Unit-I :Introduction to Cloud Computing

Importance of Cloud Computing, Characteristics, Pros and Cons of Cloud Computing, Migrating into the Cloud, Seven-step model of migration into a Cloud, Trends in Computing. Cloud Service Models: SaaS, PaaS, IaaS, Storage. Cloud Architecture: Cloud Computing Logical Architecture, Developing Holistic Cloud Computing Reference Model, Cloud System Architecture, Cloud Deployment Models.

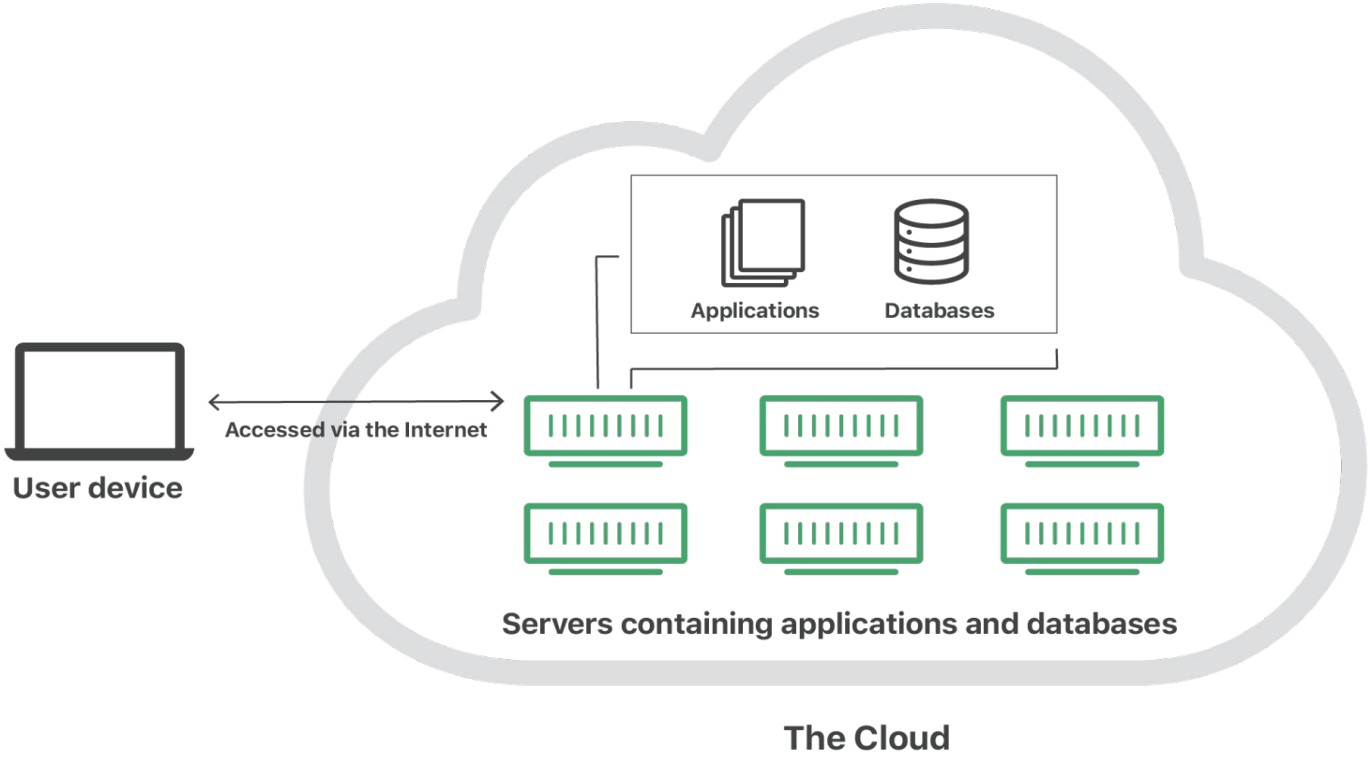
Case Study : Cloud Computing Model of IBM

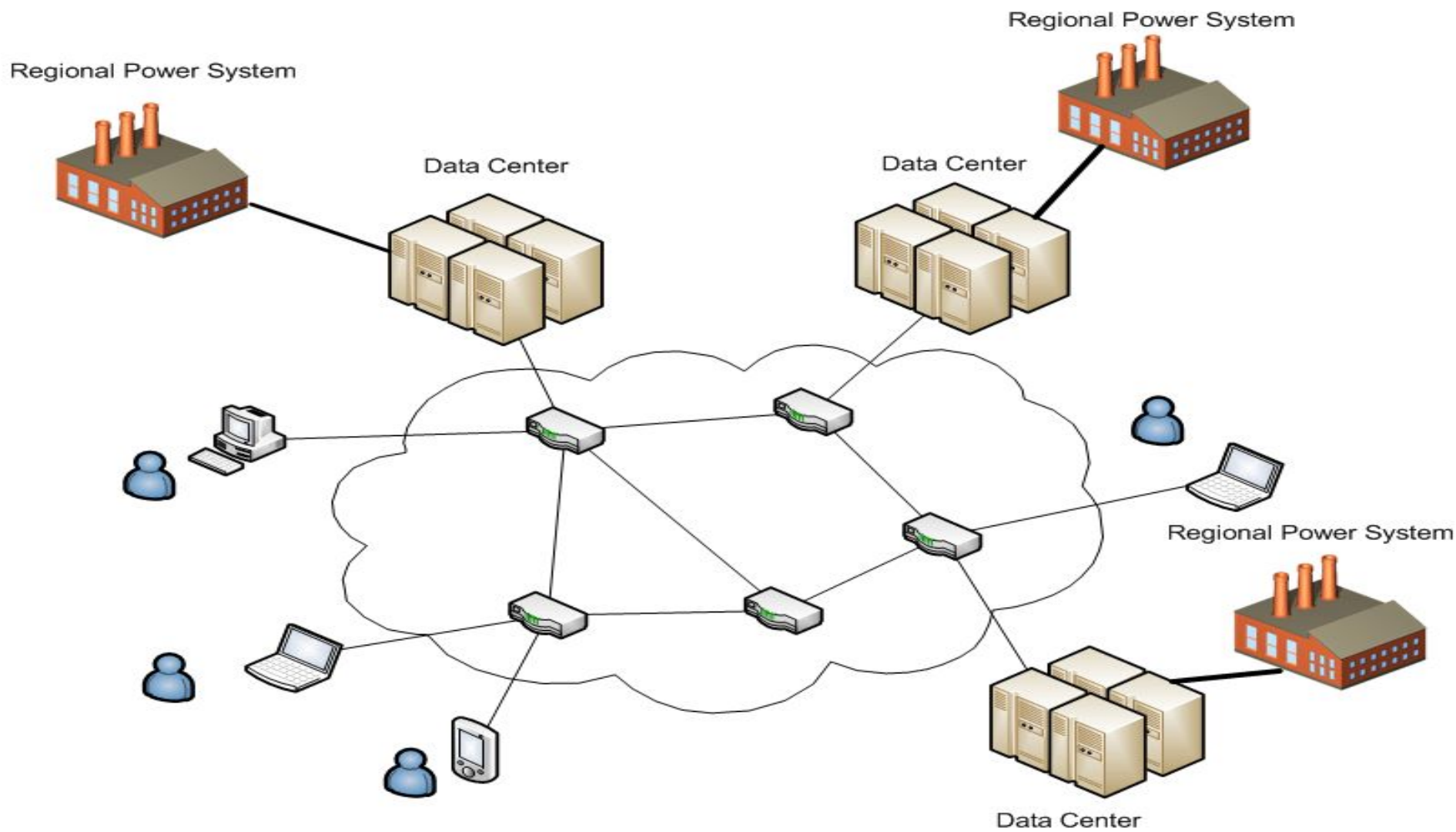
What is Cloud?

- "The cloud" refers to servers that are accessed over the Internet, and the software and databases that run on those servers.
- Cloud servers are located in data centers all over the world.
- By using cloud computing, users and companies do not have to manage physical servers themselves or run software applications on their own machines.
- public cloud service provider such as AWS, Google Cloud, or Microsoft Azure.

Cloud Computing

- Cloud computing is the the process of storing, managing, and accessing data from the Internet rather than on a local server or a personal computer
- You have an e-mail account. That's it. You are already on the cloud.
- An e-mail like Gmail, Yahoo and Hotmail are cloud-based examples of SaaS (Software as a Service).
- SaaS is a piece of cloud computing.
- Cloud computing is defined as the business of sharing some software from the 'cloud'.
- **Cloud** is an acronym of the phrase: Common, Location-independent, Online Utility that is available on Demand.


Applications
Databases
Accessed via the Internet
User device
Servers containing applications and databases
The Cloud


Regional Power System
Regional Power System
Data Center
Data Center
Regional Power System
Data Center

Importance of Cloud Computing in the Current Era

Example :from reference book

- 21st Feb 2011, Sometime in ICC Cricket World Cup, India Furious cricket fans slammed organizers of the World Cup on Monday as the official ticketing website crashed amid a scramble for 1,000 tickets available for the final.**(Source: Times of India [Magazine])**

- **The manager of ICC posted a message in his Facebook fan page:**

We are facing absolutely unprecedented amounts of traffic from all over the world with hundreds of millions of people hitting at once. Some of you may have trouble accessing the site. It seems that cricket fever has surpassed all anticipations and expectations. Please bear with us as our global network team works on bringing you the tickets you all have been waiting for. (Source: Kyazoonga FB page)

Solution to Prevent Server Crashes/Failures

The majority of us will answer as follows:

- **Add additional servers to balance the load.**

In view of these facts, it will help us to make a sensible guess.

- Facebook has 30,000 servers and is increasing its capacity on a daily basis.
- An unofficial estimate predicts Google servers to be unbelievable in numbers; With 1 million servers across the world wide at present.

WHY CLOUD COMPUTING?

LIFE WITHOUT CLOUD

- ✓ SERVER
- ✓ STORAGE
- ✓ INTERNET CONNECTION
- ✓ SECURITY
- ✓ 24X7 POWER SUPPLY, ETC.

Importance of Cloud Computing

- Before cloud computing, companies had to store all their data and software on their own hard drives and servers.
- The bigger the company, the more storage they needed.
- This way of treating data is not scalable at speed.
- **For example,** if word started spreading about your business and you suddenly had a lot of online orders, your servers would probably crash. Good business meant **hardwork** for the IT department.
- **Cloud technology** means that companies can scale and adapt at speed and scale, accelerate innovation, streamline operations, and reduce costs.

Importance of Cloud Computing

1. Scalability : Scalability refers to the expansion of infrastructure to handle an increased load for every application.

2. Flexibility: Cloud computing promotes flexibility in the workplace. It allows the employees to be flexible enough by accessing the data from home or on a holiday.

