

Exploring the Cloudscape - A Comprehensive Roadmap for Transforming IT Infrastructure from On-Premises to Cloud-Based Solutions

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ABSTRACT

Cloud computing, driven by ICT advancements, has rapidly gained ground. It equips businesses with a pay-as-you-go pricing model, reducing upfront investments by charging only for utilized resources. Key IT functions like storage, servers, operating systems, and software applications are delegated to third-party providers, necessitating strategic decision-making to optimize the benefits of cloud services. The choice of the right service provider, deployment model, and service type carries significant weight in aligning cloud solutions with business objectives. This paper explores the advantages of cloud computing, diverse deployment methods, service models, state-of-the-art migration techniques, tools, and the evolving role of Software-Defined Networking (SDN) in enhancing cloud computing capabilities.

INTRODUCTION

Cloud migration involves transferring local applications, data, and infrastructure to cloud-based environments [1]. The cloud offers computing resources on demand, eliminating the need for active management by users who can store software, hardware, and network services remotely. This shift reduces reliance on ICT helpdesks for routine tasks, minimizes wait times, and ensures services are available 24/7 through on-demand self-service models [2]. Additionally, some cloud services automate software updates and upgrades, enhancing accessibility and convenience for users accessing platform services [2].

Cloud computing offers numerous benefits and features, including:

- On-Demand Self-Service Model: Users can access computing resources independently without intervention from the cloud provider, as long as they have an internet connection. Certain applications may even function offline, providing additional storage and database access. The exception occurs during maintenance downtime when services are temporarily unavailable [2]. Public clouds typically schedule maintenance downtime, whereas in private clouds, users can manage upgrade and maintenance cycles to prevent outages and monitor systems proactively [3]. Despite occasional downtime, cloud technology significantly enhances operational efficiency in commercial settings, such as online business platforms and global companies managing diverse time zones. It facilitates continuous operations, enhances

productivity, and fosters collaboration among employees and international partners. This capability became particularly crucial during the Covid-19 pandemic, enabling seamless remote work scenarios where data sharing and updates occur effortlessly through cloud platforms [3].

Cloud computing's extensive network access facilitates global information sharing through cloud services. This capability, bolstered by cloud network bandwidth and low latency, optimizes time-sensitive manufacturing applications, enhancing operational efficiency. Such data-sharing mobility extends to mobile phones and home laptops, enabling remote work—a trend amplified post-Covid-19. This flexibility benefits international businesses, fostering seamless data exchange among employees worldwide and integrating data to reduce recording errors [4].

Data Security and Backup

Cloud computing addresses security concerns prevalent in traditional ICT infrastructures, where manual handling of databases can lead to human errors, data loss, or vulnerability to hackers. Cloud solutions automatically create backups stored on separate servers, preventing data loss. While this necessitates trust in service providers, it ensures robust data management and security protocols [4].

Choice of Public/Private Data

Cloud computing resolves the dichotomy of public versus private data storage. Unlike traditional ICT setups, where data visibility hinges on institutional access, the cloud's multi-tenancy supports hybrid

storage models. This allows users to securely share applications without revealing identities, akin to tenants in a shared condominium. Community clouds further enhance collaboration by pooling resources and expertise [5].

Optimized Resource Sharing and Allocation

Cloud computing optimizes resource allocation by dynamically adjusting CPU and memory usage across departments. Resource pools are managed independently, ensuring efficient utilization without affecting unrelated pools. Service Level Agreements (SLAs) guarantee Quality of Service (QoS), enhancing operational reliability [6].

IMPACT OF CLOUD COMPUTING ON INDUSTRIES

Cloud computing has had a transformative effect on various industries, revolutionizing the way businesses operate, collaborate, and deliver services. Cloud services have enabled organizations to streamline processes, improve efficiency, and drive innovation. In this section, we will discuss the impact of cloud computing on some key industries.

Information Technology (IT) Industry

The IT industry has been significantly impacted by cloud computing. Cloud services have provided IT companies with scalable and cost-effective infrastructure resources, enabling them to develop, test, and deploy applications more efficiently. Cloud platforms have also facilitated the growth of software-as-a-service (SaaS) providers, allowing them to deliver applications directly to end-users without complex installations or maintenance. The IT industry has also seen the rise of cloud-based development tools and collaboration platforms, enabling remote teams to work together seamlessly.

