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Chapter 11

The future of hybrid cloud: Trends, technologies, and predictions

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Abstract

The future of hybrid cloud is poised for significant transformation, driven by emerging trends and technologies that enable greater agility, scalability, and innovation. This abstract explores key developments shaping the future, such as the increasing adoption of edge computing, AI-powered automation, and the rise of multi-cloud environments. It also highlights advancements in security, interoperability, and data management that will address the complexities of hybrid cloud architectures. Predictions for the future include more seamless integration between public and private clouds, enhanced cost optimization strategies, and a shift toward more sustainable, efficient cloud solutions. These trends promise to redefine the hybrid cloud landscape.

Keywords

Hybrid Cloud, Future of Hybrid Cloud, Cloud Trends, Cloud Technologies, Multi-Cloud, Edge Computing, AI Automation, Cloud Security, Cloud Interoperability, Data Management, Cloud Integration, Cost Optimization, Sustainable Cloud Solutions, Cloud Predictions, Cloud Scalability, Cloud Innovation, Hybrid Cloud Architecture.

11.1. Introduction

Hybrid cloud computing involves employing two public clouds or private and public clouds situated separately. Hybrid cloud combines the strengths of both private and public clouds. Moreover, the combination of hybrid cloud with traditional model resulting in

distributed cloud will mean an emergence of a new concept that may also demonstrate its position in future Internet services. In the past, systems of service-oriented architecture (SOA) adopted the technology of Web service to realize the connection between the systems overall through the Web service. Essentially, the hybrid cloud is a cloud computing environment comprising public and private cloud services, which work together because of an interoperability mechanism. Nevertheless, it is still difficult for many works that require cloud-distributed services to measure cloud resources and evaluate which cloud can provide better services (Nampalli et al., 2024). For that reason, there is a need to excel in developing a new theoretical model that utilizes the same parameters for quantifying and predicting services between clouds in a hybrid cloud. There is also the need for a model that can hide complex technology namely middleware to enlarge the range of cloud users. Several trends behind stage various types of cloud computing along with the prospects of hybrid cloud in the next couple of years are addressed. It is worth stating that the hybrid cloud paradigm with SOA will be a breakthrough for establishing future cloud Internet services. Hybrid cloud computing combines the strengths of both private and public clouds, offering a flexible and scalable infrastructure that leverages the advantages of each. By integrating hybrid cloud with traditional models, resulting in a distributed cloud, a new concept is emerging that could shape the future of Internet services. Historically, systems built on service-oriented architecture (SOA) used web services to connect various systems, allowing for seamless communication across diverse platforms. Similarly, hybrid cloud environments bring together public and private clouds through interoperability mechanisms, enabling seamless interaction between them. However, a key challenge remains in measuring cloud resources and determining which cloud can provide the best services for specific workloads. To address this, there is a need for the development of a new theoretical model that can quantify and predict services across hybrid clouds using consistent parameters. This model should simplify complex technologies, such as middleware, to make cloud services more accessible to a broader range of users. As cloud computing continues to evolve, the hybrid cloud paradigm, when combined with SOA, is poised to be a transformative force in the establishment of future cloud-based Internet services.

11.2. Understanding Hybrid Cloud Computing

Cloud computing refers to the delivery of scalable, network-based services whose logical architecture is based on the proliferation of devices and the creation of distributed systems. As cloud computing is being used in more and varied fields, both cloud computing providers and clients are interested in accomplishing the best results. So, the

main goal of Improved Cloud Computing Architecture is to find and optimize a cost-effective architecture in cloud computing according to its service requirements. The hybrid cloud model, which is more important and new among the examined cloud systems, has many differences compared to the other models (Danda, et al., 2024). The enterprises, which have workload characteristics, are silent for starting to use cloud systems. It is seen that companies prefer the syntheses that are selected for their workload characteristics as a return to using both private or public clouds. Another important reason for the use of hybrid clouds is the need for better control. It should not be forgotten that the hybrid cloud model will be more reinforced by the improvement of regulatory proposals. The aim of the paper is to describe the improved cloud computing architecture that can show how virtual resources can automatically adapt to available resources, new service requests and their performance degradation or improvement.

Fig 11.1: The Future of Cloud Computing and Predictions

Equation 1: Hybrid Cloud Sustainability Metrics

$$S(t) = S_0 \times (1 - \gamma \cdot E_{cloud} + \delta \cdot E_{green})$$

Where:

- $S(t)$ = Sustainability score of a hybrid cloud at time t
- S_0 = Initial sustainability score (before cloud migration)
- γ = Weight for energy consumption related to the cloud services
- E_{cloud} = Energy consumption of the cloud infrastructure
- δ = Weight for energy efficiency through green energy or sustainable cloud strategies
- E_{green} = Energy saved or efficiency improved through green initiatives

11.2.1. Definition and Concept

Hybrid clouds have grown in popularity and their use will become even more widespread in the near future. A hybrid cloud architecture contrasts with full public cloud services in that it keeps a crossbreed of private cloud delivered services and public cloud provider services. That will be becoming a general trend among SMEs that cannot afford a high investment in the cloud infrastructure.