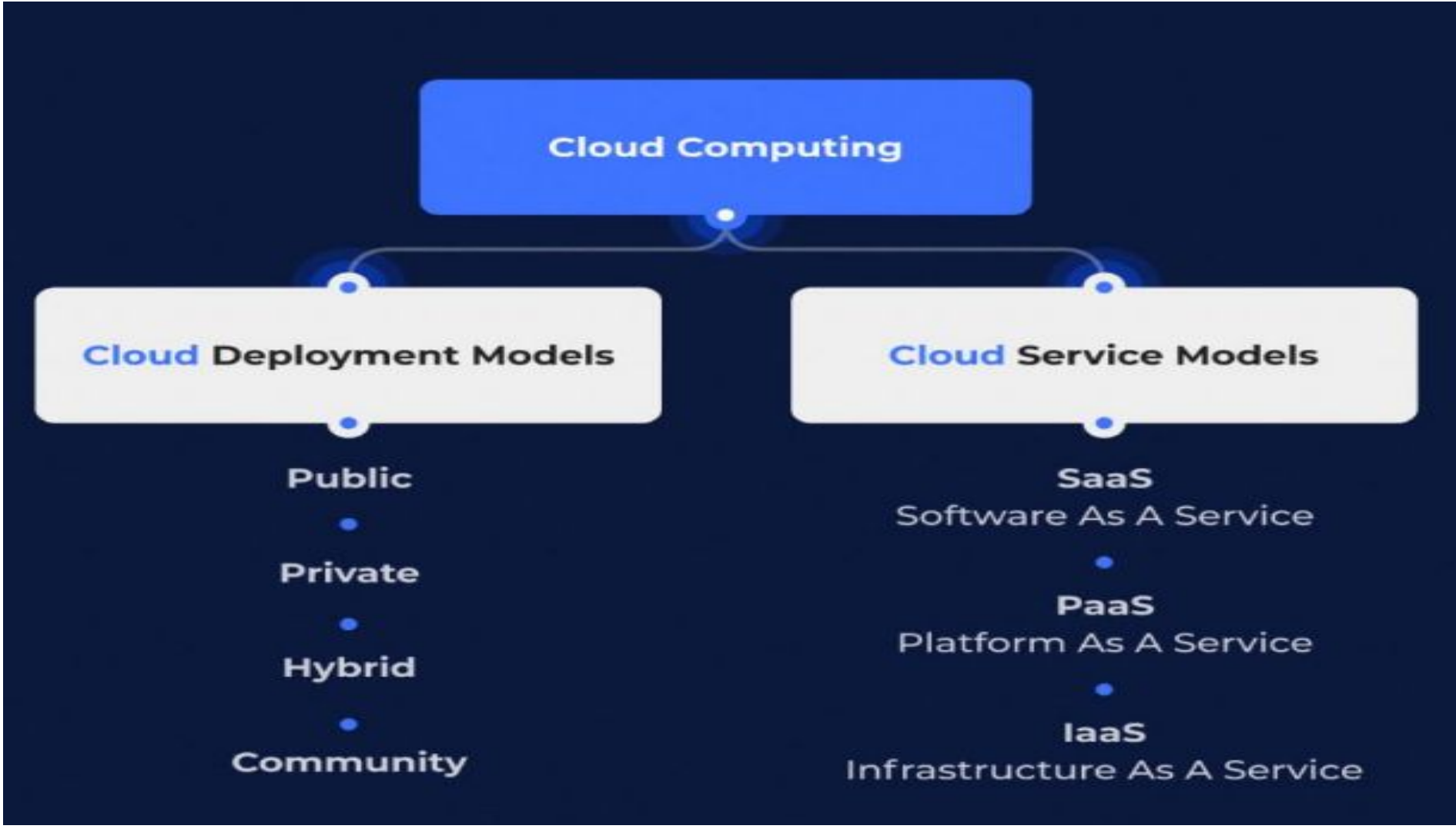
3. Saving Costs:the time to spend on computing, storage, and networking is reduced.

4. Disaster Recovery: Disaster Recovery or DRaaS is a cloud computing service model that helps an organization back up its data over the cloud with the help of an IT infrastructure third-party cloud computing environment.

5.Easy Accessibility: Cloud computing is an easy-to-access computing system.

6.Higher Level of Security: Cloud computing provides a higher level of security when it comes to both public and private clouds.

7.Automatic Updates: One of the biggest reasons why cloud computing is interesting is because it provides automatic updates


Cloud Computing
Cloud Deployment Models
Public
Private
Hybrid
Community
Cloud Service Models
SaaS
Software As A Service
PaaS
Platform As A Service
IaaS
Infrastructure As A Service

Cloud Deployment Models:CDM

- Deployment model depending on how much data you want to store and who has access to the Infrastructure

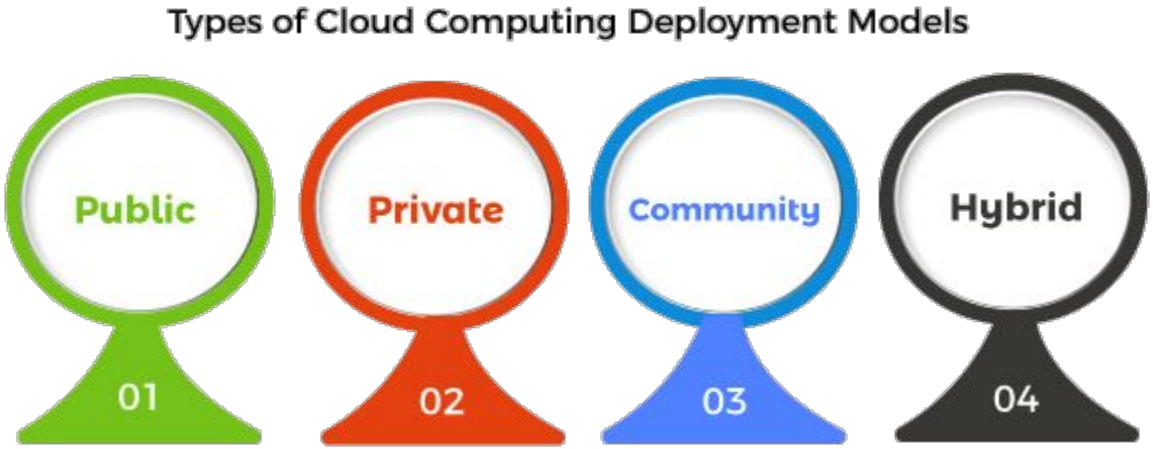


Figure 6.5 Private Cloud

Figure 6.6 Public Cloud

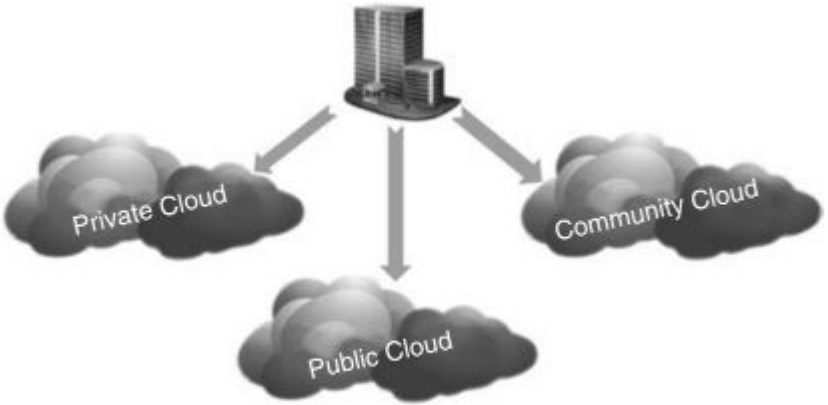
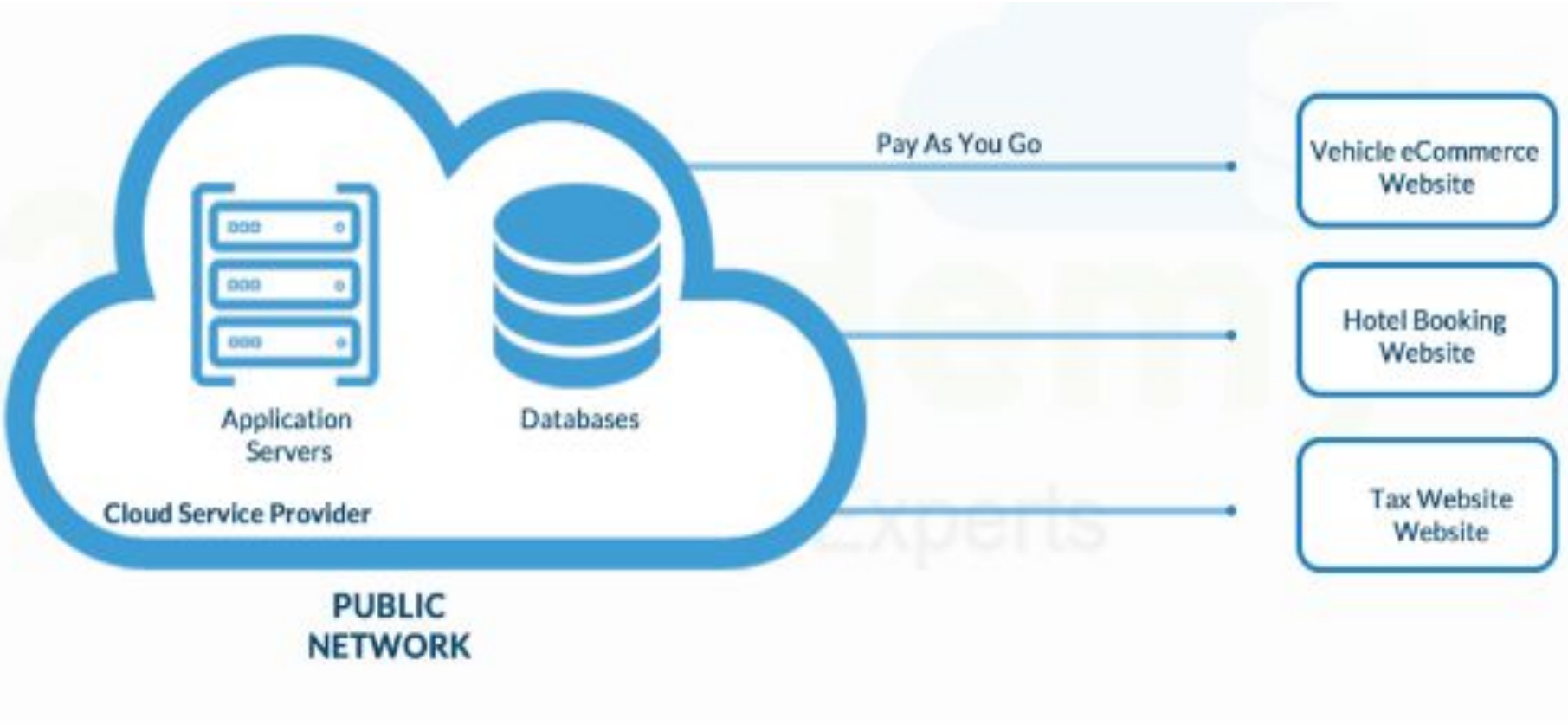
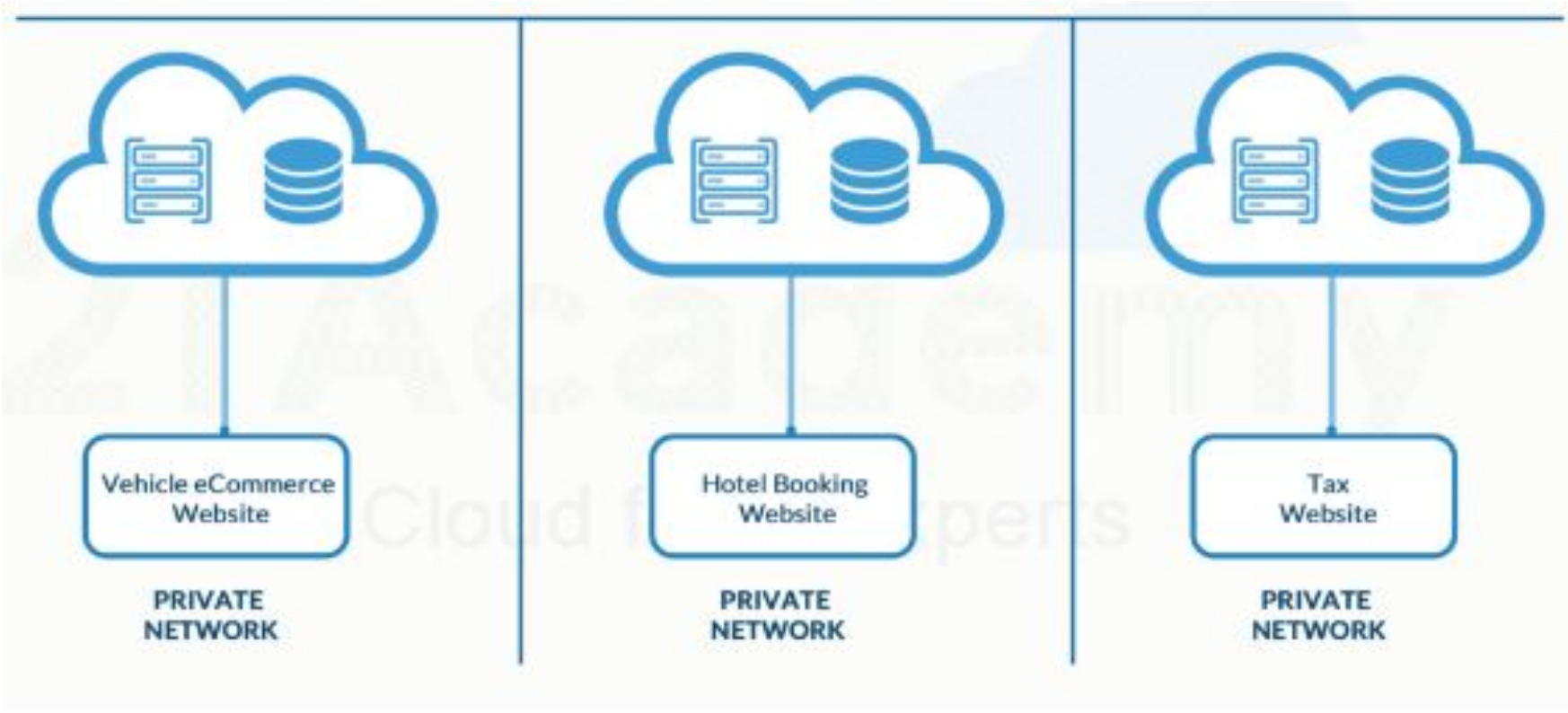


