for which we extended an advanced genetic biobjective algorithm. Figure 12 illustrates the fitness values that are generated by different models based on	Ivon Miranda Santos
Shirvani2018-An_iterative_mathematical_decision_model_for_cloud	MULTI-CLOUD ARCHITECTURE > Cost reduction	With this basis, we extend pure cost calculations for the 5-year investment along with placing the amount of cyberse-curity risk, based on our approach, cost into the total cost of cash flow to reach a sustainable decision about multicloud migration; then, it is compared with on-premises	Ivon Miranda Santos
Shirvani2018-An_iterative_mathematical_decision_model_for_cloud	MULTI-CLOUD ARCHITECTURE > Low security risks	With this basis, we extend pure cost calculations for the 5-year investment along with placing the amount of cyberse-curity risk, based on our approach, cost into the total cost of cash flow to reach a sustainable decision about multicloud migration; then, it is compared with on-premises	Ivon Miranda Santos

Shirvani2018-An_iterative_mathematical_decision_model_for_cloud	MULTI-CLOUD ARCHITECTURE > Decision Models for Multi-Cloud Adoption	With this basis, we extend pure cost calculations for the 5-year investment along with placing the amount of cyberse-curity risk, based on our approach, cost into the total cost of cash flow to reach a sustainable decision about multicloud migration; then, it is compared with on-premises option as Op1. Figure 15 depicts the comparison of options during the whole time of investment. Clearly, in all Figures, inequality Op4 < Op2 < Op3 is rationally valid. Note that since, in Op1, we can have full control on infrastructure, we neglect	Ivon Miranda Santos
Shirvani2018-An_iterative_mathematical_decision_model_for_cloud	MULTI-CLOUD ARCHITECTURE > Cost reduction	For instance, in strict mission-critical applications, the impact of matrix information depends on business criticality, which may have a drastic effect on the AMFC variable and, consequently, on the total amortized cost, creating hesitation for multicloud adoption from policymakers, ie, the Op2 bar would be taller than that of Op1.	Ivon Miranda Santos
Shirvani2018-An_iterative_mathematical_decision_model_for_cloud	MULTI-CLOUD ARCHITECTURE > Cost reduction	However, the flexibility and choice features of multicloud provide an opportunity for customers to find better cost and better QoS/SLA in the market.	Ivon Miranda Santos
Shirvani2018-An_iterative_mathematical_decision_model_for_cloud	MULTI-CLOUD ARCHITECTURE > Flexibility and choice	However, the flexibility and choice features of multicloud provide an opportunity for customers to find better cost and better QoS/SLA in the market.	Ivon Miranda Santos
Shyamasundar2017-Information_flow_control_for_building_security	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	School of Mathematics, Computer Science and Engineering City University London London, United Kingdom Email: r.muttukrishnan@city.ac.uk Abstract—A hybrid cloud is a cloud computing environment in which an organization provides and manages some internal resources (private cloud) while the other resources are provi-sioned externally (public cloud). Rapid deployment of hybrid clouds for utility, cost, effectiveness and flexibility has made it necessary to assure the security and privacy of hybrid clouds as it transcends different domains. Further, successful hybrid cloud implementation requires a well-structured architecture supporting the functionalities of both private and public clouds and the seamless transitions between them. One of the challenges in a hybrid cloud is securing resource access, in particular, enforcing that the owners policy never gets violated even when the data gets consumed and processed in multiple domains. Existing mechanisms for achieving this, including industry standards such	Ivon Miranda Santos
Shyamasundar2017-Information_flow_control_for_building_security	MULTI-CLOUD ARCHITECTURE > Private cloud	School of Mathematics, Computer Science and Engineering City University London London, United Kingdom Email: r.muttukrishnan@city.ac.uk Abstract—A hybrid cloud is a cloud computing environment in which an organization provides and manages some internal resources (private cloud) while the other resources are provi-sioned externally (public cloud). Rapid deployment of hybrid clouds for utility, cost, effectiveness and flexibility has made it necessary to assure the security and privacy of hybrid clouds as it transcends different domains. Further, successful hybrid cloud implementation requires a well-structured architecture supporting the functionalities of both private and public clouds and the seamless transitions between them. One of the challenges in a hybrid cloud is securing resource access, in particular, enforcing	Ivon Miranda Santos
Shyamasundar2017-Information_flow_control_for_building_security	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	The Readers-Writers Flow Model (RWFM) is a novel security model with an intuitive security policy that tracks and controls the flow of information in a decentralized system. In this paper, we present an approach to building a hybrid cloud that preserves the given security and privacy policy by integrating an RWFM security module into a cloud service manager. An advantage of RWFM is that it provides a uniform solu-tion for securing various kinds of hybrid cloud architectures ranging from the simple pairwise federation to the complex interclouds, and supporting varying degrees of flexibility in workload placement ranging from a simple static placement to fully dynamic migration. Further, RWFM framework is forensic-	Ivon Miranda Santos

Shyamasundar2017-Information_flow_control_for_building_security	MULTI-CLOUD ARCHITECTURE > Private cloud	When a cloud is made available in a pay-as-you-go manner to the general public, it is referred to as a public cloud – bringing clearly the underlying concept of utility computing. The term private cloud usually refers to the internal data centers of a business or other organization, not made available to the general public. While cloud computing has shown the promise of meeting the long-held dream of computing as a utility [2],	Ivon Miranda Santos
Shyamasundar2017-Information_flow_control_for_building_security	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	The classic-information flow security models such as DIFC [5], suffer the problem of placing no constraints on the discretionary access by owners of objects/entities. In this paper, we describe an architecture for realizing a secure hybrid cloud using the RWFM model [7]. Our approach enables compliance checking even w.r.t a combination of multiple	Ivon Miranda Santos
