Vision

To groom Motivated, Environment friendly, Self-esteemed, Creative and Oriented Engineers.

Mission

To Develop Industry Oriented Manpower to accept the challenges of Globalization by-

- Promoting Value Education through motivated trained faculty.
- Maintaining conducive environment for education at affordable cost.
- Promoting Industry Institute interaction.
- Involving alumni.

Goals and Objectives

1. To ensure all-round development of students by providing co-curricular, extra-curricular and entrepreneurship skills.
2. To imbibe research culture by encouraging students and faculty, by providing state-of-the-art research facilities and industry Institute interaction.
3. To inculcate moral integrity in students and make them socially responsible, good human beings.
4. To develop leadership qualities and the ability to work as a team among students by encouraging participation in various activities.

Modern Education Society's Wadia College of Engineering, Pune

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CLOUD COMPUTING
ELECTIVE – II
310254(C)
DR. (MISS) REVATI M WAHUL

Savitribai Phule Pune University

Third Year of Computer Engineering (2019 Course)

Elective II

310254(C): Cloud Computing

Teaching Scheme:	Credit: 03	Examination Scheme:
Theory: 04 Hours/Week		Mid-Semester (TH) : 30 Marks End-Sem (TH): 70 Marks

Prerequisites Courses: Computer Networks and Security(310244), Distributed Systems (310245C)

Companion Course: Laboratory Practice II (310258)

Course Objectives:

- To study fundamental concepts of cloud computing
- To learn various data storage methods on cloud
- To understand the implementation of Virtualization in Cloud Computing
- To learn the application and security on cloud computing
- To study risk management in cloud computing
- To understand the advanced technologies in cloud computing

Course Outcomes:

On completion of the course, learners should be able to

CO1: Understand the different Cloud Computing environment

CO2: Use appropriate data storage technique on Cloud, based on Cloud application

CO3: Analyze virtualization technology and install virtualization software

CO4: Develop and deploy applications on Cloud

CO5: Apply security in cloud applications

CO6: Use advance techniques in Cloud Computing

Course Contents		
Unit I	**Introduction to Cloud Computing**	**07 Hours**
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.		
#Exemplar/Case Studies	Cloud Computing Model of IBM	
***Mapping of Course Outcomes for Unit I**	CO1	

Unit II	Data Storage and Cloud Computing	07 Hours
Data Storage: Introduction to Enterprise Data Storage, Direct Attached Storage, Storage Area Network, Network Attached Storage, Data Storage Management, File System, Cloud Data Stores, Using Grids for Data Storage. **Cloud Storage**: Data Management, Provisioning Cloud storage, Data Intensive Technologies for Cloud Computing. **Cloud Storage from LANs to WANs**: Cloud Characteristics, Distributed Data Storage.		
#Exemplar/Case Studies	Online Book Marketing Service, Online Photo Editing Service	
*Mapping of Course Outcomes for Unit II	CO2	

Unit III	Virtualization in Cloud Computing	07 Hours
Introduction: Definition of Virtualization, Adopting Virtualization, Types of Virtualization, Virtualization Architecture and Software, Virtual Clustering, Virtualization Application, Pitfalls of Virtualization. **Grid, Cloud and Virtualization**: Virtualization in Grid, Virtualization in Cloud, Virtualization and Cloud Security. **Virtualization and Cloud Computing**: Anatomy of Cloud Infrastructure, Virtual infrastructures, CPU Virtualization, Network and Storage Virtualization.		
#Exemplar/Case Studies	Xen: Para virtualization, VMware: Full Virtualization, Microsoft Hyper-V	
***Mapping of Course Outcomes for Unit III**	CO3	

Unit IV	Cloud Platforms and Cloud Applications	07 Hours
Amazon Web Services (AWS): Amazon Web Services and Components, Amazon Simple DB, Elastic Cloud Computing (EC2), Amazon Storage System, Amazon Database services (Dynamo DB).**Microsoft Cloud Services:** Azure core concepts, SQL Azure, Windows Azure Platform Appliance. **Cloud Computing Applications:** Healthcare: ECG Analysis in the Cloud, Biology: Protein Structure Prediction, Geosciences: Satellite Image Processing, Business and Consumer Applications: CRM and ERP, Social Networking, Google Cloud Application: Google App Engine. Overview of OpenStack architecture.		
#Exemplar/Case Studies	Multiplayer Online Gaming	
***Mapping of Course Outcomes for Unit IV**	CO4	

Unit V	Security in Cloud Computing	07 Hours
Risks in Cloud Computing: Risk Management, Enterprise-Wide Risk Management, Types of Risks in Cloud Computing. **Data Security in Cloud**: Security Issues, Challenges, advantages, Disadvantages, Cloud Digital persona and Data security, Content Level Security. **Cloud Security Services**: Confidentiality, Integrity and Availability, Security Authorization Challenges in the Cloud, Secure Cloud Software Requirements, Secure Cloud Software Testing.		
#Exemplar/Case Studies	Cloud Security Tool: Acunetix.	
*Mapping of Course Outcomes for Unit V	CO5	

Unit VI	Advanced Techniques in Cloud Computing	07 Hours
Future Tends in cloud Computing, Mobile Cloud, **Automatic Cloud Computing**: Comet Cloud. **Multimedia Cloud**: IPTV, Energy Aware Cloud Computing, Jungle Computing, Distributed Cloud Computing Vs Edge Computing, Containers, Docker, and Kubernetes, Introduction to DevOps. **IOT and Cloud Convergence**: The Cloud and IoT in your Home, The IOT and cloud in your Automobile, PERSONAL: IoT in Healthcare.		
#Exemplar/Case Studies	Case studies on Dev Ops: DocuSign, Forter, Gengo.	
*Mapping of Course Outcomes for Unit VI	CO6	

Learning Resources

Text Books :

1. A. Srinivasan, J. Suresh, "Cloud Computing: A Practical Approach for Learning and Implementation", Pearson, ISBN: 978-81-317-7651-3
2. Rajkumar Buyya, Christian Vecchiola, S. Thamarai Selvi, "Mastering Cloud Computing", McGraw Hill Education, ISBN-13:978-1-25-902995-0

Reference Books :

1. James Bond ,"The Enterprise Cloud", O'Reilly Media, Inc. ISBN: 9781491907627
2. Dr. Kris Jamsa, "Cloud Computing: SaaS, PaaS, IaaS, Virtualization and more", Wiley Publications, ISBN: 978-0-470-97389-9
3. Anthony T. Velte Toby J. Velte, Robert Elsenpeter, "Cloud Computing: A Practical Approach", 2010, The McGraw-Hill.
4. Gautam Shrof, "ENTERPRISE CLOUD COMPUTING Technology Architecture, Applications", Cambridge University Press, ISBN: 9780511778476
5. Tim Mather, Subra K, Shahid L.,"Cloud Security and Privacy", Oreilly, ISBN-13 978-81-8404-815-5
6. Dr. Kumar Saurabh, "Cloud Computing, 4ed: Architecting Next-Gen Transformation Paradigms", Wiley publication, ISBN: 9788126570966
7. Rishabh Sharma, "Cloud Computing: Fundamentals, Industry Approach and Trends", Wiley publication, ISBN:

UNIT I

INTRODUCTION TO CLOUD COMPUTING

POINTS TO COVER PART I

- 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

Reading Material :
Srinivasan, J. Suresh, "Cloud Computing: A Practical Approach for Learning and Implementation",
Chap 2 pg 15 - 34

Reading Material :
Srinivasan, J. Suresh, "Cloud Computing: A Practical Approach for Learning and Implementation",
Chap 4 pg 46- 48

POINTS TO COVER
PART II CLOUD SERVICE MODELS

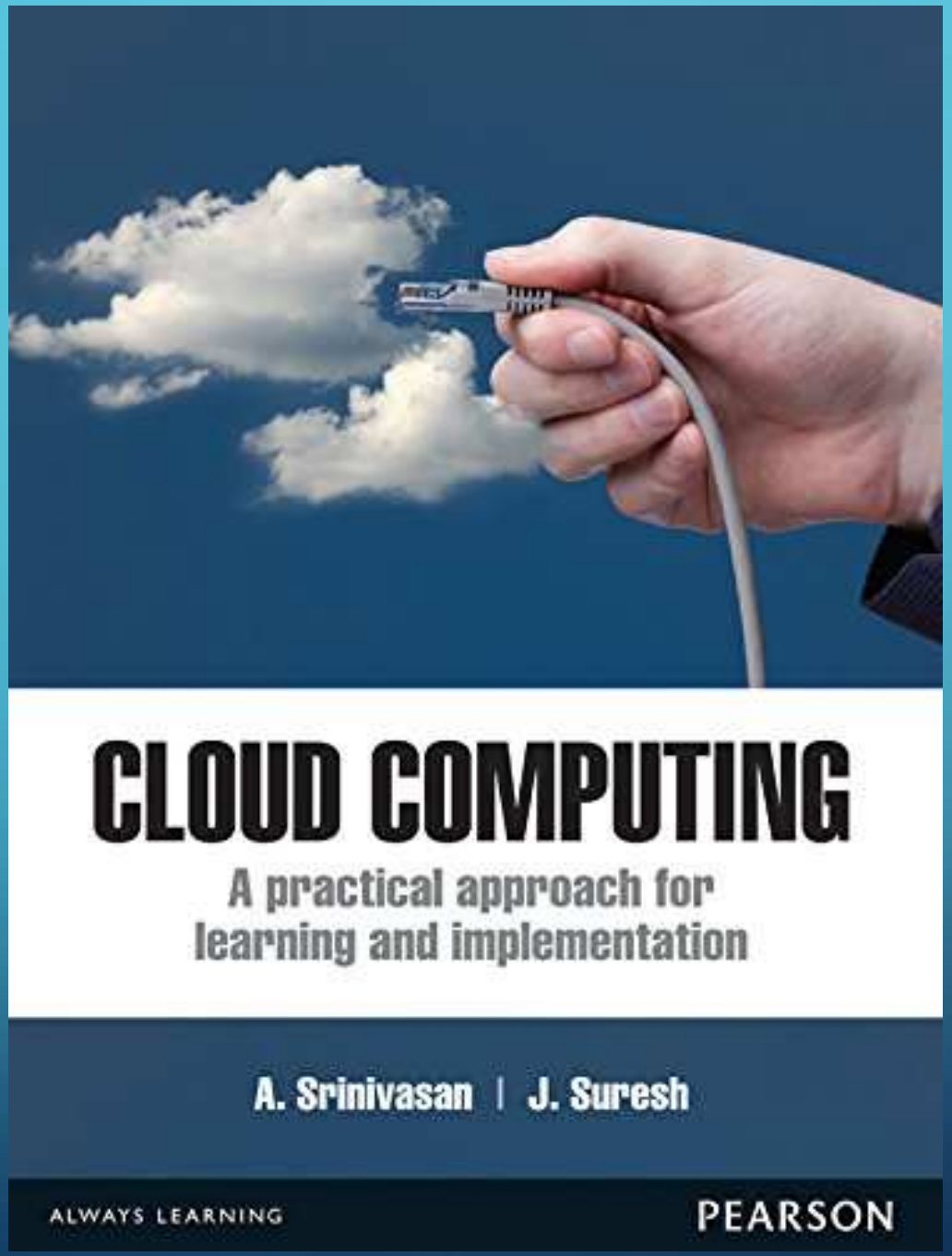
- SaaS
- PaaS
- IaaS
- Storage

Reading Material :
Srinivasan, J. Suresh, "Cloud Computing: A Practical Approach for Learning and Implementation",
Chap 4 , pg 48 - 52

POINTS TO COVER
PART III CLOUD ARCHITECTURE

- Cloud Computing Logical Architecture
- Developing Holistic Cloud Computing Reference Model
- Cloud System Architecture
- Cloud Deployment Models

Reading Material :
Srinivasan, J. Suresh, "Cloud Computing: A Practical Approach for Learning and Implementation",
Chap 6 pg 71-83


CLOUD COMPUTING
A practical approach for learning and implementation
A. Srinivasan | J. Suresh
ALWAYS LEARNING
PEARSON

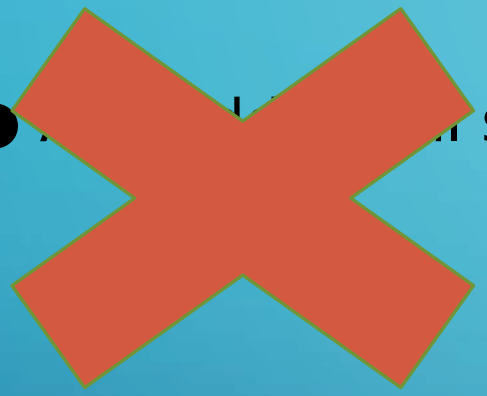
IMPORTANCE OF CLOUD COMPUTING

Reason for Server Crashes/Failures (As of 2014)

- only 25% of the world population has Internet access.
- Compared to Television and other mass media, it is still adjudged as the best medium of communication.
- At present, India and China have roughly 15% or less Internet penetration.
- Even a reasonable increase in Internet access and usage, say 50%, will add more than a billion Internet users

SOLUTION TO PREVENT SERVER CRASHES/FAILURES

- [redacted] servers to balance the load.



??????????

- How often service (server) is going to crash?
  - The majorities of the traffic spikes are predictable and can be easily planned. Even if the traffic is expected, but there is no enough time to respond and plan to handle the crisis.

SCENARIO

- An organization will face heavy traffic on some particular day or days.
- Thus, number of servers to face that kind of traffic needs to be enhanced, may be 1,000 times more than what they have in normal days.
- Purchase extra servers and use it as standby to be used only on those heavy traffic days.
- Waste of valuable resources
- No one can predict when the business will speed up
- The reverse can also happen; a recession can hit and the infrastructure may have to be reduced significantly.
- Example ?
- Pandemic hit in 2020

WHAT TO DO?

- The competition and economics have led to a scenario where a business needs the following, when it comes to computing as a whole.

1. **Dynamism**: your infrastructure should support your changing needs
2. **Abstraction** : The business/consumer should focus his attention more on its core competency rather than distressing himself over secondary resources such as the OS or the software.
3. **Resource Sharing** : The whole architecture should be implemented such that it provides you the flexible environment where it is possible to share applications as well as other network resources, i.e. need-based elastic architecture, where the resources will grow without any major configuration modifications.

THE SOLUTION

- One model satisfies 3 business requirements :

CLOUD COMPUTING

- Is it new?
- I am using Yahoo since early 2000s…….
- Cloud based SaaS (Yahoo, Hotmail, Gmail……..)
- **C**ommon
- **L**ocation-independent
- **O**nline
- **U**tility which is available on
- **D**emand

CLOUD

BASIC COMPONENTS OF CLOUD COMPUTING

1. **World wide connectivity**: users should have near-ubiquitous access to the Internet.

2. **Open access**: Users should have fair, open-minded access to the Internet.

3. **Reliability**: The cloud’s performance should equal to or better than recent standalone systems.

4. **Interoperability and user choice**: Users must be able to progress among different clouds.

5. **Security**: It should ensure that data of users are safe.

BASIC COMPONENTS OF CLOUD COMPUTING

6. **Privacy**: Users’ rights must be clearly defined and allow access based on rights.
7. **Economic value**: The cloud must provide substantial savings and benefits.
8. **Sustainability**: The cloud must increase power effectiveness and reduce environmental impact.

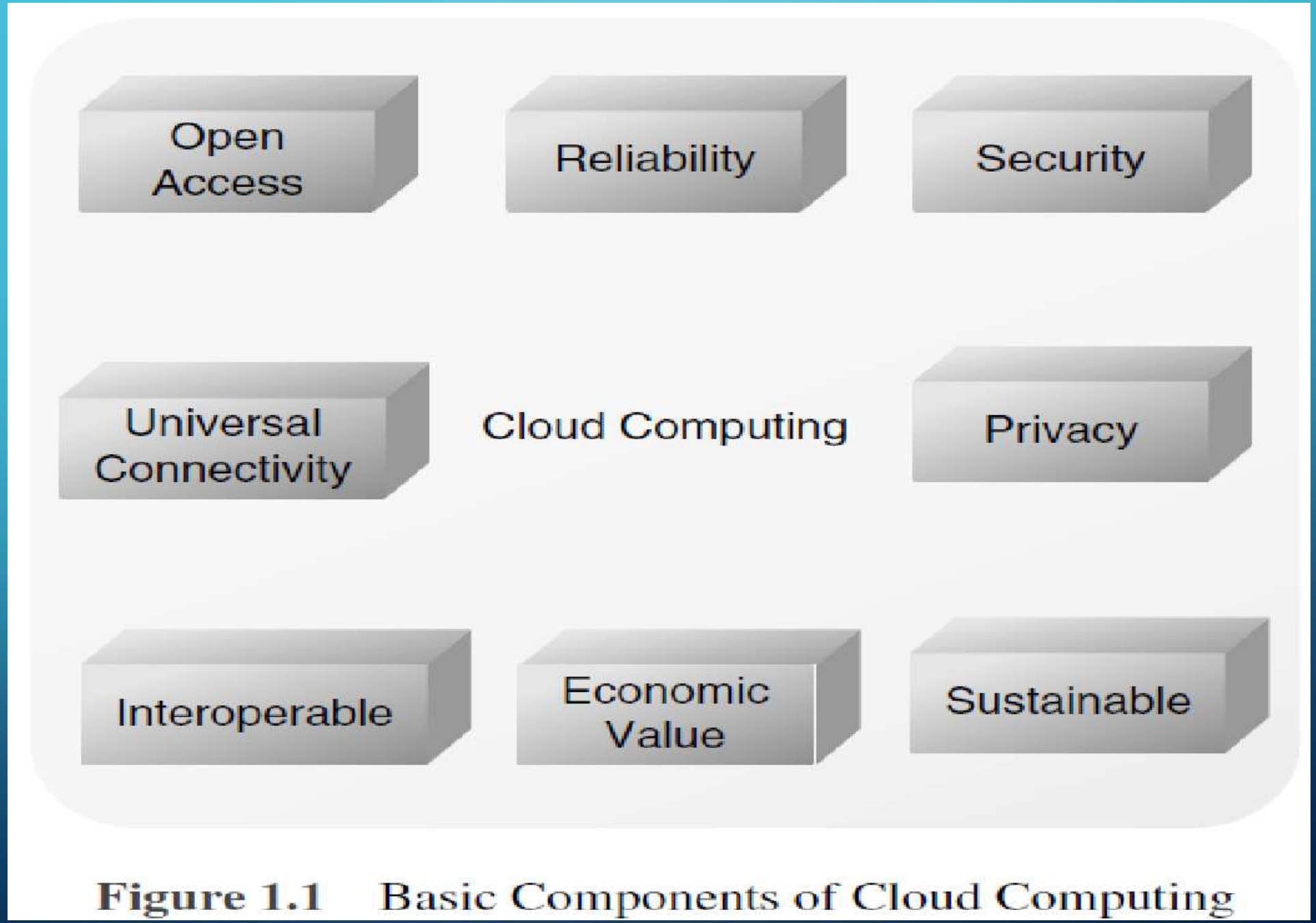


Figure 1.1 Basic Components of Cloud Computing

What is cloud computing?

Buyya's Scientific definition of Cloud Computing

- "Cloud is a **market-oriented** distributed computing system consisting of a collection of inter-connected and **virtualised** computers that are **dynamically provisioned** and presented as one or more unified computing resources based on **service-level agreements (SLAs)** established through **negotiation** between the service provider and consumers."

- SLA = {negotiated and agreed QoS parameters + rewards + penalties for violation of agreement....}

Organization.....

- *Server* : the ability of an organization to tie together the power of inexpensive hardware on a larger scale
- *Data* : portable organization with improved data security
- *Business model :* flexible & managerial style & being global
- *Organize H/W and S/W :* organized more effectively
- *Power consumption :* power efficiency techniques within the serv environment
- *Economy :* unnecessary overhead can be trimmed
- *Space occupation :* outsourcing the processing work
- *Administration :* costs remain reasonable

CHARACTERISTICS OF CLOUD COMPUTING

1.Dynamic Computing Infrastructure :

- ✓ Standardized, scalable and secure physical infrastructure
- ✓ High levels of availability
- ✓ Scalable as per the demand
- ✓ Virtualized environment
- ✓ the flexible nature of service provisioning and de-provisioning as requested by a client
- ✓ maintain high levels of reliability and security

CHARACTERISTICS OF CLOUD COMPUTING

2. **IT Service-centric Approach :**

- ✓ Service-centric instead of Server-centric
- ✓ users can effortlessly get access to pre-defined computing environments conceived especially around their service
- ✓ customer acceptance and enterprise agility
- ✓ Less difficult and speedier
- ✓ A customer can perform an administrative work, the more expedient, the enterprise progresses, reducing are the charges or propelling is the revenue

CHARACTERISTICS OF CLOUD COMPUTING

3.Self-service Based Usage Model :

- ✓ user self-service
- ✓ users to upload, build, deploy, schedule, manage and report on their business services on-demand basis
- ✓ To provide easy-to-use, intuitive user interfaces to help the users to effectively manage the service-delivery life cycle
- ✓ least managerial participation from service provider
- ✓ saves time and money
- ✓ allows administrative staff to concentrate on strategic and high-valued responsibilities

CHARACTERISTICS OF CLOUD COMPUTING

4. **Minimally or Self-managed Platform :**

- Self-managed platform is very essential for a service provider in cloud environment.
- Best-of-breed clouds make self-management through software automation, leveraging the following capabilities:
  - ✓ A provisioning engine where the services are deployed should have high levels of reuse.
  - ✓ Mechanisms for scheduling the resources and reserving resource capacity.
  - ✓ Capabilities for configuring, organizing and reporting to make sure resources are allocated and reallocated to several groups of users.
  - ✓ Tools must be available for controlling access to resources and policies for resources to be utilized or operations to be performed.

