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Identification of Hybrid Cloud Architecture Best Practices with a Focus on Data Center Optimization and Orchestration Gap Avoidance

CAPSTONE REPORT

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Abstract

This annotated bibliography provides a source of scholarly references that highlight hybrid cloud solutions developed within the past decade to reflect the most recent changes in technology. Current challenges in designing hybrid cloud solutions are to optimize the data center and avoid orchestration gaps. The target audience members for the study are marketing groups within the enterprise who market hybrid cloud solutions.

Keywords: hybrid cloud, cloud orchestration, data center optimization, cloud models: SaaS, IaaS, PaaS

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Introduction

Problem

The hybrid cloud is a conglomerate of private on-premise and public off-premise cloud environments that maximize performance, capacity, and cost optimization in a virtualized environment (Mazhelis & Tyrvainen, 2012). The benefits of the hybrid cloud derive from the coupling of the public cloud with greater control supplied by private clouds as a driver for high levels of quality, scalability, and customer satisfaction (Quarati, Clematis, Galizia, & D’Agostino, 2013). What makes the hybrid cloud solutions appealing, according to Linthicum (2011) is that the solution allows specific aspects of existing information technology (IT) infrastructure to remain on-premise while storage and computing can occur in public environments. The hybrid cloud allows datacenter workloads to move between private and public cloud environments, giving businesses flexibility and data deployment options (Rouse, 2015). Rivera and van der Meulen (2014) add that the hybrid cloud allows maximization of value by balancing internal assets; cost-efficiencies, in particular reduced capital costs; the ability to scale; improved disaster recovery; and often a more flexible introduction of functionality. Kavis (2014) highlights regulatory and data privacy issues for the enterprise that make hybrid solutions more attainable by retaining some private control of applications and data rather than potentially exposing these assets in public cloud solutions (p. 45).

Cloud computing history traces back to the late 1960s. Salsforce.com took the first move in the cloud space by introducing a concept of delivering enterprise applications via a website (Mohamed, 2009). Movement into the cloud soon followed by an industry-wide collaboration in 2007 between Google, IBM and a number of universities across the United States (Biswas, 2011). OpenNebula took credit as the first organization to deploy open source software to both the private and hybrid clouds in 2008 (Biswas, 2011). Since the birth of the hybrid cloud in 2008, the service grew to consist of 39 percent of the overall cloud computing service model by 2013 (White, 2013). Today cloud computing and hybrid solutions from various vendors appear plentiful within the cloud space on multiple platforms and include offerings from Microsoft Corporation; VMware, Inc.; Dell, Inc.; and Hewlett-Packard Company that top the 2014 list of solution providers (Shinder, 2014).

Independent software vendors (ISVs) that specialize in cloud solutions must have expertise in hybrid cloud solutions, not only to deploy effective solutions, but also to market them. The area of focus in designing hybrid cloud solutions from a Software Solution Marketing perspective is to drive optimization in the datacenter (P. Nist, personal communication, February, 2015). Software Solution Marketing groups within Enterprise Information Technology (IT) organizations such as Intel Corporation that consult on and market cloud solutions take part in building strategies through engagements with ISVs to define solutions that encompass server technology and hybrid cloud solutions (P. Nist, personal communication, February, 2015). The solutions of combined technologies that arise through engagements often introduce orchestration gaps in how software technologies, similar to those produced by VMware, Microsoft, and Oracle: (a) interface with each other, (b) preserve security, (c) show cost effectiveness, and (d) demonstrate scalability (Zaino, 2014). The importance of these deficiencies according to Yoo (2011) is that the mitigation strategies for these issues have implications for the industry structure for datacenters and cloud computing (p. 405). McDonald (2010) explains that datacenters only use up to 15 percent of available capacity using a hybrid structure, and thus can regain idle capacity and lower operating costs (p. 7). To recommend and market the best hybrid cloud solutions, Software Solution Marketing groups need to be aware of orchestration gaps that are common with cloud solutions and the best practices to avoid these gaps.

Key areas that are important in defining strategies for building the path to the hybrid cloud include selection of the specific appliance, software virtualization solution, and other server related technologies (Yoo, 2011). Guevara, Lubin, and Lee (2014) add that an optimal balance of server class processors aids in not only datacenter computing performance, but also in energy efficiency and system welfare (p. 15). All of these components of the hybrid cloud solution offer considerations for optimization, both in the design of individual components as well as the integration of the components into optimal solutions.

As datacenters continue to expand, there is a need to identify hybrid cloud architecture best practices with a focus on data center optimization and orchestration gap avoidance to inform the marketing of these solutions. One of the challenges in identifying best practices supporting hybrid cloud solutions is the complexity that results from the orchestration of the countless combinations of solutions. The level of orchestration required to balance enterprise controls over multiple hybrid environments can also become burdensome (Sturrus & Kulikova, 2014). Additional challenges with hybrid cloud solutions that relate to the problem include security concerns, achieving a positive cost benefit ratio, and stabilization of the environment (p. 85). Pedram (2012) also notes that with the rise in cloud computing, high costs from energy consumption pose concerns for organizations that are considering deploying cloud solutions within the enterprise (p. 1465). Erbes, Motahari-Nezhad, and Graupner (2012) highlight adoption issues with the cloud solutions for Enterprise IT that call on new methods in managing a hybrid portfolio (p. 66). Yoo (2011) adds that potential disadvantages of cloud computing can come from one of two avenues: interfaces that link users and the software that connects the network to the datacenter (p. 413).

Erbes et al. (2012) address the hype and challenges of cloud adoption by identifying new methodologies, tools, and skill sets that Enterprise IT personnel should embrace with externally acquired services (p. 66). The use of similar techniques has the potential to increase the effectiveness of strategies employed by Software Solution Marketing groups. Frameworks to address the orchestration of cloud adoption can also provide benefits in the areas of facilitation and control for the enterprise (Sturrus & Kulikova, 2014).

Purpose Statement

The purpose in researching scholarly literature on hybrid cloud best practices and related topics is to better understand how Enterprise IT marketing groups within consulting companies that engage in hybrid cloud projects can better define marketing plans for specific hybrid cloud solutions by understanding and employing best practices in architecting these solutions to achieve datacenter optimization and avoid potential orchestration gaps. The focus of the research is on literature sources that address the challenges associated with the implementation of cloud solutions in the datacenter, including architecture differences and orchestration gaps, to inform marketing groups of key concept and best practices. The preliminary search for reference sources over the larger field of information management includes IT architecture design. Reference sources are selected within a frame that relates closely to knowledge management and also some areas of change management with respect to various processes in the building and maintenance of information infrastructure and datacenter environments.