Shyamasundar2017-Information_flow_control_for_building_security	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	The rest of the paper is organized as follows: a brief overview of the security model RWFM is presented in Section II, followed by a discussion on the security concerns in hybrid clouds in Section III. Section IV describes our approach to securing hybrid clouds, and the security guarantees it provides. Merits of our approach in comparison to some of the literature is discussed in Section IV-C, and conclusions and future directions are given in Section V.	Ivon Miranda Santos
Shyamasundar2017-Information_flow_control_for_building_security	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	(i) readers component of the label of an object provides information to decide whether it is safe to be processed by a public cloud, and (ii) owner and writers components of the label of an object provide information about which cloud has created the data, and which were all the clouds that participated in the processing of data during its entire lifetime respectively. In a hybrid cloud computing environment, an organization provides and manages some of the internal resources and manages its interaction or	Ivon Miranda Santos
Shyamasundar2017-Information_flow_control_for_building_security	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	Figure 1 depicts varieties of cloud computing [12], [4]. In Figure 1, the structure Hybrid Cloud I, can be treated as an organization that uses a public cloud service such as Amazon's EC2 for general computing purposes while storing customers' data within its own data center in a private cloud. The hybrid clouds are being adopted for a variety of reasons like: (i) providing clients with the same features found in commercial public clouds, (ii) providing a uniform and homogeneous view of virtualized resources, and (iii) providing requirements of resources to meet the	Ivon Miranda Santos
Shyamasundar2017-Information_flow_control_for_building_security	MULTI-CLOUD ARCHITECTURE > Private cloud	Figure 1 depicts varieties of cloud computing [12], [4]. In Figure 1, the structure Hybrid Cloud I, can be treated as an organization that uses a public cloud service such as Amazon's EC2 for general computing purposes while storing customers' data within its own data center in a private cloud. The hybrid clouds are being adopted for a variety	Ivon Miranda Santos
Shyamasundar2017-Information_flow_control_for_building_security	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	IV. A SECURE ARCHITECTURE FOR HYBRID CLOUD In this section, we provide a general approach for securing a hybrid cloud by integrating an RWFM monitor into the cloud service manager. Further, we also illustrate the working of the approach with a concrete example (no loss of generality), and compare the benefits of our approach with related works. A. A General Approach to Securing Hybrid Cloud Consider the architecture shown in Figure 2. In Figure 2 the cloud service manager (CSM) serves as the cloud manager for the organization	Ivon Miranda Santos
Shyamasundar2017-Information_flow_control_for_building_security	MULTI-CLOUD ARCHITECTURE > Private cloud	From the perspective of an audit, the CSM is also required to maintain provenance information, for which it needs to keep track of the set of influencers of incoming data, for example the results that are being returned by the public cloud providers. The CSM can in fact provide a complete multi-level secure platform for computations on the organization's private cloud as it has full control over the resources of the private cloud. However, the CSM has to consider	Ivon Miranda Santos

Shyamasundar2017-Information_flow_control_for_building_security	MULTI-CLOUD ARCHITECTURE > Private cloud	1) The CSM is essentially a receptionist that does not have the capability to read any data except public data. It forwards the data and the request to the private cloud with the initial labeling as given. 2) The CSM passes the request (along with data) to the public cloud only if the label on the data	Ivon Miranda Santos
Shyamasundar2017-Information_flow_control_for_building_security	MULTI-CLOUD ARCHITECTURE > Private cloud	3) The CSM automatically labels the result returned by public cloud to reflect the fact that it has been influenced by the respective public cloud, before it is sent to the principal who submitted the request. 4) The CSM prevents information leaks in the inter-nal/private cloud by enforcing the RWFM rules on the flow of information among subjects and objects in the private cloud. a) The labels keep track of the influences from the	Ivon Miranda Santos
Shyamasundar2017-Information_flow_control_for_building_security	MULTI-CLOUD ARCHITECTURE > Private cloud	B. Illustration of Security In this section, we shall illustrate with an example that the general approach presented in the previous section indeed preserves the security. Consider the example scenario depicted in Figure 3, where an RWFM monitor is integrated in to the CSM - represented as a thin layer on top of the private cloud. For simplicity, the figure depicts a hybrid cloud with only one public cloud provider attached, but the methodology works even with	Ivon Miranda Santos
Shyamasundar2017-Information_flow_control_for_building_security	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	Consider the example scenario depicted in Figure 3, where an RWFM monitor is integrated in to the CSM - represented as a thin layer on top of the private cloud. For simplicity, the figure depicts a hybrid cloud with only one public cloud provider attached, but the methodology works even with multiple public cloud providers attached. A typical usage scenario in a hybrid cloud is described below using the notations of Figure 3: • User (unaware of the security classification of	Ivon Miranda Santos
Shyamasundar2017-Information_flow_control_for_building_security	MULTI-CLOUD ARCHITECTURE > Private cloud	User also specifies the data (D) on which the computation is to be performed. • RWFM monitor intercepts the user submitted job, identifies the various classes of data (D1 is sensitive and trusted data and D2 is public and untrusted data) involved in the computation, and splits the user job into multiple jobs (job J1 for computing on the sensitive data D1, and J2 for computing on the public data D2) based on the sensitivities of input and submits these jobs to the appropriate (since sensitive data will be stored in the private cloud, J1 is submitted to it, while J2 is submitted to the public cloud on which public data resides) cloud providers. For simplicity, we assume that the organization stores in its private cloud all the sensitive data, and all public data is stored on a public cloud. Note that, this immediately also	Ivon Miranda Santos
Shyamasundar2017-Information_flow_control_for_building_security	MULTI-CLOUD ARCHITECTURE > Private cloud	Further note that our method is generic and applies even in case of general lattice security policy. • Once the clouds complete their computation and return their results (private cloud returns R1 which is sensitive and trusted output, and the public cloud	Ivon Miranda Santos