Note

- All of these competencies sanction finance agility while concurrently enacting valued and necessary administrative power.
- This balance of power and delegation
  - ✓ maintains security and uptime,
  - ✓ reduces the level of administrative efforts,
  - ✓ maintains working expenses low, and
  - ✓ releases resources to focus on higher-value projects.

CHARACTERISTICS OF CLOUD COMPUTING

5. Consumption-based Billing :

- ✓ usage based
- ✓ Pay per usage
- ✓ a user’s point of view : low cost
- ✓ a provider’s perspective : monitor usage for billing

Summary of CC characteristics

- Necessary for producing enterprise private cloud
- capable of achieving compelling business value
- Capex to Opex business model shift
- Reduced support costs
- Increased business agility
- Improves profit margins and competitiveness

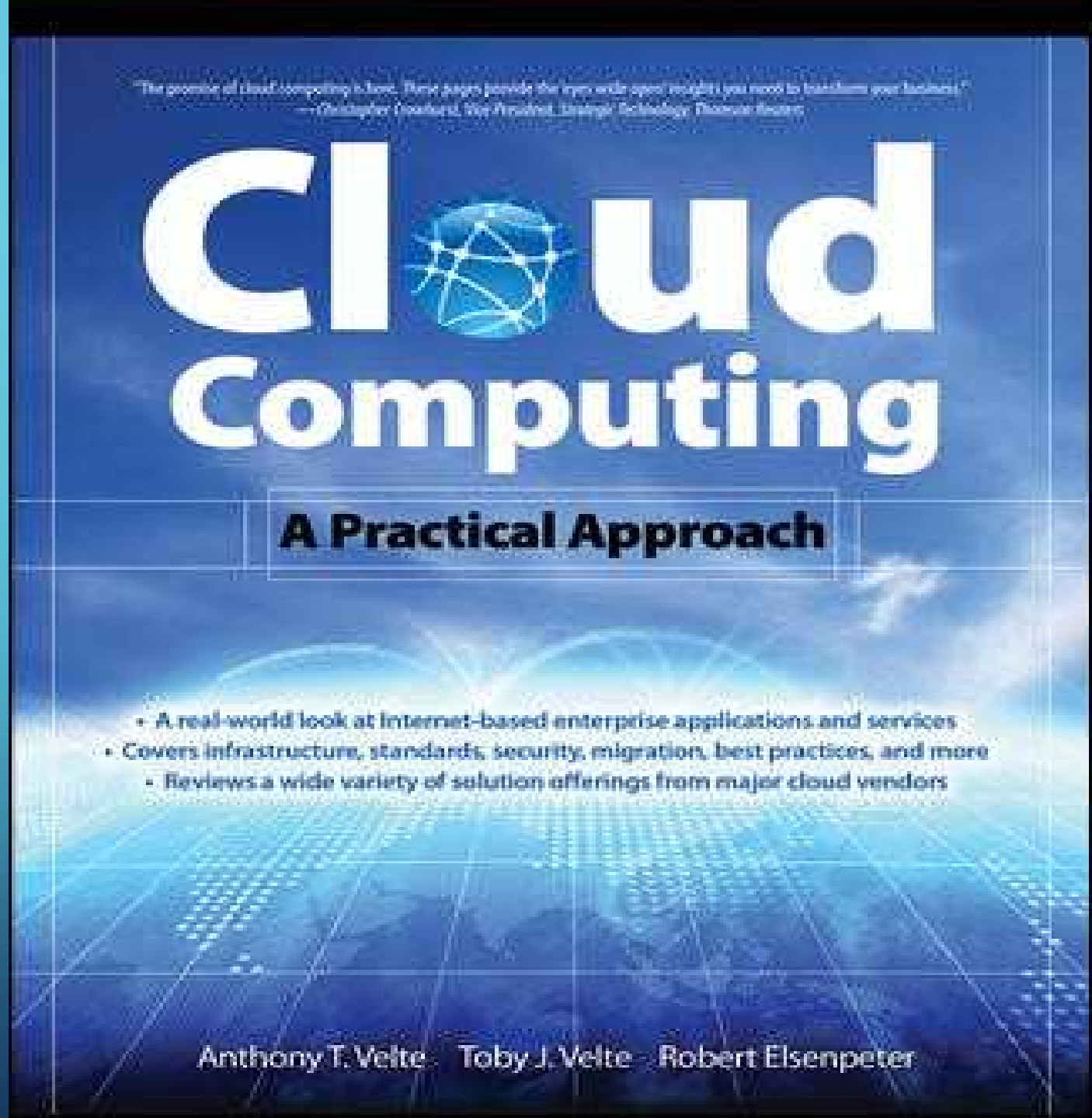
WHAT CLOUD COMPUTING REALLY IS?

- ✓ a browser-based application that is hosted on a remote server
- ✓ facilitates small organizations to compete with much larger ones
- ✓ helps in saving lot of money and to utilize energy efficiency in operations
- ✓ Remote resource access via network connection
- ✓ Inexpensive massive storage
- ✓ Data loss prevention

What Cloud Computing Really Isn’t?

- ***Not a data centre***, although they can certainly play a part. Users can deploy an environment that supports cloud computing in a data centre, but cloud computing is not about data centres.
- The cloud computing is an ***unique technique*** that incorporates even the basic ***client- server computing*** concepts. With cloud computing, we have a generalized resource to which one can initiate the work and that could form part of a client/server application. The cloud computing has more autonomy.
- ***Not a grid computing***, but again users can avail cloud computing environments to support grid computing.
- ***Not a comeback to mainframes and mini systems or centralized computing***, cloud computing generally involves multiple computers rather than one and reduces computing power according to user needs.

Anthony T. Velte Toby J. Velte, Robert Elsenpeter, “Cloud Computing: A Practical Approach”, 2010, The McGraw-Hill.



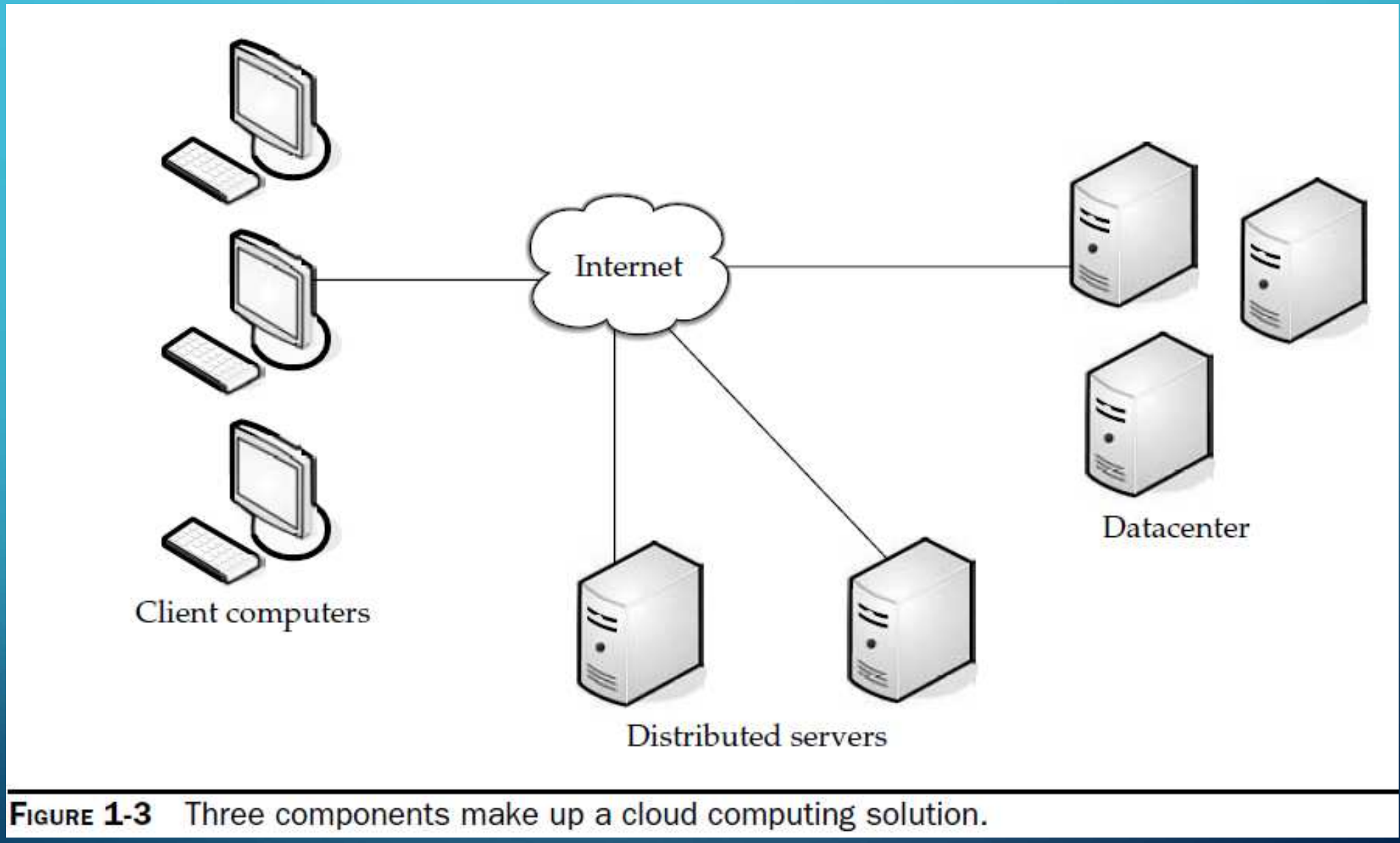


FIGURE 1-3 Three components make up a cloud computing solution.

Clients

Clients are, in a cloud computing architecture, the exact same things that they are in a plain, old, everyday local area network (LAN). They are, typically, the computers that just sit on your desk. But they might also be laptops, tablet computers, mobile phones, or PDAs—all big drivers for cloud computing because of their mobility.

Anyway, clients are the devices that the end users interact with to manage their information on the cloud. Clients generally fall into three categories:

- **Mobile** Mobile devices include PDAs or smartphones, like a Blackberry, Windows Mobile Smartphone, or an iPhone.
- **Thin** Clients are computers that do not have internal hard drives, but rather let the server do all the work, but then display the information.
- **Thick** This type of client is a regular computer, using a web browser like Firefox or Internet Explorer to connect to the cloud.

Datacenter

The *datacenter* is the collection of servers where the application to which you subscribe is housed. It could be a large room in the basement of your building or a room full of servers on the other side of the world that you access via the Internet.

A growing trend in the IT world is virtualizing servers. That is, software can be installed allowing multiple instances of virtual servers to be used. In this way, you can have half a dozen virtual servers running on one physical server.

Distributed Servers

But the servers don't all have to be housed in the same location. Often, servers are in geographically disparate locations. But to you, the cloud subscriber, these servers act as if they're humming away right next to each other.

This gives the service provider more flexibility in options and security. For instance, Amazon has their cloud solution in servers all over the world. If something were to happen at one site, causing a failure, the service would still be accessed through another site. Also, if the cloud needs more hardware, they need not throw more servers in the safe room—they can add them at another site and simply make it part of the cloud.

As per NIST CC is…….

- Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.
- This cloud model is composed of five essential characteristics, three service models, and four deployment models.

CC Characteristics as per NIST.....

1) **Broad network access**: Resources are virtually accessible via the Internet regardless the location and the device used (i.e., mobile phones, tablets, laptops, and workstations).

2) **On-demand self-service**: Computing capabilities, such as server and processing time, and network storage, are provided automatically as needed.

3) **Resource pooling**: The resources are pooled to serve different clients with physical and virtual resources dynamically appointed and reassigned as per client request.

4) **Measured service**: Controlling and optimizing resource use by assigning a measured capability appropriate to the type of service (i.e., storage, processing and bandwidth).

5) **Rapid elasticity**: Resources can be provisioned and to be scaled rapidly outward and inward commensurate with demand.

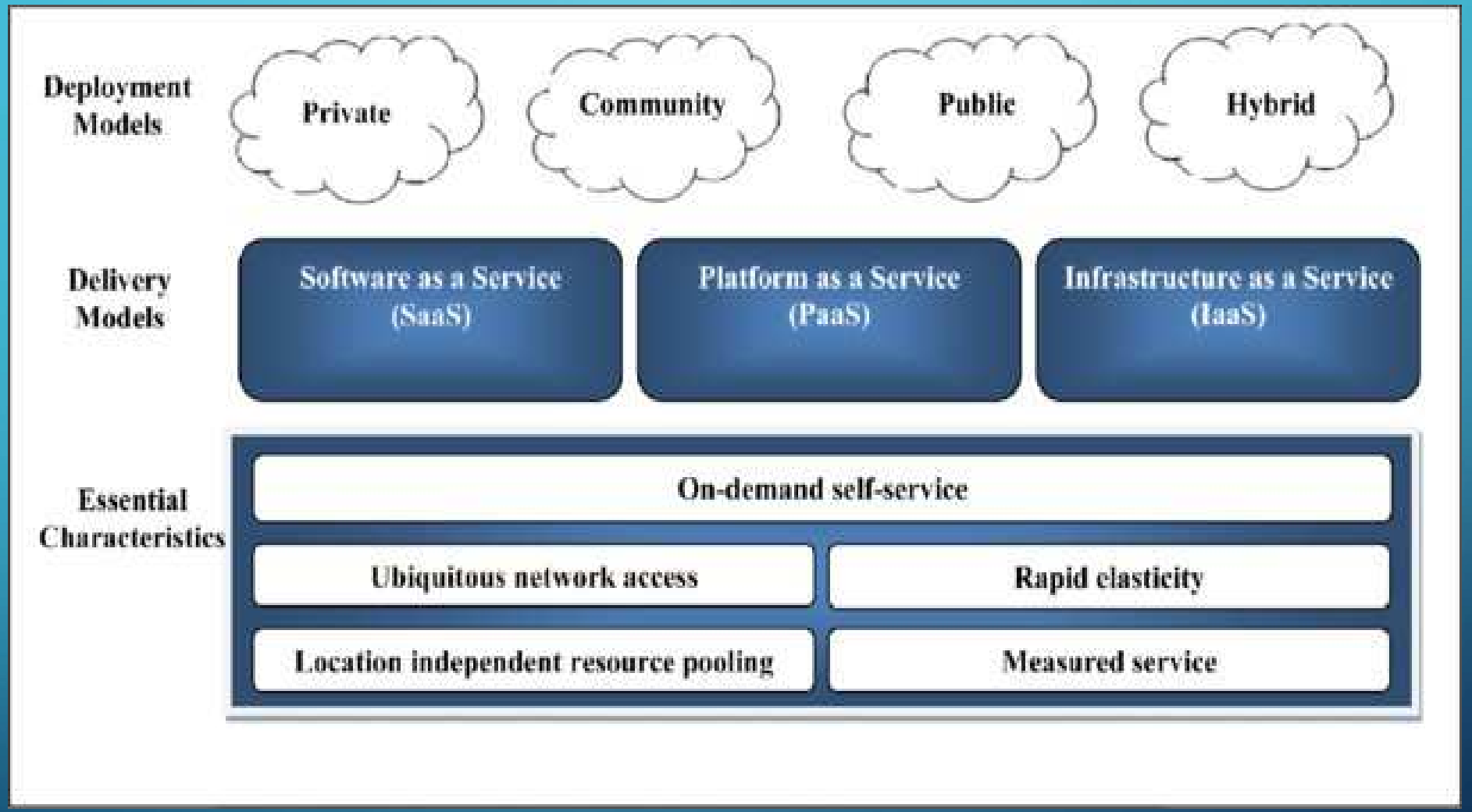


Fig : NIST Cloud Computing Definition

Points to cover
Part I

- ✓ 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

PROS AND CONS OF CLOUD COMPUTING

- Advantages of Cloud Computing in IT Field
- Disadvantages of Cloud Computing

Advantages of Cloud Computing in IT Field

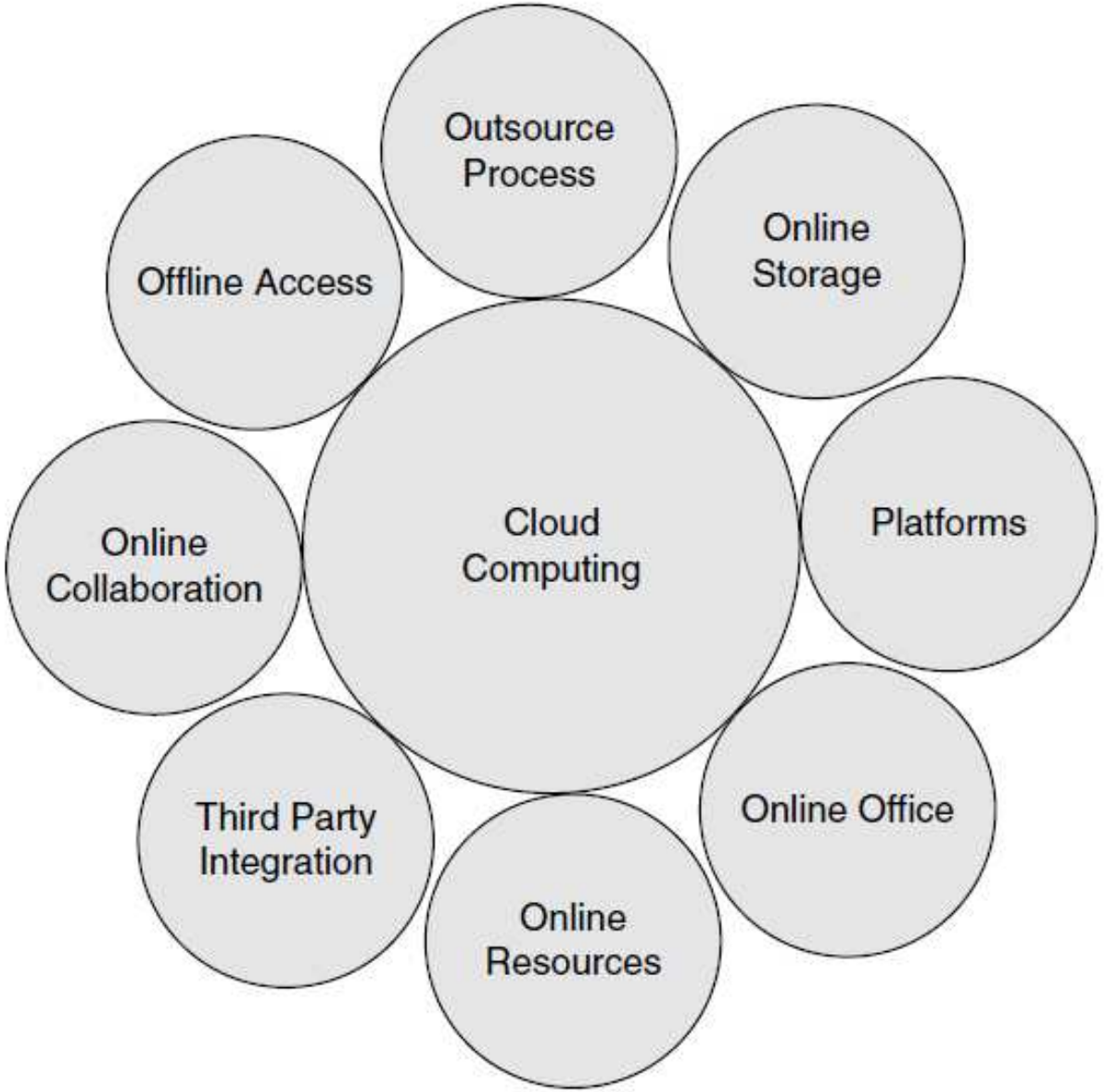


Figure 2.1 Advantages of Cloud Computing

Advantages of Cloud Computing in IT Field

CC supports/provides the following benefits:

- Online storage
- Accessible in different platforms
- Using online resources
- Online collaboration and
- Easy outsourcing processes

key elements of cloud computing

- Elements are divided into four layers.
- Layer 1 contains the physical machines, where the required software and operating systems are installed.
- Layer 2 forms virtual machines.
- Layer 3 explains the service level agreements (SLA) and resource allocator to the virtual machines (VM).
  - ✓ This layer also accounts for the job, prices it and dispatches the jobs to the VM.
- Layer 4 contains the users or brokers using the computing.