Research Question

As Software Solution Marketing groups set out to optimize the datacenter using hybrid cloud solutions, what are the best techniques and practices in designing architectures with these solutions to achieve datacenter optimization and avoid potential orchestration gaps?

Audience

The intended target audience for this particular study includes Marketing Managers, Business Development Managers, Field Sales Managers, and Chief Marketing Officers (CMOs). The targeted groups focus on related marketing tasks in developing marketing solutions, brand awareness, and increasing market share for the purpose of promoting or selling products (American Marketing Association, 2013). The goal of this study is to provide specific information on hybrid cloud infrastructure best practices, methodologies, and guidance to support the marketing of solutions for strategies to optimize the datacenter using hybrid cloud solutions.

Search Report

Search strategy. Finding literature related to hybrid cloud and datacenter optimization by using search tools provided by the University of Oregon Library site requires focus on keyword search criteria. Keyword searching on phrases includes hybrid cloud and datacenter optimization as a foundation to help in identifying appropriate literature. Initial searches using the quick search method provide narrow results; further refinement of search criteria is essential in finding related links to literature through specialized databases.

Search Engines and Databases

- Academic Search Premier
- JSTOR

- Project Muse
- Web of Science
- Computer Source
- ArXiv.org
- Academic Search Premier
- Science Direct

Key Search Terms

- Hybrid Cloud
- Hybrid Cloud + Strategies
- Hybrid Cloud + Security
- Hybrid Cloud + Scalability
- Hybrid Cloud + Orchestration
- Datacenter
- Datacenter + Optimization
- Datacenter + Software Interface
- Datacenter + Scalability
- Xeon Datacenter
- OpenStack
- Virtualization
- Software as a Service (SaaS)
- Marketing SaaS

In addition to using the UO Library site, Google Scholar is an additional source for searches on key terms.

Reference Evaluation Criteria

The selected references identified during the developing search strategy are analyzed to ensure the proper adherence to Bell and Frantz's (2014) criteria for authority, currency, relevancy, objectivity, and quality to support the information within this study.

Authority. The credentials of each author are reviewed to ensure that the author has relevant university degree(s) and employment or field experience and has established a strong reputation among peers, as evidenced by citations of the author's work in other publications (Bell & Frantz, 2014).

Currency. To evaluate the currency of references, Bell and Frantz (2014) state that searching by publication date for the most up-to-date literature within the current decade is a requirement as the topic relates to the technology field within the science category. Selecting references within the current decade helps to ensure that the selected literature is addressing the most current best practices related to the problem.

Relevancy. To determine relevance of select references, literature is selected where the source content is scholarly and secondary in nature (Bell & Frantz, 2014).

Objectivity. Bell and Frantz (2014) add that to evaluate the objectivity of an author, one should check to see if the author exhibits particular bias on a specific point of view that does not point to supported evidence. Each reference source in this Annotated Bibliography is evaluated for signs of bias and to ensure that conclusions that are supported by evidence rather than opinion.

Quality. The reference sources are evaluated for quality by ensuring the authors use proper grammar and avoid typographical errors and that the text flows logically and the information provided is well organized (Bell & Frantz, 2014).

Documentation Approach

The specifics of the search are documented by developing categories to understand the content and sorting references by (a) background or context of the problem, and (b) information that supports potential solution alternatives. Zotero is the primary electronic resource used to collect references for the bibliography and for citations within the text. Information on the references collected via Zotero includes the abstract, author, publication date, and title of the publication.

Annotated Bibliography

The purpose of this annotated bibliography is to provide 15 unique references highlighting cloud computing and hybrid cloud solutions in relation to optimizing the datacenter. The ideas presented in the summary are those of the author(s) of the references and are not opinions expressed by the writer of this annotated bibliography. Selected references in this bibliography aid in the approach to defining best practices in relation to understanding the challenges of deploying solutions from different architectures and orchestration gaps to inform the marketing of these solutions. The annotations found within the bibliography consist of a reference citation, abstract, and summary of the authors' literature.

Background or Context of the Problem

Erbes, J., Motahari-Nezhad, H. R., & Graupner, S. (2012). The future of enterprise IT in the cloud. *Computer, 45*(5), 66–72. doi:10.1109/MC.2012.73. Retrieved from http://ieeexplore.ieee.org.libproxy.uoregon.edu/stamp/stamp.jsp?tp=&arnumber=6155711

Abstract. The widespread availability and adoption of cloud services creates new challenges for enterprise IT and prompts the need for new methodologies, tools, and skill sets for managing a hybrid portfolio of these services and traditional IT systems.

Summary. This article focuses on trends forcing change for enterprise IT departments away from closed ecosystems. IT personnel need an understanding of the types of services consumed within the enterprise addressing trends in (a) cloud services, (b) IT consumerization, and (c) increasing cross-enterprise collaboration in managing a cloud ecosystem. A hybrid cloud portfolio can include a mix of internal and external providers and cloud based IT infrastructures. The challenge for IT departments can range from creating, maintaining, and optimizing hybrid services within a datacenter. The article adds that Enterprise IT personnel need to embrace change with new tools, methods, and frameworks to support new opportunities offered from hybrid cloud solutions. A service-centric approach to the IT ecosystem and the hybrid environment using a framework that approaches strategy, design, implementation, operation, and continuous improvement is shifting the basis of value and fundamentally changing the IT role. The shift requires support for end-to-end service life cycles through strategic planning, service design, integration, support, and continuous improvement for a hybrid cloud portfolio (Erbes et al., 2012).

Li, Q., Wang, Z., Li, W., Li, J., Wang, C., & Du, R. (2013). Applications integration in a hybrid cloud computing environment: Modelling and platform. *Enterprise Information Systems*, *7*(3), 237–271. doi:10.1080/17517575.2012.677479. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=89660181&site=ehost-live&scope=site

Abstract. With the development of application services providers and cloud computing, more and more small- and medium-sized business enterprises use software services and even infrastructure services provided by professional information service companies to replace all or part of their information systems (ISs). These information service companies provide applications, such as data storage, computing processes, document sharing and even management information system services as public resources to support the business process management of their customers. However, no cloud computing service vendor can satisfy the full functional IS requirements of an enterprise. As a result, enterprises often have to simultaneously use systems distributed in different clouds and their intra enterprise ISs. Thus, this article presents a framework to integrate applications deployed in public clouds and intra ISs. A run-time platform is developed and a cross-computing environment process modelling technique is also developed to improve the feasibility of ISs under hybrid cloud computing environments.