Shyamasundar2017-Information_flow_control_for_building_security	MULTI-CLOUD ARCHITECTURE > Private cloud	{U, C1, C2}, where U, C1, and C2 stand for the user, private cloud and public cloud respectively. Initially the system con-tains objects D1 and D2 representing sensitive and public data respectively stored on the private cloud and the public cloud. Recollect that the initial label of a subject s is (s, S, {s}). Label of D1 is (C1, {C1}, {C1}), which says that it is (i) owned by the private cloud, (ii) sensitive, and hence readable only by the private cloud, and (iii) trustworthy, and hence can be influenced by the private cloud alone. Label of D2 is (C2, {C1, C2}, {C1, C2}) and says that it is (i) owned by the public cloud, (ii) non-confidential, and hence readable by both the private and public clouds, and (iii) un-trustworthy since it can be influenced by the public cloud.	Ivon Miranda Santos
Shyamasundar2017-Information_flow_control_for_building_security	MULTI-CLOUD ARCHITECTURE > Private cloud	(i) Req - stands for the job submitted by the user, (ii) R1 and R2 are results produced by the private and public clouds respectively, and (iii) R is the simplified final result produced by the private cloud. R has label (C1, {C1}, {C1, C2, U})	Ivon Miranda Santos

Shyamasundar2017-Information_flow_control_for_building_security	MULTI-CLOUD ARCHITECTURE > Private cloud	Specifically, the figure conveys the following information flows: • D1 to R1 - R1 is the result of private cloud's processing on D1, • D2 to R2 - R2 is the result of public cloud's processing on D2, and	Ivon Miranda Santos
Shyamasundar2017-Information_flow_control_for_building_security	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	• R1 and R2 to R - R is the result of combining the intermediate results R1 and R2. The approach illustrated for the example above is general enough to be used for realizing the following properties in hybrid clouds: 1) Complete control of privacy and security in the	Ivon Miranda Santos
Shyamasundar2017-Information_flow_control_for_building_security	MULTI-CLOUD ARCHITECTURE > Private cloud	Lattice of objects in the example scenario of hybrid cloud 2) Assure desensitization of the data before the date leaves the private cloud into the public cloud. 3) The CSM is not over privileged, but just has the	Ivon Miranda Santos
Shyamasundar2017-Information_flow_control_for_building_security	MULTI-CLOUD ARCHITECTURE > Multiple clouds	C. Discussion Zhu et al. [12] present a technique for scalable service and data migration in a collaborative cloud scenario where multiple public cloud providers store and maintain an organi-zations data. Their technique employs cryptographic	Ivon Miranda Santos
Shyamasundar2017-Information_flow_control_for_building_security	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	For example, whereas the method of [12] can only tell us that a given piece of data is currently residing in a particular public cloud, our approach can provide additional information about which all cloud providers have influenced it during the course of its computation and storage. We have developed a dynamic labelling approach for mapreduce computations using RWFM that complements the approach presented in this paper and provides an end-to-end security in a hybrid cloud. This work is currently under review	Ivon Miranda Santos
Shyamasundar2017-Information_flow_control_for_building_security	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	V. CONCLUSIONS In this paper, we have demonstrated that the RWFM model provides a secure architecture for a hybrid cloud assuring full security and privacy compliance in its private cloud and has the capability to keep track of the influences by the public cloud on the data entities. Such a capability establishes a sort of a provenance on the de-sensitised data flowing through the public	Ivon Miranda Santos
Shyamasundar2017-Information_flow_control_for_building_security	MULTI-CLOUD ARCHITECTURE > Private cloud	V. CONCLUSIONS In this paper, we have demonstrated that the RWFM model provides a secure architecture for a hybrid cloud assuring full security and privacy compliance in its private cloud and has the capability to keep track of the influences by the public cloud on the data entities. Such a capability establishes a sort of a provenance on the de-sensitised data flowing through the public	Ivon Miranda Santos
Shyamasundar2017-Information_flow_control_for_building_security	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	In a related work of ours [9] we have shown how the privacy infringements (note that due to the division of data in map-reduce, there is a possibility that the original privacy of the data may be compromised) that are possible in map-reduce frameworks can be overcome through the RWFM model. Work on integrating both these aspects for realizing an end-to-end security and privacy preserving hybrid cloud is in progress.	Ivon Miranda Santos
Sousa2016-Automated_Setup_of Multi-Cloud_Environments_for_Micro	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Email: firstname.lastname@inria.fr Abstract—Multi-cloud computing has been proposed as a way to reduce vendor dependence, comply with location regulations, and optimize reliability, performance and costs. Meanwhile, microservice architectures are becoming increasingly popular in cloud computing as they promote decomposing applications into small services that can be independently deployed and scaled, thus optimizing resources usage. However, setting up a multi-cloud environment to deploy a microservices-based application is still a very complex and time consuming task. Each microservice may require different functionality	Ivon Miranda Santos
Sousa2016-Automated_Setup_of Multi-Cloud_Environments_for_Micro	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	Selection of cloud providers should take into account the individual requirements of each service, as well as the global requirements of	Ivon Miranda Santos

Sousa2016-Automated_Setup_of Multi-Cloud_Environments_for_Micro	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Moreover, cloud providers can be very heterogeneous and offer disparate functionality, thus hindering comparison. In this paper we propose an automated approach for the selection and configuration of cloud providers for multi-cloud microservices-based applications. Our approach uses a domain specific language to describe the application's multi-cloud re-quirements and we provide a systematic method for obtaining proper configurations that comply with the application's require-ments and the cloud providers' constraints. Index Terms—multi-cloud; microservices; cloud management; variability management; software product lines I. INTRODUCTION Multi-cloud computing is the use of resources and services from multiple cloud providers where there is no agreement between providers to offer an integrated view of the system [1]. It is up to the customer or a third-party to integrate services from different providers. Multi-cloud computing is a way to avoid vendor dependence and to better exploit offerings in the cloud market by employing	Ivon Miranda Santos