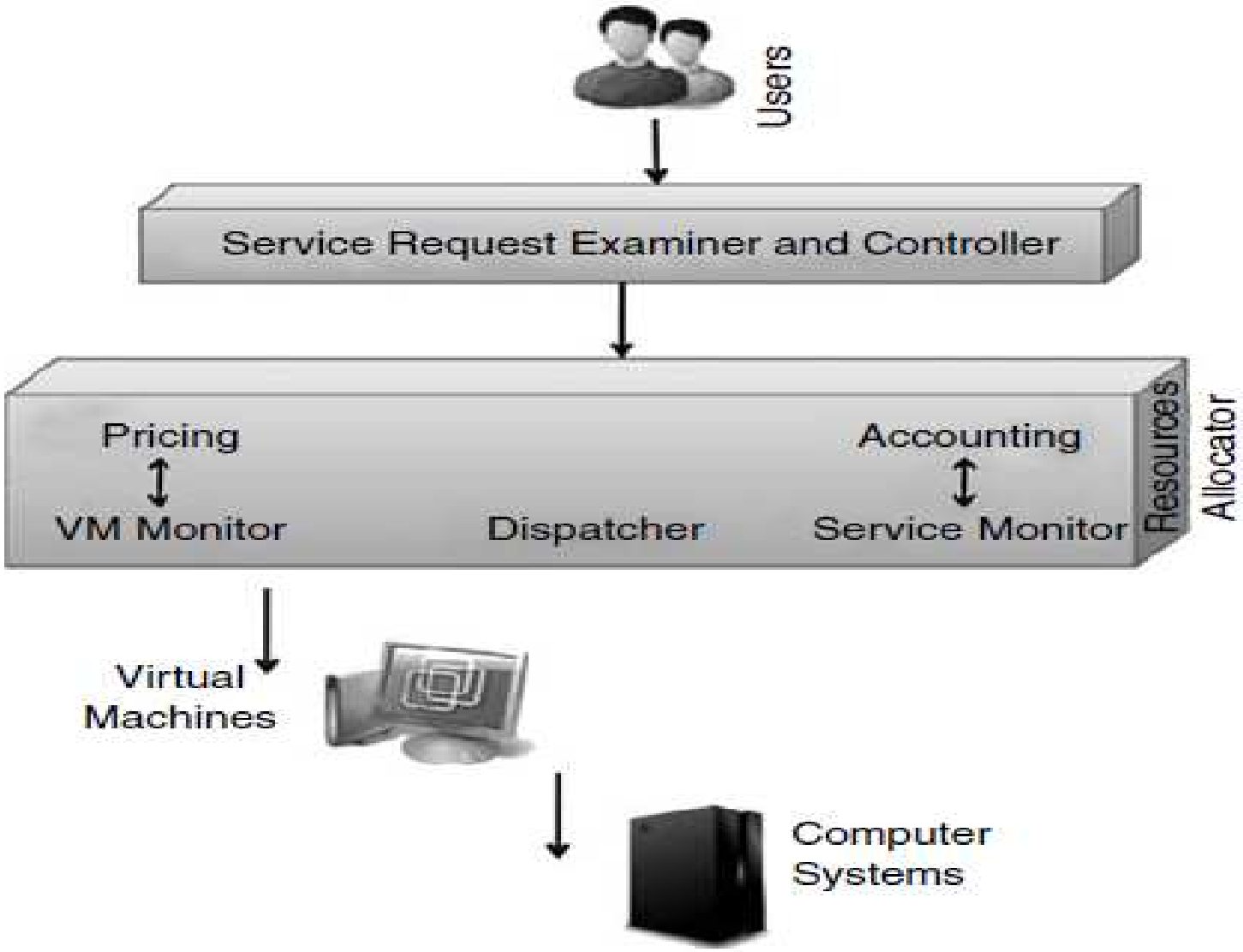


Figure 2.2 Key Elements of Cloud Computing

Advantages of Cloud Computing

1. **Cost reduction**: Cloud computing lessens paperwork, enterprise deal charges and minimizes the financial endeavor in hardware. Moving your enterprise to ‘the cloud’ in addition lessens the want for an employee.
2. **Scalability**: Cloud computing services sanction enterprises to only compensate for what they use like electrical power and water. As the business grows, user can put up by adding more server space.
3. **Levels the playing field**: Sharing IT resources with other companies reduces the cost of licensing software and retail servers.

Advantages of Cloud Computing (2)

4. **Easier collaboration**: Cloud computing services allow to access any time from any computer, it is easy to work together with employees in remote locations.

5. **Affordable**: With cloud computing, it is possible to reduce operational costs and investment expenditures on hardware, software licenses and implementation services.

Advantages of Cloud Computing (3)

6. **Scalable and flexible**: Cloud computing can sanction to maximize supplies for better competence and lessen unused capacity. It can also scale up or downward to meet the varying demands of the business.
7. **Efficiency**: Cloud computing renders the gain of divided hardware, automated and recognizable technologies. The employees have the right to use the database from everywhere by using any PC, mobile device or browser. It also reduces overall energy usage and physical presence.

Disadvantages of Cloud Computing

1. **Security concerns**: easily reachable data
2. **Risk of losing internet connection**: If there is no Internet connection, the database accessing is very difficult.
3. **Limited resources for customizations**: One can require in-depth customizations and integration with his current systems for his daily business functions. Cloud computing may not be accommodating to his needs.

Disadvantages of Cloud Computing (2)

4. **Availability**: If it happens, the cloud service goes down unexpectedly, leaving you without important information for hours or more? Then how is it possible to get ***reliability*** in retrieval of data is yet another challenge.
5. **Data mobility and ownership**: In cloud environment, it is possible get back the data safely even when the cloud service is stopped. How can you be assured that the service provider will wipe out your data once you have cancelled the service?
6. **Privacy**: How much data the cloud service companies are collecting and how are they using the information?

- Cloud computing provides enterprises with two-fold solutions:

1. Organizational perspective :
   - the cloud give services for client and enterprise needs in a simplified way
   - drives the capability for expansion and innovation
2. User’s perspective :
   - it enables computing services in a simpler, more responsive model
   - without complete knowledge of the underlying technology
   - effective service acquisition and delivery model for IT resources

Other Cloud-related Technologies

- **Grid computing**: It defined as an extension of distributed and parallel computing in which a super and virtual computer consists of a number of networked and loosely coupled computers that act together to perform enormous tasks.
- **Utility computing**: When the resources used in computing process are packaged as a metered service similar to electricity—a traditional public utility.
- **Autonomic computing**: It defines that systems are capable of self-management.

Key Characteristic of Cloud and its Role

1. **Virtualization Technique**

- Virtualization works on the management of how the likeness of the OS, middleware and programs procreated and assigned to a personal system or part of the server stack away.
- These technologies in addition helps in reusing certificates of OS, middleware or programs requests after the customer distributes their service from the cloud computing platform.

Key Characteristic of Cloud and its Role

2. Service-oriented Architecture (SOA)

- Cloud computing : a collection of services, which communicate with each other
- Diagram : the basic architecture of SOA and its components
  - ✓ (i) service providers,
  - ✓ (ii) service requestor and
  - ✓ (iii) contract details or service level agreements
- Services : are used to pass the data, and to execute some specific activities
- Applications : Mostly standalone and are designed for a single use
- Google, Microsoft, Sun and Amazon :
  - ➢ the competence of providing services instead of directly promoting the software to the user
  - ➢ desire cost cuts through choosing to rent rather than purchasing

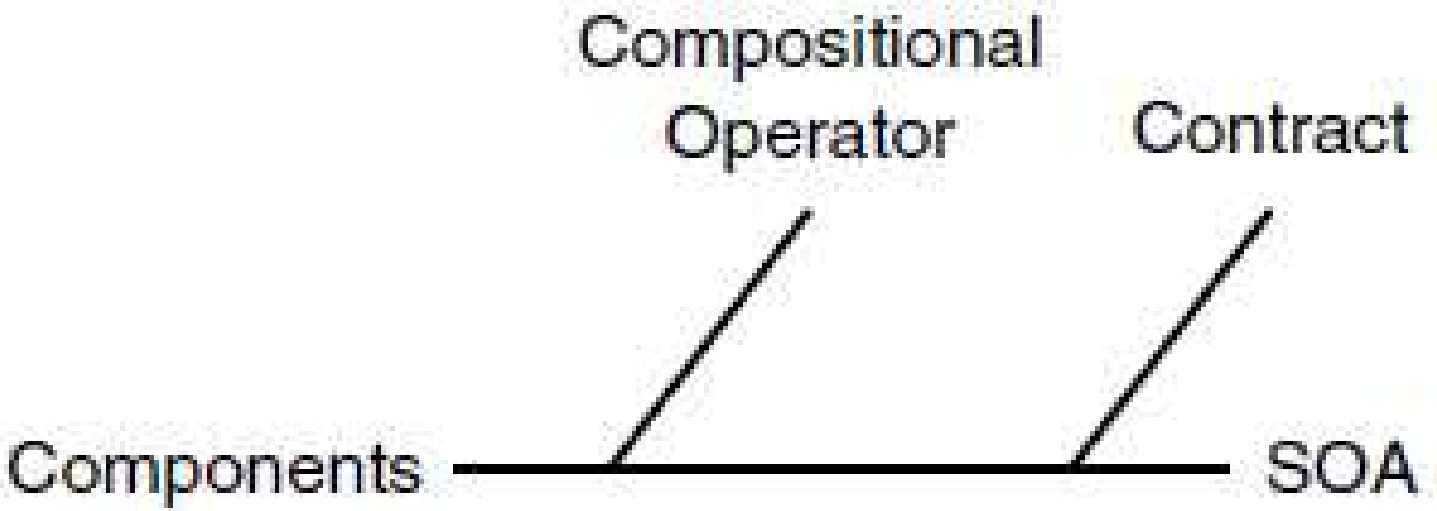


Figure 2.3 Service-oriented Architecture

Points to cover
Part I

- ✓ Importance of Cloud Computing
- ✓ Characteristics
- ✓ Pros and Cons of Cloud Computing
- Migrating into the Cloud
- Seven-step model of migration into a Cloud
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MIGRATING INTO THE CLOUD

- Cloud Computing Migration Issues

1. Security
2. Vendor Management
3. Technical Integration
4. Process and Culture
5. The Business View

Points to cover
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MIGRATING INTO THE CLOUD

- Cloud Computing Migration Issues

1. Security
2. Vendor Management
3. Technical Integration
4. Process and Culture
5. The Business View

Migrating to the Cloud: Deployment Considerations

How many of the following complaints have you heard about your company?

- The IT environment is too large and complex.
- Sluggishness of the existing systems that do not meet user expectations.
- Inability to consistently and effectively scale to support rapid growing requirements.
- Composite rules to obtain performance metrics.
- Widening gap between available functionality and tangible features used.
- We can’t find the aptitude to support new technology.
- High operating costs, high investment costs

How CC address the following key questions:

- What are the underlying drivers for tapping into the cloud?
  - Is it for new functionality/application or moving from an existing result?
  - How clearly are these distinct and communicated to the project team?
- What business needs and solution do cloud serve?
- Will the cloud-based solution work in segregation or work with other systems?
- Is the planned solution part of a recognized cloud platform?
- How many customers will access the cloud? What are the training and support levels necessary?
- What is the total lifecycle cost of the solution and reason?
- Does the ‘pay-per-use’ model improve our cash flow?

To Process Cloud migration

- Clearly state business objectives for the cloud migration.
- Define project scope of the cloud migration.
- Provide a set of guiding principles for all to follow.

Cloud migration process

- Cloud migration process can be divided into three areas:

1. Plan
2. Execute
3. Monitor

1. Plan

1.Determine key business drivers

2.Define business objectives

3.Get executive sponsorship

4.Set project guiding principles

5.Form project team made up of IT and business representatives

6.Develop a project plan by including the following:

- ✓ Define business requirements
- ✓ Set key success metrics
- ✓ Set timeline
- ✓ Identify decision-making authorities

2.Execute

- Execute the plan
- Stay away from ‘scope creep’—stay focused on original project scope; this becomes a challenge particularly in cases, where a major legacy application with large users set is being replaced
- Remember to follow the guiding principles at all times
- Communicate to all stakeholders regularly
- Train users

3.Monitor

- Monitor adoption
- Track success metrics
- Stay away from scope creep (this one may well decide the success or failure of the project)
- Follow guiding principles
- Only implement changes based on quantifiable business needs

5 things to be known while migrating to cloud

(i) Start small,

(ii) trust cloud vendors to protect data,

(iii) consider importance of security aspects,

(iv) be an identity provider (authentication & access rights)

(v) plan for latency and outages.

SEVEN-STEP MODEL

1. Know that there are many different variances of cloud services
2. Move towards the cloud as a tool or an additional option to supply IT functionality
3. Recognize which constituent of your environment may be ‘cloud compatible’
4. To better compute the advantage of cloud services lies on understanding about current costs
5. Preparation of organization to ‘manage’ rather than ‘operate’
6. To simplify and de-risk your migration
7. Question to gain more knowledge

Points to cover
Part I

- ✓ 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

Home Assignment #1

- Create your AWS account.
- Install GAE on your machine and list the steps to install GAE.
- Install Microsoft Azure and list the steps to install Microsoft Azure.

TRENDS IN COMPUTING

- IT Maturity Analysis
- Technology Trends to Watch

IT Maturity Analysis

- Diagram
- Current Rate: Investment V/s Adoption
- Assessment provides the success rate of the technology and its deployment and also the organizations, that will find this technology beneficial.
- How developed a technology is related to other technologies and how rapidly it will expand in the market.

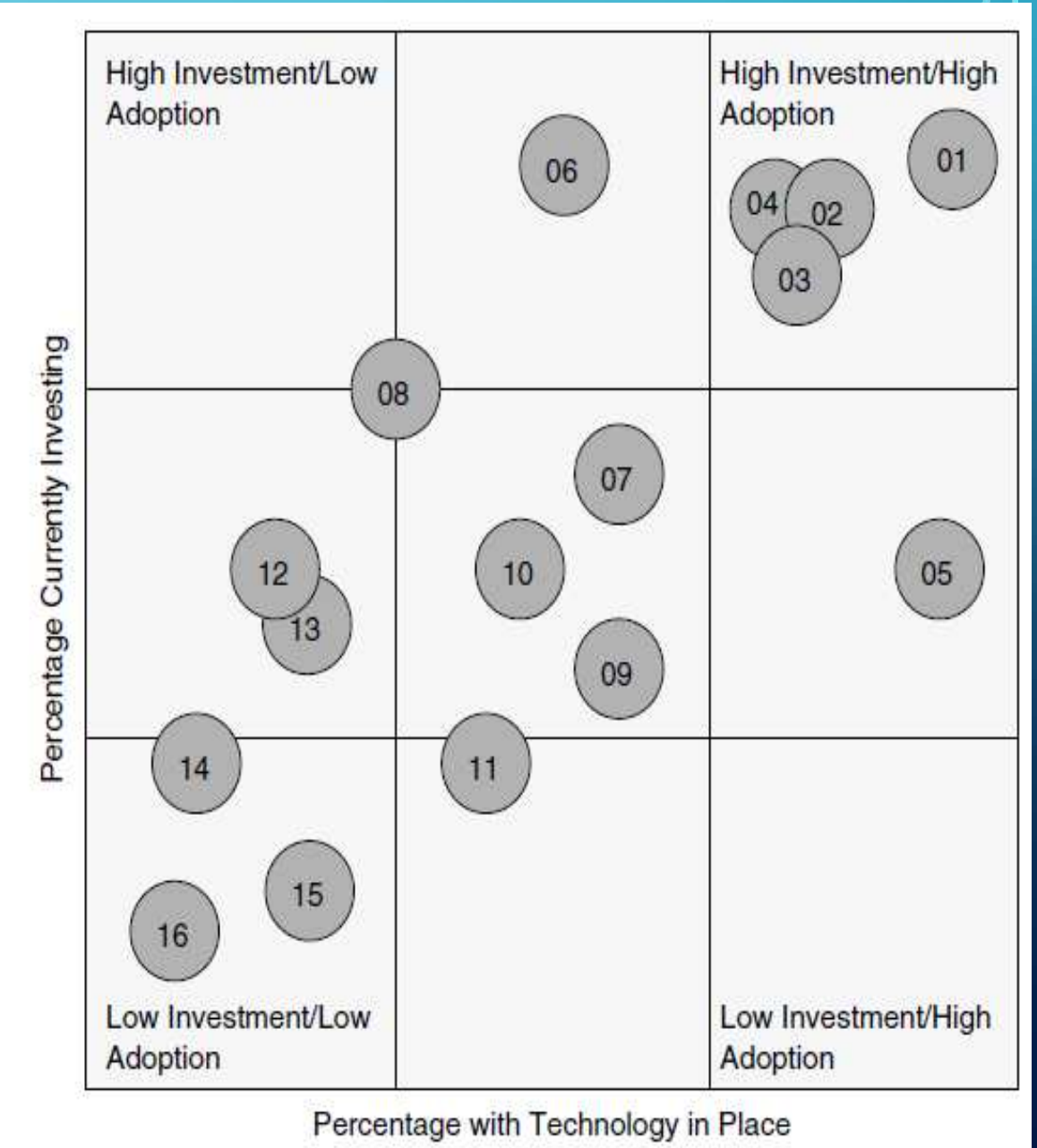


Figure 4.1 IT Maturity Analysis

- X-axis ‘percentage with technology in place’ → the rate of adoption
- Y-axis ‘percentage currently investing’ → the rate of investment
- In this analysis, the terms ‘low’ and ‘high’ are relative to the technologies that are being developed.
- The diagonal line represents technologies falling from low investment and adoption to high investment and adoption rate.
- Technologies falling in the upper right corner are more matured.

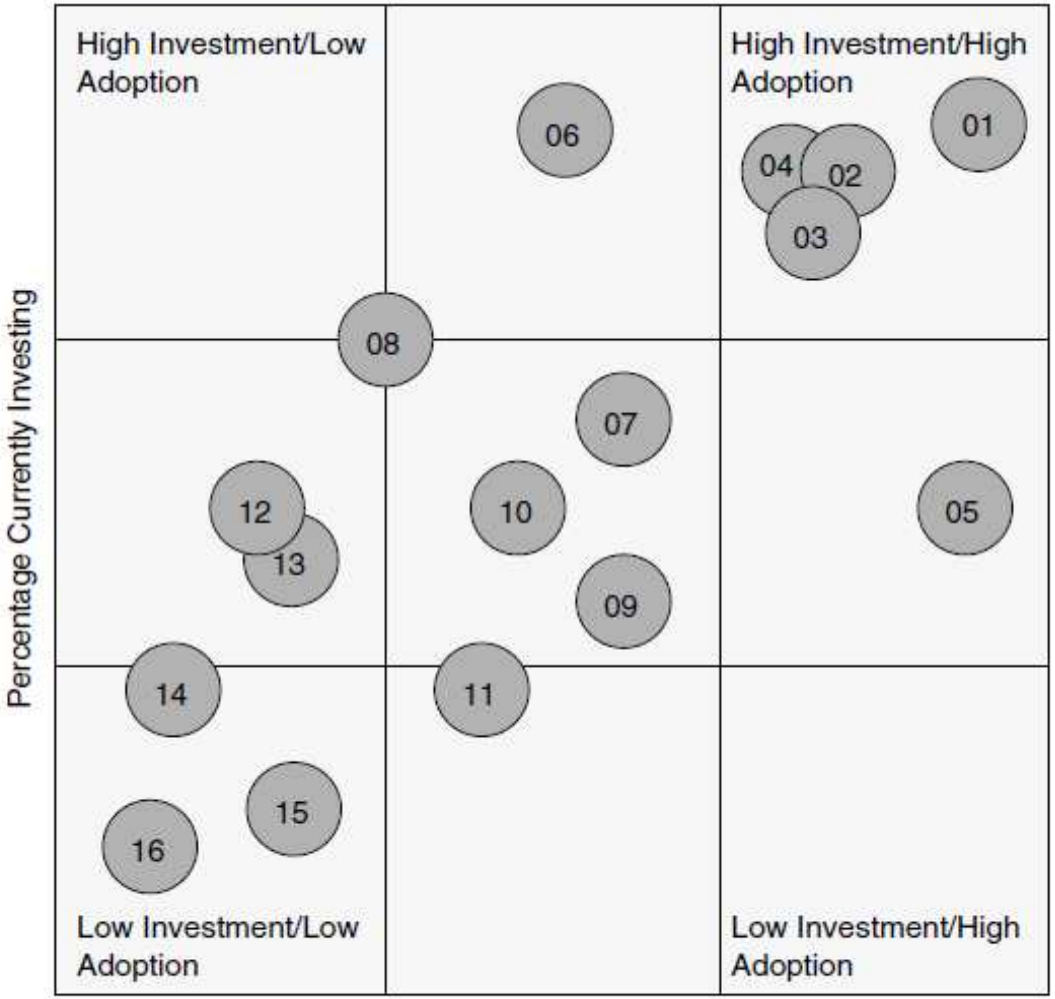


Figure 4.1 IT Maturity Analysis

Diagram 4.1

- *A chart with nine different parameters such as*
  - *low, moderate and high rate of investment; and*
  - *low, moderate and high rate of adoption.*
- *Each technology falls in any one of the nine parameters.*

- **High rate of investment/adoption:** ERP, business intelligence systems, CRM systems and enterprise collaboration falls under this sector.
- **Moderate rate of investment/high rate of adoption:** Systems like human resource management systems (HRMS) fall in this sector.
- **High rate of investment/moderate rate of adoption:** When there is an increase in investment than the adoption, it results in growth of technology. Windows 7 falls in this sector.
- **Moderate rate of investment/moderate rate of adoption:** Technologies such as legacy system renewal, SaaS and unified communication fall in this category. These technologies will grow in a slow and steady pace.
- **High rate of investment/low rate of adoption:** Mobile applications falls in this sector, which has high rate of investment, but adoption rate is minimal.
- **Low rate of investment/moderate rate of adoption:** Supply chain management
- **Low rate of investment/low rate of adoption:** Technologies like virtualization (desktop), tablet, IaaS, environmental management solutions and PaaS fall in this sector. When a technology has more capability, but adoption rate is low, then organizations will not be interested in adopting them.