The Post-Snowden internet targets privacy. Companies start to move to physical forms of cyber security after revelations on wide scale snooping by intelligence services were revealed (Shakir, 2024). In Germany, for example, data sovereignty is one of the arguments that drives electronic data storage sales in order to keep data locally. In turn towards privacy, hybrid clouds will offer a solution for customers who want to take their services away from cloud service providers. US-based service providers will find it hard to acquire new non-US customers as concerns on privacy remain.

11.2.2. Benefits and Challenges

The need to move around bits and control things was an overwhelming reason individuals and businesses pushed Oracle to rethink their design. One researcher's experiment found that the average distance a device traveled to reach a new destination was akin to a vehicle driving around the earth at the equator for 12 years. Public and profitable clouds attempt to solve this problem by providing a finite number of destinations for all computational resources. Public cloud infrastructure providers have acquired, built, and distributed edge caching/data transfer appliances near their points of peerage in order to increase and bridge the networking performance and scripting language barriers. The hybrid cloud model democratizes this concept by placing essentially "cloud-enabled" edge appliances in a wider distribution outside of the public cloud networks themselves (Vankayalapati et al., 2021). This allows for the formation of a global network of relatively independently managed and operated "Oracle Machines" that can solve the networking performance issues on a global scale. In this scenario, bits can easily move between clouds, clients can configure virtually any destination for their computational resources, and significant power will be shifted from service providers back to cloud clients and their developers.

Fig: Cloud Computing Trends to stay beyond 2022

11.3. Current Trends in Hybrid Cloud Adoption

There has been a significant increase in hybrid cloud adoption in the past few years. With enterprises rapidly expanding their cloud-based applications and services, there is growing interest and a need for comprehensive solutions to easily model and automate these applications, and to manage and orchestrate them across their data center, private,

and public clouds. Hybrid and multi-clouds are increasingly seen in the industry as a way to replace the traditional backup and disaster recovery systems. Innovations in enterprise application development are now possible through platforms such as Cloudify. Cloudify gives the consumer the flexibility to write his own G-CPD (Generic-Cloudify Provider Definition) and plugin. G-CPD can be defined for any cloud provider. It should describe how attributes chosen by the consumer must be transformed in a request for the specific cloud provider. The generation of the request must also take care of transforming regions, availability zones, data centers and possibly also zones of the provider. Cloudify can be used also as a development environment where blueprints can be developed and tested in the local testbed and then moved in the cloud. There is also a command that automatically creates a zip artifact from a blueprint file. The portability is guaranteed.

By 2018, 451 Research found that companies around the world were spending 28% of their external budget on cloud services. By 2019, market estimates are that the worldwide public cloud services supplies will reach up to $206 Billion, up from $111 Billion in 2016, and the infrastructure spending will reach $50 Billion. Cloud computing has now become the new normal rather than emerging, and soon, with its growing importance and demand, it is going to be a commodity which everyone will have to move to (Kothapalli et al., 2021). Hence, the demand for easy resource management and control will also grow and the hybrid cloud will play a vital role in this. Oracle has recently integrated a new “bring your own license” strategy that will allow the customers to shift the existing licenses and have them accepted on the Oracle public cloud. On another side, IBM showed a significant improvement on the cloud profit, and Microsoft Azure is previewing the arrival of the Microsoft Azure Stack.

11.4. Key Technologies Shaping the Future of Hybrid Cloud

Cloud computing service models of IaaS and PaaS, hybrid cloud computing, and the current situation of container technology are surveyed to make future predictions about hybrid cloud and container technology. Hybrid cloud may continue to grow due to dominance of large enterprises, which have legacy systems due to advantages of scale of hybrid cloud and are necessary for the first step in cloud-native. Cloud will become a private cloud or hybrid cloud, and high-performance computing, which is limited by public cloud, will be led by private cloud. Service models of cloud computing are based on SAAS, but in the future, IaaS currently in the leading position will be overtaken by PaaS. PaaS simplifies development of applications by providing a development environment and middleware, and goods management will center around web services.

Fig 11.2: The Future of Cloud Computing In A Changing Digital Landscape

This survey reports about cloud computing, which is a recent technology trend in IT business. It has rapidly spread in the industry (Kothapalli et al., 2022). This is because of cost reduction and efficiency improvement in IT resources. Cloud computing service has several distinct service types or models. Some fundamental service models will be discussed.