Healthcare Industry

Cloud computing has transformed healthcare by providing secure and efficient storage, sharing, and medical data analysis. Cloud-based electronic health record (EHR) systems have improved patient care by making medical records accessible to healthcare providers across different locations. Cloud platforms also facilitate the processing and analysis of large volumes of medical data, enabling advanced research, personalized medicine, and predictive analytics. Additionally, cloud computing has facilitated telemedicine and remote patient monitoring, allowing healthcare services to be delivered to patients in their homes.

Financial Services Industry

The financial services industry has experienced significant benefits from cloud computing. Cloud

services have allowed financial institutions to store and process large volumes of data securely and efficiently. Cloud-based solutions have enabled faster and more accurate financial modelling and risk analysis. They have also facilitated the development of innovative financial technology (FinTech) solutions, such as mobile banking apps, peer-to-peer lending platforms, and digital payment systems. Cloud computing has enabled financial institutions to improve customer experience, increase operational efficiency, and reduce costs.

Education Industry

Cloud computing has revolutionized the education industry by enabling remote learning, collaboration, and access to educational resources. Cloud-based learning management systems (LMS) have allowed educational institutions to deliver online courses and virtual classrooms, expanding access to education globally. Cloud platforms have also facilitated the storage and sharing of educational content, allowing teachers and students to collaborate and access resources from anywhere. Additionally, cloud solutions have improved administrative processes in educational institutions, including student information management, admissions, and online assessments.

Manufacturing Industry

Cloud computing has significantly impacted the manufacturing industry, enabling manufacturers to improve operational efficiency, optimize supply chain management, and enhance product development processes. Cloud-based enterprise resource planning (ERP) systems have streamlined manufacturing operations by providing real-time visibility into inventory, production, and distribution processes. Cloud platforms have facilitated collaboration between manufacturers and suppliers, enabling better coordination and faster response times. Additionally, cloud services have enabled manufacturers to leverage IoT (Internet of Things) technologies for predictive maintenance, remote monitoring, and data-driven decision-making.

Retail Industry

Cloud computing has transformed the retail industry, enabling retailers to deliver personalized and omnichannel shopping experiences to customers. Cloud-based e-commerce platforms have made it easier for retailers to set up and manage online stores, reach a global customer base, and handle peak traffic demands. Cloud solutions have also enabled retailers to leverage data analytics and customer relationship management (CRM) tools to gain insights into customer behaviour and preferences, enabling targeted marketing campaigns and personalized recommendations. Cloud computing has facilitated inventory management, supply chain optimization,

and seamless integration between physical and online retail channels. These are just a few examples of the impact of cloud computing on industries. Cloud services have brought about significant changes, empowering organizations to innovate, improve efficiency, reduce costs, and deliver better services to customers. The scalability, flexibility, and accessibility offered by cloud computing has revolutionized the way industries operate, paving the way for digital transformation and creating a more connected and productive society.

MEETING CHANGING BUSINESS NEEDS

Cloud computing's scalability addresses dynamic business needs by offering rapid elasticity. This feature enables users to swiftly scale resources up or down, eliminating the need for excess infrastructure. Flexible resource management minimizes operational disruptions, such as downtime from under- or over-provisioning, thus optimizing cost-efficiency [7].

In essence, cloud computing enhances global connectivity and data security and offers unparalleled flexibility in resource management, making it indispensable for modern enterprises aiming to adapt to evolving business landscapes [8, 9].

Cloud computing encompasses various service and deployment models that cater to diverse user needs, transforming how computing resources are accessed, managed, and utilized. These models are crucial for understanding the evolution and impact of cloud technology on digital societies.

CLOUD COMPUTING SERVICE MODELS

Cloud computing offers three primary service models, each differing in the level of control and management they provide to users:

Infrastructure as a Service (IaaS)

IaaS is foundational in cloud computing, offering virtualized computing resources over the Internet. Users have control over infrastructure components such as virtual machines, storage, and networking. They manage these resources, scaling them as needed, while the users are responsible for operating systems, middleware, and applications.