Figure 6.7 Hybrid Cloud

Public Cloud



Private Cloud

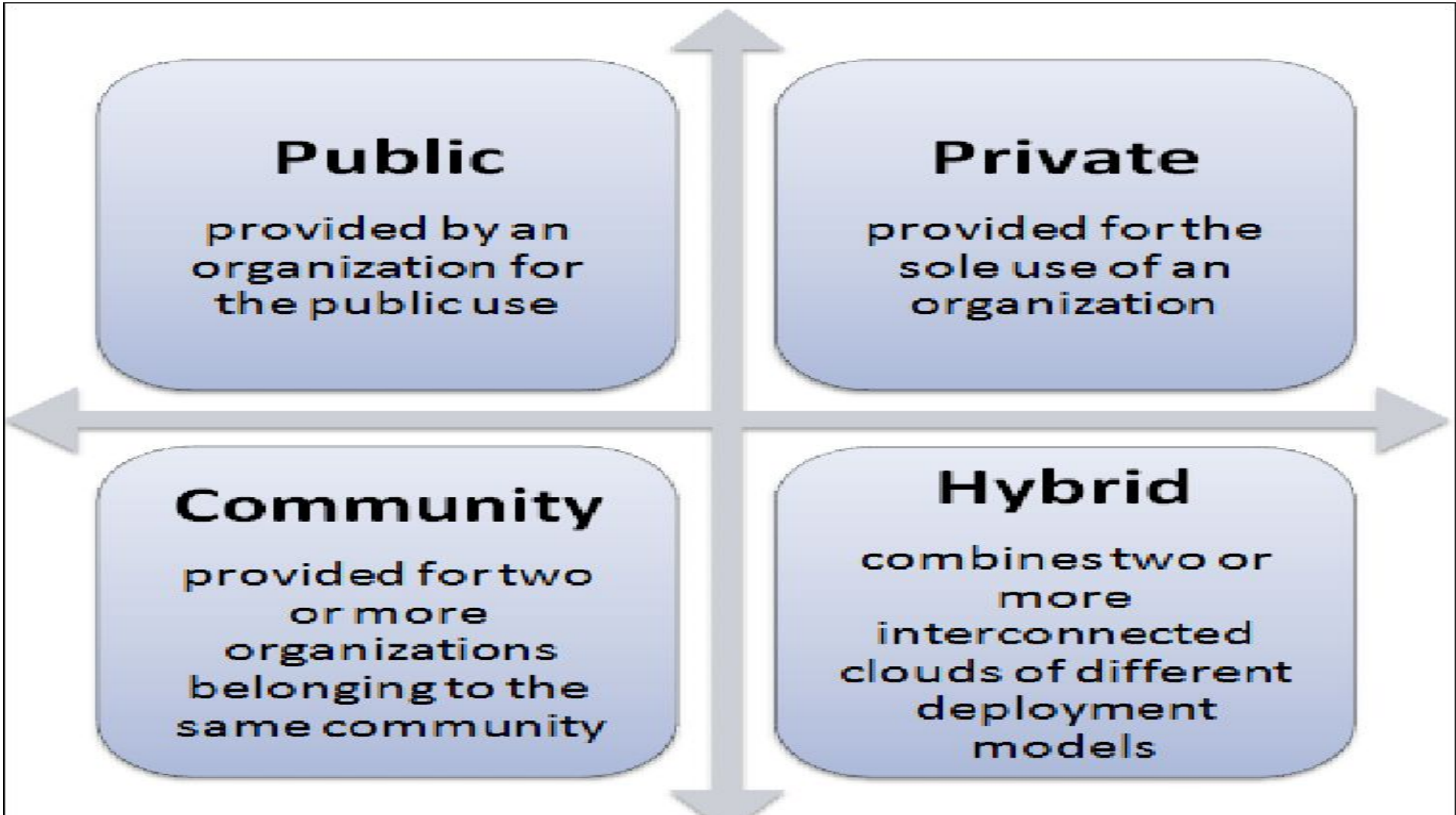


HYBRID CLOUD

Community Cloud

Community Cloud

All Other Services


Public
provided by an organization for the public use
Private
provided for the sole use of an organization
Community
provided for two or more organizations belonging to the same community
Hybrid
combines two or more interconnected clouds of different deployment models

Important Factors to Consider	Public	Private	Community	Hybrid
Setup and ease of use	Easy	Requires professional IT Team	Requires professional IT Team	Requires professional IT Team
Data Security and Privacy	Low	High	Very High	High
Scalability and flexibility	High	High	Fixed requirements	High
Cost-Effectiveness	Most affordable	Most expensive	Cost is distributed among members	Cheaper than private but more expensive than public
Reliability	Low	High	Higher	High

Benefits of having a public cloud

Types of cloud deployments

- **Private cloud:** A private cloud is a server, data center, or distributed network wholly dedicated to one organization.
- **Public cloud:** A public cloud is a service run by an external vendor that may include servers in one or multiple data centers. Unlike a private cloud, public clouds are shared by multiple organizations. Using virtual machines, individual servers may be shared by different companies, a situation that is called "multitenancy" because multiple tenants are renting server space within the same server.

Types of cloud deployments

- Hybrid cloud: hybrid cloud deployments combine public and private clouds, and may even include on-premises legacy servers. An organization may use their private cloud for some services and their public cloud for others, or they may use the public cloud as backup for their private cloud.
- Community Cloud:It allows systems and services to be accessible by a group of organizations.It is a distributed system that is created by integrating the services of different clouds to address the specific needs of a community, industry, or business.
- The infrastructure of the community could be shared between the organization which has shared concerns or tasks.
- It is generally managed by a third party or by the combination of one or more organizations in the community.

Difference between Multi cloud and Hybrid cloud

Multi-cloud

VS

Hybrid cloud

Difference between Multi cloud and Hybrid cloud

- Differ in the kinds of cloud infrastructure they include.
- The first key difference is that a **hybrid** cloud always includes **private and public clouds.** This isn't the case of a **multi-cloud,** that includes **multiple public clouds**.
- **hybrid cloud** provides **direct connectivity between** the public and private cloud. When you opt for a **multi-cloud** strategy the **two cloud providers are often completely separate.**

Cloud Service Model

- Service models are types of services that are required by customers
- Models are based on the kind of operation and requirement of the business.
- A cloud service can be replaced with any one of the following as Cloud * as a Service—'Desktop, data, platform, IT, infrastructure, testing,computing, security, software, testing, storage, hardware, database, etc.'