Sousa2016-Automated_Setup_of Multi-Cloud_Environments_for_Micro	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	In this paper we propose an automated approach for the selection and configuration of cloud providers for multi-cloud microservices-based	Ivon Miranda Santos
Sousa2016-Automated_Setup_of Multi-Cloud_Environments_for_Micro	MULTI-CLOUD ARCHITECTURE > Private cloud	It is up to the customer or a third-party to integrate services from different providers. Multi-cloud computing is a way to avoid vendor dependence and to better exploit offerings in the cloud market by employing a combination of public and private cloud resources. Customers can build configurations that better fit their needs while	Ivon Miranda Santos
Sousa2016-Automated_Setup_of Multi-Cloud_Environments_for_Micro	MULTI-CLOUD ARCHITECTURE > Multiple clouds	We argue that these two approaches have strong synergism. On the one hand, building a multi-cloud application in-volves deploying to different clouds. Having independent well-isolated services	Ivon Miranda Santos
Sousa2016-Automated_Setup_of Multi-Cloud_Environments_for_Micro	MULTI-CLOUD ARCHITECTURE > Private cloud	Having independent well-isolated services facilitates this. On the other hand running microservices across private and public clouds from different providers allows for improved scalability and reliability.	Ivon Miranda Santos
Sousa2016-Automated_Setup_of Multi-Cloud_Environments_for_Micro	MULTI-CLOUD ARCHITECTURE > Multiple clouds	On the other hand running microservices across private and public clouds from different providers allows for improved scalability and reliability. However, building a multi-cloud solution is complex. Cus-tomers must consider factors such as functional requirements, configuration options, pricing policy, data center location, availability	Ivon Miranda Santos
Sousa2016-Automated_Setup_of Multi-Cloud_Environments_for_Micro	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Also, local regulations may require data to be stored within a given region, imposing further constraints. We propose an automated approach for the selec-tion and configuration of cloud providers for multi-cloud microservices-based applications. Our approach relies on on-tology reasoning [3] and software product line techniques [4] to get from a high-level description of multi-cloud require-ments to a configuration for a multi-cloud environment. While some approaches deal with aspects of multi-cloud manage-ment [5], [6], [7], [8], [9], they do not take into account the rich variability that exists in cloud providers' configura-tion options, losing valuable insight. Work done to manage variability in the cloud [10] does not consider multi-cloud requirements. Our approach goes further than existing work by dealing with multi-cloud requirements for microservices-based applications, while considering provider configuration variability. Our key contributions are: • An approach to build multi-cloud environments that han-dles the intrinsic variability in existing providers. • A method for translating high-level multi-cloud require-ments to a set of provider specific feature model config-urations. • Domain specific languages for specifying an application's multi-cloud requirements. • An experimental assessment of the approach	Ivon Miranda Santos

Sousa2016-Automated_Setup_of Multi-Cloud_Environments_for_Micro	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	We propose an automated approach for the selec-tion and configuration of cloud providers for multi-cloud microservices-based applications.	Ivon Miranda Santos
Sousa2016-Automated_Setup_of Multi-Cloud_Environments_for_Micro	MULTI-CLOUD ARCHITECTURE > Multiple clouds	MOTIVATION Motivations for using multiple clouds have been discussed in recent research [11], [12]. A list of 10 reasons were identified in a survey conducted	Ivon Miranda Santos
Sousa2016-Automated_Setup_of Multi-Cloud_Environments_for_Micro	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Combining them can improve QoS or costs. Multi-clouds can also be used to offload processing to other clouds when dealing with peaks, or to deploy services closer to the end user. • Complying with requirements, constraints or	Ivon Miranda Santos
Sousa2016-Automated_Setup_of Multi-Cloud_Environments_for_Micro	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Also, regulations may require sensitive data to be stored in a particular location, such as the user's country. Multi-cloud applications exist for different reasons and approaches to manage them should take this into account. To illustrate the complexity faced when building a multi-cloud system, we introduce an example scenario of an e-commerce application that requires the use of multiple clouds. This application is composed of the following services:	Ivon Miranda Santos
Sousa2016-Automated_Setup_of Multi-Cloud_Environments_for_Micro	MULTI-CLOUD ARCHITECTURE > Private cloud	• data concerning European customers should be stored in a country that is a member of the European Union. • the credit card database should be kept in a private cloud controlled by the company. Apart from these requirements, there are no further restric-tions on	Ivon Miranda Santos
Sousa2016-Automated_Setup_of Multi-Cloud_Environments_for_Micro	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Apart from these requirements, there are no further restric-tions on application services. Thus, when setting up a multi-cloud environment to deploy this application, we will be look-ing to optimize costs or improve the quality of service while complying with application requirements and constraints. Even from this simple example we can see that taking all relevant factors into account for setting up a multi-cloud environment can be a very complex task, which calls for automation and supporting tools. In this paper, we present an automated approach	Ivon Miranda Santos
Sousa2016-Automated_Setup_of Multi-Cloud_Environments_for_Micro	MULTI-CLOUD ARCHITECTURE > Cost reduction	Thus, when setting up a multi-cloud environment to deploy this application, we will be look-ing to optimize costs or improve the quality of service while complying with application requirements	Ivon Miranda Santos
Sousa2016-Automated_Setup_of Multi-Cloud_Environments_for_Micro	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	In this paper, we present an automated approach for the selection of cloud providers and generation of proper config-urations that	Ivon Miranda Santos