Summary. This article focuses on cloud computing enabling technology from service and resource models to achieve low cost and high efficiency through the cloud. Obstacles to cloud and hybrid cloud computing often include availability of a service, data lock-in, challenges with data confidentiality, data transfer bottlenecks, performance unpredictability, a lack of scalable storage, the need to scale quickly, and software licensing (Armbrust et al., 2010). Data lock-in from a cloud perspective can derive from a nonstandard application program interface (API) to limit or prevent data extraction (Armbrust et al., 2010). The software licensing obstacle limits the computer or cloud environment to the available software license. In some cloud environments, open source software will eliminate the restriction, but the solution might not always be compatible with other commercial software. In a hybrid cloud computing environment a single enterprise may adopt several cloud environments to support business processes and a preliminary integration across the network. The solution to adopt multiple cloud environments will allow low cost, high efficient, use of cloud services over the network. The article adds, however this type of adoption brings a new problem of integration among multiple computing environments (Li et al., 2013).

Marston, S., Li, Z., Bandyopadhyay, S., Zhang, J., & Ghalsasi, A. (2011). Cloud computing — The business perspective. *Decision Support Systems*, *51*(1), 176–189. doi:10.1016/j.dss.2010.12.006

Abstract. The evolution of cloud computing over the past few years is potentially one of the major advances in the history of computing. However, if cloud computing is to achieve its potential, there needs to be a clear understanding of the various issues involved, both from the perspectives of the providers and the consumers of the technology. While a lot of research is currently taking place in the technology itself, there is an equally urgent need for understanding the business-related issues surrounding cloud computing. In this article, we identify the strengths, weaknesses, opportunities and threats for the cloud computing industry. We then identify the various issues that will affect the different stakeholders of cloud computing. We also issue a set of recommendations for the practitioners who will provide and manage this technology. For IS researchers, we outline the different areas of research that need attention so that we are in a position to advice the industry in the years to come. Finally, we outline some of the key issues facing governmental agencies who, due to the unique nature of the technology, will have to become intimately involved in the regulation of cloud computing.

Summary. This article focuses on the fundamental change from the emergence of cloud computing and hybrid cloud systems that represents a new approach to information technology (IT) managed services and infrastructure. The key advantages that cloud computing offers to organizations include: (a) lower cost in computing power from business analytics, (b) immediate access to hardware resources involving nearly zero capital investment from users, (c) lower IT barriers to innovation, (d) easier scaling of services in the cloud, and (e) creation of a path for new classes of applications and delivery services (Marston et al., 2011). The infrastructure for a hybrid system consists of some information services transferred to the cloud, while a portion of the services remains in-house. According to the authors, some corporate datacenters found servers grossly underutilized, with performance ranging from 10 to 30 percent of compute power (Marston, Li, Bandyopadhyay, Zhang, & Ghalsasi, 2011). This underutilization is an issue from a maintenance and service cost perspective against corporate IT staffing budget, which is often constrained with limited resources to provide any additional IT coverage.

For large enterprises, implementation of an organization-wide and consistent information service policy across different cloud computing services is becoming an important management tool in building an overall cloud strategy. In building a cloud strategy the authors suggest that information services (IS) and IT departments build a roadmap to help develop an understanding of the technology landscape to address reliability, stability, and security needs when considering implementation of a cloud solution into the corporate landscape.

Mazhelis, O., & Tyrväinen, P. (2012). Economic aspects of hybrid cloud infrastructure: User organization perspective. *Information Systems Frontiers, 14*(4), 845–869. doi:10.1007/s10796-011-9326-9

Abstract. Adoption of cloud infrastructure promises enterprises numerous benefits, such as faster time-to-market and improved scalability enabled by on-demand provisioning of pooled and shared computing resources. In particular, hybrid clouds, by combining the private in-house capacity with the on-demand capacity of public clouds, promise to achieve both increased utilization rate of the in-house infrastructure and limited use of the more expensive public cloud, thereby lowering the total costs for a cloud user organization. In this paper, an analytical model of hybrid cloud costs is introduced, wherein the costs of computing and data communication are taken into account. Using this model, a cost-efficient division of the computing capacity between the private and the public portion of a hybrid cloud can be identified. By analyzing the model, it can be shown that, given fixed prices for private and public capacity, a hybrid cloud incurs the minimum costs. Furthermore, it is shown that, as the volume of data transferred to/from the public cloud increases, a greater portion of the capacity should be allocated to the private cloud. Finally, the paper illustrates analytically that, when the unit price of capacity declines with the volume of acquired capacity, a hybrid cloud may become more expensive than a private or a public cloud.

Summary. This article focuses on hybrid cloud architecture benefits from related research papers detailing aspects of three subsystems: (a) open subsystems provided by the public cloud, (b) open subsystems provided by the private cloud, and (c) closed subsystems. Subsystems mentioned in the article consist of legacy systems (i.e., software applications connected to the cloud). The article adds that cloud infrastructure promises a reduction in enterprise IT costs, faster time to market, and improved scalability (Mazhelis & Tyrväinen, 2012).

When comparing different cloud infrastructure deployment models, the hybrid model assumes a more cost efficient model than the private and the public cloud by supplementing the limited capacity of the private infrastructure with the capacity of the public cloud. Mazhelis and Tyrväinen (2012) add, to minimize the costs of the hybrid cloud, a balance must exist between the reserved private cloud capacity and the public cloud capacity. This relates to the higher price of the public cloud capacity and balances this factor with a relative short duration in utilization of the public cloud. The two cost components considered in the article include (a) costs of computing capacity often incurred by hardware, software, and data storage, and (b) data communication costs (Mazhelis & Tyrväinen, 2012).

Adoption of the hybrid cloud is often dependent on system functionality and usage patterns that may or may not incur additional costs. Additional costs may come from computing and data communication, load balancing of workloads in the hybrid cloud and costs of persistent storage in the public cloud (Mazhelis & Tyrväinen, 2012). Application usage may require significant volumes of data to be continually stored in the public cloud, creating noticeable storage-related cost. Pricing the unit of capacity is not necessarily fixed, but often subject to market segmentation and price discrimination (Kotler & Keller, 2012; Mazhelis & Tyrväinen, 2012)(Kotler & Keller, 2012).