Major Trends that emerged in CC

- Cloud computing technology changed its focus from industry to real-world problems.
- The major trends that emerged in cloud computing technology are:
  - ✓ Small, medium business and micro-business
  - ✓ Supply chain management, media and digital content, and legacy systems
  - ✓ On-the-fly access
  - ✓ Hybrid cloud model
  - ✓ Growth in stack-as-a-service

Technology Trends to Watch : 1.Virtualization

- Infrastructure, applications, server, desktop, storage, network and hardware virtualization
- Can supply extra power on demand and is compatible with today’s environmental measures.
- Affords incredibly easy migration for small and medium business (SMBs)
- Organizations need to review consolidation plans and check whether all virtualization bases are covered without delay.
- To find out new ways to store media using client-side virtualization concept
- The virtual desktops that conceive a ‘thick client’ likeness by a ‘thin client’ consignment form a long, flexible workforce which decreases complexity and simplifies measures in alignment, review and command by adopting to new client virtualization.

2.Data Growth

- According to Gartner, enterprise data growth is expected to increase more in the next five years and 80% will remain unstructured.
- Due to this trend in the IT, the complexity will also increase, despite continued budget constraints.
- More access will lead to more data, resulting in increased compliance, backup, audit and security.
- To keep up with the tide, companies must virtualize storage quickly, preparation of reduplication, calculate all data inputs, keep up the needs, segments and prioritize data.
- Thin provisioning, data reduplication, automated tiering, HSM (heterogeneous storage management) principles and virtual tapes are included in the key technologies to manage the data growth.

https://www.gartner.com/en/articles/gartner-top-10-strategic-technology-trends-for-2023

https://www.gartner.com/en/articles/gartner-top-10-strategic-technology-trends-for-2024

https://www.gartner.com/en/articles/top-technology-trends-2025

3.Energy and Green IT

- In Green IT, performance and its effectiveness will play a vital role.
- Corporate social responsibility will become a primary concern as the power issue moves up the food chain

4. Complex Resource Tracking

- Monitors energy consumption made by resources
- Automatically optimizes it by moving workloads dynamically
- Organizations will have to manage new KPI (knowledge power infrastructures) based on power
- There will be a growing demand for new vendors and skills.

5.Consumerization and Social Software

- Social collaboration (wikis, blogs, Facebook, Twitter), social media (content sharing and aggregation) and social validation (social ratings, rankings and commentary) will continue to be a major force in shaping consumerization and the software, compelling organizations to focus on early pattern detection and ‘collectiveness’.
- Establishing the rules of engagement, monitoring and looking for signals, becoming active participants in the social web and including some dimension to internal and external websites of the organizations, will need to respond to the distributed social web in years to come.

Points covered
Part I

- ✓ 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

Points to cover
Part II Cloud Service Models

- SaaS
- PaaS
- IaaS
- Storage

CLOUD SERVICE MODELS

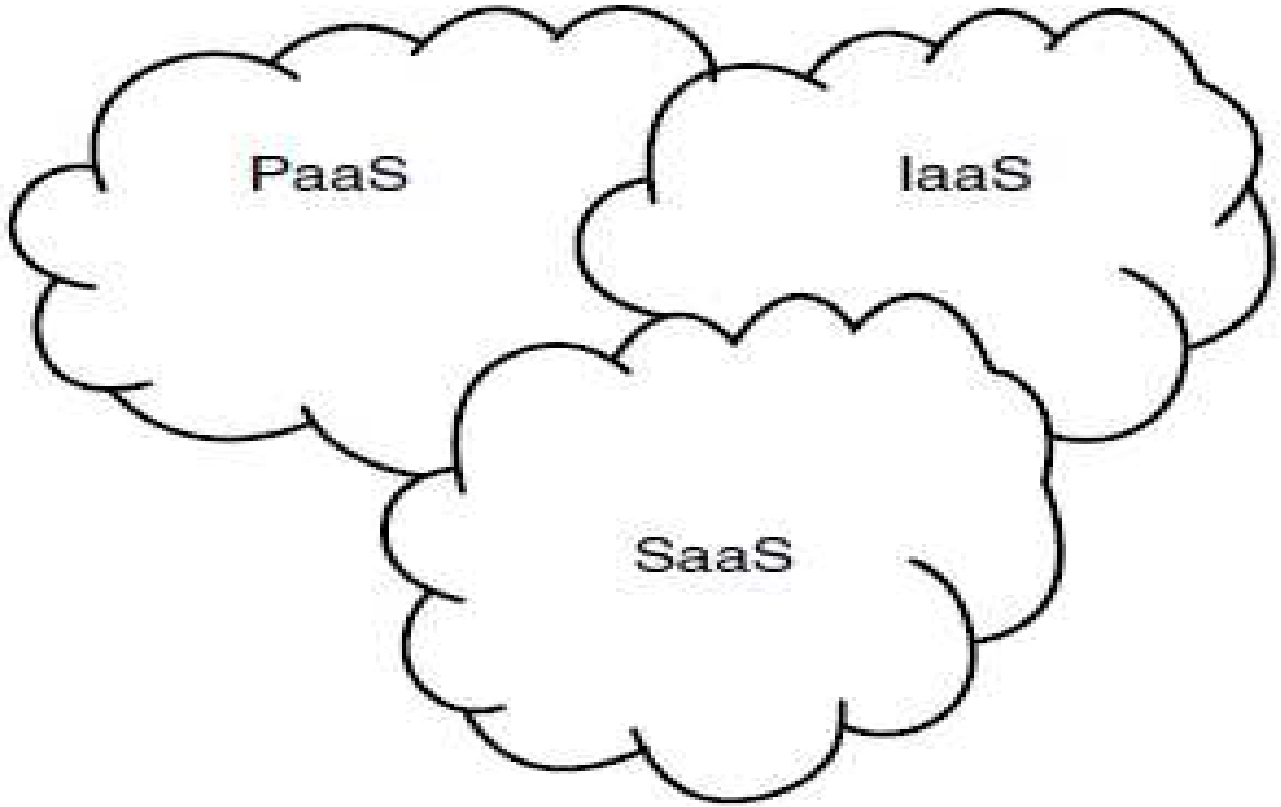


Figure 4.2 Cloud Service Models

Cloud Service models

- Service models : types of services 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, storage, hardware, database, etc.’

Middleware?????

- A general-purpose service that sits between platforms and applications.
- Software layer located between the operational system and the applications, it allows the execution of a application in different hardware platforms.
- A software that hides the heterogeneity of various hardware components, operating systems and communication protocols by providing uniform, standard, high-level interfaces to application developers.
- An enabling layer of software that resides between the application program and the networked layer of heterogeneous platforms and protocols. It decouples applications from any dependencies on the plumbing layer that consists of heterogeneous operating systems, hardware platforms and communication protocols.

Service Models

1. SaaS (Software as a Service)
2. PaaS (Platform as a Service)
3. IaaS (Infrastructure as a Service)

1.SaaS

- Provider has full administrative rights for its application and responsible for activities such as deployment, maintenance and update.
- Suitable for customers, who want less management hassles and worries regarding installation of application, software and its update
- SaaS subscribers can be individual users, users from organizations and users from enterprises.
- If the focus is on improving of the business, SaaS is the best option.

SAAS.....

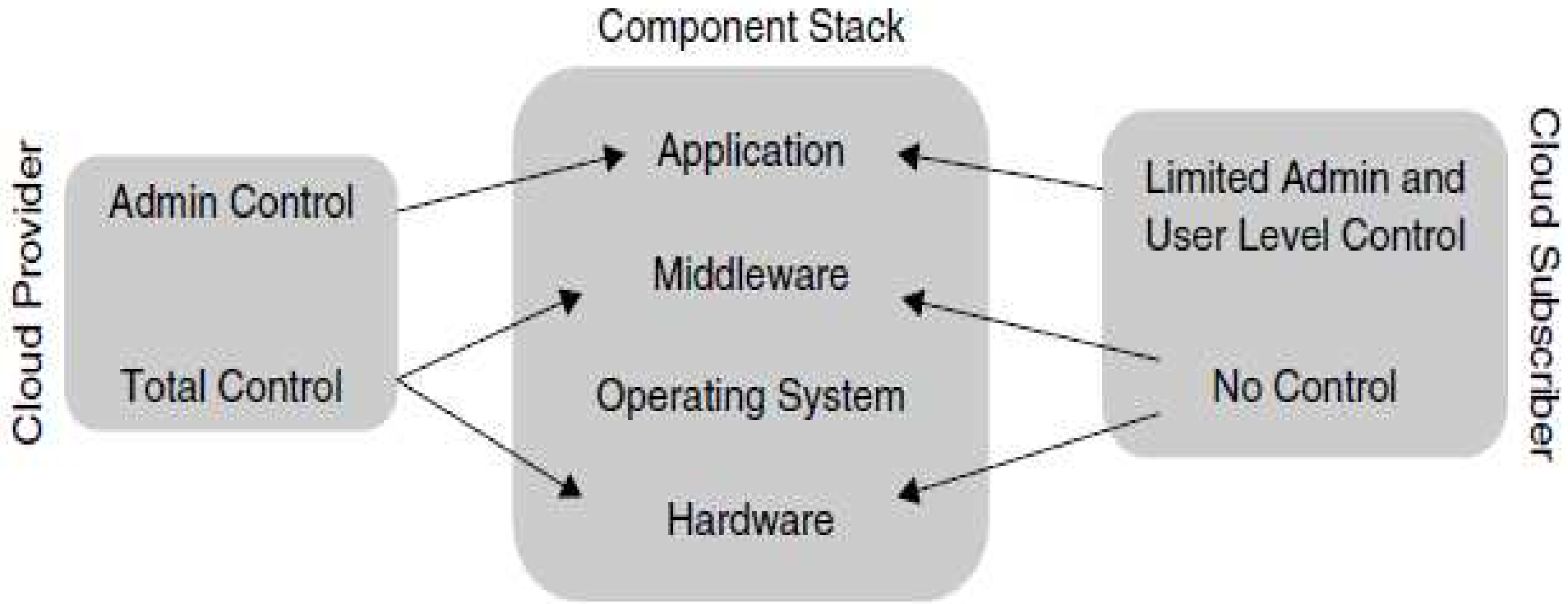
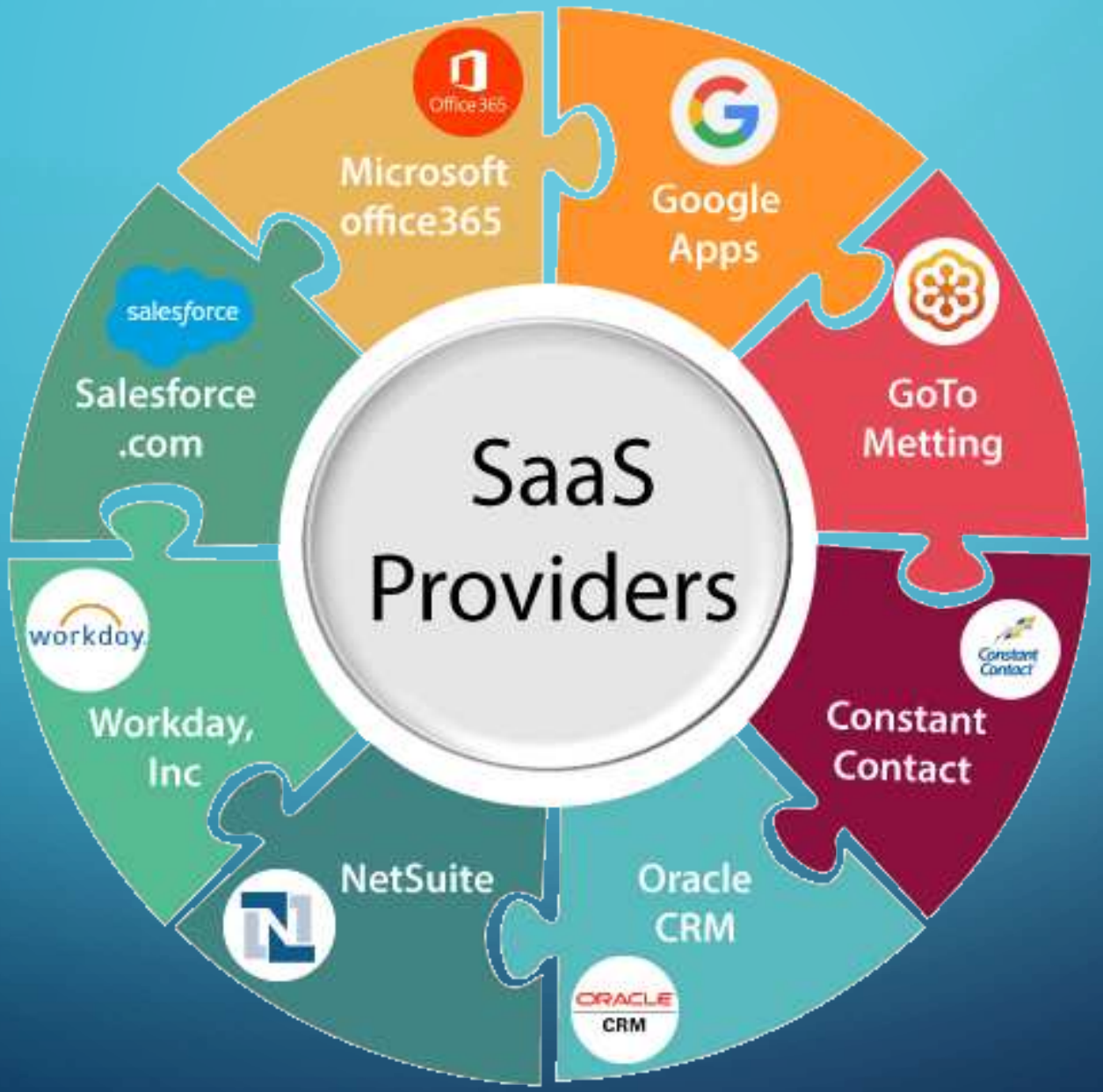


Figure 4.3 SaaS Component Stack and Scope of Control

SaaS…..

- By opting SaaS, replacing of old hardware and maintaining infrastructure can be avoided, thus saving on time and cost of hiring of technical staff.
- Applications, which supports productivity and collaboration are the best options.
- Example:
  - Google Apps
  - Online project management apps such as Zoho Mail, Deskaway.
  - CRM apps such as Salesforce.com, Impel CRM and Microsoft Dynamics
  - Cloud services such as Skydrive, Google Docs and Dropbox
  - Small and medium enterprises (SMEs)/small and medium business (SMBs) and user services such as EazeWork


SaaS Providers
Microsoft office365
Google Apps
GoTo Metting
Constant Contact
Oracle CRM
NetSuite
Workday, Inc
Salesforce .com

Top 10 Software as a Service (SaaS) Companies

networkinterview.com

(An Initiative By ipwithease.com)

2. PaaS

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

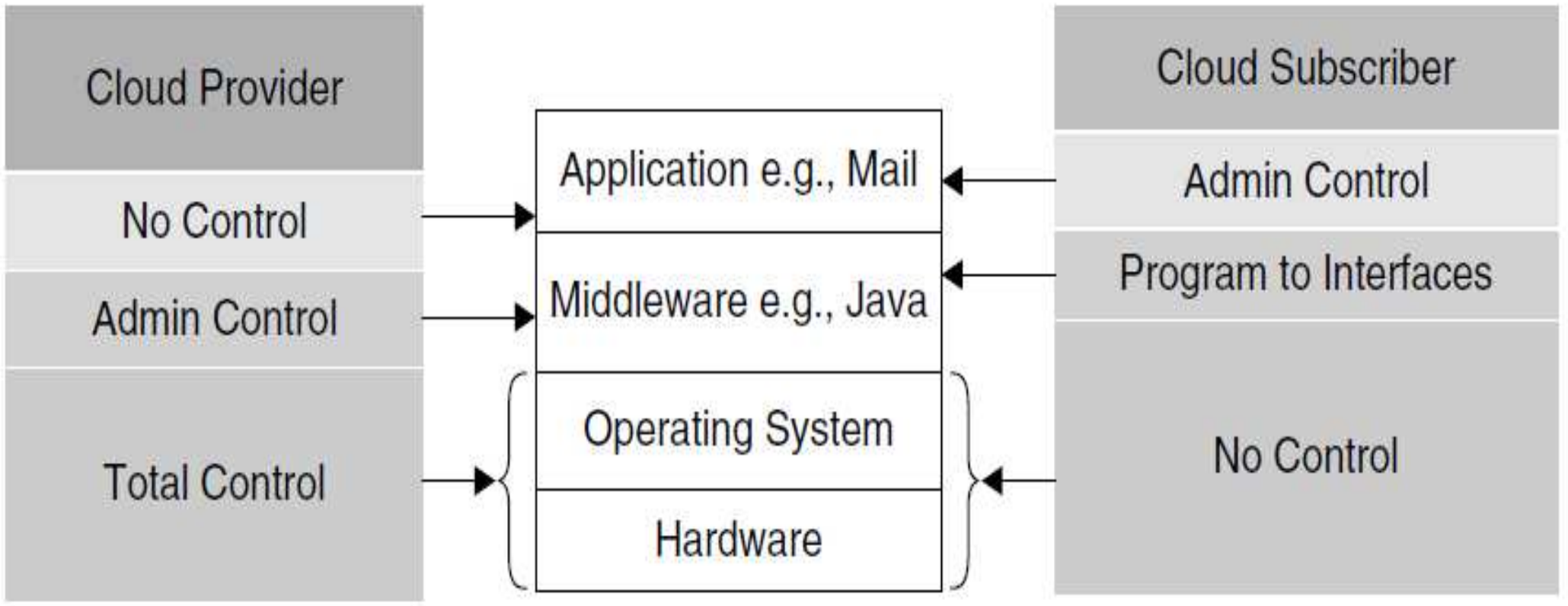


Figure 4.4 PaaS Component Stack and Scope of Control

PaaS

- Consists of environment for developing applications, languages for writing programs, compilers and tools for testing and deployment.
- PaaS subscribers : 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.

PaaS….

- 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.

PaaS Providers

3. 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.