Cloud Service Model

There are the following three types of cloud service models -

01 **Software** as a Service (SaaS)

02 **Platform** as a Service (PaaS)

03 **Infrastructure** as a Service (IaaS)

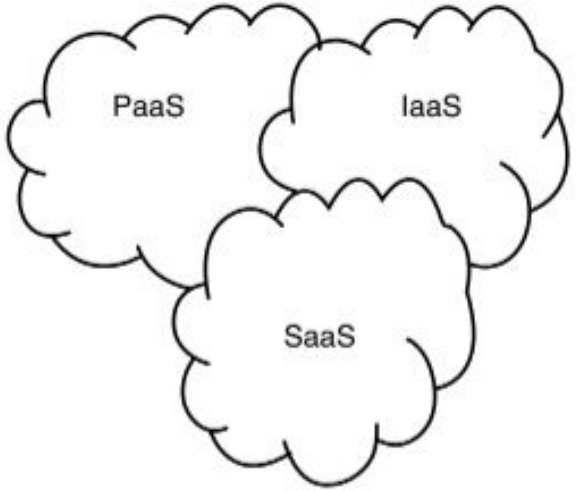


Figure 4.2 Cloud Service Models

01 Software as a Service (SaaS)

Provider of SaaS has full administrative rights for its application and responsible for activities such as deployment, maintenance and update.

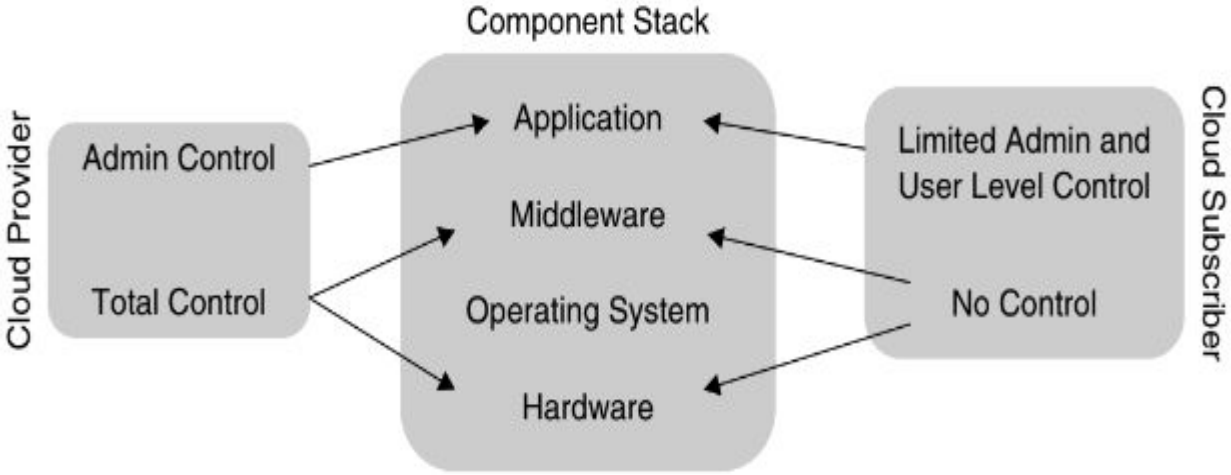


Figure 4.3 SaaS Component Stack and Scope of Control

01 Software as a Service (SaaS)

- Figure 4.3 shows the levels of rights between the subscriber and the provider,
- From the figure, it is clear that a cloud provider has total control over the hardware, middleware and operating system.
- It also has administrative control over the application residing in the server.
- Cloud subscriber subscribes the service, it has limited admin and user level control.
- Cloud users do not have control over the OS or the hardware.
- SaaS subscribers can be individual users, users from organizations and users from enterprises.
- If the focus in on improving of the business, SaaS is the best option.

01 Software as a Service (SaaS)

There are the following characteristics of SaaS -

- Managed from a central location
- Hosted on a remote server
- Accessible over the internet
- Users are not responsible for hardware and software updates. Updates are applied automatically.
- The services are purchased on the pay-as-per-use basis

Example: BigCommerce, Google Apps, Salesforce, Dropbox, ZenDesk, Cisco WebEx, ZenDesk, Slack, and GoToMeeting.

02 Platform as a Service (PaaS)

- PaaS is service, where application/software can be build, tested and deployed as a single unit.
- PaaS is useful for application builders, developers, deployers and testers.

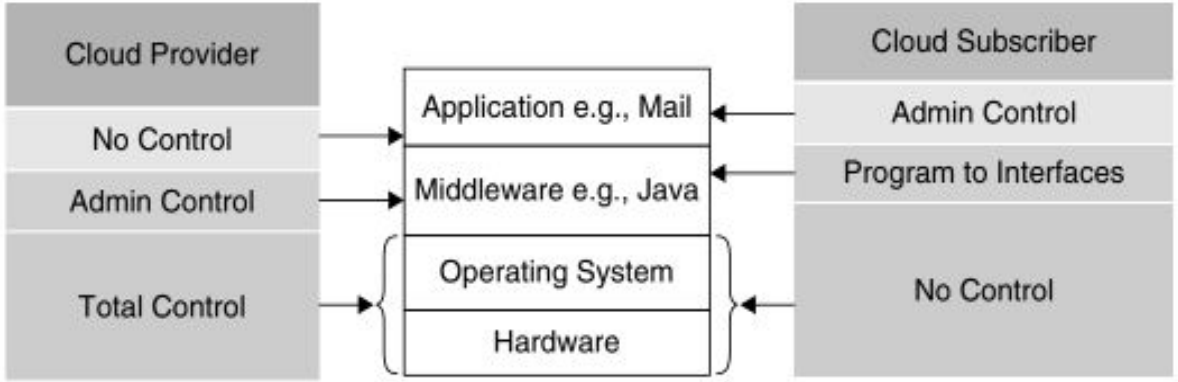


Figure 4.4 PaaS Component Stack and Scope of Control

02 Platform as a Service (PaaS)

- From the figure, we can understand that the cloud provider has total control over the hardware and operating system, admin control over the middleware and no control over the application.

- A cloud subscriber subscribes to the services and has full admin rights over the application deployed and minimal rights over the middleware.

- Cloud users do not have control over the OS or the hardware.

02 Platform as a Service (PaaS)

- PaaS consists of environment for developing applications, languages for writing programs,compilers and tools for testing and deployment.
- PaaS subscribers can be third party software vendors, individual developers and IT service providers.
- Users can opt for PaaS, if his/her focus is only on application development and to finishing it before the deadline.
- By opting PaaS, everything else (other than the application development) will be maintained by the provider.
- Customers must choose the PaaS based on the platforms they work.
- PaaS providers in India are Wolf Frameworks and OrangeScape.
- Developers working on PHP can choose PHP Fog or/and CloudControl.

03 Infrastructure as a Service (IaaS)

- When the customer requires an end-to-end infrastructure such as computer resources, storages and network, he/she can opt for IaaS.
- The usage fee is billed at CPU hour, size (GB) of data accessed or stored/hour, bandwidth consumed, etc.

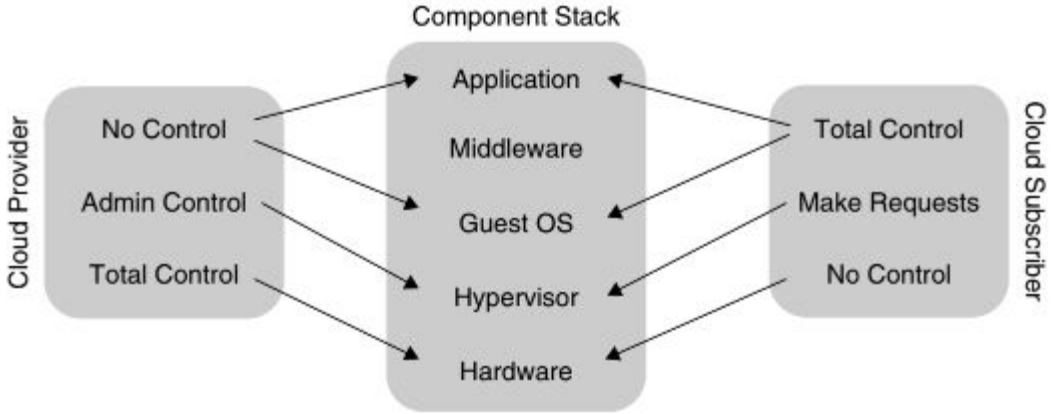


Figure 4.5 IaaS Component Stack and Scope of Control

03 Infrastructure as a Service (IaaS)

- From the figure, it is clear that cloud provider has total control only over the hardware and has admin rights for virtualization part, that is, hypervisor.
- He/she has no control over the application, middleware and guest operating system. Cloud subscriber subscribes the service and has full admin rights for the application deployed, middleware and the OS. Cloud users can make requests to hypervisor but don't have control over the hardware.
- Enterprises comprising of many servers can act as an IaaS provider such as Facebook, Orkut and Twitter.

Common examples of PaaS, SaaS, and IaaS

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Platform	Examples
PaaS	AWS Elastic Beanstalk, Google App Engine, and Adobe Commerce
SaaS	Gmail, Slack, and Microsoft Office 365
IaaS	Amazon Web Services, Microsoft Azure, and Google Compute Engine

IaaS	Paas	SaaS
It provides a virtual data center to store information and create platforms for app development, testing, and deployment.	It provides virtual platforms and tools to create, test, and deploy apps.	It provides web software and apps to complete business tasks.
It provides access to resources such as virtual machines, virtual storage, etc.	It provides runtime environments and deployment tools for applications.	It provides software as a service to the end-users.
It is used by network architects.	It is used by developers.	It is used by end users.
IaaS provides only Infrastructure.	PaaS provides Infrastructure+Platform.	SaaS provides Infrastructure+Platform +Software.

Storage as a Service (STaaS)

- STaaS is cloud storage that you rent from a Cloud Service Provider (CSP) and that provides basic ways to access that storage.

- Enterprises, small and medium businesses, home offices, and individuals can use the cloud for multimedia storage, data repositories, data backup and recovery, and disaster recovery

- There are three main types of cloud storage:
  - block storage,
  - file storage,
  - object-based storage.

Data Storage

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- **File storage**

- In file storage, **data is stored in files, the files are organized in folders**, and the folders are organized under a hierarchy of directories and subdirectories.
- To locate a file, all you or your computer system need is the path—from directory to subdirectory to folder to file.
- If you need to store very large or unstructured data volumes, you should consider block-based or object-based storage
- **Example**:Harddrive,google drive etc.

Data Storage

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- **Block Storage:**
- Block storage breaks a file into equally-sized chunks (or **blocks**) of data and stores each block separately under a unique address.
- Rather than conforming to a rigid directory/subdirectory/folder structure, blocks can be stored anywhere in the system.
- To access any file, the server's operating system uses the unique address to pull the blocks back together into the file, which **takes less time** than navigating through directories and file hierarchies to access a file.
- Example:Block Storage are SAN, iSCSI, and local disks.