Equation 2: Cloud-Specific Technologies Impact on Hybrid Cloud

$$I(t) = I_0 \cdot (1 + \delta_1 \cdot T_{AI} + \delta_2 \cdot T_{ML} + \delta_3 \cdot T_{Containers})^t$$

Where:

- $I(t)$ = Impact of advanced technologies on hybrid cloud at time t
- I_0 = Initial impact of these technologies
- $\delta_1, \delta_2, \delta_3$ = Weight or contribution of AI, ML, and Containers respectively to hybrid cloud improvement
- $T_{AI}, T_{ML}, T_{Containers}$ = Technological advancements or adoption rates in AI, machine learning, and containerization
- t = Time

11.4.1. Containers and Microservices

Containers and microservices are quickly becoming the foundation for the new cloud-native application platform. Both allow developers to architect, build, deploy, and manage applications in a more consistent and simplified way regardless of the target environment. Docker containers and Kubernetes are becoming the de facto standard for building, deploying, and managing (containerized) workloads on-premises and, in public clouds, creating a clear path for the hybrid cloud approach. Different studies highlight the trend towards Docker containers and Kubernetes. The most notable are the Docker Ecosystem and the CNCF landscape covering Kubernetes, CNIs, CD tools, etc.

11.4.2. Software-Defined Networking

The public and hybrid clouds are expected to continue their growth trend, fuelled by the expansion of data centers and cloud services provided beyond the borders of industries. From the public cloud services end, numerous actors will introduce endeavors integrating computing, storage, communication, or even specialty services such as GIS as automated services, accelerating the pace of service proliferation and technological innovation. Whatever platform is chosen, the ability for systems and services to be portable seems an almost ubiquitous requirement for the 3rd platform. Hybrid and multi-clouds are developing to support this, with a slew of different but interoperable technologies (Subhash et al., 2022). For network providers in data centers—how the new idea of software defined network (SDN) will impact equipment choices and the design and provisioning of the network is assessed. Currently, the network plays an important role in many applications that are deployed in clouds. This is particularly true for latency-sensitive or high-throughput applications. Often, when we consider cloud applications, the focus tends to be on computing and data storage resources, with the underlying assumption that the network will be able to deal appropriately with the requirement. an assumption that will not always be justified. This leads to the conclusion that SDN deployments will tend to be most useful in applications where the network matters most; in particular, applications that are sensitive to network delay or throughput.

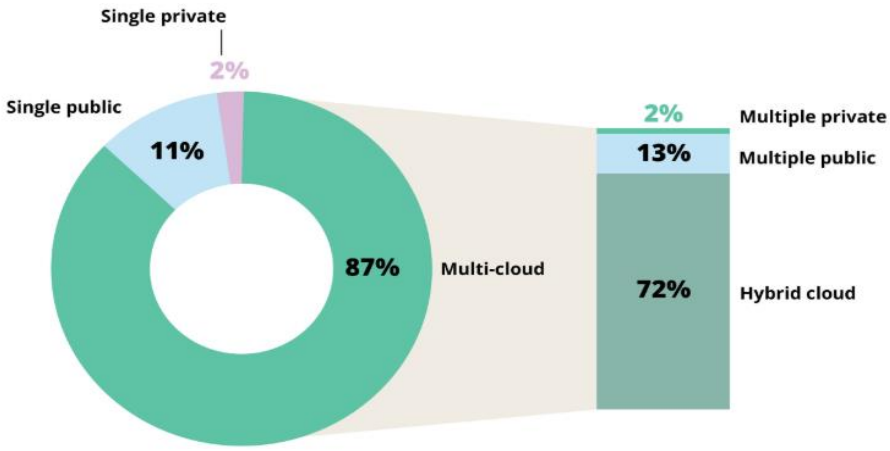

Fig: Hybrid Cloud and Multi-Cloud the Future of Enterprise

11.5. Predictions for the Future of Hybrid Cloud

Over the past few years, hybrid cloud has evolved and become a significant option for businesses. Knowing and understanding the challenges of hybrid cloud computing will allow for their follow-up in terms of research endeavors. So far, the existing challenges and trends in hybrid cloud computing are explored and a conceptual model is also proposed to illustrate the many aspects and further understanding of this recent research development.

Hybrid cloud is the natural choice of the many cloud users as it offers the benefits of both public and private clouds (Sondinti et al., 2023). This smart model is a composition of two or more cloud deployment types. It has similar characteristics of public and private clouds. A small business can put the gem of data on the private cloud. While other data and applications could be distributed to the other cloud providers. pointed out that trade is going faster than ever because of competition. Though, companies have migration options such as cloud.