Sousa2016-Automated_Setup_of Multi-Cloud_Environments_for_Micro	MULTI-CLOUD ARCHITECTURE > Multiple clouds	These as well as other complex constraints can be found in cloud providers and should all be considered to obtain a proper configuration. Multi-cloud requirements for microservices-based applica-tions: Microservices can be developed by different teams, relying on different technologies and methodologies and may therefore require functionalities at different levels of ab-straction. In a multi-cloud environment, microservices can be deployed across private and public clouds from different providers to implement scalability and redundancy mecha-nisms or to comply with location constraints.	Ivon Miranda Santos
Sousa2016-Automated_Setup_of Multi-Cloud_Environments_for_Micro	MULTI-CLOUD ARCHITECTURE > Private cloud	Microservices can be developed by different teams, relying on different technologies and methodologies and may therefore require functionalities at different levels of ab-straction. In a multi-cloud environment, microservices can be deployed across private and public clouds from different providers to implement scalability and redundancy mecha-nisms or to comply with location constraints.	Ivon Miranda Santos
Sousa2016-Automated_Setup_of Multi-Cloud_Environments_for_Micro	MULTI-CLOUD ARCHITECTURE > Multiple clouds	APPROACH Our approach to deal with the concerns identified in Sec-tion II relies on (i) a high-level domain-specific language for describing multi-cloud requirements; (ii) feature models to manage the variability in cloud providers; and (iii) ontologies for dealing with the heterogeneity across cloud providers.	Ivon Miranda Santos

Sousa2016-Automated_Setup_of Multi-Cloud_Environments_for_Micro	MULTI-CLOUD ARCHITECTURE > Multiple clouds	which includes a selection of clouds providers and information on how to configure them for deploying the application. A. A DSL for multi-cloud application requirements We propose a language for defining multi-cloud require-ments based on three main constructs: service requirements, cloud variables and instance groups. The service requirements are intended to describe the functionality required by	Ivon Miranda Santos
Sousa2016-Automated_Setup_of Multi-Cloud_Environments_for_Micro	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	which includes a selection of clouds providers and information on how to configure them for deploying the application.	Ivon Miranda Santos
Sousa2016-Automated_Setup_of Multi-Cloud_Environments_for_Micro	MULTI-CLOUD ARCHITECTURE > Multiple clouds	IMPLEMENTATION To evaluate the feasibility of our approach, we developed a set of modeling and processing tools for modeling to find a multi-cloud configuration that suits the application's require-ments. The following subsections provide more information about the implementation of these tools and their evaluation. A. Modeling To model the artifacts required by our approach, we de-signed three domain-specific languages for describing (i) multi-cloud requirements; (ii) cloud provider variability; and (iii) cloud provider mappings. We then used the xText [19]	Ivon Miranda Santos
Sousa2016-Automated_Setup_of Multi-Cloud_Environments_for_Micro	MULTI-CLOUD ARCHITECTURE > Multiple clouds	. B. Reasoning The problem of finding a multi-cloud configuration that suits a set of application requirements can be seen as an assignment problem subject to constraints. As illustrated in Fig.	Ivon Miranda Santos
Sousa2016-Automated_Setup_of Multi-Cloud_Environments_for_Micro	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	After verifying that the assigned providers comply with cloud conditions we still need to check if each selected provider supports all functionality required by the services assigned to it.	Ivon Miranda Santos
Sousa2016-Automated_Setup_of Multi-Cloud_Environments_for_Micro	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	After mapping service requirements to a se-lection of features, we know that the assigned providers support the services assigned to them.	Ivon Miranda Santos
Sousa2016-Automated_Setup_of Multi-Cloud_Environments_for_Micro	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Besides this, the output solution also defines for each selected provider a complete configuration of the corresponding feature model, detailing a hierarchy of feature instances that should be selected. Our strategy for processing application requirements enables us to get from a set of requirements for microservices-based multi-cloud applications to a concrete set of selected features in each cloud provider. By decomposing this process into three steps we avoid doing more	Ivon Miranda Santos
Sousa2016-Automated_Setup_of Multi-Cloud_Environments_for_Micro	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	Besides this, the output solution also defines for each selected provider a complete configuration of the corresponding feature model, detailing a hierarchy of feature instances that should be	Ivon Miranda Santos
Sousa2016-Automated_Setup_of Multi-Cloud_Environments_for_Micro	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Information from cloud providers was obtained from their documentation and through the use of their configuration tools. We performed 20 executions of the developed tool to convert application requirements to a multi-cloud configuration. All experiments were run on a MacBook Pro Computer with a 2 GHz Intel Core i7 processor and 8GB of memory.	Ivon Miranda Santos
Sousa2016-Automated_Setup_of Multi-Cloud_Environments_for_Micro	MULTI-CLOUD ARCHITECTURE > Multiple clouds	This indicates, that despite the time needed to process and generate a valid solution, invalid assignments can be discarded more quickly and reduce the search space. D. Limitations Our approach focus on the selection and configuration of cloud providers for a multi-cloud scenario and does not deal directly with the deployment of applications. Generation of deployment scripts from feature models has been	Ivon Miranda Santos

Sousa2016-Automated_Setup_of Multi-Cloud_Environments_for_Micro	MULTI-CLOUD ARCHITECTURE > Multiple clouds	V. RELATED WORK Several recent works were proposed to deal with aspects of the management of multi-cloud systems. CloudMF [8] relies on a domain-specific language and models@runtime to deal with heterogeneity across providers and support pro-visioning and deployment of multi-cloud systems. We also employ domain-specific languages for modeling requirements and provider descriptions, but in addition we also support the selection of cloud providers and variability management. The mOSAIC [7] and soCloud [25] projects propose a multi-cloud PaaS for interoperability across multiple clouds. Instead of proposing developers a new platform service, our approach aims at supporting them to choose and combine existing	Ivon Miranda Santos