Data Storage

- **Object Storage:**
- unstructured media and web content like email, videos, image files, web pages, and sensor data produced by the Internet of Things (IoT).
- object is a simple, self-contained repository that includes the data, metadata (descriptive information associated with an object), and a unique identifying ID number.
- This information enables an application **to locate** and **access the object.**
- **Example:** storing objects like **videos and photos on Facebook**, songs on Spotify, or files in online collaboration services, such as Dropbox

Characteristics of cloud computing

- Server is the most important element in cloud computing.
- It is the brain behind the entire processing environment.
- Server required high in quality.
- All the data for a user is available in one physical location allows its hardware and software to be organized more effectively by a respective on-location team, who are responsible for updating of the hardware and software.
- The more the numbers of servers, higher will be the power consumption. Usually servers are placed near power plants or hydroelectric power plants.

Characteristics of cloud computing

Following are the five characteristics of cloud computing.

1. On-demand self-service
2. Broad network access
3. Resource pooling,
4. Rapid elasticity
5. Measured service.
6. Muti-tenancy

Characteristics of cloud computing

1 On-demand self-service

- One of the important and usable features of Cloud computing .
- Services include storage, networking, analysis, etc.
- Users can select and use single or multiple services depending on their needs.
- Users become more accountable for their intake, which improves their ability to make wise decisions.
- Users can make use of resources following their needs and specifications.

Characteristics of cloud computing

2 **Broad network access**

- All computing resources offered by cloud server are available over the network and user can access them from anywhere and at any time with the help of their devices and internet connection

Characteristics of cloud computing

3 **Resource pooling,**

- To **serve** multiple customers,Service provider create a pool of various physical as well as virtual computing resources.
- This pool should be large and flexible enough to meet all the requirements of multiple clients.
- These resources can be assigned and reassigned on the customer demand.

Characteristics of cloud computing

4 Rapid elasticity(Scalability)

- One of the key features of Cloud computing.
- Computing services can be elastically provisioned or released
- This means that CC has the ability to assign resources when they are in need by the customers and remove them when they don't need them.
- Computing services should have IT resources that can be scaled out and in quickly on a need basis .
- The usage,capacity and cost can be scaled up or down with no additional contract or penalty.

Characteristics of cloud computing

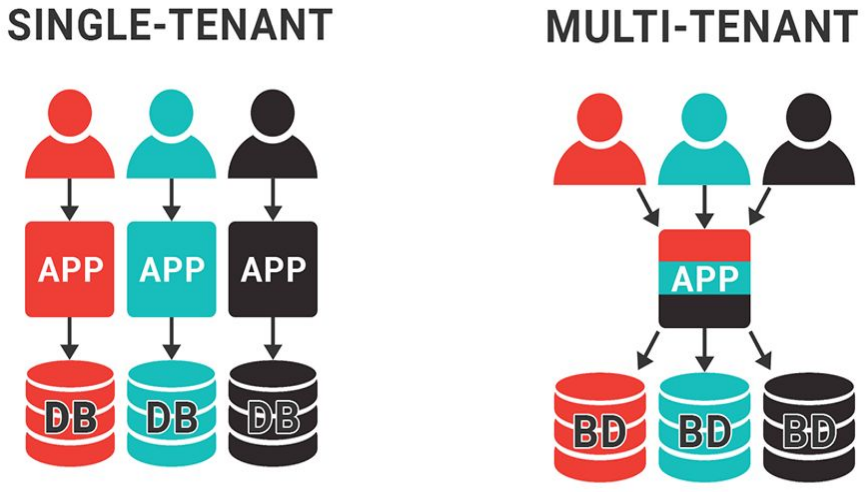
5 Measured service

- Cloud systems automatically manage and manage resource utilization by using a metering capability.
- The consumption of resources is tracked for each application.
- Monitoring, controlling , and reporting resource utilization allows for transparency for the service provider and the service user.
- Each user must be billed according to how much of the service they use, and the cloud provider must be able to measure this usage.
- This measurement is helpful for service providers in allocating resources to the customer in the best possible way.

Characteristics of cloud computing

6 Muti-tenancy

Multitenancy means that multiple customers of a cloud vendor are using the same computing resources



Characteristics of cloud computing

6 Muti-tenancy

- Cloud computing supports a multi tenant model,
- The multiple customers can share the same resource or application while maintaining privacy and security .
- With this,only one server instance can run among a large number of customers and updates can be deployed to them easily.

Pros and Cons of Cloud Computing

- Cloud computing can enable constant flow of information between service providers and the end users.
- Business and organizations are getting various benefits because of Cloud Computing.
- So, on the basis of user requirement we divide these pros and cons of Cloud Computing(advantages and Disadvantage of Cloud Computing)

Advantage(Pros) of Cloud Computing

According to a study by the International Data Group, 69% of businesses are already using cloud technology and 18% say they plan to implement cloud

Following are advantages of cloud computing.

1. Cost Savings
2. Security
3. Flexibility
4. Mobility
5. No hardware required
6. Boundless storage capacity
7. Automatic Software Integrations

Advantage(Pros) of Cloud Computing

1. **Cost Savings**:

- Initial cost required for implementing cloud based server
- Once you're on the cloud, easy access to data will save time and money in project startups.
- Most cloud-computing services are pay as you go.
- These factors result in lower costs and higher returns.

Advantage(Pros) of Cloud Computing

2. Security

- a cloud host's full-time job is to carefully monitor security, which is significantly more efficient than a conventional in-house system
- By using encryption, information is less accessible by hackers or anyone not authorised to view your data.
- different security settings can be set based on the user.

Advantage(Pros) of Cloud Computing

3. Flexibility

- The cloud offers businesses more flexibility than hosting on a local server.
- If you need extra bandwidth, a cloud-based service can meet that demand instantly, rather than undergoing a complex (and expensive) update to your IT infrastructure.
- This improved freedom and flexibility can make a significant difference to the overall efficiency of your organisation

Advantage(Pros) of Cloud Computing

4. Mobility

- Cloud computing allows mobile access to corporate data via smartphones and devices

5. No hardware required

- the cloud hosts everything, there is no requirement for a physical storage center

Advantage(Pros) of Cloud Computing

6. Boundless storage capacity

- No storage capacity is predefined, so you can increase or decrease storage capacity according to your needs at any time.

7. Automatic Software Integrations

- Cloud computing allows you to set automation of software updates and upgrades.
- So as soon as a newer version of any software is released, it will automatically integrate into the services you are using

Disadvantage(Cons) of Cloud Computing

- Following are the limitations of Cloud Computing

Disadvantage(Cons) of Cloud Computing

Internet Connectivity(Downtime)

- Cloud Computing needs internet connectivity as if there will be no internet connection you won't be able to access the cloud.

- Moreover, there is no other way to gather the data from the cloud.

Disadvantage(Cons) of Cloud Computing

Lower Bandwidth

- Lower bandwidth reduces the benefits of the clouds such that it cannot use properly.
- A satellite connection can lead to quality disruption, due to higher latency or higher bandwidth.

Disadvantage(Cons) of Cloud Computing

Affect of Speed

- If a client is using an internet which use by multiple users to download files such as music, documents, and many more.
- This will reduce the speed to use the Cloud.

Disadvantage(Cons) of Cloud Computing

Security Issues

- As Cloud Computing is very secure but still it requires an IT consulting firm's assistance and advice.
-
- Neglecting this can lead to the fact that the business will become vulnerable to the hackers and the threats.

Disadvantage(Cons) of Cloud Computing

Lacks of Support

- Cloud Computing companies sometimes fail to provide proper support to the customers.

- Moreover, they want customers to depend fully on FAQs, which can be a tedious job

Disadvantage(Cons) of Cloud Computing

Variation is Cost

- Cloud Computing is an economical option, but if you will consider the installation of the software it can be costly.

- Installation can lead to some costly feature which can be non-beneficial in the future

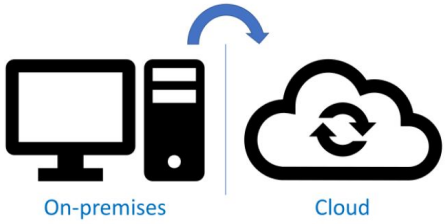
Disadvantage(Cons) of Cloud Computing

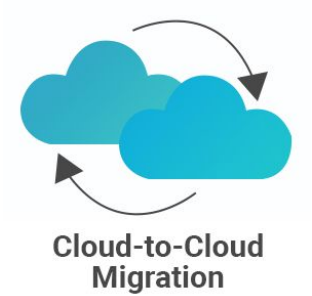
Technical Issues

- Cloud technology is known to experience outages and other technical issues.
- Despite high standards of maintenance, there are possibilities of technical issues.

Migrating into the Cloud computing

- Cloud migration is the process of moving digital business operations into the cloud.
- Cloud migration is sort of **like a physical move**, except it involves moving data, applications, and IT processes **from some data centers to other data centers**, instead of packing up and moving physical goods.





Migrating into the Cloud computing

- Cloud Migration is a transformation from old traditional business operations to digital business operations and the process refers to moving the digital business operations to cloud.
- Cloud migration is **the process of moving a company's digital assets, services, databases, IT resources, and applications either partially, or wholly, into the cloud**.
- As more and more companies have already converted to the cloud, migrations are increasingly taking place within the cloud, as companies migrate between different cloud providers (known as cloud-to-cloud migration).

Migrating into the Cloud computing

- **Benefits of cloud migration**
- **Issues of Cloud Migration**
- **Seven steps model**

Migrating into the Cloud computing

Benefits of cloud migration :

- **Scalability:** Scalable enough to support various workloads and users. So it offers to expand without impacting performance.
- **Performance:** Moving into cloud provides higher performance and customer satisfaction as compared to traditional business processes.
- **Productivity:** As it manages the complexity of infrastructure, so improved productivity is more focused with a continuous process of growing business.
- **Flexibility:** It allows to use the services flexibly as well as from anywhere and any time cloud services can be accessed as per demand/need.

Migrating into the Cloud computing

Benefits of cloud migration :

- **Cost:** Moving into cloud technology offers reduced cost in managing, operating, upgrading and maintaining IT operations or infrastructure.
- **Security:** Security is a major concern which is taken care by cloud service providers.
- **Profitability:** As it follows pay per use model so it delivers a greater profitability to the customers.
- **Recovery:** It provides backup and recovery solutions to businesses with less time and upfront investment.

Migrating into the Cloud computing

Cloud Computing Migration Issues:

- Security
- Vendor Management
- Technical Integration
- Long migration process
- Adaptability
- Training users on the new systems.