3. IaaS

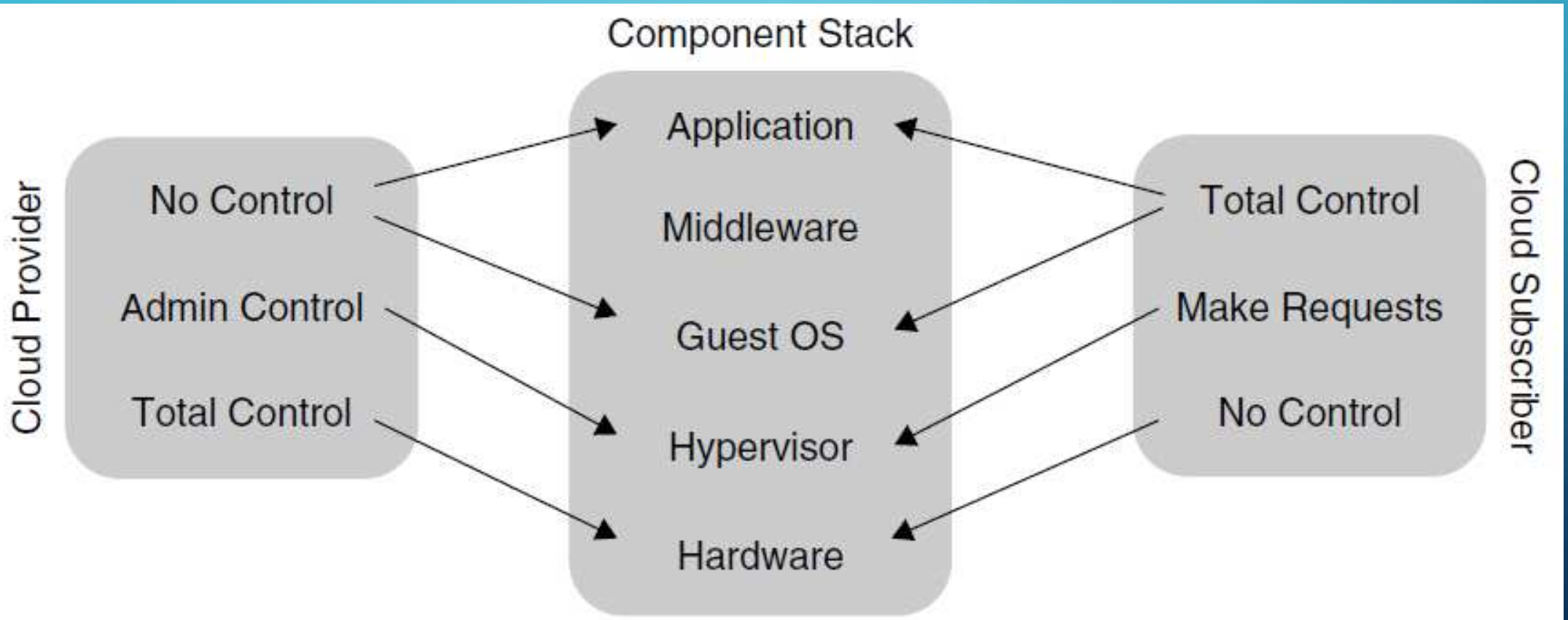


Figure 4.5 IaaS Component Stack and Scope of Control

Guest OS

- A guest operating system (Guest OS) is the operating system installed on either a virtual machine (VM).
- It is usually different from the host operating system.

Hypervisor

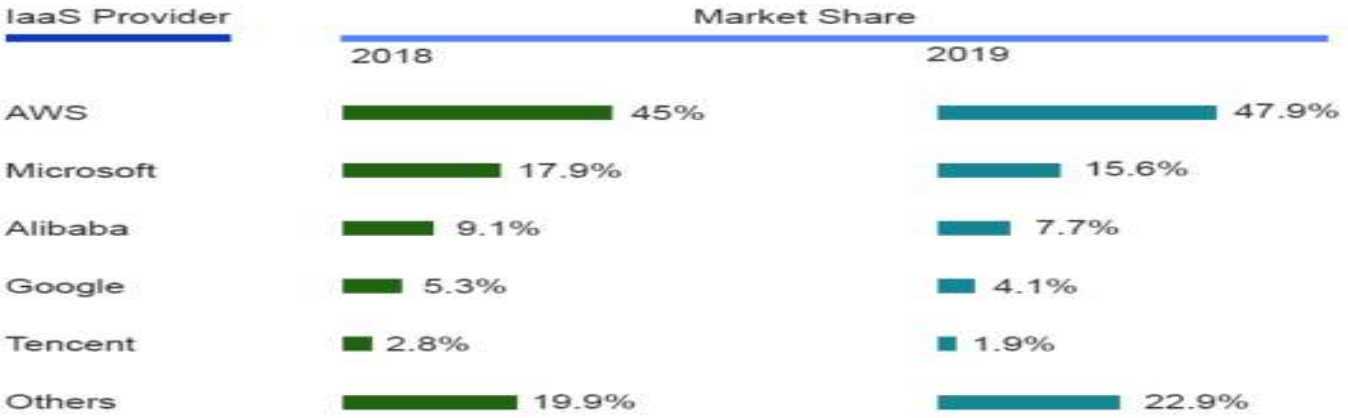
- A hypervisor is a software that you can use to run multiple virtual machines on a single physical machine.
- Every virtual machine has its own operating system and applications.
- The hypervisor allocates the underlying physical computing resources such as CPU and memory to individual virtual machines as required.
- Thus, it supports the optimal use of physical IT infrastructure

Iaas….

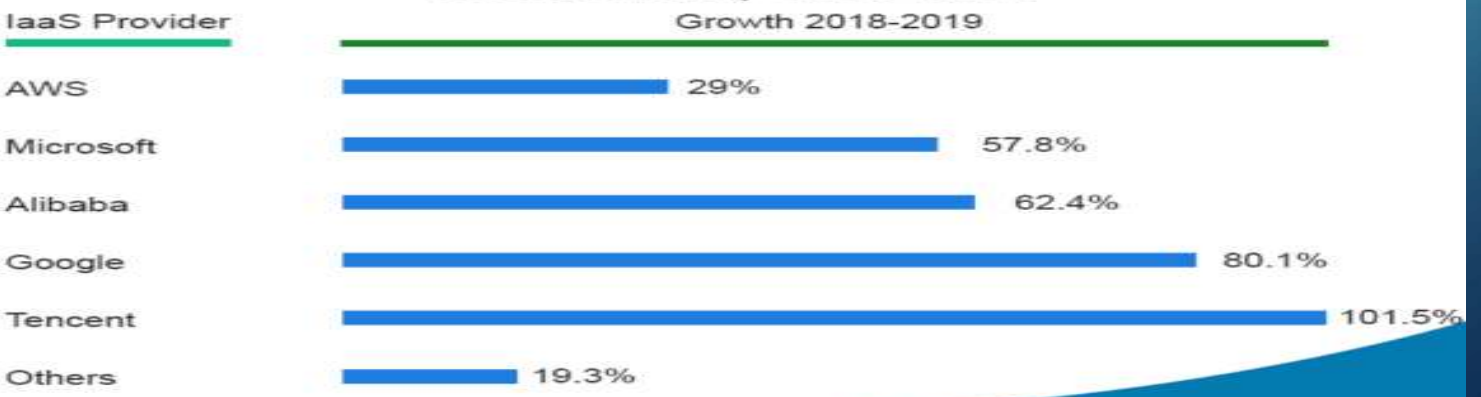
- Enterprises comprising of many servers can act as an IaaS provider such as Facebook, Orkut and Twitter.
- IaaS is very useful for beginners, who are not in a position to predict the success rate of their application.
- IaaS customers can choose between different OS, databases and platforms.
- IaaS providers in India are Amazon, Rackspace, Joyent, GoGrid, Verizon Teeremark and Rightscale. NetMagic Solutions and InstaCompute (from Tata Communications)

Infrastructure as a Service

Worldwide IaaS Public Cloud Services Market Share, 2018-2019



Worldwide IaaS Public Cloud Services Growth rate, 2018-2019



-Source: Gartner (August 2020)

TOP IAAS VENDORS

FILECLOUD

filecloud.com

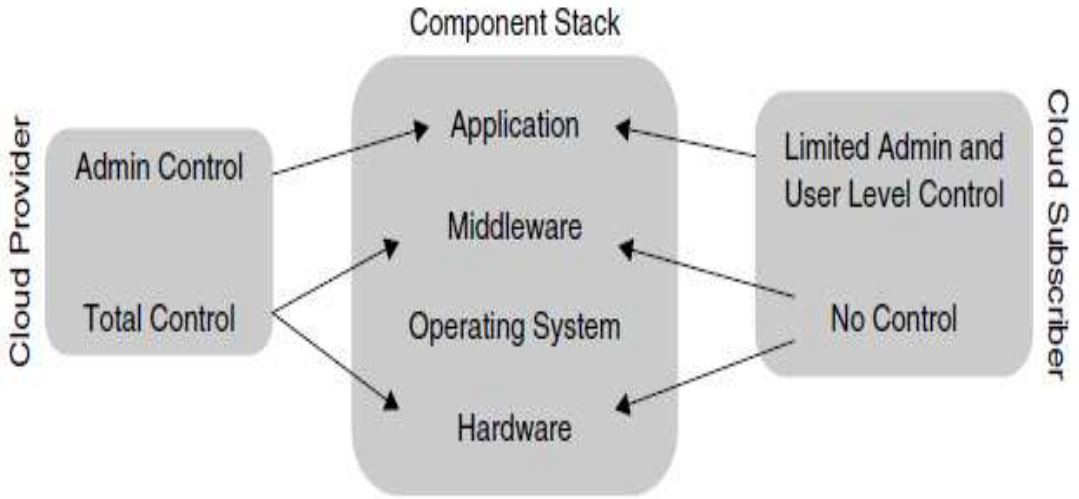


Figure 4.3 SaaS Component Stack and Scope of Control

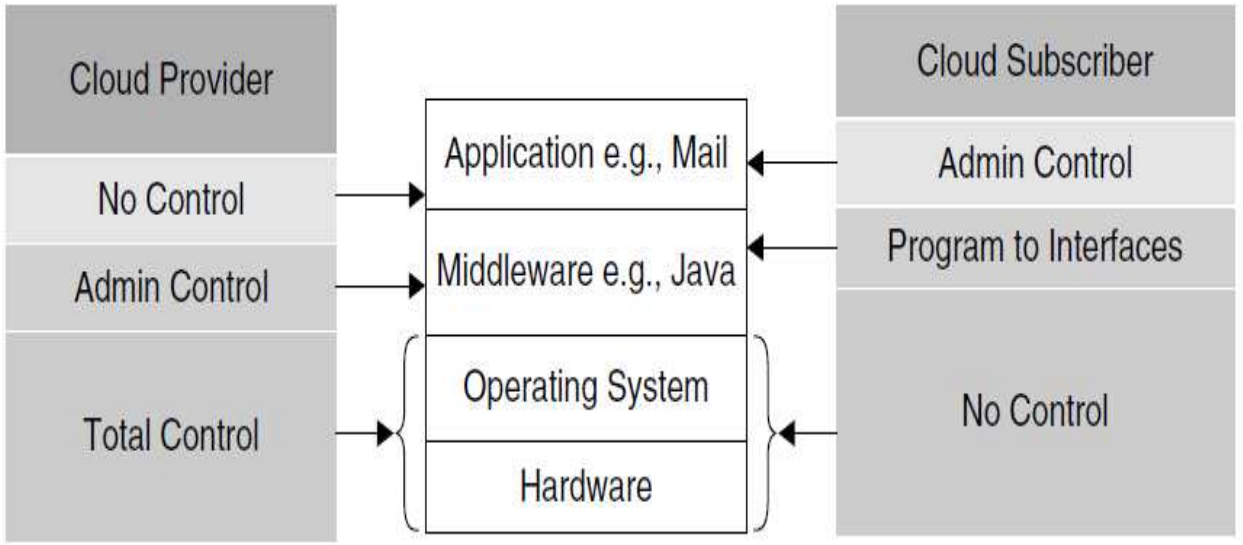


Figure 4.4 PaaS Component Stack and Scope of Control

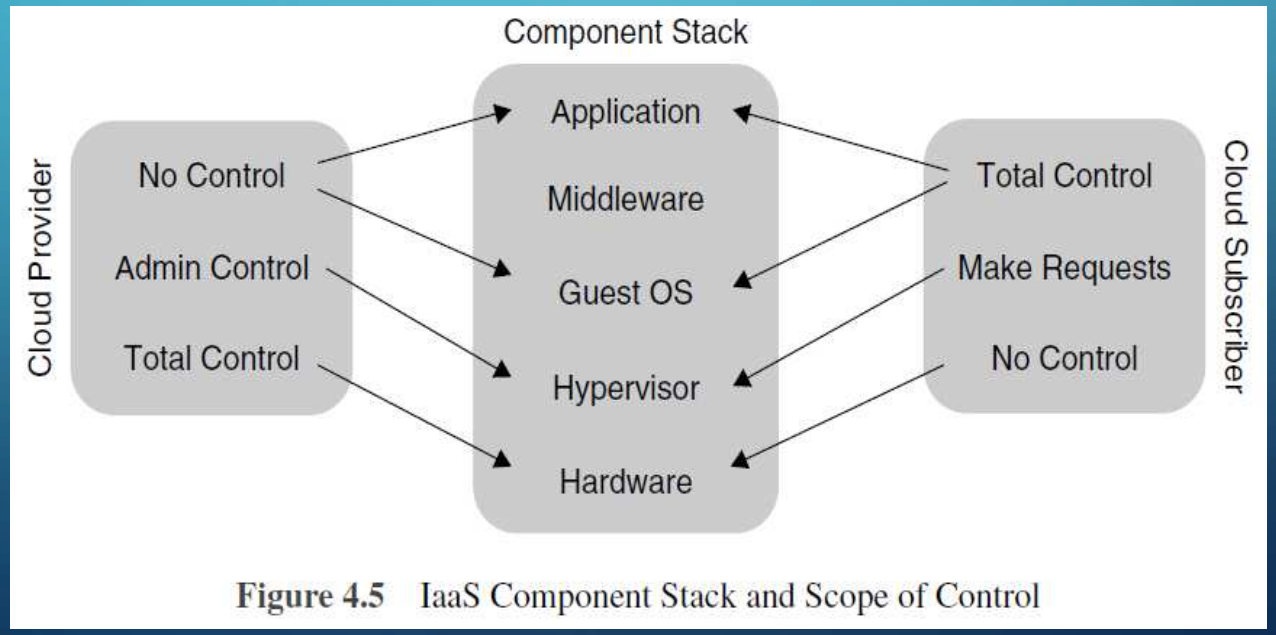


Figure 4.5 IaaS Component Stack and Scope of Control

IaaS vs. PaaS vs. SaaS Examples

IaaS	PaaS	SaaS
Amazon Web Services	Google App Engine	HubSpot
Google Cloud	Red Hat OpenShift	JIRA
Microsoft Azure	Heroku	Dropbox
IBM Cloud	Apprenda	DocuSign

HubSpot

Cloud Service Models

- Diagram
- The levels of service provided by each service model
- Service models are categorized into five types:

1. Business as a service
2. Software as a service
3. Platform as a service
4. Infrastructure as a service
5. Management as a service

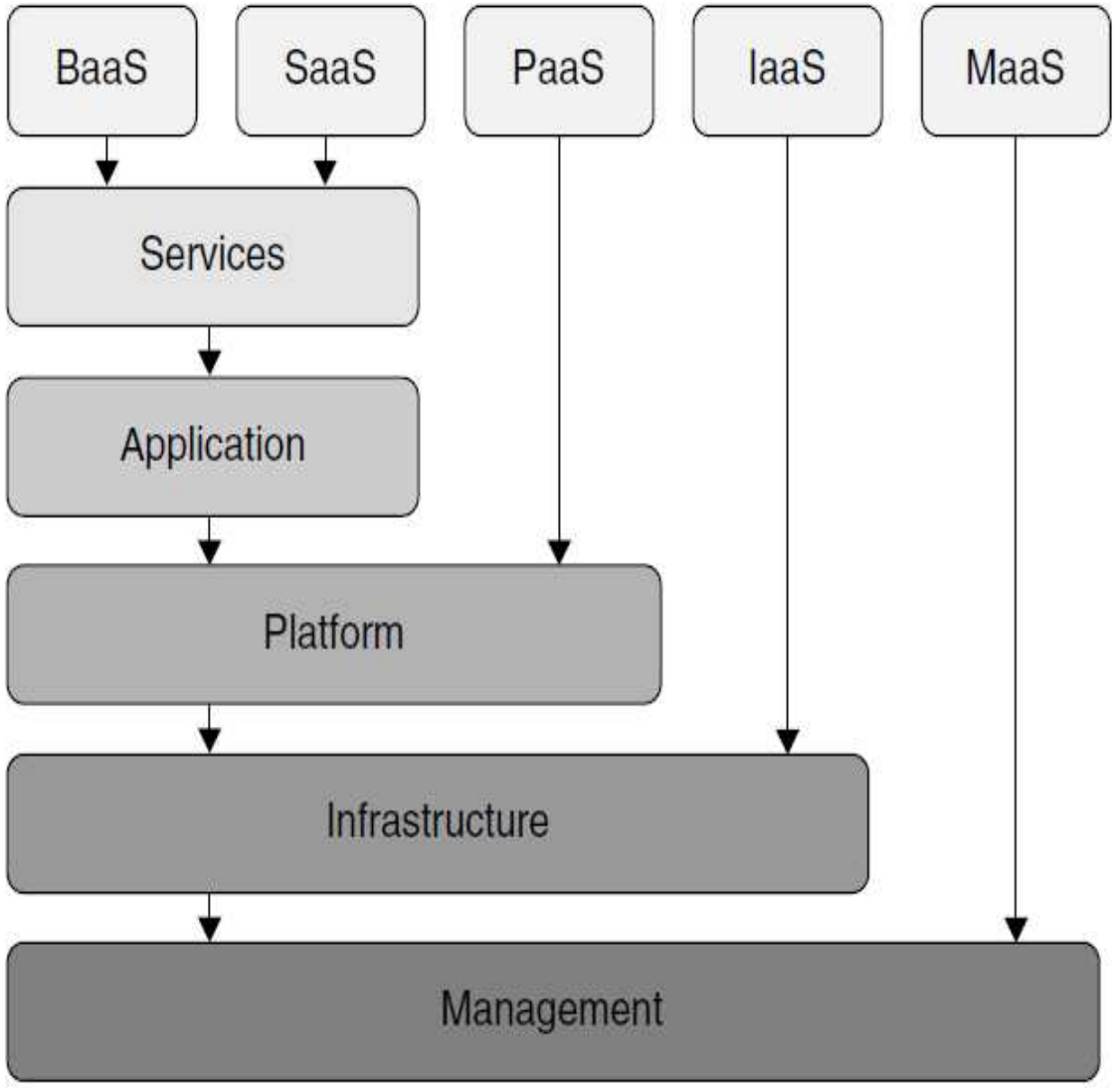


Figure 4.6 Cloud Service Models Comparison

Other aspects of cloud service models are as follows:

- It provides management as a part of the service. Managing multiple services, service models and on-premise applications and systems are management functions of large organizations.
- An infrastructure service from a cloud service provider, which can be built on top of your applications and services, and if a development platform is required, you can build this on the infrastructure service as well.
- A platform service includes the required infrastructure service to support the platform.
- An application (software) service includes the overall infrastructure and platform services to support the application.
- Business process systems facilitate the development of business processes including business process inventory, definition, development, deployment, management and measurement.

CLOUD DEPLOYMENT MODELS

- The cloud is a simplified representation of the convoluted, internet-worked systems and attachments that form the Internet.
- Private and public clouds are defined based on their relationship and as a subset of the Internet, and also it is referred as internal or external clouds.
- The differentiation is based on the relationship of the cloud with the enterprise.