Sousa2016-Automated_Setup_of Multi-Cloud_Environments_for_Micro	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	We also employ domain-specific languages for modeling requirements and provider descriptions, but in addition we also support the selection of cloud providers and variability management.	Ivon Miranda Santos
Sousa2016-Automated_Setup_of Multi-Cloud_Environments_for_Micro	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	CloudPick [9] is a framework that supports the selection of IaaS providers and the deployment of a network of virtual appliances (preconfigured	Ivon Miranda Santos
Sousa2016-Automated_Setup_of Multi-Cloud_Environments_for_Micro	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	In [27] and [28], feature models are used to model variability in infrastructure resources (e.g. virtual machine, storage, network, etc) and support provider selection.	Ivon Miranda Santos
Sousa2016-Automated_Setup_of Multi-Cloud_Environments_for_Micro	MULTI-CLOUD ARCHITECTURE > Multiple clouds	The SALOON [10] approach also relies on feature models to capture cloud provider configuration options and ontologies to map from requirements to cloud features. However, it does not consider applications that can be composed of multiple services and do not support multi-cloud requirements. Our approach shares with existing work the use of ontolo-gies to deal with heterogeneity across cloud providers and of software product line	Ivon Miranda Santos
Sousa2016-Automated_Setup_of Multi-Cloud_Environments_for_Micro	MULTI-CLOUD ARCHITECTURE > Multiple clouds	of concerns between different user roles. We support the description of requirements for microservices-based applica-tions and mechanisms to achieve multi-cloud requirements of location, scalability and redundancy. Overall, our approach differentiates from others by taking into account variability in cloud configuration options, multi-cloud requirements and service composition to build a suitable environment.	Ivon Miranda Santos
Sousa2016-Automated_Setup_of Multi-Cloud_Environments_for_Micro	MULTI-CLOUD ARCHITECTURE > Multiple clouds	CONCLUSION Multi-cloud computing has the potential of reducing vendor dependence, increasing application reliability and optimizing resource usage. However, the wide number of available cloud providers, their high heterogeneity and their intricate configu-ration options, make it very complex to exploit these benefits. In this paper, we describe an approach to deal with this com-plexity, by supporting the selection and configuration of multi-cloud environments for microservices-based applications. Our approach relies on a domain-specific modeling lan-guage for defining multi-cloud requirements and a combina-tion of reasoning	Ivon Miranda Santos
Sousa2016-Automated_Setup_of Multi-Cloud_Environments_for_Micro	MULTI-CLOUD ARCHITECTURE > Multiple clouds	For future work, we intend to include pricing and quality of service information as part of our analysis and investigate search algorithms and heuristics to deal with this as an optimization problem. This goes into the direction of our longterm goal, which is towards self-adaptive multi-cloud environments capable of identifying optimization opportunities as application requirements and cloud market evolve.	Ivon Miranda Santos
Tona2020-DPS-AA_Intranet_migration_strategy_model_for_clouds	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	The study deeply investigated and analyzed the issues, challenges and limitations i.e. features and performances of the current state of the art of the intranets in general and on-premise Intranet of AMU in specific. Finally, an Intranet Migration Strategy Model over Hybrid Cloud was designed	Ivon Miranda Santos

Tona2020-DPS-AA_Intranet_migration_strategy_model_for_clouds	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	D. Prototype Designing In this research study, the Hybrid Cloud [9, 24] was proposed for deployment of the services of Intranet as the university functions consists of both the public and private of data and information. The AMU Cloud-Net prototype was designed and demonstrated over premium version of Interact Intranet technology platform for	Ivon Miranda Santos
Tona2020-DPS-AA_Intranet_migration_strategy_model_for_clouds	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	At this phase, an Ideal Intranet Prototype is required to be designed, developed and demonstrated over the selected Cloud Service	Ivon Miranda Santos
Weerasinghe2022-Taxonomical_classification_and_systematic_revie	MULTI-CLOUD ARCHITECTURE > Multiple clouds	Services in the microservice architecture are deployed in the distributed environment. This could be different networks, multi-cloud or hybrid clouds. Therefore, data needs to be transferred to each service to complete the business requirement, which ultimately leads to	Ivon Miranda Santos
Weerasinghe2022-Taxonomical_classification_and_systematic_revie	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	Services in the microservice architecture are deployed in the distributed environment. This could be different networks, multi-cloud or hybrid clouds. Therefore, data needs to be transferred to each service to complete the business requirement, which ultimately leads to	Ivon Miranda Santos
Weerasinghe2022-Taxonomical_classification_and_systematic_revie	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	in-memory resources that conduct real-time analytics will be the trend in this concept. On the other hand, people try to deploy their solutions in hybrid cloud environments. The reason behind moving to hybrid cloud deployment is to minimize network latency based on geographical areas and to gain several cloud vendor services. The industry is rapidly moving to microservice architecture to associate with considerable challenges as well.	Ivon Miranda Santos
Wright2011-A_commodityfocused_multi-cloud_marketplace_exemplar_	MULTI-CLOUD ARCHITECTURE > Private cloud	In particular, we consider the management of resources for the media services application cloud from a collection of resource providers. The appli-cation is hosted on a resource cloud consisting of owned infrastructure (organised as a collection of four private cloud resource providers) and a range of commercial providers. This has proved a versatile and robust approach to infrastruc-ture provisioning and permitted a	Ivon Miranda Santos
Wright2011-A_commodityfocused_multi-cloud_marketplace_exemplar_	MULTI-CLOUD ARCHITECTURE > Private cloud	Restrictions apply.Aas providers), private cloud toolkits such as Eucalyptus[5], OpenNebula or OpenStack – as well as a number of user libraries such as libcloud.org, Dasein, jclouds, Deltacloud, etc. to allow users to talk to these APIs. The cloud APIs are often very different in form and in model since they conform closely to	Ivon Miranda Santos
Wright2011-A_commodityfocused_multi-cloud_marketplace_exemplar_	MULTI-CLOUD ARCHITECTURE > Selecting appropriate providers and services	Following the commodity approach we have taken, de-ployment adjustments are made as commodity resource future requests to Zeel/i which selects a provider to satisfy the request, plans deployment and returns a resource future	Ivon Miranda Santos