Migrating into the Cloud computing

- **Cloud Computing Migration Issues:**
- **Security:**
- As organizations move to the cloud, data security is major concerns.
- The external SAAS providers can also give satisfaction to the customers in security level,
- **example** the Banking sector excellent feature in Cloud security.

Migrating into the Cloud computing

- **Cloud Computing Migration Issues:**

Vendor Management

- Cloud providers offer numerous services, many of which have their counterparts in the offer of other vendors but aren't compatible with each other.
- As a result, moving the system to another cloud platform can be **time-consuming and earn high egress costs.**
- Since switching between vendors isn't exactly a piece of cake, it's good to have a solid cloud strategy in place.
- So if you assume that at some point you may need to move to another cloud provider,
- it's important to pick the services that won't impede this process.
- This task can be a challenge in itself, so you may want to **use some expert help** to minimise potential vendor lock-in issues.

Migrating into the Cloud computing

- **Cloud Computing Migration Issues:**
- **Technical Integration:**
- The technical issues are also complex.
- Now most firms that migrate to the cloud environment **in a hybrid model**, are keeping certain key elements of their infrastructure in-house and under their direct control, while outsourcing less control on components.
- **Integrating internal and external infrastructures can be a technical concern.**
- A VM template should incorporate infrastructure, application and security to fullfill the need of the user.

Migrating into the Cloud computing

- **Cloud Computing Migration Issues:**

Long migration process

- Cloud migrations are not a quick and easy process.
- Often, migrations are performed in multiple stages with in-depth testing and validation between each stage of the process.
- The speed and smoothness of the cloud migration process depend on the quality and detail of the cloud migration strategy

Migrating into the Cloud computing

Cloud Computing Migration Issues:

- **Adaptability:**

Adaptability in cloud migration refers to an organization's ability to co-op and become efficient with new systems and policies.

Seven step model of migration into cloud

- How to migrate one application into a cloud; what part or component of the IT application to migrate into a cloud and what not to migrate into a cloud; what kind of customers really benefit from migrating their IT into the cloud; and so on.

- the above questions answer give by this Seven-Step Model of Migration into the Cloud.

Seven step model of migration into cloud

FIGURE 2.5. The iterative Seven-step Model of Migration into the Cloud. (*Source:* Infosys Research.)

Seven step model of migration into cloud

1. ASSESSMENT

- Migration starts with an assessment of the issues relating to migration, at the application, code, design, and architecture levels.
- Moreover, assessments are also required for tools being used, functionality, test cases, and configuration of the application.
- The proof of concepts for migration and the corresponding pricing details will help to assess these issues properly

Seven step model of migration into cloud

2. ISOLATE

- The second step is the isolation of all the environmental and systemic dependencies of the enterprise application within the captive data center.
- These include library, application, and architectural dependencies.
- This step results in a better understanding of the complexity of the migration.

Seven step model of migration into cloud

3. MAP

- A mapping construct is generated to separate the components that **should reside in the captive data center** from the ones that will go into the cloud.

Seven step model of migration into cloud

4. RE-ARCHITECT(Rebuild)

- It is likely that a substantial part of the application has to be re-architected and implemented in the cloud.
- This can affect the functionalities of the application and some of these might be lost.
- It is possible to approximate lost functionality using cloud runtime support API.

Seven step model of migration into cloud

5. AUGMENT

- The Internal features of the cloud computing service to Augment our enterprise application in its own small ways.

6. TEST

- Once the augmentation is done, the application needs to be validated and tested.
- This is to be done using a test suite for the applications on the cloud.
- New test cases due to augmentation and proof-of-concepts are also tested at this stage.

Seven step model of migration into

7. OPTIMISE

- The test results from the last step can be mixed and so require iteration and optimization.
- It may take several optimizing iterations for the migration to be successful.
- It is best to iterate through this seven step model as this will ensure the migration to be robust and comprehensive.

Cloud System Architecture

- Cloud architectures can be viewed as a collection of different functionalities and capabilities.
- A cloud computing system has various IT resources deployed in remote places designed to run applications dynamically.
- DIfferent Ways of Cloud Computing Architecture:

  1.Basic Architecture

  2.Logical Architecture

  3.Holistic Cloud Computing Reference Model

Cloud System Architecture

- Cloud architecture basically describes the **communication between** the client and server via network, which is mostly the internet.
- We can divide cloud architecture into two parts:

  1.Frontend

  2.Backend

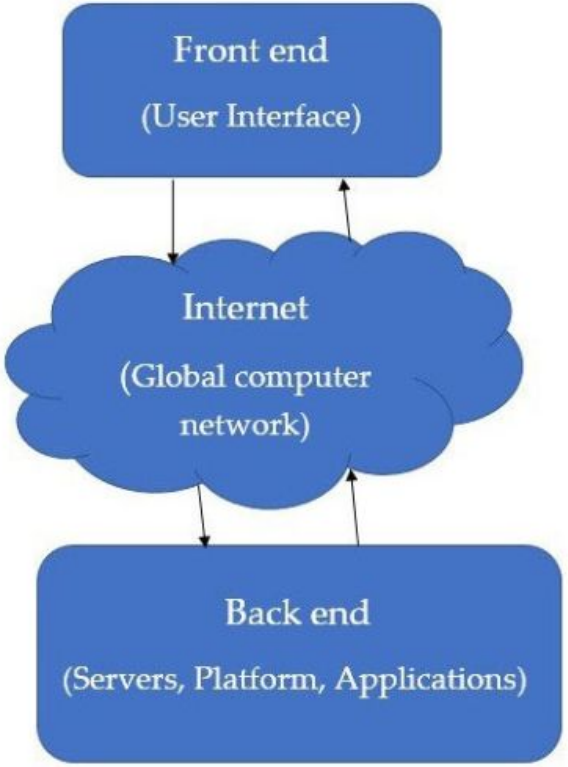


Figure 2.1: *Basic overview of cloud architecture*

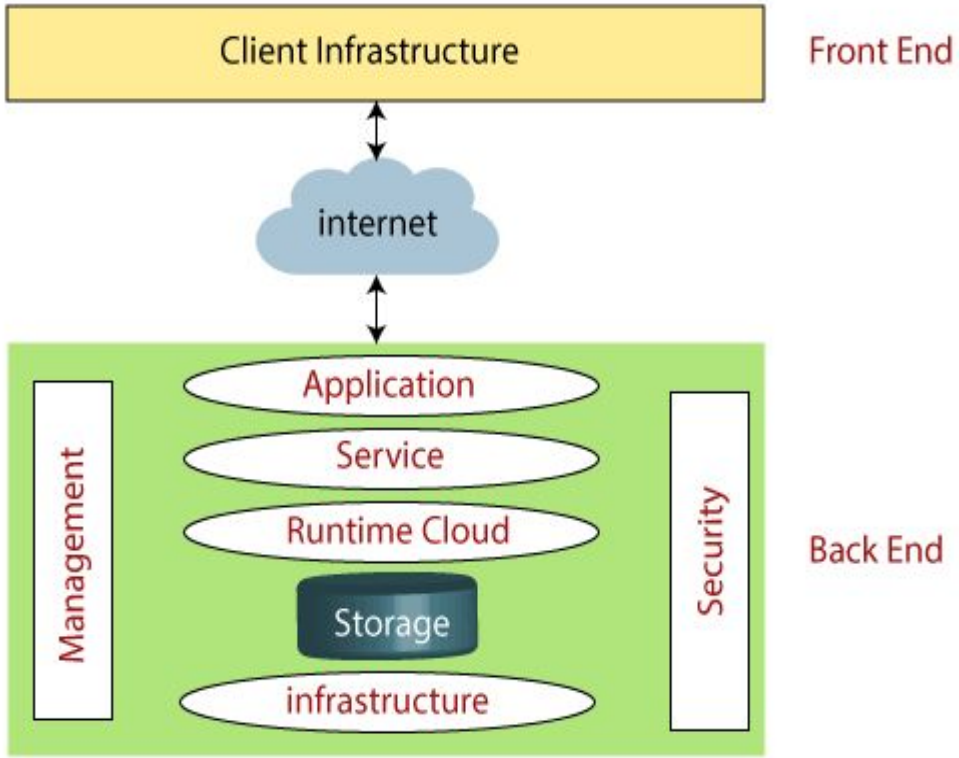
Cloud System Architecture

- **Front end:** It is that part of a cloud system which is visible to the user or client.
- All that which a user can see, whether it is on a computer, laptop, web browser, or apps come under the front end.
- It consists of the user or client's computer or computer network, interfaces, and applications that are required to access the cloud platform.
- Users can access all networked services through the front end which can be any web-enabled interface.
- **Let us consider an example.** If you want to access email, open the web browser and go to your Gmail account. Whatever you see on the screen, i.e. the interfaces or applications are termed as the front end.

Cloud System Architecture

- **Backend:** Back end refers to the cloud itself. By the term "cloud," we mean the data center ,where the cloud server provider stores and manages the data.
- It is managed by the **host** or **cloud service provider.**
- It comprises of huge data storage, virtual machines, security mechanisms, deployment models, service models, and servers.
- It is also responsible for managing traffic and protecting data.
- Various processes run inside the backend to ensure the smooth functioning of the cloud system.
- It also provides protocols to connect networked computer for
- communication.

Cloud System Architecture



Cloud System Architecture

Components of Cloud Computing Architecture

There are the following components of cloud computing architecture -

1. Client Infrastructure

Client Infrastructure is a Front end component. It provides GUI (Graphical User Interface) to interact with the cloud.

2. Application

The application may be any software or platform that a client wants to access.

3. Service

A Cloud Services manages that which type of service you access according to the client's requirement.

Cloud computing offers the following three type of services:SaaS,IaaS,PaaS

Components of Cloud Computing Architecture

There are the following components of cloud computing architecture -

4. Runtime Cloud

Runtime Cloud provides the **execution and runtime environment** to the virtual machines.

5. Storage

Storage is one of the most important components of cloud computing. It provides a huge amount of storage capacity in the cloud to store and manage data.

6. Infrastructure

It provides services on the **host level**, **application level**, and **network level**. Cloud infrastructure includes hardware and software components such as servers, storage, network devices, virtualization software, and other storage resources that are needed to support the cloud computing model.

Components of Cloud Computing Architecture

There are the following components of cloud computing architecture -

7. Management

Management is used to **manage components** such as application, service, runtime cloud, storage, infrastructure, and other security issues in the backend and establish coordination between them.

8. Security

Security is an in-built back end component of cloud computing. It implements a security mechanism in the back end.

9. Internet

The Internet is medium through which front end and back end can interact and communicate with each other.

Components of Cloud Computing Architecture

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Cloud Computing Logical Architecture

- A logical architecture is a structure of technology concepts that **does not name specific technologies or brands,** while a physical architecture does contain specific technologies and brands.