Platform as a Service (PaaS)

PaaS provides a complete platform for application development and deployment. It includes infrastructure resources, development tools, middleware, and runtime environments. Users focus on application development, leveraging the platform's scalability and security. PaaS providers manage the underlying infrastructure, operating systems, and runtime environments.

Software as a Service (SaaS)

SaaS delivers fully functional applications over the internet. Users access these applications without needing installation or maintenance. SaaS providers manage hardware, software, and data storage, offering applications via web browsers or thin clients. Users have limited customization but benefit from accessibility and usability from any device.

CLOUD COMPUTING DEPLOYMENT MODELS

Cloud computing also offers different deployment models that dictate how resources are provisioned and shared:

1. Public Cloud:

Public cloud resources are owned and operated by a cloud service provider and accessible to the general public over the Internet. Users benefit from scalability, cost-effectiveness, and on-demand access without upfront investments. Examples include AWS, Azure, and Google Cloud.

2. Private Cloud:

Private cloud resources are dedicated to a single organization, providing enhanced security and control. They can be hosted on-premises or by a third-party provider, catering to organizations with specific compliance or data sovereignty requirements.

Benefits of Private Cloud over Other Cloud Deployment Models

Control Over Maintenance & System Logs

- One of the key advantages of a private cloud solution is its level of control. Unlike public clouds, where users may lack control over critical aspects like audit logs and maintenance schedules, a private cloud empowers businesses to manage their resources independently. This allows for timely maintenance and system upgrades as needed, with unrestricted access to audit logs [26].

Geographical Access

- Private clouds provide reliable geographical access, ensuring stable connectivity for employees across different locations. Unlike public cloud providers, which have predefined availability zones globally, companies leveraging a private cloud can customize their infrastructure to meet specific compliance requirements of each office location. This guarantees consistent and compliant access to resources [25].

Enhanced Security & Privacy

- Security and privacy are significantly strengthened in a private cloud environment. Private clouds ensure

strict control over access rights and data handling by storing all data within the organization's infrastructure. This mitigates the risks associated with data breaches and unauthorized access, offering robust data privacy measures that exceed those of public cloud services where data resides on third-party servers [25].

COMMUNITY CLOUD

The community cloud model caters specifically to groups with high-security demands, limiting resource access to members of the same community or organization.

HYBRID CLOUD

- Definition: Hybrid cloud combines multiple cloud deployment models while keeping each as independent entities connected through technology that facilitates seamless data and application portability. This approach allows organizations to leverage the scalability and cost-efficiency of public clouds for less sensitive data and applications while retaining critical data in private cloud environments.

SDN-ENABLED CLOUD COMPUTING

- Overview: Traditional networking in cloud data centres faces challenges of scalability and operational complexity due to the dynamic nature of virtualized resources. Software-defined networking (SDN) addresses these issues by centralizing network control, enabling agile and flexible management of network resources. Major cloud providers like Google and AWS utilize SDN to enhance network manageability and scalability in their data centres [28-30].

ROLE OF CLOUD COMPUTING IN BUSINESS GROWTH

- Impact: Cloud computing is pivotal across various sectors, including health, IoT, AI, and sports, due to its transformative benefits in management and accessibility [31-36]. It facilitates easy deployment for startups and small companies at lower costs, ensuring 24/7 service availability and scalability [53-66].

Benefits and Advantages of Cloud Computing

Cloud computing brings significant advantages that have reshaped digital societies:

- Scalability and Elasticity: Easily scale resources up or down based on demand, optimizing costs and resource usage.
- Cost Efficiency: Pay-as-you-go models reduce upfront costs, making powerful resources accessible to startups and small businesses.
- Accessibility and Ubiquity: Access applications and data from anywhere with an internet connection, promoting collaboration and productivity.

- Reliability and High Availability: Robust infrastructures ensure consistent access to applications and data, even during failures.

Flexibility and Agility: Rapid deployment and adaptation to changing business needs foster innovation and faster time to market.

- Data Security and Disaster Recovery: Advanced security measures and built-in disaster recovery capabilities protect data and ensure business continuity.