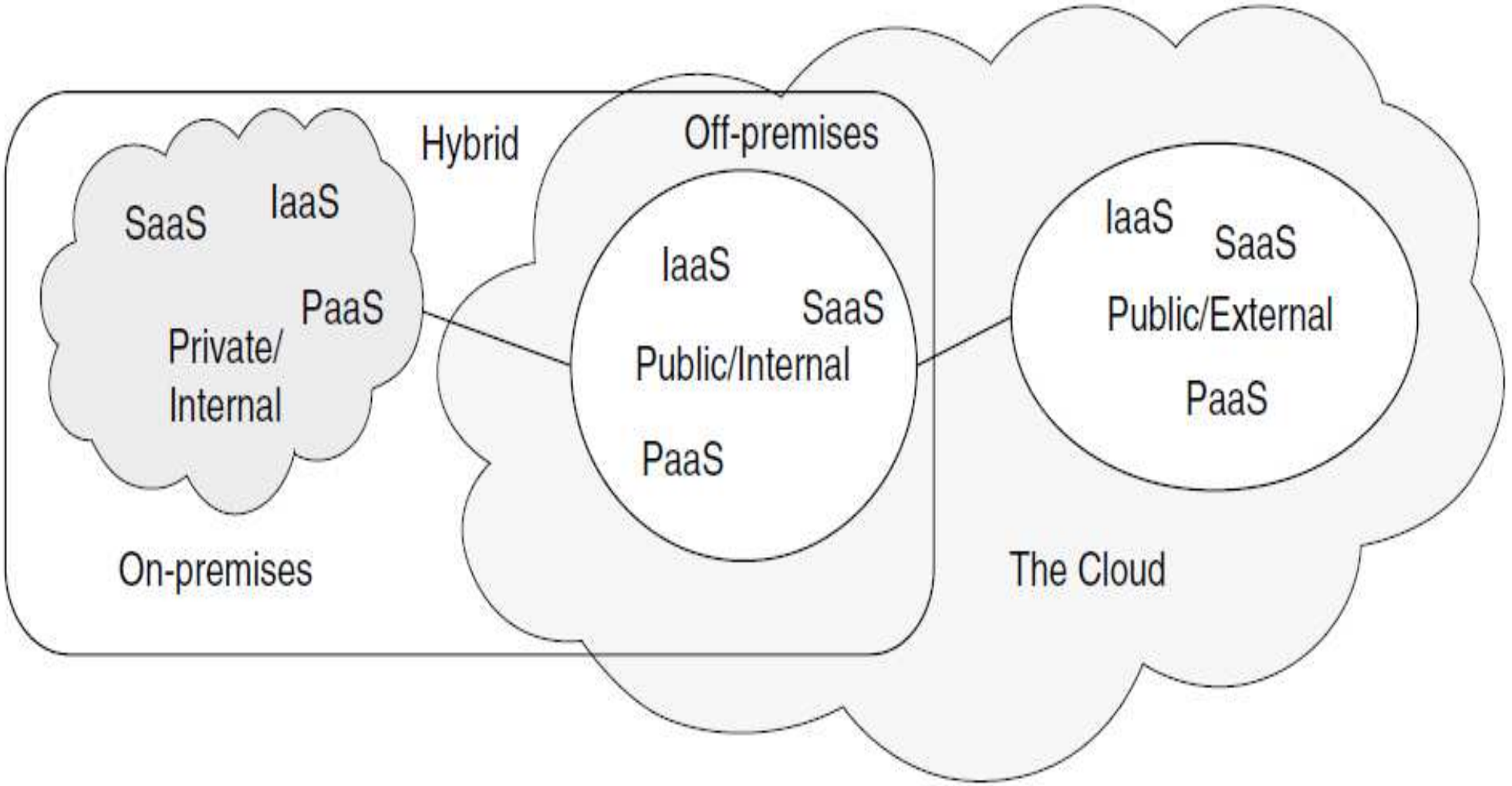


Figure 4.7 Cloud Deployment Models

Types of Cloud Computing

- Cloud computing can be classified into four types based on the location of the cloud:

1. Public cloud: This computing infrastructure is hosted at the vendor's workplace. The end user cannot view the infrastructure. The computing infrastructure is shared between companies.

2. Private cloud: Here the computing infrastructure is dedicated to the customer and is not shared with any other companies. They are costly and highly secure than public clouds. Private clouds may be hosted externally as well as in their own premise hosted clouds.

3. Hybrid cloud: Organizations can submit less valued applications in public cloud and high valued applications in the private cloud. The combination is known as hybrid cloud. Cloud bursting is used to define a system where the organization uses its own infrastructure for normal usage and cloud is used for peak times.

4. Community cloud: The cloud infrastructure is shared between the companies of the same community. For example, all the government organizations in a city can share the same cloud but not the non-governmental organizations.

Public Cloud

- A public cloud is based on the standard cloud computing model, where the service provider makes the resources such as storage and applications available to the public over the WWW.
- These services may be free or on a pay-per-usage model.
- The advantages of using a public cloud computing service are as follows:
  - Inexpensive and easy to setup
  - Scalability
  - No resources are wasted
- Examples are IBM’s Blue Cloud, Amazon Elastic Compute Cloud (EC2), AppEngine, Sun Cloud and Windows Azure Services Platform.

Drawbacks of public cloud

The public cloud does come with limitations:

- **Lack of cost control.** The total cost of ownership (TCO) can rise exponentially for large-scale usage, specifically for midsize to large enterprises.
- **Lack of security.** Public cloud is the least secure, by nature, so it isn’t best for sensitive mission-critical IT workloads.
- **Minimal technical control.** Low visibility and control into the infrastructure may not meet your compliance needs.

Private Cloud (Internal Cloud or Corporate Cloud)

- Private cloud is a proprietary computing model that provides services to users who are behind a firewall.
- Advances in distributed computing and virtualization allowed administrators of network and data centres to provide effective services that meets the needs of their ‘end users’ within the organization.

Drawbacks of private cloud

The private cloud has drawbacks that might limit use cases:

- **Price.** The private cloud is an expensive solution with a relatively high TCO compared to public cloud alternatives, especially for short-term use cases.
- **Mobile difficulty.** Mobile users may have limited access to the private cloud considering the high security measures in place.
- **Scalability depends.** The infrastructure may not offer high scalability to meet unpredictable demands if the cloud data center is limited to on-premise computing resources

What is hybrid cloud?

- The hybrid cloud is any cloud infrastructure environment that combines both public and private cloud solutions.
- The resources are typically orchestrated as an integrated infrastructure environment.
- Apps and data workloads can share the resources between public and private cloud deployment based on organizational business and technical policies around aspects like:
  - Security
  - Performance
  - Scalability
  - Cost
  - Efficiency

Advantages of hybrid cloud

- **Policy-driven option.** Flexible policy-driven deployment to distribute workloads across public and private infrastructure environments based on security, performance, and cost requirements.
- **Scale with security.** Scalability of public cloud environments is achieved without exposing sensitive IT workloads to the inherent security risks.
- **Reliability.** Distributing services across multiple data centers, some public, some private, results in maximum reliability.
- **Cost control.** Improved security posture as sensitive IT workloads run on dedicated resources in private clouds while regular workloads are spread across inexpensive public cloud infrastructure to tradeoff for cost investments

Drawbacks of hybrid cloud

Common drawbacks of the hybrid cloud include:

- **Price.** Toggling between public and private can be hard to track, resulting in wasteful spending.
- **Management.** Strong compatibility and integration is required between cloud infrastructure spanning different locations and categories. This is a limitation with public cloud deployments, for which organizations lack direct control over the infrastructure.
- **Added complexity.** Additional infrastructure complexity is introduced as organizations operate and manage an evolving mix of private and public cloud architecture.

bmc

Cloud Comparison

Key benefits & drawbacks of cloud computing types

Public Cloud	Private Cloud	Hybrid Cloud
No maintenance costs	Dedicated, secure	Policy-driven deployment
High scalability, flexibility	Regulation compliant	High scalability, flexibility
Reduced complexity	Customizable	Minimal security risks
Flexible pricing	High scalability	Workload diversity supports high reliability
Agile for innovation	Efficient	Improved security
Potential for high TCO	Expensive with high TCO	Potential for high TCO
Decreased security and availability	Minimal mobile access	Compatibility and integration
Minimal control	Limiting infrastructure	Added complexity

Benefits Drawbacks

PROS AND CONS OF CLOUD COMPUTING

- Risks in the Cloud
- Cloud Storage as Service: Pros and Cons
  - ✓ Storage services based on cloud computing cuts cost
  - ✓ Increase in data transfer (bandwidth) : main concern
  - ✓ Usage of bandwidth and its charge exceeds the cost incurred for storage
  - ✓ security reasons
  - ✓ cheaper in cost

CC AND SERVICES: PROS AND CONS

1. Centralized Data Storage in Cloud Computing:

- Pros: All of your data, applications and software reside on centralized servers, which can be accessed from anywhere, any time and from any device.
- Cons:
  - ✓ Everyone may not be comfortable to share all their confidential data and applications on a third party server.
  - ✓ Accessing of the data is not possible if the Internet is not connected. There is no option to work offline in case of connectivity failure.
  - ✓ Also, there may be limits to the amount of data a customer can store on these servers, especially for those using shared servers.
  - ✓ The speed and bandwidth usage will also be limited for shared server.

CC AND SERVICES: PROS AND CONS

2. Cloud Servers Maintenance and Security

- Pros: The end user do not have to maintain the hardware, software and all the security and antivirus software updates, the responsibility lies with the service provider totally.
- Cons: As the whole loads of data and applications of customers are centralized , in case of a cyber attack or hacking the entire data is susceptible to easy access.

CC AND SERVICES: PROS AND CONS

3. Data Access and Network Connectivity :

- Pros: It offers the end users to use the utmost mobility without bothering about bearing their burdens of data from one location to another by any hardware.
- Cons: The unavailability of connectivity may leave users with nothing to do as they will lose access to all the latest data and applications when the connection remains down.

CC AND SERVICES: PROS AND CONS

4. Cost Factor :

Pros:

- ✓ Beneficial for corporates and multinationals
- ✓ can save substantially on their operation costs,
- ✓ can also save a lot on hiring huge manpower and technical experts for providing hardware and software supports.

Cons:

- ✓ It may requires a detailed analysis to understand the real cost saving, if any.
- ✓ Major corporates and companies are concerned more on speedy access the data, security and availability
- ✓ They will have to look for dedicated server options rather than shared servers, which will only add to the cost rather than cutting it down.

CC AND SERVICES: PROS AND CONS

5. Cloud Servers Data Backup and Availability:

- Pros: Retaining a back-up of data is also a service provider’s responsibility. It means that the back-up should be fool-proof enough for the user in terms of losing data or missed back-up routines.
- Cons:
  - ✓ centralized back-ups
  - ✓ There is a chance of losing the data updated during the period of taking two consecutive back-ups, because the back-up schedule of the customer’s plan may vary.
  - ✓ More so, since the same operator has the back-up responsibility, should there be some hiccups in their back-up process.
  - ✓ This can prove quite fatal to customers relying only on their service providers for furnishing of data.

Points covered
Part II Cloud Service Models

- ✓ SaaS
- ✓ PaaS
- ✓ IaaS
- ✓ Storage

Cloud Lifecycle

- Cloud lifecycle management provides:
  - Ease in administrating cloud and service portal
  - Manageable service
  - Established multi-tenancy
  - Include performance and capacity management
  - Support heterogeneity

Working Group

- The objectives of Cloud Lifecycle working group are as follows:
  - To identify questions related to cloud lifecycles.
  - To maximize the efforts of the investigator by answering the questions.
  - To make understanding easy for cloud lifecycle process by prioritizing the strategies and observational data.

- CC: an effective model which enables convenient on-demand network access for the shared resources thus reducing the burden of the management.
- Scope of CC : to offer scalable and inexpensive on-demand computing infrastructures with high quality services.
- A cloud engineering discipline has its own lifecycle model for a systematic and scientific development of the cloud known as *cloud development lifecycle model [CDLC].*

The Cloud Life Cycle (CDLC)

- The repeated life cycle model for growth, deployment and delivery of cloud
- Cloud is organized in a linear manner and every phase is processed individually. Therefore, it is the most simplest and flexible process model.
- The outcome of the one phase of CDLC becomes input to another phase.
- In this model, a cloud environment development begins with requirement and analysis phase.
- After effectively demonstrating and understanding the requirement, the architect phase starts.
- The quality assurance and verification phase continues after completion of implementation and integration, monitor and migrate.
- Audit begins after completion of the deployment, testing, maintenance and improvement.

Phases of CDLC

- Diagram
- The different activities and feedback of CDLC in achieving the desired cloud
- In this lifecycle model, feedback is used in which a phase gives the necessary information to the preferred upper phase.
- Among these phases, the second, fourth, fifth and sixth phase give response to the first phase.

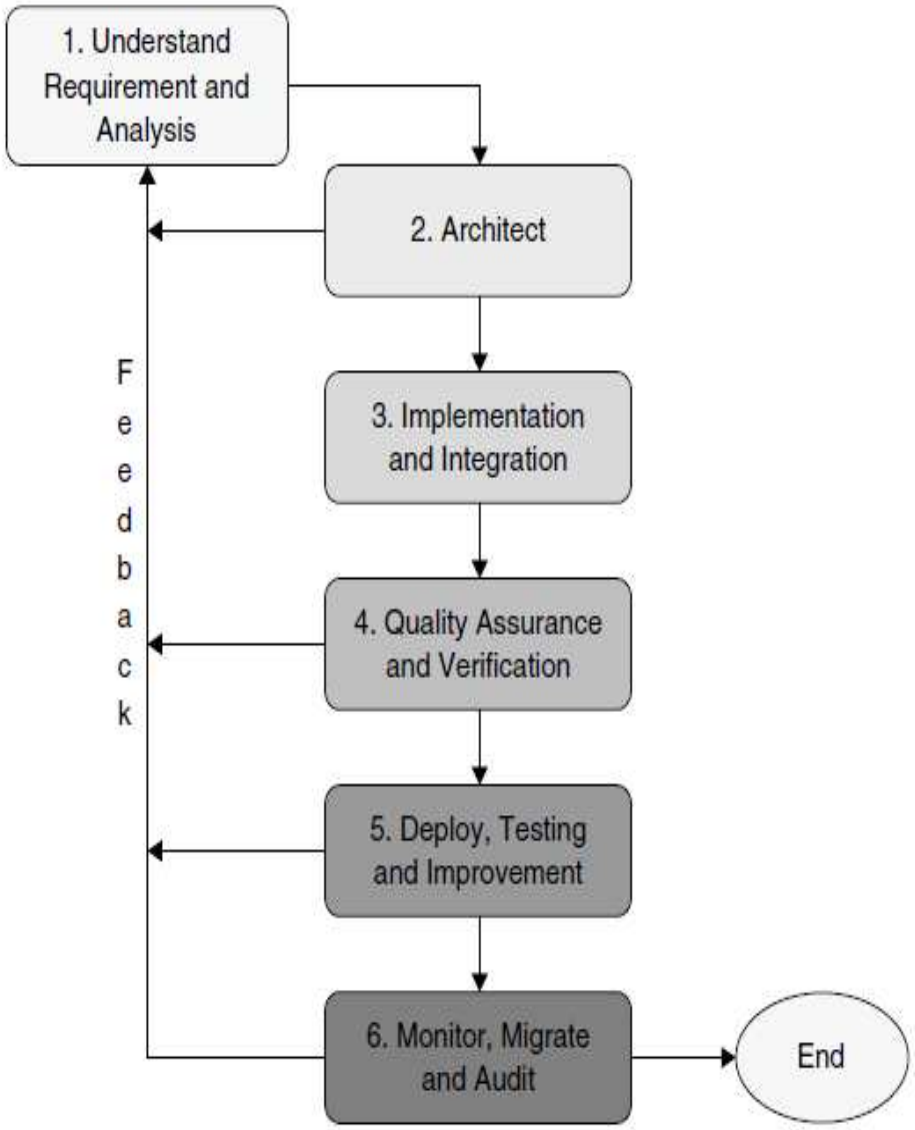


Figure 5.1 The Cloud Development Lifecycle

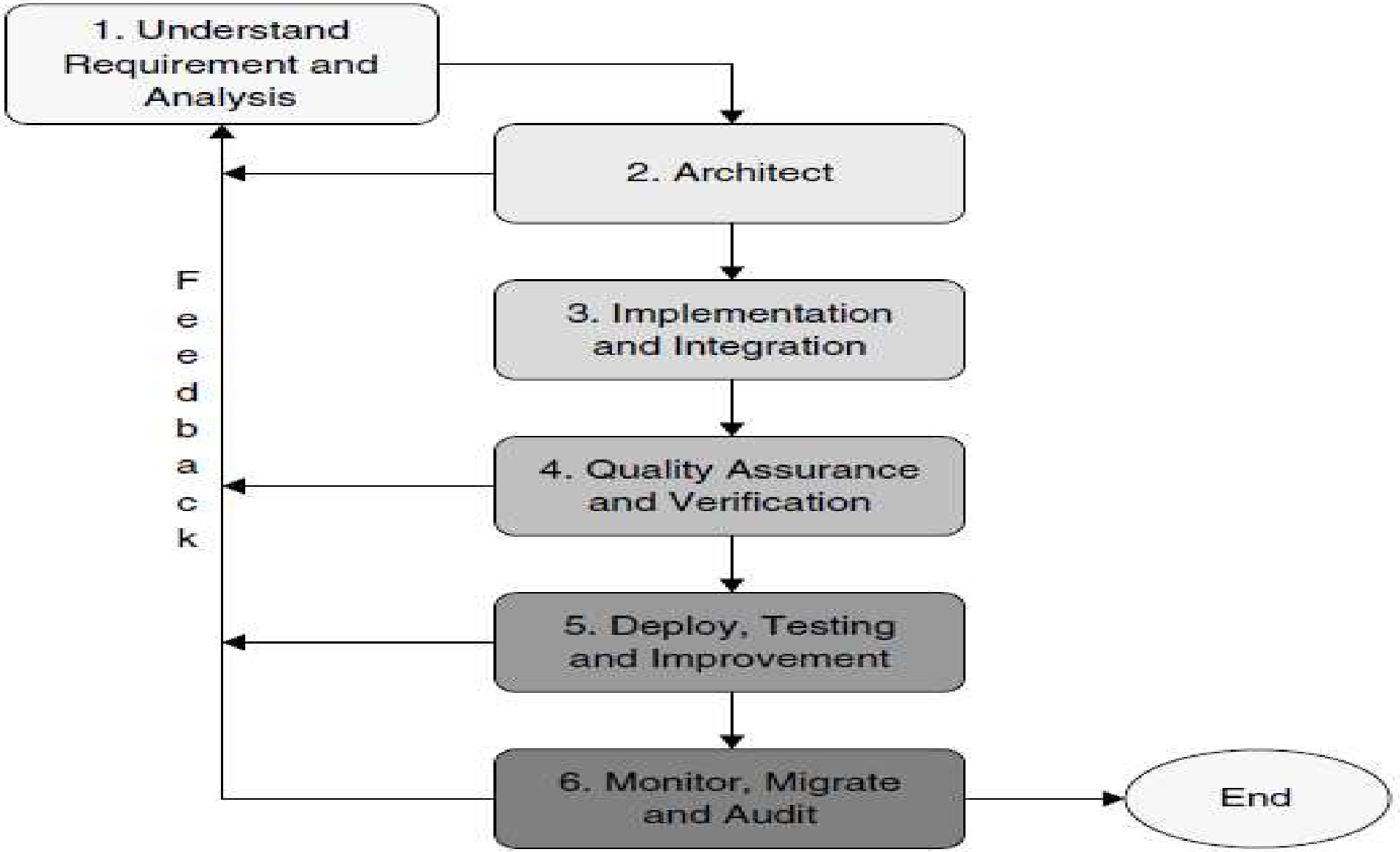


Figure 5.1 The Cloud Development Lifecycle

Phase I : Requirement and Analysis

- Requirement and analysis method is used to evaluate and understand the requirements of an end user.
- This is done by taking up the significant complaints from the user, network solution, management and customers of the present system.
- Once these complaints are thoroughly studied, a tentative cloud computing solution is arrived, which minimizes the deficiencies and meets one’s requirements.
- Solution such as computing cost, scalability, organizational agility and benefits can be assessed through this phase.
- CC results : privacy, security, maturity of the organization, risk involvement, reliability, performance and portability
  - aspects to be considered before adoption.