Serrano, N., Gallardo, G., & Hernantes, J. (2015). Infrastructure as a service and cloud technologies. *IEEE Software, 32*(2), 30–36. doi:10.1109/MS.2015.43

Abstract. To choose the most appropriate cloud-computing model for your organization, you must analyze your IT infrastructure, usage, and needs. To help with this, this article describes cloud computing's current status.

Summary. This article focuses on best practices of cloud computing related to new technology and the migration of cloud services, including descriptions of limitations of cloud computing and the main players. Best practices include employing an elastic architecture and designing for failure, high availability, performance, security, and monitoring of cloud solutions. When adopting a cloud architecture, organizations should consider the importance of the benefits the technology can offer along with any issues that IT departments may encounter with new infrastructures. From a cost perspective, the main competitive advantages are the flexibility and speed the cloud architecture can add to the organizational IT environment. Cloud computing architecture can provide faster deployment of and access to IT resources, and fine-grain scalability (Serrano, Gallardo, & Hernantes, 2015).

Yoo, C. S. (2011). Cloud computing: Architectural and policy implications. *Review of Industrial Organization, 38*(4), 405–421. Retrieved from http://web.a.ebscohost.com.libproxy.uoregon.edu/ehost/pdfviewer/pdfviewer?sid=ae65a700-4275-4987-be3b-c68e0c96a26e%40sessionmgr4002&vid=1&hid=4114

Abstract. Cloud computing has emerged as perhaps the hottest development in information technology. Despite all of the attention it has garnered, existing analyses focus almost exclusively on the issues surrounding data privacy without exploring cloud computing's architectural and policy implications. This article offers an initial exploratory analysis in that direction. It begins by introducing key cloud computing concepts, such as service oriented architectures, thin clients, and virtualization, and discusses the leading delivery models and deployment strategies being pursued by cloud computing providers. It then analyzes the economics of cloud computing in terms of reducing costs, transforming capital expenditures into operating expenditures, aggregating demand, increasing reliability, and reducing latency. It then discusses the architectural

implications of cloud computing for access networking (focusing on bandwidth, reliability, quality of service, and ubiquity) and data center interconnectivity (focusing on bandwidth, reliability, security and privacy, control over routing policies, standardization, and metering and payment). It closes by offering a few observations on the impact of cloud computing on the industry structure for data centers, server-related technologies, router-based technologies, and access networks, as well as its implications for regulation.

Summary. This article focuses on the emergence of cloud computing and the breakthrough, transformative development that cloud solutions provide to organizations that deploy these type of solutions. In addition the article provides an overview of key concepts and basic economics of cloud computing. Concepts in the article include (a) service oriented architecture, (b) thin clients, (c) virtualization, (d) delivery models, and (e) deployment strategies. Economics of cloud computing cited by the authors include cost reductions from the amortization of fixed costs, transfer of capital into operating expenditures, aggregation of demand, increased reliability, and reduced latency. Architectural implications in the article include (a) access networking, (b) bandwidth, (c) reliability of the network, (d) quality of service through network management, and (e) ubiquity for mobile users. Cloud computing also requires data centers, networks, and networking hardware to be ever-present, reliable, efficient, and secure (Yoo, 2011).

Information that Supports Potential Solution Alternatives

Chung, L., Hill, T., Legunsen, O., Sun, Z., Dsouza, A., & Supakkul, S. (2013). A goal-oriented simulation approach for obtaining good private cloud-based system architectures. *Journal of Systems and Software, 86*(9), 2242–2262. doi:10.1016/j.jss.2012.10.028

Abstract. The fast-growing Cloud Computing paradigm makes it possible to use unprecedented amounts of computing resources at lower costs, among other benefits such as fast provisioning and reliability. In designing a good architecture – the numbers, types and layouts of devices – for a cloud-based system, which meets the goals of all stakeholders, such goals need to be factored in from the earliest stages. However, there seems to be a lack of methodologies for incorporating stakeholder goals into the design process for such systems, and for assuring with higher confidence that the designs are likely to be good enough for the stated goals. In this paper, we propose a goal-oriented simulation approach for cloud-based system design whereby stakeholder goals are captured, together with such domain characteristics as workflows, and used in creating a simulation model as a proxy for the cloud-based system architecture. Simulations are then run, in an interleaving manner, against various configurations of the model as a way of rationally exploring, evaluating and selecting among incrementally better architectural alternatives. We illustrate important aspects of this approach for the private cloud deployment model and report on our experiments, using a smartcard-based public transportation system.

Summary. This article focuses on the architecture of cloud-based solutions from an implementation standpoint, addressing the perspective of multiple stakeholder concerns of performance, profitability, and scalability goals. The multiple stakeholders in the article include a multi-dimensional list ranging from hardware vendors, cloud service vendors, service providers, and end users. In addition, the article establishes a foundation from an early stage design architecture by establishing methods of goal-oriented requirements engineering and a simulation model through CloudSim to test parameters of a virtualized datacenter. Simulation processes are iterative and focus on discrete design constraints that include scaling, server performance, and profitability goals. A systemic approach is needed to integrate resources into a cloud-based architecture based on requirements to attain success, including a private cloud based deployment model in the datacenter, while giving shared access though a Software-as-a-Service (SaaS) solution (Chung et al., 2013). A solution that the authors propose is CloudSim, a toolkit for the modeling and simulation of cloud computing environments and evaluation of resource provisioning (Calheiros, Ranjan, Beloglazov, De Rose, & Buyya, 2011).

Guevara, M., Lubin, B., & Lee, B. C. (2014). Market mechanisms for managing datacenters with heterogeneous microarchitectures. *ACM Transactions on Computer Systems, 32*(1), 1–31. doi:10.1145/2541258. Retrieved from http://web.b.ebscohost.com.libproxy.uoregon.edu/ehost/pdfviewer/pdfviewer?sid=36982b24-a7ef-43dd-939e-8f10ba67ad71%40sessionmgr111&vid=1&hid=124

Abstract. Specialization of datacenter resources brings performance and energy improvements in response to the growing scale and diversity of cloud applications. Yet heterogeneous hardware adds complexity and volatility to latency-sensitive applications. A resource allocation mechanism that leverages architectural principles can overcome both of these obstacles. We integrate research in heterogeneous architectures with recent advances in multi-agent systems. Embedding architectural insight into proxies that bid on behalf of applications, a market effectively allocates hardware to applications with diverse preferences and valuations. Exploring a space of heterogeneous datacenter configurations, which mix server-class Xeon and mobile-class Atom processors, we find an optimal heterogeneous balance that improves both welfare and energy-efficiency. We further design and evaluate twelve design points along the Xeon-to-Atom spectrum, and find that a mix of three processor architectures achieves a 12× reduction in response time violations relative to equal-power homogeneous systems.