- Environmental Sustainability: Optimized resource utilization and energy-efficient operations contribute to a greener IT infrastructure.

Cloud computing has revolutionized businesses' operations, enabling innovation, collaboration, and efficiency across various sectors. It has empowered individuals with seamless access to resources and services while governments have enhanced service delivery and reduced IT costs. Understanding and leveraging these models and benefits are essential for maximizing cloud computing's transformative impact on digital societies.

CLOUD MIGRATION METHODS

Cloud migration methods can be categorized into two main approaches: online Migration.

Online Migration

Online Migration involves migrating systems that provide online services from one location to another without downtime or disruption to services, ensuring transparency to users. This method functions akin to encapsulating a virtual machine in a file, maintaining the configuration and memory state of the business environment on another physical machine over the network. The original running state is preserved throughout the process, culminating in the Migration from the migration to the destination host on the cloud.

Offline Migration

In contrast, offline Migration, also known as migration Migration, is more complicated and involves shutting down the host before Migration. The system Migrations are then copied to the destination host via storage or the network. Subsequently, the system is reconfigured on the target cloud host and powered back on. While this method is straightforward, it requires a clear procedure for stopping the virtual machine and entails downtime during which business services may be unavailable. Offline Migration is suitable for migration scenarios where low business impact during Migration is acceptable Cloud Migration Scenarios

Companies typically undertake cloud migration in two primary scenarios: partial Migration and overall migration.

a. Part Migration

Partial migration involves dividing Migration into two parts: one part is migrated to the cloud platform while the other remains locally hosted. The local server and cloud platform collaborate and share resources to achieve operational continuity and utility.

b. Overall Migration

Overall migration refers to Migrating all data and processes to a single cloud platform in one comprehensive step. This approach ensures all business operations are consolidated into the cloud, simplifying management and potentially reducing costs.

The comparison between Partial and Overall Migration is summarized in Table 1:

Table 1. Comparison of partial migration and overall migration in cloud computing.

Parameters	Partial migration	Overall migration
Protection of original equipment	Use existing equipment effectively	Unable to use the original equipment, resulting in the waste of the original equipment investment
Cost of construction	The direct construction cost of this project is relatively high, but the overall cost is relatively low considering the expense of resource occupation of cloud platform.	The direct construction cost of this project is low, but the overall cost is high considering the expense of cloud platform
Risks to the business	Some devices depend on the stability and maturity of the cloud. Therefore, the impact on services and risks are relatively small	The entire system depends heavily on the stability and maturity of the cloud. When a fault occurs, the system must be rolled back in time to ensure services.
System Architecture	The original system architecture needs to be changed into the functions of central node and sub-node, which may affect the performance and stability of the system. Only a few modifications to the system architecture are needed to migrate to the cloud platform	The complexity of project implementation requires cutting over some user data and system architecture adjustment. The project's complexity is high, and the implementation duration is lengthy.

This restructuring aims to enhance clarity and readability while retaining the original information and structure provided in the text.

Cloud Migration Tools and Services

This section highlights various tools and techniques commonly used for cloud migration.

a. PlateSpin Migrate

PlateSpin Migrate, developed by Novell, is a robust tool for workload portability and migration. It offers secure and reliable capabilities for migrating entire server systems, including operating systems, applications, and business data, across different data centers. This tool is particularly noted for its ability to

accommodate various server models from different manufacturers without requiring the original physical server to go offline [10]. PlateSpin Migrate is recognized as one of the most versatile and high-performing tools in its category.

PlateSpin Migrate supports multiple migration scenarios such as physical to virtual, virtual to mirror, mirror to physical, and more. It simplifies the

migration of physical machines to any virtual environment seamlessly. Additionally, it facilitates synchronization of modifications to maintain virtual copies up to date while the original remains in production. The tool automates the entire process of transferring physical or virtual servers to enterprise cloud platforms over the network [11]. Figure 1 illustrates the automated server workload migration across the network using PlateSpin Migrate.