Phase 2 : Architect

- The structural behavior of the cloud architecture gives solution to the cloud system
- Comprises of on-premise resource, cloud resources, cloud services, cloud middleware, software components, data server location and externally visible properties of data server location
- Diagram
- The components of cloud architecture are reference architecture, technical architecture and deployment and operational architecture

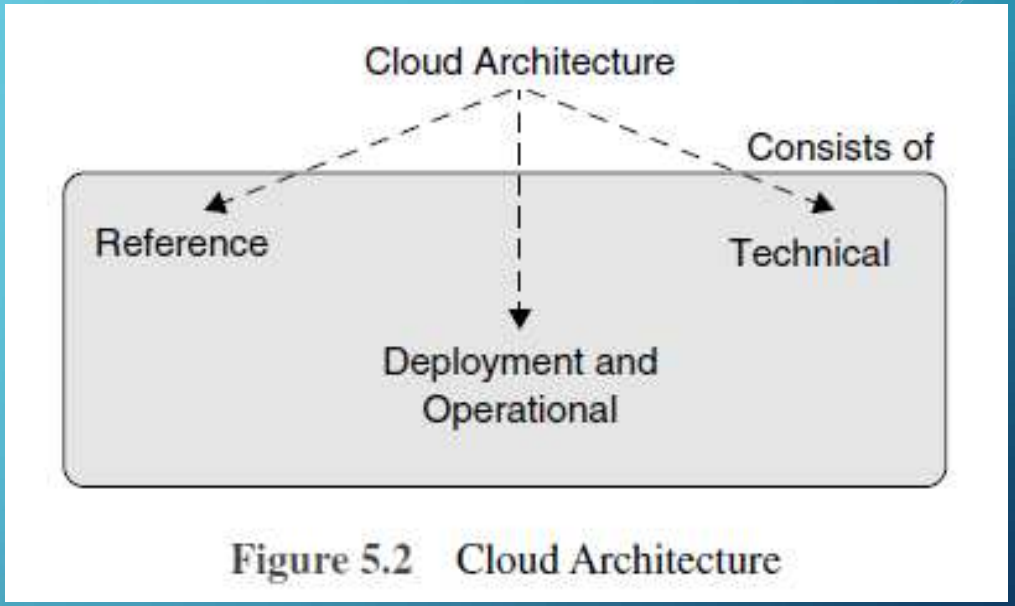


Figure 5.2 Cloud Architecture

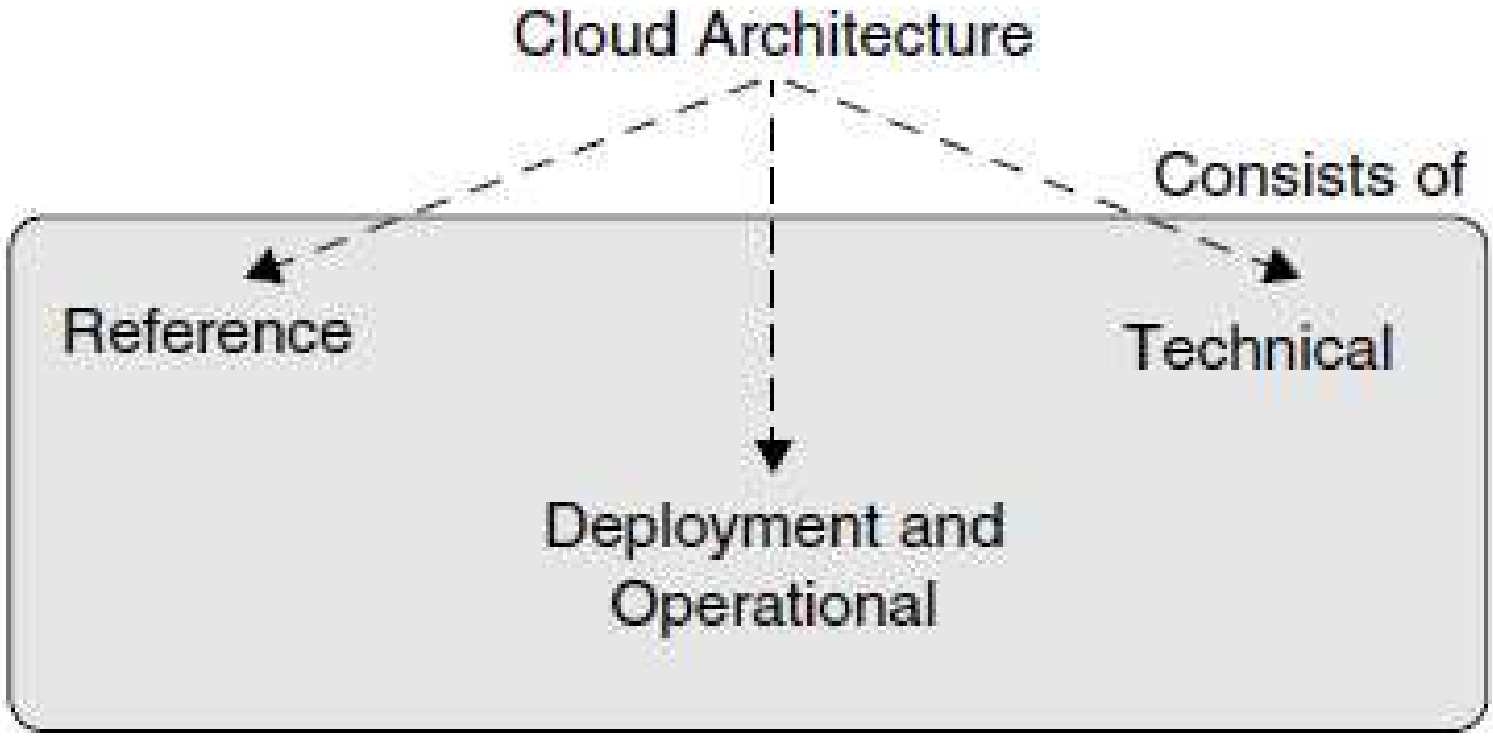


Figure 5.2 Cloud Architecture

Phase 3: Implementation and Integration

- Third phase of CDLC is the actual formation and enablement of the private, public, community, hybrid, inter and hosted cloud solutions to a computing problem.

Phase 3: Implementation and Integration Implementation:

- Events such as privacy, protection, regular, legality, mentality, inter-machine message and privacy theory are addressed within the implementation phase.
- Two components of cloud computing are implemented in this phase.
  1. The implementation of file system
  2. The implementation of map-reduce system
- The file system is the key component of the system to support massive data storage and management.
- The implementation of map-reduce system also performs the task of integrating the different cloud solutions in one cloud environment.
- This phase deploys different resources, services and applications to the cloud.
- This phase also gives training to the end user so that he/she can accept the new network solution easily.

Phase 3: Implementation and Integration
Integration:

- Intermediate between the source and target systems for extracting data, mediating and publishing it.
- Large organizations integrate into cloud environment with their available systems.
- Five possibilities and recommendations for integrating into cloud effectively :
    1. Plan and set realistic goals
    2. Learn from other’s experience
    3. Require IT specialist team
    4. Address security concerns
    5. Maximize connectivity options

Phase Iv:
Quality Assurance and Verification

- In this phase, cloud auditing is done to ensure the quality of the cloud network.
- It also confirms the performance, reliability, availability, elasticity and safety of cloud network at the service level.

Phase v: Deploy, Testing and Improvement

- Different platform service providers drastically reduce the deployment cost of the application by pre-building and pre-configuring a stack of application infrastructure in this phase.

Phase vi: Monitor, Migrate and Audit

- This phase is marked by periodically monitoring the cloud environment and measuring the performance of the system.
- The extra cost and worth that a client incurs moving to cloud from the traditional SOA method and furthermore integration with the existing methods are considered in this phase.

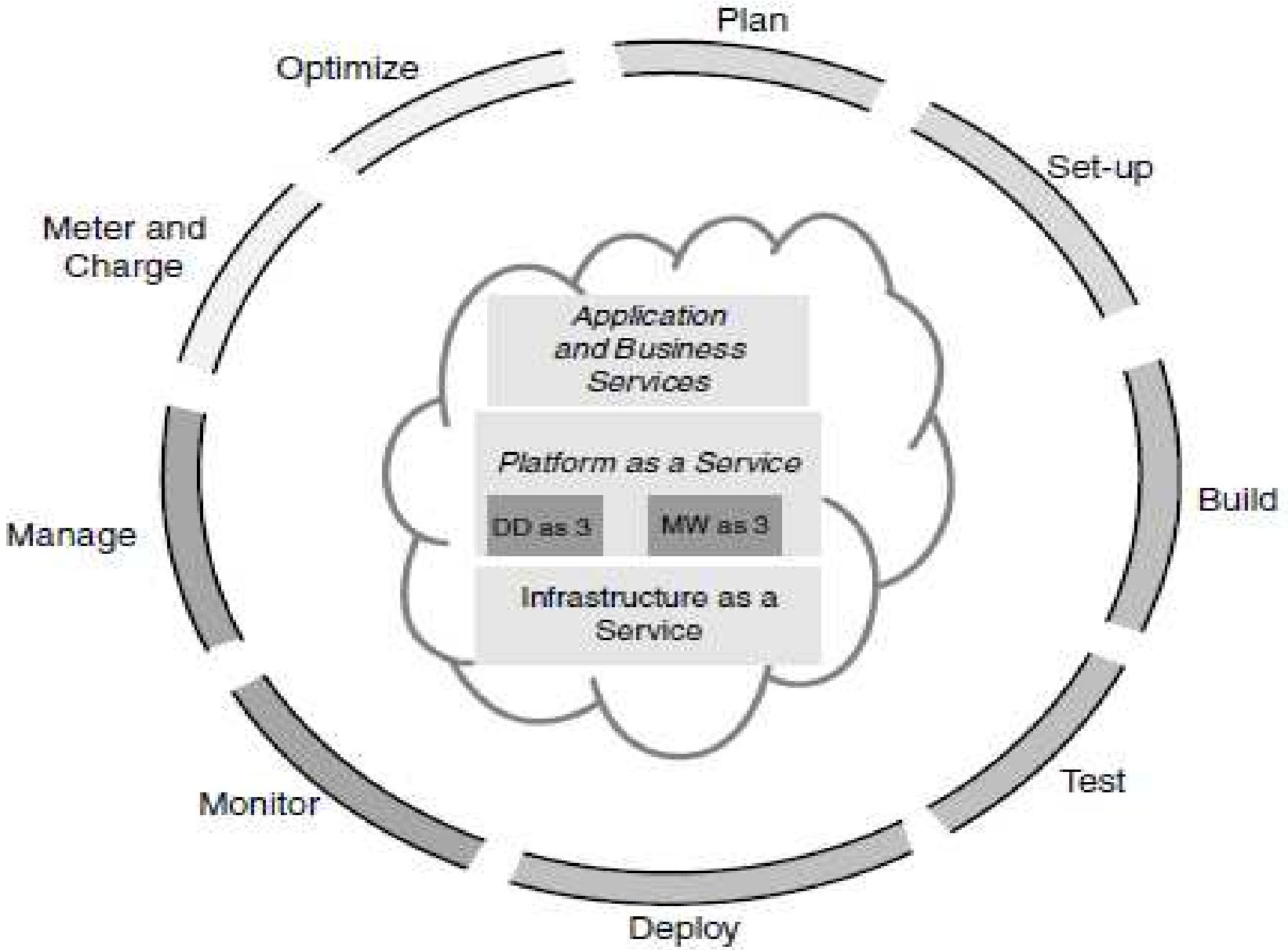


Figure 5.3 The Cloud Lifecycle

Points to cover
Part III Cloud Architecture

- Cloud Computing Logical Architecture
- Developing Holistic Cloud Computing Reference Model
- Cloud System Architecture
- Cloud Deployment Models

ROLE OF CLOUD MODELLING AND ARCHITECTURE

- Cloud Computing Model :
  - supports convenient, on-demand software using the Internet
  - The computing devices used are released after usage without any manual intervention.
  - supports the availability comprising of
    - 5 required characteristics
    - 4deployments
    - 3 service structures

Cloud Computing Model : Necessary Characteristics

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

Cloud Computing Model : Deployment Models

- Private cloud: These are functions within the organization and behind the firewall.
- Community cloud: This cloud infrastructure is common to several organizations.
- Public cloud: This cloud infrastructure is available to public or large industries.
- Hybrid cloud: It is a composite of two and more clouds.

Cloud Computing Model : Service Models

- Cloud software as a service
- Cloud platform as a service
- Cloud infrastructure as a service

REFERENCE MODEL FOR CLOUD COMPUTING

- 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.
- Diagram
- The detailed and generalized version of reference framework

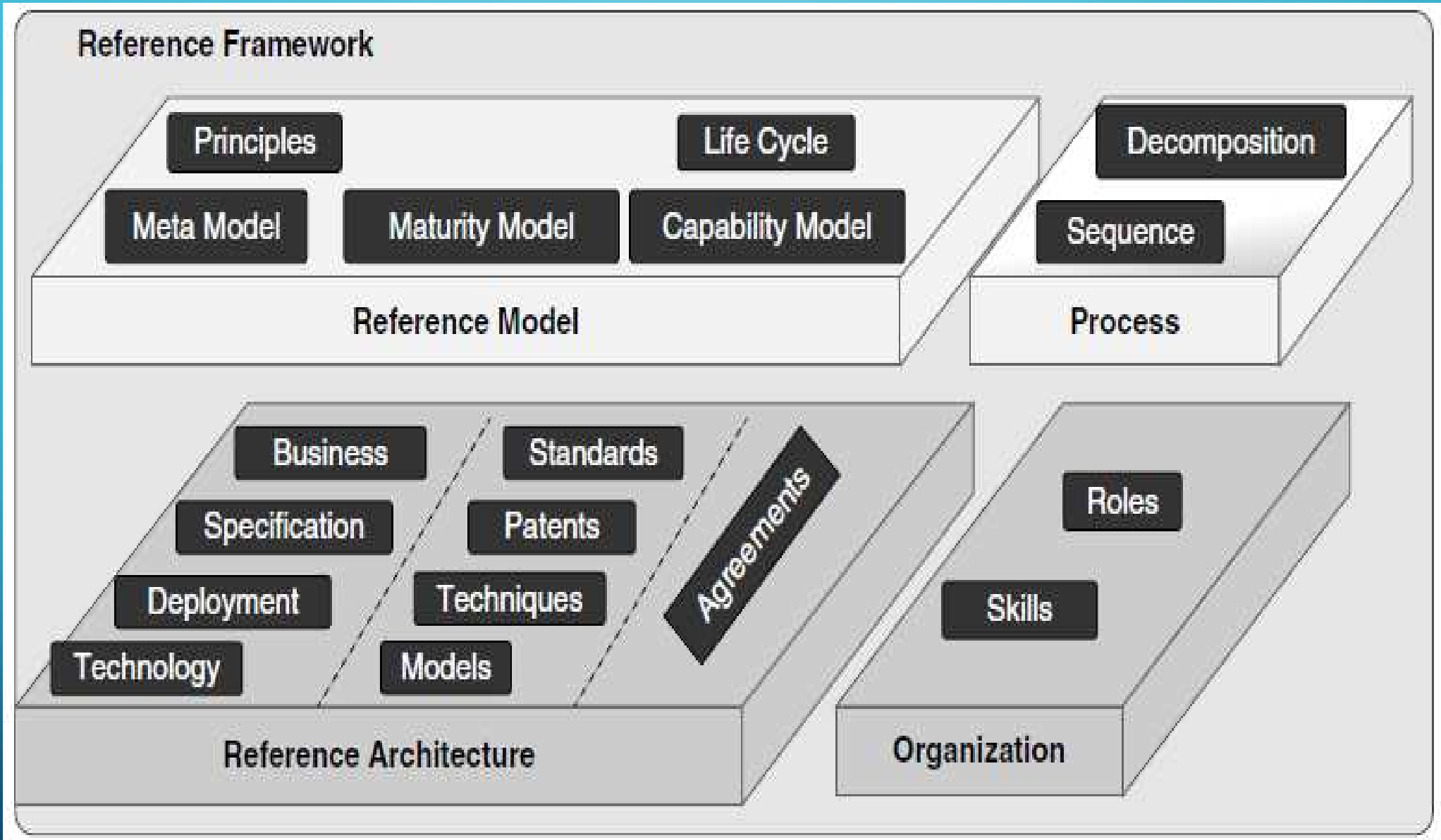


Figure 5.4 Generalized Reference Framework

Generalized Reference framework

- A reference framework consists of reference model, reference architecture, process and organization.
- Reference model takes care of laying foundations in principal and designs models such as meta model, maturity model and capability model.
- Reference architecture is divided into two parts:

1. Views in-terms of business, implementation, deployment and technology
2. Practice in-terms of standards, patterns, deliverables and models

- Process does decomposition of the given job and sequences it.
- Organization specifies the roles and responsibilities of the in-house staff according to their skills.
- The advantage of this framework is that elements can be mapped in different ways, that is, different problem scenarios and solutions, but a single framework.

Reference Architecture, Frameworks and Models for CC

- There are many frameworks and models 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.
    - Ex. 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.

Case Study 1: Cloud Computing Model of IBM

- Diagram
- 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
- Private cloud was built by IBM for their customers

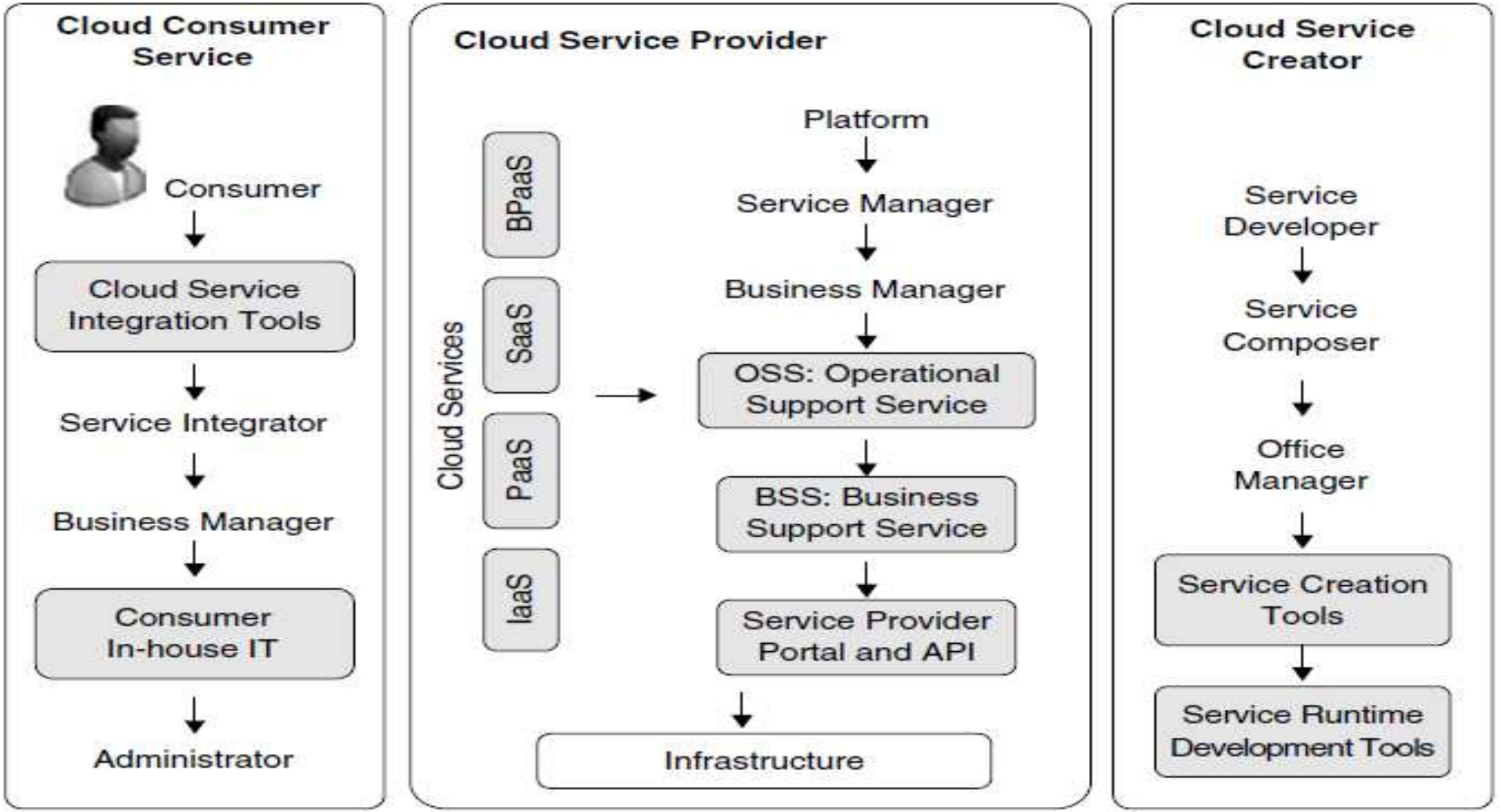


Figure 5.5 Cloud Computing Model of IBM

A Customer-focused Approach

- The architecture has more than 14 user types and their interest varies from creators to end-users in CC.
- ‘Cloud Service Consumer’ comprises of the end-user, service integrator, business manager and administrator function.
- ‘Cloud Service Provider’s part’ consist of services and business manager roles cooperating at the top with the common cloud management policy, while includes deployment architect, security and risk, operations and transition manager and customer care roles.
- ‘Cloud Service Creator’ area includes service component developer, service composer and offering manager roles.

Four types of cloud services in IBM cloud architecture

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.

Four types of cloud services in IBM cloud architecture

3. SaaS: IBM has a number of middleware, which is available ‘as a service ex. LotusLive, 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.