- The primary benefit to this approach is that **it allows the architect to think more objectively about an overall technical solution.**

- **For Example** :picking public clouds before they know and understand the problem.

Cloud Computing Logical Architecture

- If you do logical architecture planning before committing to a specific technology, you'll make better decisions.

- A logical architecture **contains** a list, configuration, and interrelationships with technology as concepts.

- Once you have a logical architecture with conceptual solutions to specific problems, then and only then do you move to the physical architecture.

Cloud Computing Logical Architecture

- Cloud computing logical architecture refers to the way different components and services are logically arranged and interconnected to provide cloud computing capabilities.
- Logical architecture of cloud computing comprises the following components:
- Clients:
- Applications:
- Services:
- Infrastructure:
- Management and Orchestration:
- APIs:

Cloud Computing Logical Architecture

Clients: These are the end-users or devices that connect to the cloud service provider to access cloud resources and services.

Applications: These are the software programs that run on the cloud infrastructure and provide various services to clients.

Services: Cloud computing services can be broadly categorized into Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS). Each service category provides different levels of abstraction and functionality.

Infrastructure: This includes the underlying physical and virtual resources such as servers, storage, networking equipment, and data centers that provide the necessary computing power and storage for cloud computing services.

Cloud Computing Logical Architecture

- **Management and Orchestration:** This layer comprises tools and systems used to manage and orchestrate cloud computing resources and services. It includes components such as workload management, monitoring, security, and governance.
- Orchestration is the automated configuration, management, and coordination of computer systems, applications, and services
- **APIs:** Application Programming Interfaces (APIs) provide a standardized interface **to access cloud computing services and resources**.
- APIs enable clients and applications to interact with cloud services and automate various tasks.
- The above components provide a general framework for understanding the logical architecture of cloud computing.

Holistic Cloud Computing Reference Model

- A reference architecture (RA) provides the blueprint and/or architecture reused by others with some changes.
- A reference model (RM) explains what the reference architecture comprises and its various relationships.
- RA and RM help cloud computing in terms of quick formation of framework.
- The detailed and generalized version of reference framework is shown in Figure 5.4.

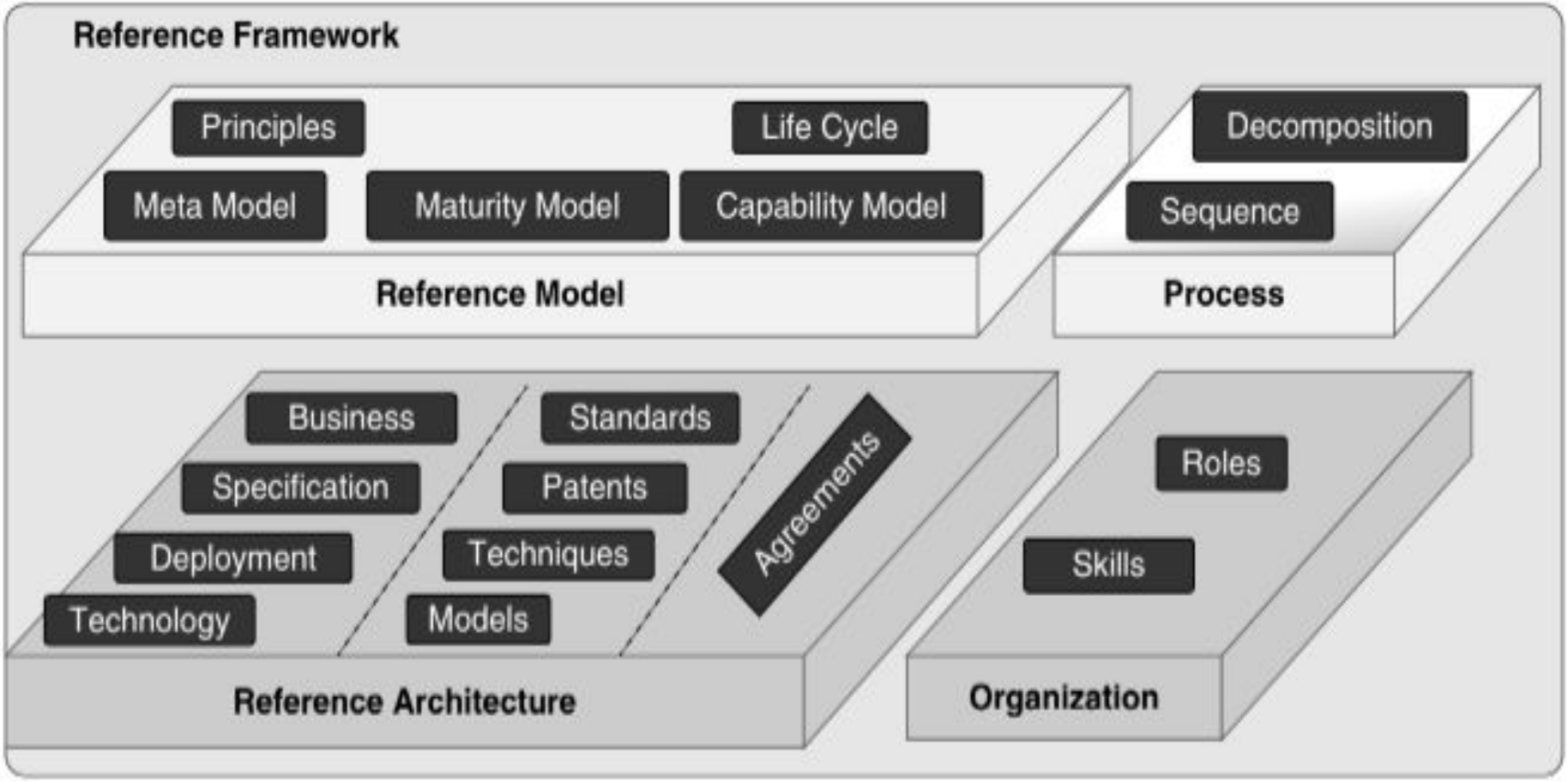


Figure 5.4 Generalized Reference Framework

Holistic Cloud Computing Reference Model

- The Cloud Reference Model is a framework used by customers and vendors to define best practices for cloud computing.
- Reference models are of two types—**role based and layer based**.
- **In role-based model,** cloud provider and consumer are considered as roles.
- **Examples** are DMTF, IBM and NIST cloud models.
- **In layer-based model,**application and resources are considered and layers and their capabilities are mapped.
- In both types, they contain roles, activities and layered architecture.

Holistic Cloud Computing Reference Model

- An holistic approach considers the **importance of the whole organisation** rather than performing a separate analysis of isolated units

- The holistic view **to develop a framework that covers multiple perspectives;** such as: Human, Business, Organisational and Environmental factors.

Holistic Cloud Computing Reference Model

- The Holistic Cloud Computing Reference Model is a conceptual framework that provides a **high-level view** of the key components, functions, and interactions involved in cloud computing.
-
- It is designed to help organizations understand and evaluate cloud computing services and solutions, and **to develop a comprehensive**(including everything) **strategy** for adopting and implementing cloud computing technologies.

Holistic Cloud Computing Reference Model

- **The Holistic Cloud Computing Reference Model consists of four main layers:**

1. **Business layer:** This layer includes the business processes, goals, and objectives of the organization, as well as the requirements and expectations for cloud computing services.
   The business layer provides the context for the other layers and helps to ensure that cloud computing initiatives align with the organization's overall strategy.

1. **Service layer:** This layer includes the various cloud computing services that are available, such as Iaas,PaaS,SaaS.

Holistic Cloud Computing Reference Model

- **The Holistic Cloud Computing Reference Model consists of four main layer**

3. Infrastructure layer: This layer includes the underlying physical and virtual infrastructure that supports cloud computing, such as servers, storage, networking, andsecurity.
The infrastructure layer is responsible for providing the resources and capabilities required to support the cloud computing services provided by the service layer.

4. Management layer: This layer includes the tools, processes, and policies used to manage and operate the cloud computing environment.

** The management layer is responsible for ensuring the reliability, availability, and security of the cloud computing services, as well as providing the necessary monitoring, reporting, and optimization capabilities.

Trends in cloud Computing.

- Cloud Computing has become an **essential tool** for business, a helpful way to store and share data.
- It is used by every corporation that wants business continuity, cost reduction, and enhanced future scalability.
- The following are some of the biggest cloud computing trends
- Edge Computing
- AI and ML
- Multi and Hybrid Cloud Solution
- Cloud Gaming
- Cloud Security and Resilience
- Serverless Computing
- Kubernetes
- Blockchain
- IOT

Trends in cloud Computing.

- Activity **Based**
- Student Added Recent Trend in shared Spreadsheet
- Link:

  https://docs.google.com/spreadsheets/d/1hhB3422uNSV8gPGvm2d7QSLsjL54XQCAwWMjuNgojr0/edit?usp=sharing

Trends in cloud Computing.

- The following are some of the biggest cloud computing trends

1. Edge Computing:

- In edge computing, data is stored, processed, and analyzed geographically closer to its source
- Edge computing applications that process and analyze data at the network's edge are expanding as a result of the increasing use of 5G.
- Edge computing also allows companies to streamline operations, automate procedures, boost performance, and, most importantly, accelerate their digital transformation.
- Most cloud platforms will feature a sizable number of distributed cloud services that operate at the edge,

Trends in cloud Computing.

- The following are some of the biggest cloud computing trends

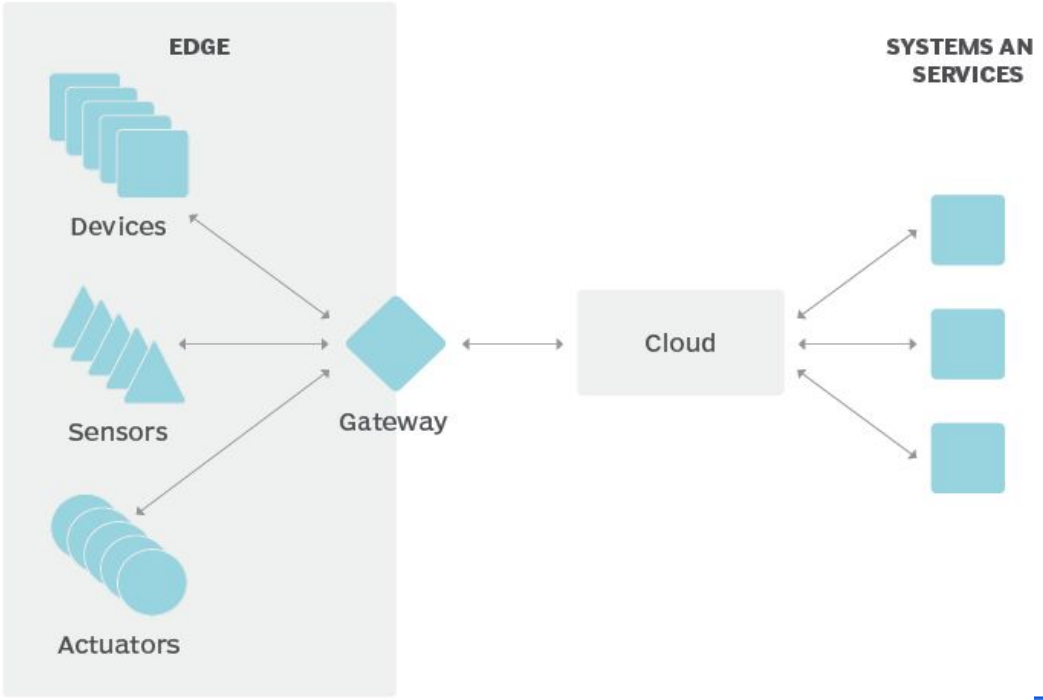
1. Edge Computing:

- Cloud computing is the act of running workloads within clouds, while edge computing is the act of running workloads on edge devices.
- An **edge device** is any piece of hardware that controls data flow at the boundary between **two networks.**

Trends in cloud Computing.