Summary. This article focuses on datacenter efficiencies using system architecture and microarchitecture technology. With lightweight core processors often found in mobile and embedded platforms, these architectures often provide several times more energy efficiencies in comparison to high performance processors (Guevara et al., 2014). (Guevara et al., 2014) add that heterogeneous datacenters with Xeon processors and small Atom core mixtures exercise three key aspects of the economic mechanism: (a) combination of Xeons and Atoms often optimally represent heterogeneous microarchitectures, (b) cycles from in-order and out-of-order data paths are not mutually interchangeable, from heterogeneous tasks contend for these cycles with different preferences, and (c) valuations and large processor power differences are representative of trends in heterogeneity and specialization (p. 9).

Javadi, B., Abawajy, J., & Buyya, R. (2012). Failure-aware resource provisioning for hybrid cloud infrastructure. *Journal of Parallel and Distributed Computing*, *72(*10), 1318–1331. doi:10.1016/j.jpdc.2012.06.012

Abstract. Hybrid Cloud computing is receiving increasing attention in recent days. In order to realize the full potential of the hybrid Cloud platform, an architectural framework for efficiently coupling public and private Clouds is necessary. As resource failures due to the increasing functionality and complexity of hybrid Cloud computing are inevitable, a failure-aware resource provisioning algorithm that is capable of attending to the end-users quality of service (QoS) requirements is paramount. In this paper, we

propose a scalable hybrid Cloud infrastructure as well as resource provisioning policies to assure QoS targets of the users. The proposed policies take into account the workload model and the failure correlations to redirect users' requests to the appropriate Cloud providers. Using real failure traces and a workload model, we evaluate the proposed resource provisioning policies to demonstrate their performance, cost as well as performance–cost efficiency. Simulation results reveal that in a realistic working condition while adopting user estimates for the requests in the provisioning policies, we are able to improve the users' QoS about 32% in terms of deadline violation rate and 57% in terms of slowdown with a limited cost on a public Cloud.

Summary. This article focuses on failure-aware resource provisioning for hybrid cloud infrastructures and the architecture framework needed to couple public and private cloud solutions. The authors in the article add that the hybrid cloud platform will help organizations leverage cost effectiveness and scalability of the public cloud by paying only server, connectivity, and storage resources consumption while delivering the performance and control available from the private cloud environments (Javadi, Abawajy, & Buyya, 2012). Integration of the public and private cloud can create complexity from increased functionality, often leading to resource failures. Javadi et al. (2012) explain that failures can include performance degradation, termination of execution, data corruption and loss, and Service Level Agreements (SLAs) violations and can cause a devastating loss of customers and revenue (p. 1318). A combination of failure-aware provisioning policies and flexible hybrid cloud architecture ensures quality of service (QoS) and the ability to trace workload failures, thus meeting business user needs. The proposed cloud architecture mentioned in the article utilizes an InertGrid model based on virtualization technology for connecting multiple resource providers, as well as failure-aware brokering strategies to increase user QoS from the use of public cloud resources instead of private cloud resources.

Kavis, M. (2014). Architecting the cloud : Design decisions for cloud computing service models (SaaS, PaaS, and IaaS). Hoboken: Wiley.

Abstract. An expert guide to selecting the right cloud service model for your business Cloud computing is all the rage, allowing for the delivery of computing and storage capacity to a diverse community of end-recipients. However, before you can decide on a cloud model, you need to determine what the ideal cloud service model is for your business. Helping you cut through all the haze, Architecting the Cloud is vendor neutral and guides you in making one of the most critical technology decisions that you will face: selecting the right cloud service model(s) based on a combination of both.

Summary. This book focuses on the evolution of cloud computing, with a breakdown of three service models: (a) software as a service (SaaS), (b) infrastructure as a service (IaaS), and (c) platform as a service (PaaS), to aid enterprise organizations in the selection of a cloud model suited for their business needs. Each of the service models provides benefits through automation to reduce the amount of time IT departments spend performing routine software installations, server management and security maintenance and installing software patches. The IaaS service model provides tasks related to managing and maintaining the physical data center and infrastructure that include servers, disk storage, and networking. Additionally, the services provided in IaaS service models can be accessed and automated from code and/or web-based management consoles (Kavis, 2014).

The PaaS service model sits on top of the IaaS service model to provide a delivery mechanism on the computing platform to facilitate deployment of applications on the server to avoid the cost of procurement and managing the hosting of hardware (Kavis, 2014). Essentially the PaaS service model will allow vendors to manage the application platform, freeing up IT resource time from developing complex code to build an application management console. The SaaS model sits higher up in the server stack to provide a method for software licensing and delivery on a subscription and on-demand basis. The service provider handles much of the infrastructure and deployments of the product or service in this case (Kavis, 2014). The book also includes examples of failed practices for moving and migrating content to the cloud, architecture fundamentals, data considerations, security design, logging and monitoring strategies, disaster recovery approaches, and best practices for software development and operations (DevOps), and approaches to assess the organizational impact of cloud models.

Li, J., Li, J., Chen, X., Liu, Z., & Jia, C. (2014). Privacy-preserving data utilization in hybrid clouds. *Future Generation Computer Systems, 30*, 98–106. doi:10.1016/j.future.2013.06.011. Retrieved form http://www.sciencedirect.com/science/article/pii/S0167739X13001258

Abstract. As cloud computing becomes prevalent, more and more sensitive data is being centralized into the cloud, which raises a new challenge on how to utilize the outsourced data in a privacy-preserving manner. Although searchable encryption allows for privacy-preserving keyword search over encrypted data, it could not work effectively for restricting unauthorized access to the outsourced private data. In this paper, aiming at tackling the challenge of privacy-preserving utilization of data in cloud computing, we propose a practical hybrid architecture in which a private cloud is introduced as an access interface between the data owner/user and the public cloud. Under this architecture, a data utilization system is provided to achieve both exact keyword search and fine-grained access control over encrypted data. Security and efficiency analysis for the proposed system are presented in detail. Then, further enhancements for this system are considered in two steps. (1) We show how to extend our system to support efficient fuzzy keyword search while overcoming the disadvantage of insignificant decryption in the existing privacy-preserving fuzzy keyword search scheme. (2) We demonstrate approaches to realize an outsourcing cryptographic access control mechanism and further reduce the computational cost at the data user side.