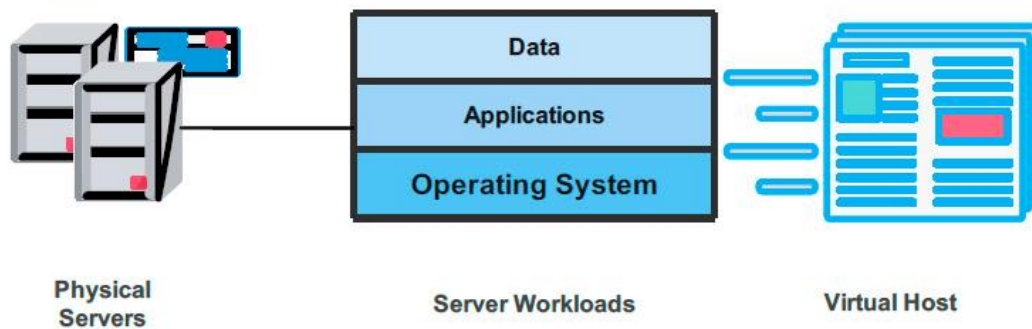


Figure 1. PlateSpin Migrate

b. AWS Migration Services

Amazon, a leading provider in the public cloud sector, offers a range of highly integrated cloud migration services. These include AWS Migration Hub, the Snow series of offline data transfer devices, AWS Database Migration Service, and AWS Server Migration Service. These tools are typically complimentary for AWS customers but are exclusive to the AWS cloud platform. Clients can leverage AWS's physical hardware appliances for data migration to their data centres. This involves placing equipment in their facilities, transferring data to AWS, and uploading additional equipment [12].

Microsoft provides a comprehensive service called Azure Migrate, which includes a database migration service and utilizes data box hardware for offline data transfer, facilitating workload migration to Azure for clients. Initially focused on VMware vSphere migrations, Azure Migrate has evolved into a versatile tool supporting migration to the Azure cloud for various workloads. It is tailored for Windows and other Microsoft software environments [13]. Azure Migrate supports only Azure as a cloud provider and, like its counterparts, offers most migration services at no cost. Figure 2 provides an overview of Azure Migrate Hub for datacenter migrations.

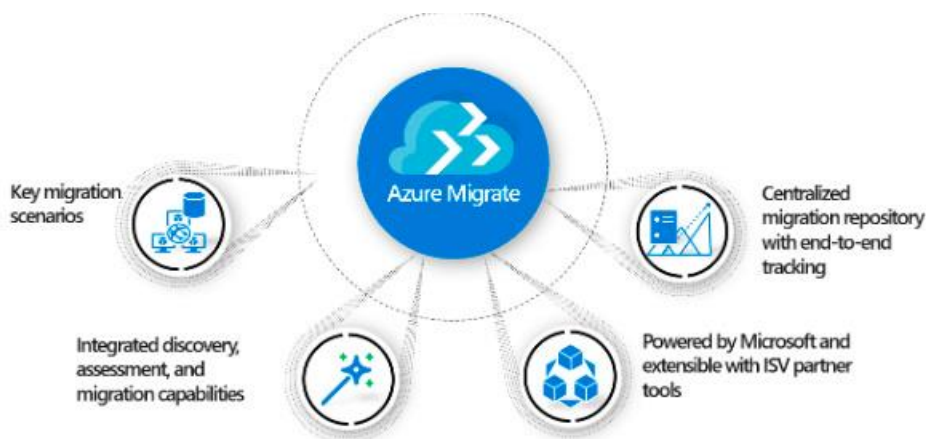
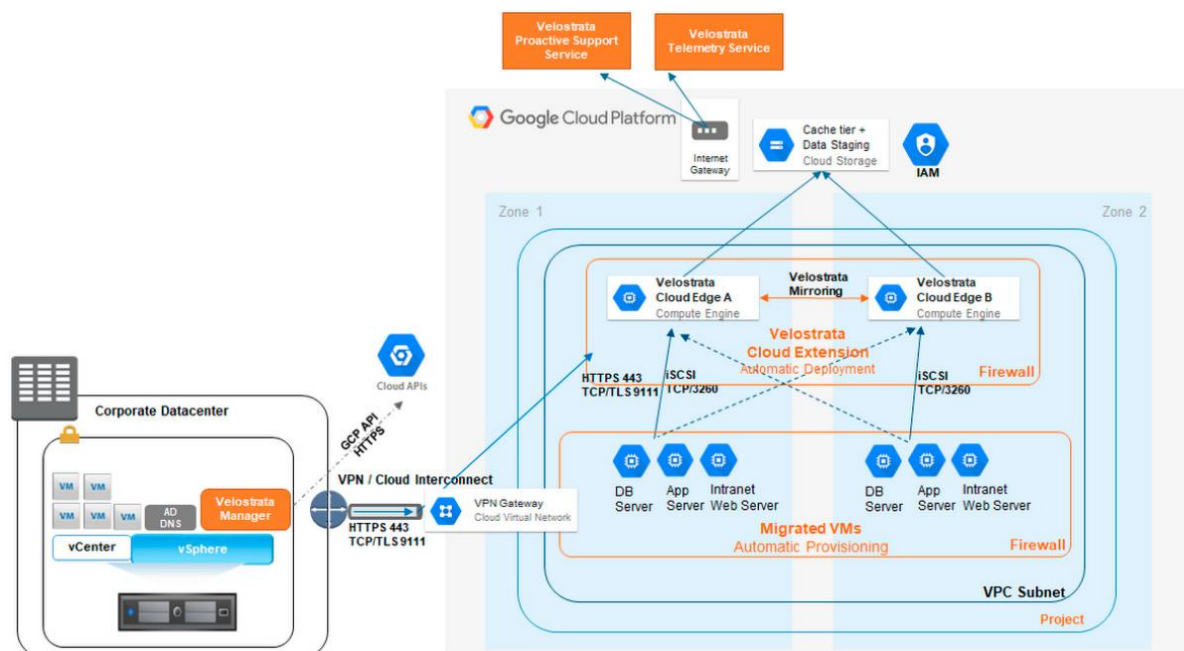