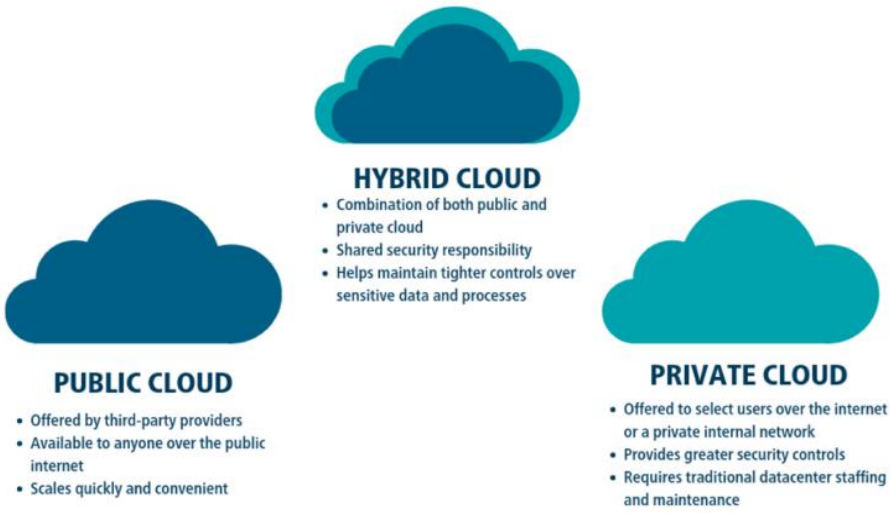

Fig Trends Shaping the Future of Cloud Computing Hybrid Cloud

11.5.1. Security and Compliance Enhancements

Public, private and hybrid Cloud computing for deploying, managing, and improving applications is a key trend for delivering products, services and computing infrastructures. Due to the flexibility of Cloud computing, businesses switch traditional IT infrastructure to Cloud systems. At the same time, Cloud vendors extend their offers with more and more hybrid models of IT infrastructure, which contains physical, virtual, and Cloud components. Nevertheless, the hybrid solutions bring new challenges such as Security, Automation, and SLA Assurance.

11.5.2. Edge Computing Integration

More devices are being connected to the cloud and to other devices than ever before. As a result, there is a growing need for low latency for many devices and users. Typically most devices are connected to the internet through a local network router which, in turn, connects back to the cloud. In this setup, there are many intermediate network switches as well as lengthy connections to a remote site which can all introduce delay, collectively known as latency.

To improve how applications are served at low latency “edge computing” is proposed where the computing capacities are moved to the edge of the network, closer to where data is produced and consumed (Vankayalapati et al., 2023). It is a new notion where the Cloud provides resources to the components associated with the devices. However, hosting servers and services in every network node would lead to unsustainable costs.

11.6. Conclusion

The trend and technology suggest that the hybrid cloud is the future of cloud computing and would enhance the way globally things are done. IT experts and businessmen are starting to make a shift for the hybrid cloud due to its unique characteristic, it provides the best of the two worlds, since it combines security and control from the private cloud, and flexibility and cost savings of the public cloud. The form of hybrid cloud that would have the most potential for the future is the one that has the ability to offer workload portability, resource usage tracking, compliance monitoring, workload mobility, and a federated self-service interface across different clouds. Because of this, several technologies to improve the use case of hybrid cloud have been developed by a cloud vendor over the past few years, one of which is a hybrid cloud service broker. A cloud service broker is defined as a cloud technology delivery intermediary that facilitates cloud adoption and consumption by acting as a common point of control, integration, and security for computing services delivered across multiple cloud service offerings. While an intermediary is defined as a third-party service provider that offers intermediation or aggregation services to create a value-added user experience for one or more cloud forms.

11.6.1. Future Trends

The cloud computing model shifted from Infrastructure as a Service (IaaS) to a platform-based approach: Platform as a Service (PaaS). Like IaaS, PaaS offers essential infrastructure for hosting applications. At the same time, it allows building and managing applications with a much higher level of abstraction. In contrast to this and in contrast to pure software products, PaaS is not just code that can be bought and deployed. PaaS as a product, is more of an API, an API plus DOC which tells you how you can interact with a stack in order to get allocations of execution, storage, networking, etc. Such an abstraction provides the much-needed usability potential of PaaS (Maguluri et al., 2022). By outlining interface properties, Cloudify aims to be more of a PaaS. Though a tool, the fact that metadata is defined as a global, unchangeable state common to all nodes, limits

the scope for how deployment is engineered. With respect to iClouds, an evaluation finds that frequently requested functionalities are missing from the iClouds platform. In situations that do not allow the use of dependencies, placement of scripts, executable instructions and support for checks on target machines require tools with complex scripting capabilities. Cloudify's IaaS interaction model allows deployment on any resource, while on iClouds implementation is fixed to one or more statically selected targets through node groups and zone affinity.

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