Summary. The article focuses on preserving data privacy when utilizing multiple resources and hosting multiple users with searchable encryption embedded in a hybrid cloud solution through the internet. The searchable encryption model will allow a user to store encrypted data on a semi-trusted server and later perform searches with keywords, with each keyword independently encrypted under a specified two-layered encryption (J. Li, Li, Chen, Liu, & Jia, 2014). The article mentions two additional methods for mitigating security of searches, (a) public-key searchable encryption, and (b) twin cloud architecture. The article also suggests a hybrid architecture for data utilization, identified with four entities; (a) data owners/users, (b) attribute authority, (c) private cloud, and (d) public cloud as a basic system model. The first entity of the system model includes the

attribute authority entity, a key authority for attributes responsible for generating public and private parameters in charge of issuing, revoking, and updating attribute private keys for users (J. Li et al., 2014). The second entity of the system model includes public cloud entity, an entity that provides a data outsourcing service in charge of controlling access from outside users to stored data on storage servers while providing corresponding content services and executing proposed searching algorithm (J. Li et al., 2014). The third entity of the system model includes the data owner entity, users that owns data files with a goal to outsource them to external storage servers often through the public cloud (J. Li et al., 2014). The fourth entity of the system model includes the data user entity, an entity with a need to access an outsourced file. J. Li et al. (2014) consider the hybrid architecture in which a private clouds access interfaces between user and the public cloud to offer a practical keyword search scheme which simultaneously supports fine-grained access control over encrypted data (p. 105).

McDonald, K. (2010). Above the clouds : Managing risk in the world of cloud computing. Ely, Cambridgeshire: IT Governance Publishing. Retrieved from http://site.ebrary.com.libproxy.uoregon.edu/lib/uoregon/detail.action?docID=10438084

Abstract. Above the Clouds: Managing Risk in the World of Cloud Computing acts as a primer and strategic guide to identify Cloud Computing best practices and associated risks, and reduce the latter to acceptable levels. From software as a service (SaaS) to replacing the entire IT infrastructure, the author serves as an educator, guide and strategist, from runway to getting the organization above the clouds. Valuable tips on how to choose your provider of Cloud Services are also offered.

Summary. This book focuses on cloud computing to provide widely accessible, on-demand, elastic computing power through services that are metered and charged back to users based on a usage basis (McDonald, 2010). The premise of cloud computing often relates to virtualization to provide computing power and storage capacity based on workloads that grow or shrink based on demand. Hybrid cloud environments share features with the three service models: (a) software as a service (SaaS), (b) infrastructure as a service (IaaS), and (c) platform as a service (PaaS). The virtualization process of creating a copy of a physical machine in software devotes a small portion of the overall capacity to support a user running his or her own copy of the machine (McDonald, 2010). The ability to provide on-demand bandwidth and computing power driven by excess capacity built into the cloud allows for resource consolidation (McDonald, 2010). McDonald (2012) adds that the shift from a capital-intensive model to an operating-expense model transfers the material risk from the service user to the service provider (p. 16).

Pedram, M. (2012). Energy-efficient datacenters. *IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems, 31*(10), 1465–1484. doi:10.1109/TCAD.2012.2212898

Abstract. Pervasive use of cloud computing and the resulting rise in the number of datacenters and hosting centers (that provide platform or software services to clients who do not have the means to set up and operate their own computing facilities) have brought forth many concerns, including the electrical energy cost, peak power dissipation, cooling, and carbon emission. With power consumption becoming an increasingly important issue for the operation and maintenance of the hosting centers, corporate and business owners are becoming increasingly concerned. Furthermore, provisioning resources in a cost-optimal manner so as to meet different performance criteria, such as throughput or response time, has become a critical challenge. The goal of this paper is to provide an introduction to resource provisioning and power or thermal management problems in datacenters, and to review strategies that maximize the datacenter energy efficiency subject to peak or total power consumption and thermal constraints, while meeting stipulated service level agreements in terms of task throughput and/or response time.

Summary. This article focuses on the datacenter and the need to improve efficiencies by accelerating the use of computing technologies. Increases in cloud computing and software-as-a-service (SaaS) greatly accelerate trends, giving rise to concerns about a potential datacenter energy crisis in the near future. The article adds that developments in the use of cloud systems to replace private datacenters are less expensive to operate, consume less energy, and have higher utilization rates than traditional datacenters, and forecast that these improvements will lead to the work performed in datacenters today to be pushed to the cloud by the end of the decade (Pedram, 2012). Service options including software-as-a-service (SaaS), infrastructure-as-a-service (IaaS), and platform-as-a-service (PaaS) appear more efficient than the use of traditional datacenters, and adoption of cloud computing with an estimated compound annual growth rate of 29 percent suggests major implications for datacenter energy consumption (Hickey, 2011; Pedram, 2012). Datacenter energy consumption has a potential to be cut by 31percent with cloud computing by 2020 (Hickey, 2011). Deploying hybrid storage systems with solid-state drives that use less power due to a design with no moving parts has the potential to increase storage power efficiency in a datacenter.