Figure 2. Azure Migrate-Hub for Datacentre Migration

C. Google Migration Services /Velostrata

Google has acquired Velostrata, enhancing its cloud migration capabilities significantly. Velostrata's technology can accelerate migration rates by up to ten times. While Google offers many migration services at no cost, similar to other public cloud providers, these services are exclusive to the Google Cloud Platform

[13]. Figure 3 illustrates that establishing a VPN or Cloud Interconnect link between the on-premises data center and GCP, along with a Virtual Private Cloud (VPC) within GCP, is necessary. The Velostrata Management Server oversees the migration process and can be deployed either in the source data center or within the Google Cloud Platform. Velostrata's cloud edge components are situated within the VPC subnets.



Cloud Migration: Testing, Implementation, and Validation

To execute a successful migration to the cloud, a well-defined migration solution and appropriate tools are crucial. Below outlines the necessary steps for testing, implementation, and validation of the migration process.

a. Migration Testing

The migration testing phase involves validating the migration scheme in a controlled environment, ensuring correctness, consistency, and availability across technology and processes. Key activities include:

Scheme Testing: Execute the migration plan according to the defined scheme. Verify and refine the scheme based on test outcomes to enhance its effectiveness.

Scenario Simulation: Mimic real-world customer scenarios to assess solution and tool feasibility in various conditions.

Test Execution: Conduct comprehensive tests covering service migration servers, migration tools, service data synchronization, consistency checks, and data switchover.

Risk Assessment: Identify potential downtime and risk points, particularly during backward compatibility verification and rollback tests. Define necessary changes and gradual implementation strategies, including script execution during migration.

Collaboration: Engage with stakeholders to review test reports and refine the migration solution as needed. Output modified migration test reports reflecting collaborative adjustments with users.

b. Migration Implementation and Verification

This phase involves the actual migration execution and validation, ensuring smooth service transition and data integrity. Key activities include:

Service Migration: Deploy business environments and migration tools within the cloud platform. Synchronize service data and conduct consistency checks.

Traffic Switchover: Select an appropriate idle period to switch traffic from the source to the target system within the service cycle. Ensure real-time data updates and minimize the time window for data differences between systems.

Business Suspension and Switchover: Temporarily suspend source system operations, switch network

traffic to the target system using differential data, and verify business system functionality and data consistency by business personnel.

Optimization and Monitoring: Address and optimize any issues identified during the migration process. Continuously monitor the migration progress to ensure smooth operation.