Wright2011-A_commodityfocused_multi-cloud_marketplace_exemplar_	MULTI-CLOUD ARCHITECTURE > Private cloud	Our approach of provider agnostic and application fo-cused API has meant that our applications have remained unchanged as private and public providers have been intro-duced, or as their APIs have evolved. Indeed we migrated our own private cloud from OpenNebula to Eucalyptus without changing the application at all–a significant saving in time and effort. Many of our applications require high compute and stor-age performance and thus the correct	Ivon Miranda Santos
Zhou2017-Cost_reduction_in_hybrid_clouds_for_enterprise_computi	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	{zhoubiyu, zhangfa, zyliu}@ict.ac.cn, jiewu@temple.edu Abstract—Hybrid cloud-based deployment is a trend in cloud computing which enables enterprise to benefit from cloud infras-tructures while honoring privacy restrictions on some services. Enterprise application migration is an	Ivon Miranda Santos
Zhou2017-Cost_reduction_in_hybrid_clouds_for_enterprise_computi	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	However, it is a challenging problem to decide which parts of the applications to migrate and where to migrate. In this paper, we focus on the problem of planning the migration of enterprise applications in hybrid cloud infrastructures. Unlike previous studies, we consider a general hybrid cloud architecture that involves multiple public clouds rather than only one. Our aim is to maximize the enterprise cost reduction under the	Ivon Miranda Santos

Zhou2017-Cost_reduction_in_hybrid_clouds_for_enterprise_computi	MULTI-CLOUD ARCHITECTURE > Multiple clouds	In this paper, we focus on the problem of planning the migration of enterprise applications in hybrid cloud infrastructures. Unlike previous studies, we consider a general hybrid cloud architecture that involves multiple public clouds rather than only one. Our aim is to maximize the enterprise cost reduction under the constraint of	Ivon Miranda Santos
Zhou2017-Cost_reduction_in_hybrid_clouds_for_enterprise_computi	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	However, migrating the entire enterprise application to public cloud may introduce issues in security, performance and reliability [1]. In response to these concerns, several solutions based on hybrid cloud infrastructures, which involve both on-premise cloud and public cloud, have been proposed. A hybrid cloud based solution enables enterprise to find the right balance between costs, user experience and privacy considerations. It is reported that about 60% of IT decision-makers in the US and UK choose to adopt hybrid cloud architecture to deploy their applications [2]. Typically, enterprise applications involve multi-	Ivon Miranda Santos
Zhou2017-Cost_reduction_in_hybrid_clouds_for_enterprise_computi	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	Servers belong-ing to different tiers may communicate with each other. To deploy an enterprise application in a hybrid cloud environment, a key challenge is determining the location of each server. In order to solve this issue, both academia and industry have	Ivon Miranda Santos
Zhou2017-Cost_reduction_in_hybrid_clouds_for_enterprise_computi	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	Several more sophisticated approaches in planning the placement of virtual machines that minimizes the financial cost while obeying the deadlines constraint are proposed in [4, 5, 7, 8]. In [3], the authors focus their attention on dynamic migration of content distribution services into hybrid cloud infrastructures. Their aim is to minimize operational costs with a service	Ivon Miranda Santos
Zhou2017-Cost_reduction_in_hybrid_clouds_for_enterprise_computi	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	They propose a solution that employs Lyapunov optimization techniques. Unfortunately, most previous studies on enterprise applica-tion migration to hybrid cloud infrastructure use a centralized optimization solver to obtain the optimal placement of each server. These methods are effective when the	Ivon Miranda Santos
Zhou2017-Cost_reduction_in_hybrid_clouds_for_enterprise_computi	MULTI-CLOUD ARCHITECTURE > Multiple clouds	However, they are ineffective against typical medium-scale enterprise applications in which thousands of servers are involved. In addition, while existing works have done a good job exploring the benefits of deploying applications in the simple two clouds environment(which contains both a private and a public cloud), they seldom evaluate the benefits of employing a hybrid cloud architecture with a private cloud and multiple geographically distributed public clouds. In fact, many large cloud providers (e.g., Amazon Web Services [9] and Microsoft Azure [10]) enabled the placement of instances in multiple locations. In this paper, our objective is to explore the benefits of migrating medium- and large-scale enterprise applications to hybrid cloud infrastructures, in which a local cloud and multiple	Ivon Miranda Santos
Zhou2017-Cost_reduction_in_hybrid_clouds_for_enterprise_computi	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	However, they are ineffective against typical medium-scale enterprise applications in which thousands of servers are involved. In addition, while existing works have done a good job exploring the benefits of deploying applications in the simple two clouds environment(which contains both a private and a public cloud), they seldom evaluate the benefits of employing a hybrid cloud architecture with a private cloud and multiple geographically distributed public clouds. In fact, many large cloud providers (e.g., Amazon Web Services [9] and Microsoft Azure [10]) enabled the placement of instances in multiple locations. In this paper, our objective is to explore the benefits of migrating medium- and large-scale enterprise applications to hybrid cloud infrastructures, in which a local cloud and multiple	Ivon Miranda Santos

Zhou2017-Cost_reduction_in_hybrid_clouds_for_enterprise_computi	MULTI-CLOUD ARCHITECTURE > Private cloud	However, they are ineffective against typical medium-scale enterprise applications in which thousands of servers are involved. In addition, while existing works have done a good job exploring the benefits of deploying applications in the simple two clouds environment(which contains both a private and a public cloud), they seldom evaluate the benefits of employing a hybrid cloud architecture with a private cloud and multiple geographically distributed public clouds.	Ivon Miranda Santos