Quarati, A., Clematis, A., & D'Agostino, D. (2015). Delivering cloud services with QoS requirements: Business opportunities, architectural solutions and energy-saving aspects. *Future Generation Computer Systems*. doi:10.1016/j.future.2015.02.009

Abstract. The flexible and pay-as-you-go computing capabilities offered by Cloud infrastructures are nowadays very attractive, and widely adopted by many organizations and enterprises. In particular this is true for those having periodical or variable tasks to execute, and, choose to not or cannot afford the expenses of buying and managing computing facilities or software packages, that should remain underutilized for most of the time. For their ability to couple the scalability offered by public service providers, with the wider Quality of Service (QoS) provisions and ad-hoc customizations provided by private Clouds, Hybrid Clouds (HC) seem a particularly appealing solution for customers requiring something more than the mere availability of the service. The paper firstly introduces a Cloud brokering system leveraging on a promising architectural approach, based on the use of a gateway toolkit. This approach provides noticeably advantages, both to customers and to Cloud Brokers (CB), for its ability to hide all the intricacies related to the management of powerful, but often complex and heterogeneous infrastructures like the Cloud. Moreover such approach, through customized interfaces, facilitates customers in accessing Cloud resources thus easing the tailored deployment and execution of their applications and workflows. The major contribution of this work is given by the analysis of a set of brokering strategies for Hybrid Clouds, implemented by a brokering algorithm, aimed at the execution of various applications subject to different user requirements and computational conditions. With the objective of firstly maximize both user satisfaction and CB's revenues the algorithm also pursues profit increases through the reduction of energy costs by adopting energy saving mechanisms. A simulation model is used to evaluate performance, and the results show that differences among strategies depend on type and size of system loads and that the use of turn on and off techniques greatly improves energy savings at low and medium load rates thus indirectly increasing CB revenues without diminishing customers' satisfaction.

Summary. This article focuses on energy efficiencies gained through gateway frameworks to increase performance in the datacenter and quality of service to end users. Quarati, Clematis, and D'Agostino (2015) estimate that nearly two-thirds of the workload routed through the datacenter will reach 5.3 zettabytes by the year 2017 (p. 2). When reviewing forecasts of workloads that transition to the cloud the same year, estimates are roughly the same thus doubling the workload traffic through the datacenter. Quarati et al. (2015) propose gateway frameworks for the hybrid cloud to broker the system with software as a service (SaaS) services and simulation technologies. The authors note in the article that brokering through a scheduling algorithm as a part of an allocation strategy policy would allow execution requests of services in a hybrid cloud infrastructure thus providing energy savings. The algorithm scheduler manages workload requests toward the public or private cloud from a set of requirements to model computational needs and the workload of in-house resources (Quarati et al., 2015). Revenue from these services includes: (a) license costs, (b) brokering services, and (c) provisioning related to energy-aware allocation policies.

Sturrus, E., & Kulikova, O. (2014). Orchestrating hybrid cloud deployment: An overview. *Computer, 47*(6), 85–87. doi:10.1109/MC.2014.159. Retrieved from http://ieeexplore.ieee.org.libproxy.uoregon.edu/stamp/stamp.jsp?tp=&arnumber=6838945

Abstract. Balancing enterprise control over cloud data with hybrid cloud benefits will increasingly require cloud orchestration. Reaping full hybrid cloud benefits requires increased organizational focus on security and control. But as more clouds come into play, each with specific offerings and rules, implementing these controls and coordinating management over different environments can become burdensome. The cloud orchestration framework we propose can both facilitate the hybrid cloud adoption process and help enterprises establish centralized control over multiple clouds.

Summary. This article focuses on the balance of enterprise control over cloud data in the hybrid cloud to require increased orchestration of services. The authors note in the article that enterprise IT organizations in general view choices to facilitate the running of consecutive cloud resources in places that make the most sense as models that involve multiple cloud service providers (CSPs) rather than just one (Sturrus & Kulikova, 2014). The involvement of various CSPs requires decisions to be made on whether to keep data in the private cloud by deciding on (a) cost benefit from multiple CSPs, (b) reliability and performance benefits, (c) deployment speed, (d) security, (e) risks, (f) the amount of control needed, and (g) the availability of ready-to-use software as a service (SaaS) solutions (Sturrus & Kulikova, 2014). The authors note that security concerns are near the top of the list when reviewing types of cloud solutions to deploy within the enterprise and that control boundaries should therefore be included in strategies. The cloud orchestration framework should include: (a) cloud business case development, (b) cloud selection, (c) cloud on-boarding, (d) cloud governance, and (e) cloud monitoring. Sturrus and Kulikova (2014) add that orchestration from an enterprise standpoint should involve the ability to develop business cases, analyze and mitigate risk, and govern information technology (IT) services (p. 86)

Conclusion

This annotated bibliography addresses challenges of deploying hybrid cloud solutions and practices that enterprise organizations may consider when deploying these architectures within the datacenter. The hybrid cloud may offer enterprise organizations flexibility allowing (a) datacenter workloads to move between private and public cloud environments; (b) more data deployment options; (c) maximization of value by balancing internal assets; (d) cost-efficiencies, in particular reduced capital costs; (e) the ability to scale; (f) improved disaster recovery; and (g) introduction of functionality (Rivera & van der Meulen, 2014; Rouse, 2015). Cloud solutions often introduce orchestration gaps in how software technologies: (a) interface with each other, (b) preserve security, (c) show cost effectiveness, and (d) demonstrate scalability (Zaino, 2014).

Context of cloud solutions and challenges. The infrastructure for a hybrid system consists of information services transferred to the cloud, while a portion of the services remains in-house. Corporate datacenters found servers grossly underutilized, with performance ranging from 10 to 30 percent of compute power (Marston et al., 2011). Underutilization can lead to economic impacts as the volume of data transferred to/from the public cloud increases, with a greater portion of the capacity allocated to the private cloud (Mazhelis & Tyrväinen, 2012).

According to McDonald (2012), to provide computing power and storage capacity based on workloads that grow or shrink based on demand, virtualization of the data center using a hybrid solution is optimal. Additionally, McDonald (2012) states that the shift from a capital-intensive model to an operating-expense model transfers the material risk from the service user to the service provider as a way for organizations to capitalize on lower risk as well as increased efficiency from the use of cloud solutions (p. 16). The move to a hybrid cloud solution offers multiple advantages in both operating efficiency and cost savings, but is not without inherent challenges.

The challenges in identifying best practices supporting hybrid cloud solutions often include the complexity that results from the orchestration of the countless combinations of solutions (P. Nist, personal communication, February, 2015). Considering application integration, Li et al. (2013) indicate that no cloud computing service vendor can fully satisfy the functional information systems requirements of an enterprise, often resulting in simultaneously using systems distributed in different cloud environments and intra-enterprise information services. Additionally, hybrid cloud computing often includes obstacles that include (a) lack of availability of a service, (b) data lock-in, (c) challenges with data confidentiality, (d) data transfer bottlenecks, (e) performance unpredictability, (f) lack of scalable storage, (g) the need to scale quickly, and (h) software licensing expenses (Armbrust et al., 2010).