Acceptance Report: Prepare and sign an industry acceptance report to confirm that the target system meets migration and deployment requirements.

Considerations for Linux System Migration:

Network Hardware and Kernel Support: Address changes in network hardware devices and ensure kernel support for virtual devices.

Configuration Adjustments: Reconfigure Windows systems as necessary.

Environment Changes: Manage changes in the network environment and CPU instruction sets that may affect migration reliability.

By following these structured steps, organizations can ensure a systematic approach to cloud migration, minimizing risks and achieving successful outcomes aligned with business objectives.

CLOUD COMPUTING DEPLOYMENT AND SERVICE MODELS

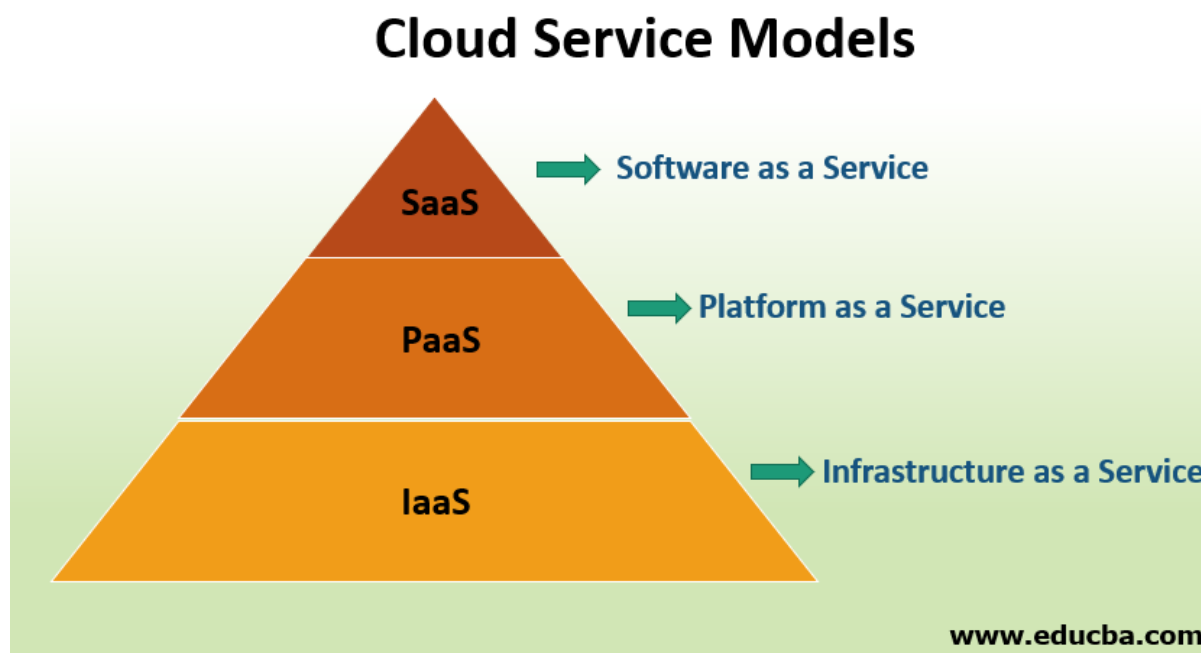


Figure 4: Cloud Service Model

Cloud Computing Service Models

Cloud computing offers several service models, namely Software-as-a-Service (SaaS), Platform-as-a-Service (PaaS), and Infrastructure-as-a-Service (IaaS). According to Figure 4, IaaS forms the fundamental layer supporting all cloud services, delivering computing, networking, storage, and database capabilities over the Internet. IaaS solutions are built on virtualization technology, allowing users to procure virtual machines (VMs) from providers instead of managing physical hardware directly. Each VM operates like a physical machine, utilizing virtualized resources like its own operating system, storage, RAM, and CPU [18].

1. Software as a Service (SaaS)

SaaS provides cloud users with comprehensive software solutions such as email, social networking services, online calendars, and various other programs hosted in the cloud. Customers utilizing the SaaS model do not manage infrastructure resources like storage, CPU, or the operating system [20]. Popular examples of SaaS providers include Salesforce, Google Apps, and Microsoft Office 365.