- The following are some of the biggest cloud computing trends

1. Edge Computing:



Trends in cloud Computing.

- The following are some of the biggest cloud computing trends

2. AI and ML

- Artificial Intelligence and Machine Learning are two technologies that are closely related to cloud computing.
- They are a solution for **managing massive volumes of data** to improve tech company productivity.
- The key trends that are likely to emerge in this area include **increased automation and self-learning capabilities,** greater data security and privacy, and more personalized cloud experiences.

Trends in cloud Computing.

- The following are some of the biggest cloud computing trends

3. Multi and Hybrid Cloud Solution

- A lot of enterprises have adopted **multi-cloud and Hybrid IT strategy which combines on-premise,** dedicated private clouds, several public clouds, and legacy platforms.
- The reason is that businesses now understand that data management involves combining a variety of appropriate cloud deployment strategies **rather than relying solely on one cloud platform or architecture.**
- They offer a combination of **public and private clouds dedicated to a specific company** whose data is key business driver, such as insurance, banks, etc.
- multi and hybrid cloud solutions will be among the **top cloud computing trends** in the coming years.

Trends in cloud Computing.

- The following are some of the biggest cloud computing trends

4. Cloud Gaming

- Video gaming services are provided by Microsoft, Sony, Nvidia, and Amazon.
- **But streaming video games require higher bandwidth** and can be possible only with high-speed internet access.
- Cloud gaming will become a significant industry in 2023 with the introduction of 5G.

Trends in cloud Computing.

- The following are some of the biggest cloud computing trends

5. Cloud Security and Resilience(Adapt well to change)

- Organizations and companies face a new range of **cyber security threats** when they migrate to the cloud.
- **Cloud migration offers many benefits**, efficiencies, and conveniences but presents several security risks.
- investing in cyber security and building resilience against everything from data loss on global business will become a priority during the coming year.
- "**security-as-a-service**" providers and AI and predictive technology to detect risks before they cause issues.

Trends in cloud Computing.

- The following are some of the biggest cloud computing trends

6. Serverless Computing:

- Serverless computing allows developers to run code without worrying about infrastructure management.
- This trend is gaining popularity because it reduces the cost and complexity of running applications in the cloud.

Trends in cloud Computing.

- The following are some of the biggest cloud computing trends

7. BlockChain:

- Blockchain is a linked list of blocks containing records and keeps growing as users add to it.
- The blockchain provides a r**obust and permanent audit trail of every transaction** in the proper order
- It can process vast amounts of data and exercise control over documents economically and securely.

Trends in cloud Computing.

- The following are some of the biggest cloud computing trends

8. IOT

- It is a technology that maintains connections between computers, servers, and networks.
- IoT functions as a **mediator,** ensuring successful communication and **assisting in data collection** from remote devices for efficient operations.

Trends in cloud Computing.

he following are some of the biggest cloud computing trends

. Kubernetes

ubernetes, also known as K8s, is an open-source system for automating deployment, caling, and management of containerized applications.

ubernetes are rapidly evolving and will continue to be major players in cloud omputing trends over the next few years.

Case Study 1: Cloud Computing Model of IBM

- Figure 5.5 shows the architecture of cloud computing reference model. It provides a technique to understand the multiple offerings and demonstrates the company's experience in addressing such a complex subject, and it is important. IBM has very reputed customers like HP and Fujitsu; infact, private cloud was built by IBM for their customers.
-

Case Study 1: Cloud Computing Model of IBM

- Four types of cloud services available in IBM cloud architecture are as follows:
- 1. IaaS: This was the earliest offering from system vendors like Google, Amazon and other public cloud suppliers. The introduction of a standard architecture should encourage users to benefit by off-loading peak workloads to their providers for many years.
- 2. PaaS: In IBM's model, focus is more on supplying tools for consumers to build, deploy,manage and integrate applications in a public or virtual private cloud with the support of processing, storage and networking.

Case Study 1: Cloud Computing Model of IBM

- 3. SaaS: Apart from LotusLive contributions IBM has a number of middleware, which is
- available ‘as a service’, for example, Tivoli Live (SaaS monitoring) and Blueworks Live
- (BPM). Additionally, it has number of Smarter Commerce SaaS offerings, which includes
- Sterling Commerce, Unica, Coremetrics and SPSS. Success in these services makes IBM the most important software broker, while its partners address the mid-market and SMB region.
- 4. Business process as a service (BPaaS): This approach is unique to IBM. IBM incorporates all its technical and business services contributions here.

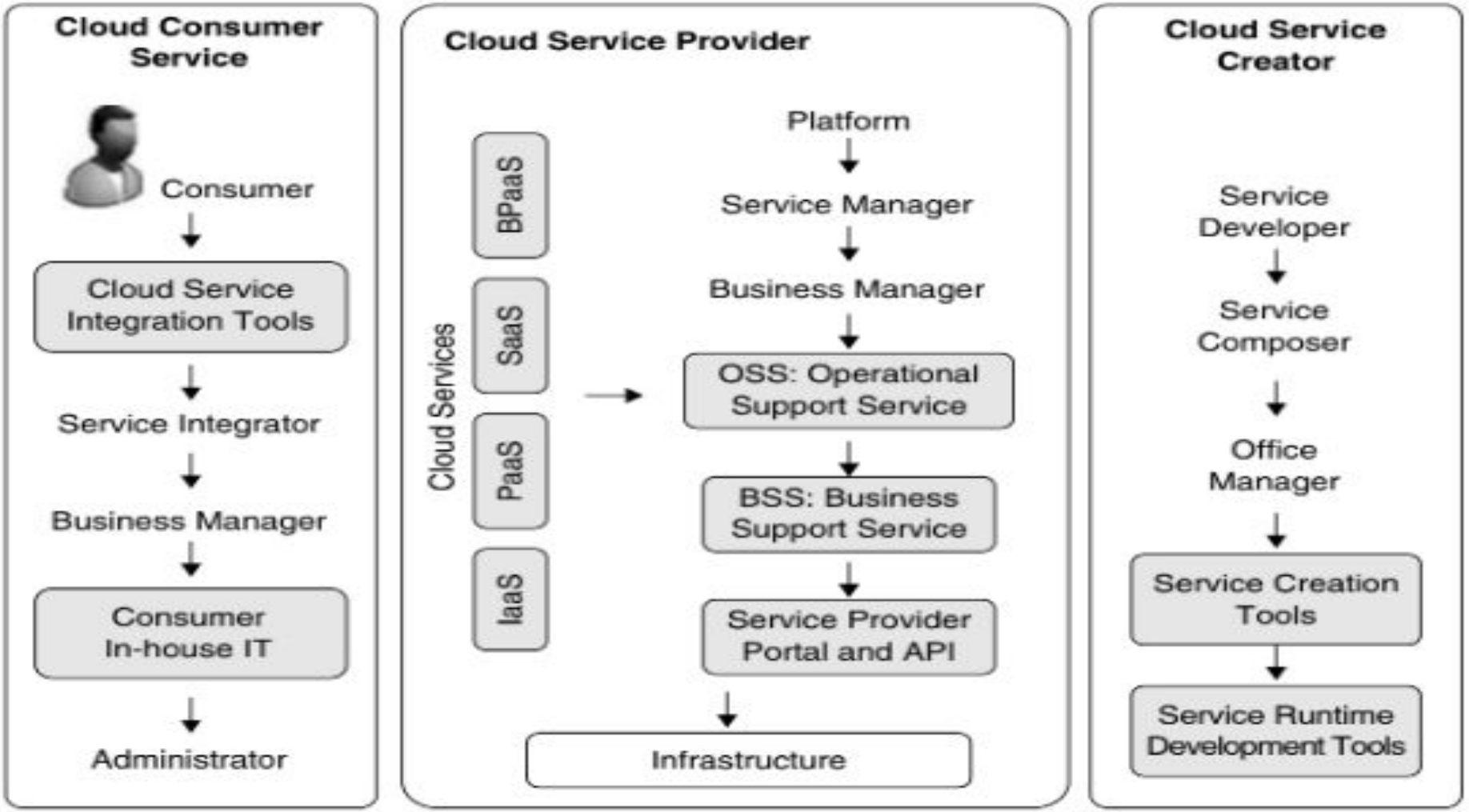


Figure 5.5 Cloud Computing Model of IBM

Reference

Basic:https://www.cloudflare.com/learning/cloud/what-is-the-cloud/

Basic:https://www.spiceworks.com/tech/cloud/articles/what-is-cloud-computing/

migration:https://bluexp.netapp.com/blog/cloud-migration-strategy-challenges-and-steps

Video https://youtu.be/_a6us8kaq0g

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Thank you

Cloud System Architecture

Architecture of cloud computing is **the combination of both**

- **SOA (Service Oriented Architecture) and**
- **EDA (Event Driven Architecture)**

- **SOA (Service Oriented Architecture) :**Service-Oriented Architecture (SOA) is an architectural pattern that provides the ability for businesses to use software resources more effectively.
- SOA is a software architecture based on the concept of a service, so its main focus is to support service orientation

Cloud System Architecture

- **EDA (Event Driven Architecture)**
- Event-Driven Architecture is a software development approach in which services (operations) of the software are triggered by events.

- And that is why this approach is known as Event-Driven Architecture.
- An e*vent* represents a change in state, or an update.

- **For example:** an item placed in a shopping cart, a file uploaded to a storage system, or an order becoming ready to ship.

- Events can either carry the state (such as the item name, price, or quantity in an order) or simply contain *identifiers* (for example, “order #8942 was shipped”) needed to look up related information.