Additional challenges from architectural implications of cloud computing through which end users connect to the data center include: (a) access network limitations from user demand volume, (b) restricted or insufficient bandwidth to support large migrations of data sets, (c) reliability of the network that is challenged by network connection failures, (d) ensuring adequate quality of service through network management to avoid latency and the delivery of services, and (e) ubiquity for mobile users to run software applications in the cloud without encountering network connection issues (Yoo, 2011). The level of orchestration required to balance enterprise controls over multiple hybrid environments can become burdensome (Sturrus & Kulikova, 2014). The enterprise will need to consider multiple decisions on whether to keep data in the private or public cloud by deciding for each alternative (a) cost benefit from multiple cloud service providers (CSPs), (b) reliability and performance benefits, (c) deployment speed,

(d) security, (e) risks, (f) the amount of control needed, and (g) the availability of ready-to-use software as a service (SaaS) solutions (Sturrus & Kulikova, 2014).

From an IT department perspective, with the continual challenges posed by creating, maintaining, and optimizing hybrid services within a datacenter, IT personnel will need to understand the types of services consumed within the enterprise by addressing trends in (a) cloud services, (b) IT consumerization, and (c) increasing cross-enterprise collaboration in managing a cloud ecosystem (Erbes et al., 2012). Along with the challenges that enterprise and IT departments continue to encounter, an organization's IT leaders must understand the equally urgent need to identify business-related strengths, weaknesses, opportunities and threats that the use of cloud computing often introduces to organizations.

Possible solutions and strategies. From a cost perspective, the main competitive advantages of cloud computing are the flexibility and speed the cloud architecture can add to the organizational IT environment. Cloud computing architecture can provide faster deployment of and access to IT resources, as well as fine-grain scalability (Serrano, Gallardo, & Hernantes, 2015). Service models that include: (a) software as a service (SaaS), (b) infrastructure as a service (IaaS), and (c) platform as a service (PaaS) often aid enterprise organizations in the selection of a cloud model suited for business needs to achieve lower costs from maintenance, optimization of storage capacity, privacy-preserving data utilization, and scalability within the data center.

Key areas that are important in defining strategies for building the path to the hybrid cloud include selection of the specific appliance, software virtualization solution, and other server related technologies (Yoo, 2011). Economic cloud computing solutions, according to Yoo

(2011), often include: (a) service oriented architecture, (b) thin clients, (c) virtualization, (d) optimized delivery models, and (e) deployment strategies to gain cost reductions from the amortization of fixed costs, transfer of capital into operating expenditures, aggregation of demand, increased reliability, and reduced latency. Achieving the best economic results from cloud computing requires data centers, networks, and networking hardware to be ever-present, reliable, efficient, and secure (Yoo, 2011).

Embedding heterogeneous architecture principles can overcome obstacles from the growing scale and diversity of cloud applications (Guevara, Lubin, & Lee, 2014). Guevara et al. (2014) indicate that an optimal balance of server class processors aids in not only datacenter computing performance, but also in energy efficiency and system welfare (p. 15). Heterogeneous datacenters with a mix of Xeon processors and small Atom core mixtures exercise three key aspects of the economic mechanism: (a) the combination of Xeons and Atoms often optimally represents heterogeneous microarchitectures, (b) cycles from in-order/ out-of-order data paths are not generally mutually interchangeable, and (c) valuations and large processor power differences are representative of trends in heterogeneity and specialization from tasks that compete for these cycles with different preferences (p. 9).

For organizations considering a move into the cloud, McDonald's (2010) *Above the Clouds: Managing Risk in the World of Cloud Computing* acts as a strategic guide to provide best practices that include a recommendation for the use of software as a service (SaaS) to replace the entire IT infrastructure. Performance within most datacenters often reflects the use of only up to 15 percent of available capacity; by using a hybrid structure, virtualization can regain idle capacity and lower operating costs (McDonald, 2010).

Enterprise organizations in search of cloud solutions need to consider an architectural framework for efficiently coupling public and private clouds, along with consideration of potential failures due to the increasing functionality and complexity of hybrid cloud computing. Javadi, Abawajy, and Buyya (2012) provide a failure-aware resource-provisioning algorithm that is capable of attending to the end-user's quality of service (QoS) requirements in terms of deadline violation about 32 percent of the time and slowdown about 57 percent of the time, with a limited cost when used with hybrid and public cloud solutions (p. 1318). The proposed solution by Javadi et al. (2012) includes recommendations for a scalable hybrid cloud infrastructure and resource provisioning policies to ensure that QoS targets for the user base are met.

The hybrid cloud can offer multiple benefits to enterprise organizations, but the marketing of these solutions can often be complicated when considering hardware and software variations. To recommend and market the best hybrid cloud solutions, Software Solution Marketing groups need to be aware of the potential benefits and pitfalls. The benefits of the hybrid cloud include high levels of quality, scalability, and customer satisfaction from the coupling of the private and public clouds (Quarati et al., 2013). Additional benefits the hybrid cloud can offer businesses are opportunities that range from (a) flexibility in data deployment options, (b) the ability to balance internal assets, (c) reduced capital costs, (d) the ability to scale, (e) improved disaster recovery, to (f) flexibility in introducing functionality (Rivera & van der Meulen, 2014; Rouse, 2015).

The benefits of hybrid cloud solutions come with inherent complexities. Cloud solutions with combined hardware and software technologies can often introduce orchestration gaps in how software technologies: (a) interface with each other, (b) preserve security, (c) show cost effectiveness, and (d) demonstrate scalability (Zaino, 2014). Additionally, gaps can include data and security risks, potential deficiencies in the areas of bandwidth and reliability of the network, and degradation of the quality of service when accessing or offloading data sets to the cloud.

Many organizations today buy external cloud services without oversight from IT leaders. Organizations cannot, however, adopt a hybrid cloud solution without first implementing a private cloud, and some organizations continue to struggle with implementing a private cloud solution and demonstrating the value of the service because this requires a shift in how IT is delivered. This shift involves changes to people, processes, and business management (Rivera & van der Meulen, 2014). To optimize the data center with a hybrid cloud solution, organizations need to identify best practices for deploying a hybrid cloud solution architecture that will address the need for reliability and performance benefits, positive economic returns, privacy-preserving data utilization, effective deployment frameworks, successful governance and policies, and scalability approaches that fit current and future business needs.

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