Zhou2017-Cost_reduction_in_hybrid_clouds_for_enterprise_computi	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	The main contributions of this paper are summarized as follows: 1) We tackle the issue of migrating enterprise applications in hybrid cloud infrastructures. Leveraging the characteristics of enterprise applications, we propose a three-stage framework	Ivon Miranda Santos
Zhou2017-Cost_reduction_in_hybrid_clouds_for_enterprise_computi	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	We describe the Enterprise Application Migration (EAM) problem that maximizes the total cost reduction while ensuring the completion time constraint in this subsection. Mathemati-cally, we model a typical hybrid cloud architecture as a node set H = H ∪ h0, where h0 represents the on-premise data center and H represents M	Ivon Miranda Santos
Zhou2017-Cost_reduction_in_hybrid_clouds_for_enterprise_computi	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	We consider a static scenario in this paper, and thus, the values of ti and ti,j can both be precomputed.	Ivon Miranda Santos
Zhou2017-Cost_reduction_in_hybrid_clouds_for_enterprise_computi	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	The goal is to de-termine a migration policy x = {xi,π(i)} which minimizes the total costs subjected to given transaction delay constraint. We adopt the application migration plan model provided by Hajjat in [1] and extend it to fit our hybrid cloud infrastructure– in which more than one public cloud site is involved–in the following. A. Cost Reduction Typically, possessing servers in public clouds is much cheaper than in small- or medium-sized	Ivon Miranda Santos
Zhou2017-Cost_reduction_in_hybrid_clouds_for_enterprise_computi	MULTI-CLOUD ARCHITECTURE > Private cloud	A. Cost Reduction Typically, possessing servers in public clouds is much cheaper than in small- or medium-sized data centers due to Economies of Scale. Some reports claim 80% savings using public clouds versus on-premise private data centers [11]. The actual savings for a specific server depend on the resource requirement of the server, the server renting price of the cloud provider and the	Ivon Miranda Santos
Zhou2017-Cost_reduction_in_hybrid_clouds_for_enterprise_computi	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	This cost mainly depends on the total communication traffic volume and the per-unit Internet communication cost of traffic from the cloud site. Deploying communicating servers to hybrid clouds will change the Internet	Ivon Miranda Santos
Zhou2017-Cost_reduction_in_hybrid_clouds_for_enterprise_computi	MULTI-CLOUD ARCHITECTURE > Multiple clouds	A linear cost model is used for computing the value of βi,π(i) and βi,j,π(i),π(j), which matches the business model of multiple cloud providers [1]. Note that the value of βi,π(i)	Ivon Miranda Santos
Zhou2017-Cost_reduction_in_hybrid_clouds_for_enterprise_computi	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	Obviously the value of γi,π(i) can also be pre-computed. Let H(x) denote the total benefits leveraging the hybrid cloud infrastructure; thus it can therefore be expressed as H(x) = vi∈V γi,π(i) −	Ivon Miranda Santos
Zhou2017-Cost_reduction_in_hybrid_clouds_for_enterprise_computi	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	C. Motivation Example In order to describe the problem more clearly, we give a motivation example in this subsection. The hybrid cloud considered here involves an local cloud (h0) and two public clouds (h1, h2). The users are from three regions (R0, R1 and	Ivon Miranda Santos
Zhou2017-Cost_reduction_in_hybrid_clouds_for_enterprise_computi	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	This is the strategy adopted in this paper. C. Time Complexity The complexity of the Algo DP(Gq) is O(Nq ∗ D ∗ M), where Nq is the number of nodes of Gq, D is the time constraint, and M is the number of hybrid clouds. Note that when Gq is a tree, as in case 1, the algorithm will output the optimal solution.	Ivon Miranda Santos
Zhou2017-Cost_reduction_in_hybrid_clouds_for_enterprise_computi	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	R1 and R2). The hybrid cloud considered in the simulation consists of one on-premise data center (h0) and two public cloud sites (h1 and h2). Note that h0 is located in region R0,	Ivon Miranda Santos

Zhou2017-Cost_reduction_in_hybrid_clouds_for_enterprise_computi	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	Besides, the cost reduction obtained by our algorithm is close to that of the optimal solution solved by COMBSPO. Finally, our framework performs better in reducing enterprise costs leveraging the hybrid cloud architecture under controllable time overhead than the other two strategies. On average, EAM Algo reduces 27.80% and 12.74% more costs compared with	Ivon Miranda Santos
Zhou2017-Cost_reduction_in_hybrid_clouds_for_enterprise_computi	MULTI-CLOUD ARCHITECTURE > Hybrid cloud	V. CONCLUSION In this paper, we study the problem of migrating enterprise applications to hybrid cloud for cost benefits maximization. Unlike previous works, this work considers a more general hy-brid cloud architecture involving multiple public clouds rather than one. By exploring the features of typical communicating applications, we propose a framework to derive an application migration plan	Ivon Miranda Santos
Zhou2017-Cost_reduction_in_hybrid_clouds_for_enterprise_computi	MULTI-CLOUD ARCHITECTURE > Multiple clouds	In this paper, we study the problem of migrating enterprise applications to hybrid cloud for cost benefits maximization. Unlike previous works, this work considers a more general hy-brid cloud architecture involving multiple public clouds rather than one. By exploring the features of typical communicating applications, we propose a framework to derive an application migration plan	Ivon Miranda Santos
Alonso2023-Understanding_the_challenges_and_novel_architectural	MULTI-CLOUD ARCHITECTURE > Multiple clouds	The traditional use of cloud services, focused on the consumption of one provider, is not valid anymore due to diferent shortcomings being the risk of vendor lock-in a critical.	Ivon Miranda Santos
Alonso2023-Understanding_the_challenges_and_novel_architectural	MULTI-CLOUD ARCHITECTURE > Multiple clouds	We are assisting to a change of paradigm, from the usage of a single cloud provider to the combination of multiple cloud service types, afecting the way in which applications are designed, developed, deployed and operated	Ivon Miranda Santos
Alonso2023-Understanding_the_challenges_and_novel_architectural	MULTI-CLOUD ARCHITECTURE > Multiple clouds	The result is an efective heterogeneity of architec- tures, methods, tools, and frameworks, copying with the multi-cloud application concept.	Ivon Miranda Santos
Alonso2023-Understanding_the_challenges_and_novel_architectural	MULTI-CLOUD ARCHITECTURE > Multiple clouds	The goal of this study is manifold. Firstly, it aims to characterize the multi-cloud concept from the application development perspective by reviewing existing defnitions of multi-cloud native	Ivon Miranda Santos