2. Platform as a Service (PaaS)

Cloud platforms offer application developers a powerful tool in the form of PaaS. PaaS customers have complete control over their deployed applications, empowering them to make changes and updates as needed. They do not manage resources such

as the operating system or storage, allowing them to focus on their applications.

3. Infrastructure as a Service (IaaS)

IaaS is the most fundamental cloud service model, offering cloud users access to virtual machine servers and associated infrastructure. Customers can utilize this infrastructure for various purposes, such as building platforms or running software on virtual machines. Unlike SaaS and PaaS, IaaS provides greater control over resources such as the operating system, storage, and applications. Here are some of the benefits of IaaS [21]:

- **Cost Saving:** Using IaaS can significantly reduce costs by eliminating the need for servers in multiple offices. Employees outside the main office can access resources like VMs via the private cloud. Additionally, IaaS supports desktop virtualization, allowing employees to work from any device with an internet connection.

- **Scalability:** IaaS enables companies to adjust resource allocation based on current needs, scaling resources up or down across departments as workload

demands fluctuate. This flexibility enhances return on investment (ROI) by optimizing resource utilization.

- **Centralized Management:** With a private IaaS solution, companies manage a single data centre instead of maintaining and upgrading multiple data centres across different offices. This centralized approach reduces the workload associated with data centre management. Updates and maintenance are streamlined, focusing on virtual machines rather than numerous physical devices.

- **Business Continuity:** IaaS, a robust and reliable cloud service, supports business continuity by enabling employees to continue working from personal devices during office disruptions such as power outages. This ensures that business operations remain largely unaffected, instilling confidence in the service's ability to maintain continuity. In contrast, traditional setups with local servers would halt operations during disruptions [23].

In cloud computing, various deployment models, such as private, public, community, and hybrid clouds, are available, as depicted in Figure 5 [24].

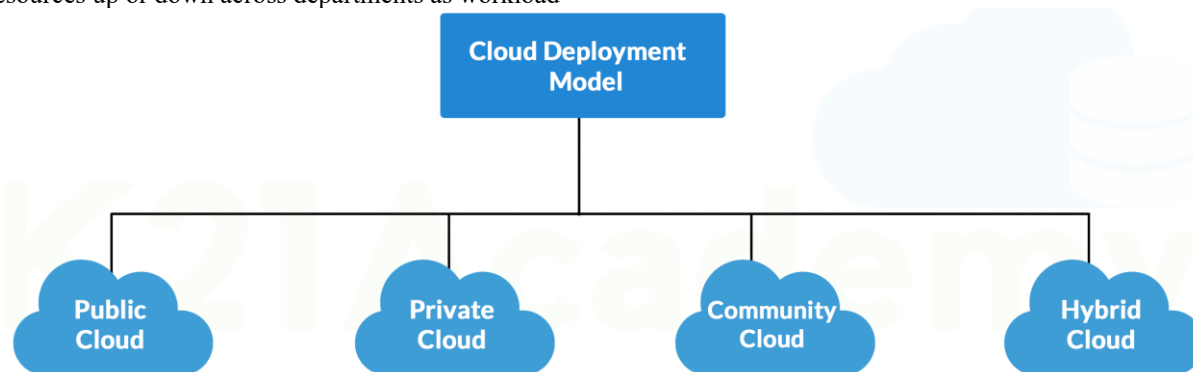


Figure 5. Cloud Deployment Models

CONCLUSION

Cloud computing (CC) is a popular web service technology with a pay-per-use model. It allows users and customers to lease services such as storage, deployment, web applications, and more, without the need for physical infrastructure investment. However, the critical step of cloud migration involves a responsible decision-selecting an appropriate service provider and an exemplary service and deployment model, a choice that can significantly impact your cloud journey.

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Cloud computing heavily relies on virtualization technology, a key component of its functionality. By integrating cloud computing with Software-Defined Networking (SDN) environments, we can unlock significant advantages in modern network virtualization. This is primarily due to the centralized control that SDN controllers offer over the network, empowering you with enhanced flexibility and efficiency in cloud-based infrastructures.