CC Definition

- *Cloud Computing is a type of computing environment, where IT businesses outsource their computing needs, which include software application services to outside vendors when they are in need of computing power or other resources like storage, database, e-mails, etc., which are accessed via WWW.*

POINTS TO COVER
PART III CLOUD ARCHITECTURE

- Cloud Computing Logical Architecture
- Developing Holistic Cloud Computing Reference Model
- Cloud System Architecture
- Cloud Deployment Models

CLOUD COMPUTING LOGICAL ARCHITECTURE

Cloud Computing Architecture

- CC is an Internet-based technique using shared resources available remotely.
- Cloud computing system can be divided into two parts:
  - ✓ front end
  - ✓ back end
- The interconnection between them is done via the Internet.
- Front end is used by the customers and back end refers to the service providers.

- The front end
  - ✓ contains customer’s devices comprising of computers and a network and applications for accessing the back end system, that is, the cloud systems.
  - ✓ refers to the interface through which a customer can make use of the services rendered by the cloud computing system.
- Back end
  - ✓ contains physical devices or peripherals.
  - ✓ Also contains various computer resources such as CPU and data storage systems.
  - ✓ A combination of these resources is termed as cloud computing system.
  - ✓ A dedicated server is used for administration purpose.

Cloud Computing Types

- Public cloud : This is off-premises or external.
- Private cloud: It is an on-premises or internal cloud set-up.
- Hybrid cloud: It is a combination of both public and private clouds

Why do We Need Cloud Computing?

- The main purpose of CC is to save on the consumer’s infrastructure and maintenance cost.
- A consumer has to pay service charges for usage of various resources.
- Moreover, consumers opting for cloud computing technology need not worry about updating software, backups and anti-virus.

Problems with Cloud Computing

- Security
- Privacy

CC Service Architecture

- The following three types of services are available with a cloud service provider

1. Infrastructure as a service: The service provider takes care of the cost for the resources such as servers, equipment for networking, backups and storage.

2. Platform as a service: The provider only renders the platform or solutions for the consumers.

3. Software as a service: The provider will provide the consumers with software applications available in his/her premises.

- Diagram

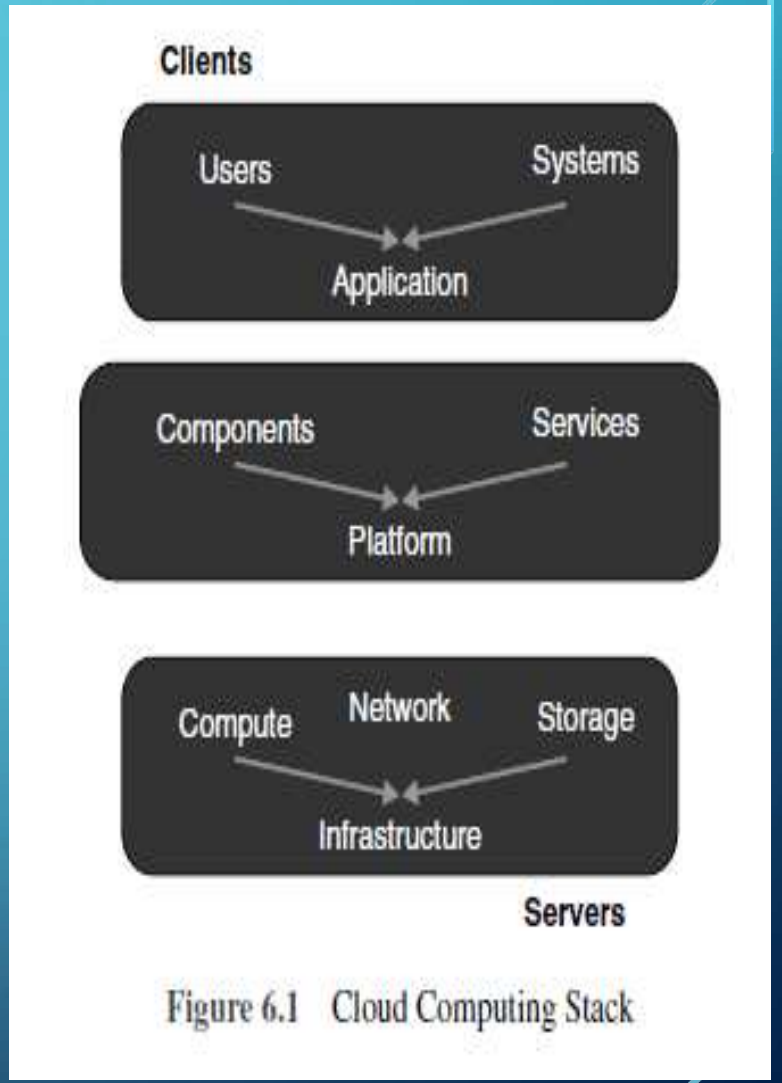


Figure 6.1 Cloud Computing Stack

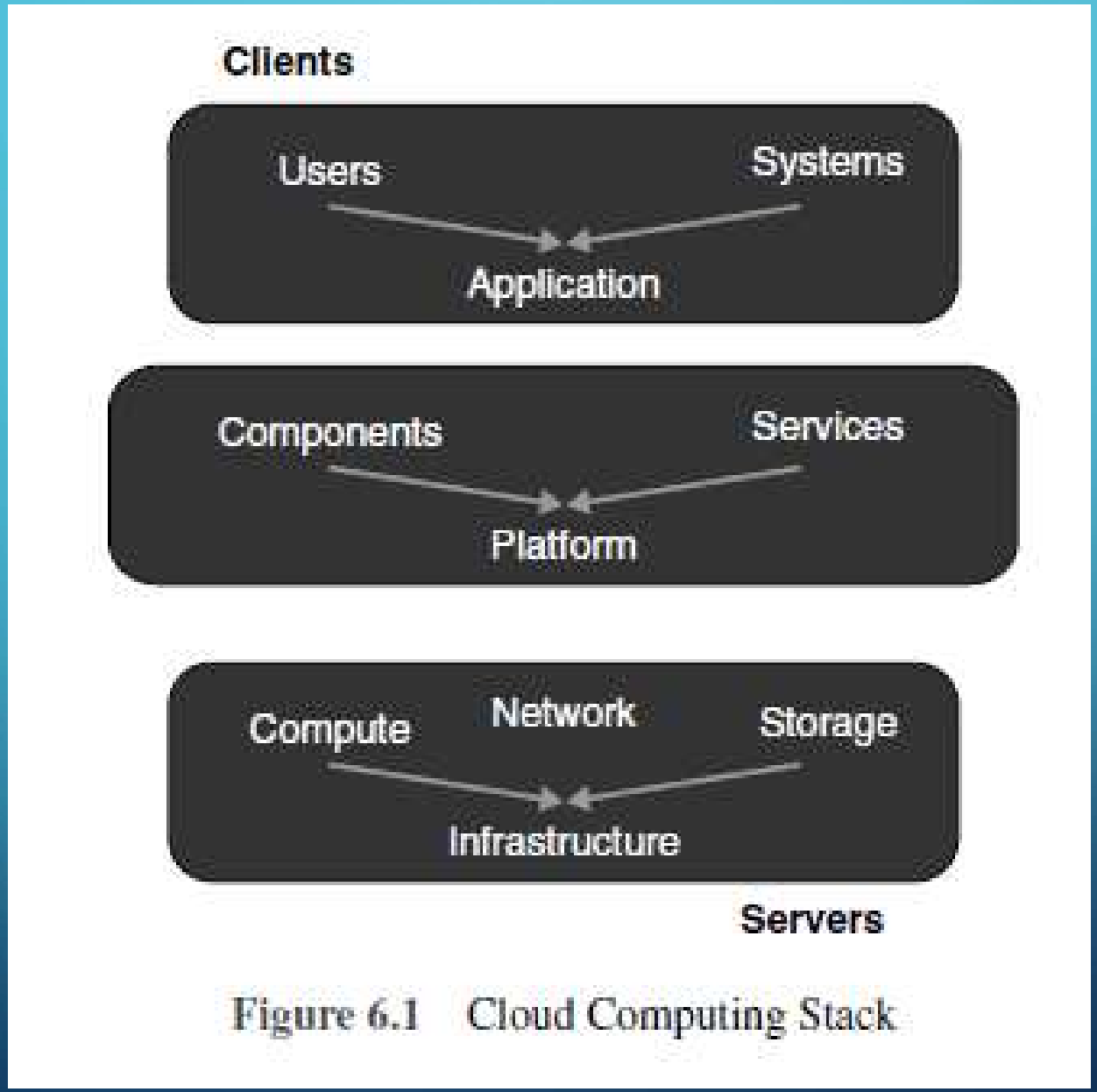


Figure 6.1 Cloud Computing Stack

Understanding CC Architecture Models

- The major CC challenge : there is no defined standard or 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.

Cloud Computing Models (1)

- The potential of CC is interesting and limitless in terms of its applications.
- A simplest CC model :
  - consists of a collection of servers,
    - which are virtualized using a tool
  - appears to be a single pool having many servers
  - Problems : servers are dedicated to a particular set of application
- Cloud architectures use a tool, that deploys the cloud supported applications.
- An example is PaaS model which is used in Salesforce.com.

Cloud Computing Models (2)

- The other model is meant for network providers, who need storage and server technology.
- The providers will render these resources and consumers will create an image or instance and make use of it.
- The original server and storage will be residing in the provider’s premises.
- The full version of CC model uses virtualization technology for making the resources virtual.
- The resources such as network, storage, computing power, etc., are virtualized. Examples are IBM/Google CC model developed by Cisco.

DEVELOPING HOLISTIC CLOUD COMPUTING REFERENCE MODEL

- Cloud Computing: Taking a Complete View
- Complete View of Cloud Management
- Cloud Computing Reference Model

Cloud Computing: Taking a Complete View

- Efficient use of resources
- Pay-per-usage
- Cost effectiveness

Complete View of Cloud Management

- CC not yet utilized with its full potential
- Confusion amongst different delivery models and deployment methods
- Data legislation issues, inability to evaluate service providers
- The five top level research areas for analyzing obstacles in cloud computing:
  1. Optimization in deployment and construction of cloud services
  2. Self-preservation in resource management
  3. Self-management for various cloud services and decision making
  4. Support for service deployment
  5. Market and legislative issues

Cloud Computing Reference Model [CC-RM]

- Facilitates the process of modelling cloud architecture and planning the deployment activities
- Also establishes a foundation for modelling cloud and its architecture, from which an IT organization can plan, architect, model and deploy
- to address business and technical challenges
- *Cloud is not a problem-solving architecture, it is a collection of services, which can be used to solve problems.*

The cloud reference model consists of the following four elements/models:

1. *Cloud enablement model :*
   - describes the various layers of cloud and its advantages for business operations
   - comprises of various CC technologies and solutions for the consumers
2. *Cloud deployment model* (CDM) *:* describes the various cloud models such as private, public, hybrid and community clouds.
3. *Cloud governance and operations model :* defines the requirements for CC such as governance, privacy, security operations, management, support and monitoring.
4. *Cloud ecosystem model (CEM) :*
   - takes cares of development and sustenance
   - consists of cloud providers, consumers, intermediaries and networks.

- The cloud computing reference model has four sub-models:

1. *Cloud virtualization tier :* focuses on the tools that provide hardware and infrastructure virtualization, computing, storage, network and security virtualization
2. *Cloud operating system tier :*
   - focuses on the technologies that enable virtualization of resources as cloud-enabled capabilities
   - provides provisioning, billing and metering, load balancing, resource management, monitoring and management, workflow and orchestration of cloud-enabled resources
3. *Cloud platform tier*: focuses on enabling the PaaS oriented services and includes SOA and Web services concepts
4. *Cloud business tier :* focuses on the various range of business capabilities and business solutions, that are designed and provisioned to consumers as services via the cloud

Cloud Deployment Model (CDM)

- provides an open framework for identifying the necessities and differences of various cloud deployment environments.
- The CDM l and the CEM are key decisions that determine aspects such as security, architectural and management challenges.
- The various CDM scenarios : private internal cloud, public external cloud, hybrid integrated cloud and community cloud.
- The CDM and CEM are central necessities of the CC-RM

Cloud Governance and Operations Model

- helps in making choices in cloud enablement approaches in terms of cloud deployment model
- The primary elements : cloud governance, security and privacy, management and monitoring and operations and support

Cloud Ecosystem Model (CEM)

- the last model in CC-RM
- the physical, logical and virtual environment in which the cloud providers, consumers, solution and technology providers help CC to run smooth and legitimate business and technology trend
- The key elements of CEM : cloud network/dial tone, cloud ecosystem enablement and cloud consumers and cloud providers

CLOUD SYSTEM ARCHITECTURE

Factors to be considered while designing cloud-based architectures :

- *Cost*: Clearly understand the pricing details for various cloud models.
- *Complexity*: Analyze the complexity before customizing the cloud solution and check the requirements thoroughly before deployment.
- *Speed*: Check the speed for cloud model. Speed in terms of advanced CPU architecture, high memory, lowest latency and network infrastructure.
- *Cloud portability*: Check the portability. This allows the consumer to move from one vendor to another without making much changes in the architecture.
- *Security*: Check for the security measurements provided by the vendor.

Example Reference Diagram

Single Cloud Site Architectures

- Diagram
- load balancer, application logic, databases and storage located in the cloud
- The load balancing server, application server and database server in cloud
- If the user is only testing the interactivity between the tiers, he may use this architecture to cut-short the resources costs.
- Dedicated servers are available for each tier of the application which forms a non-redundant architecture.
- For manufacturing industry this kind of architecture is not recommended.

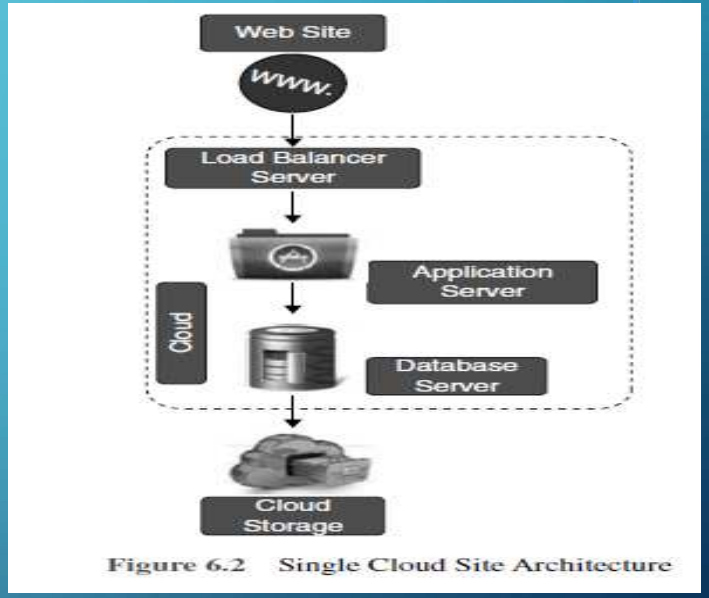


Figure 6.2 Single Cloud Site Architecture

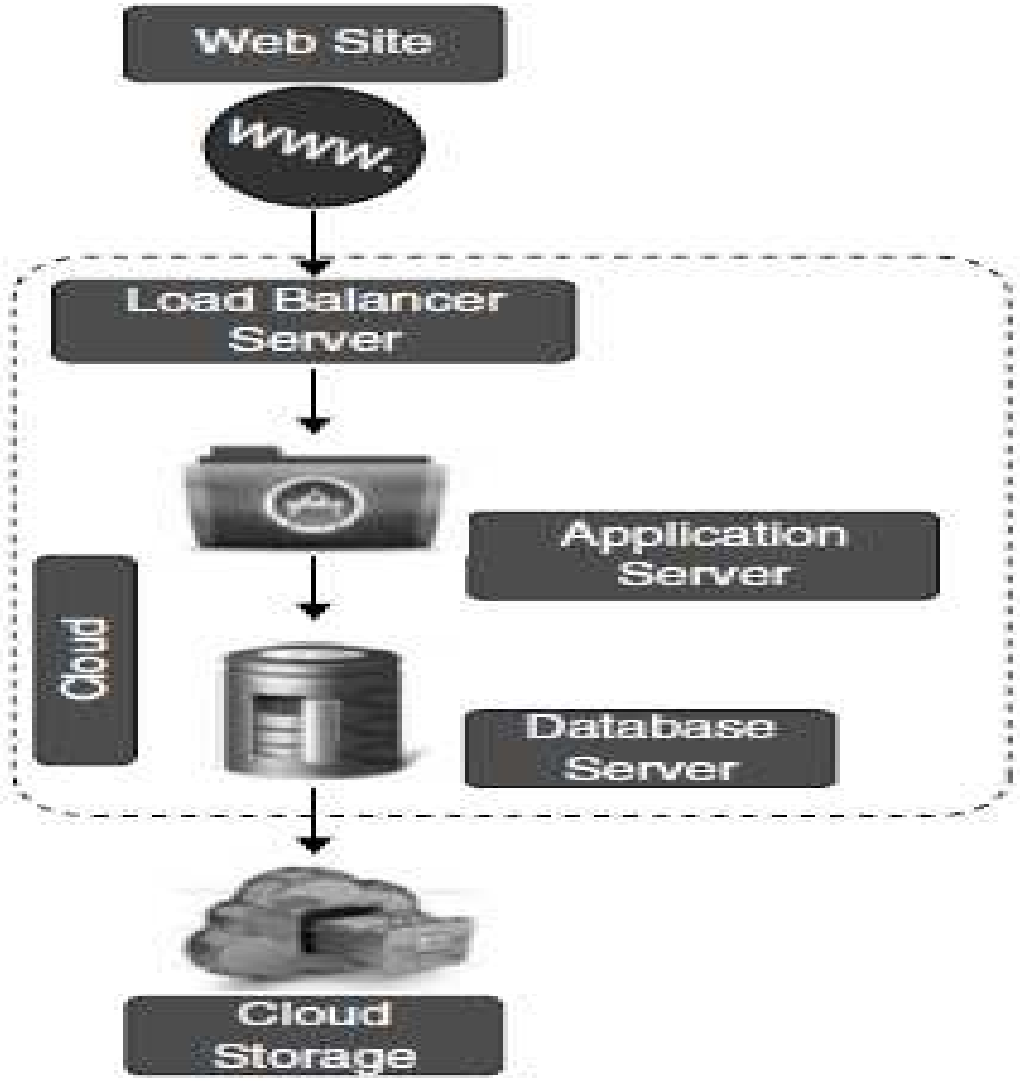


Figure 6.2 Single Cloud Site Architecture

Redundant 3-tier Architecture

- Diagram
- Two servers in load balancer, application and database are available.
- System downtime is reduced while adopting redundant architecture.
- Use of a striped volume set in redundant 3-tier architecture at the database, when it is huge and need faster backups for data storage.

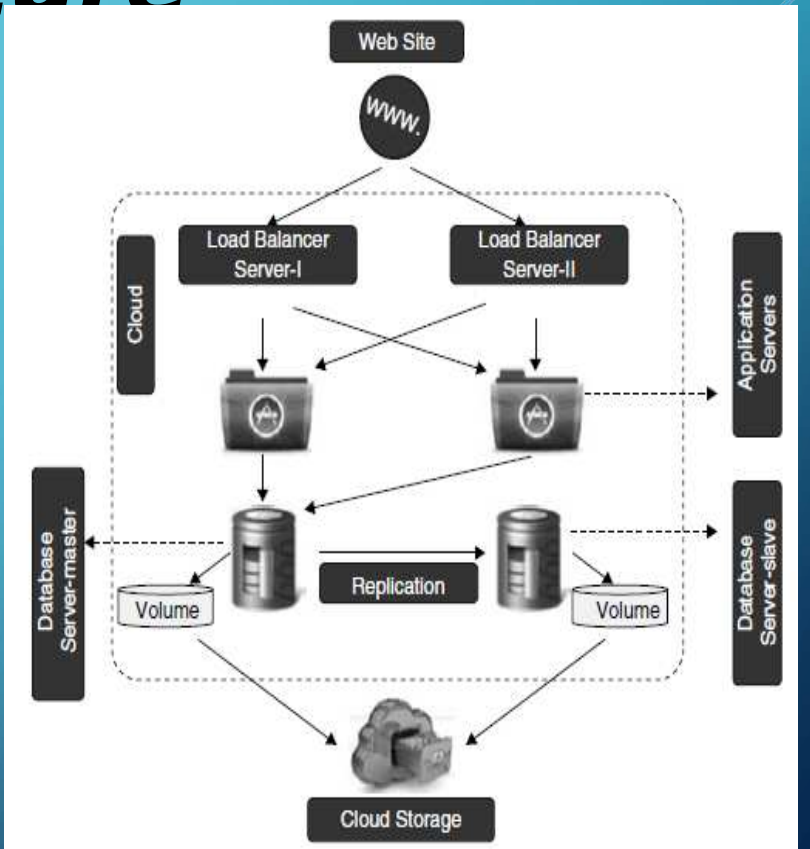


Figure 6.3 Redundant 3-Tier Architecture

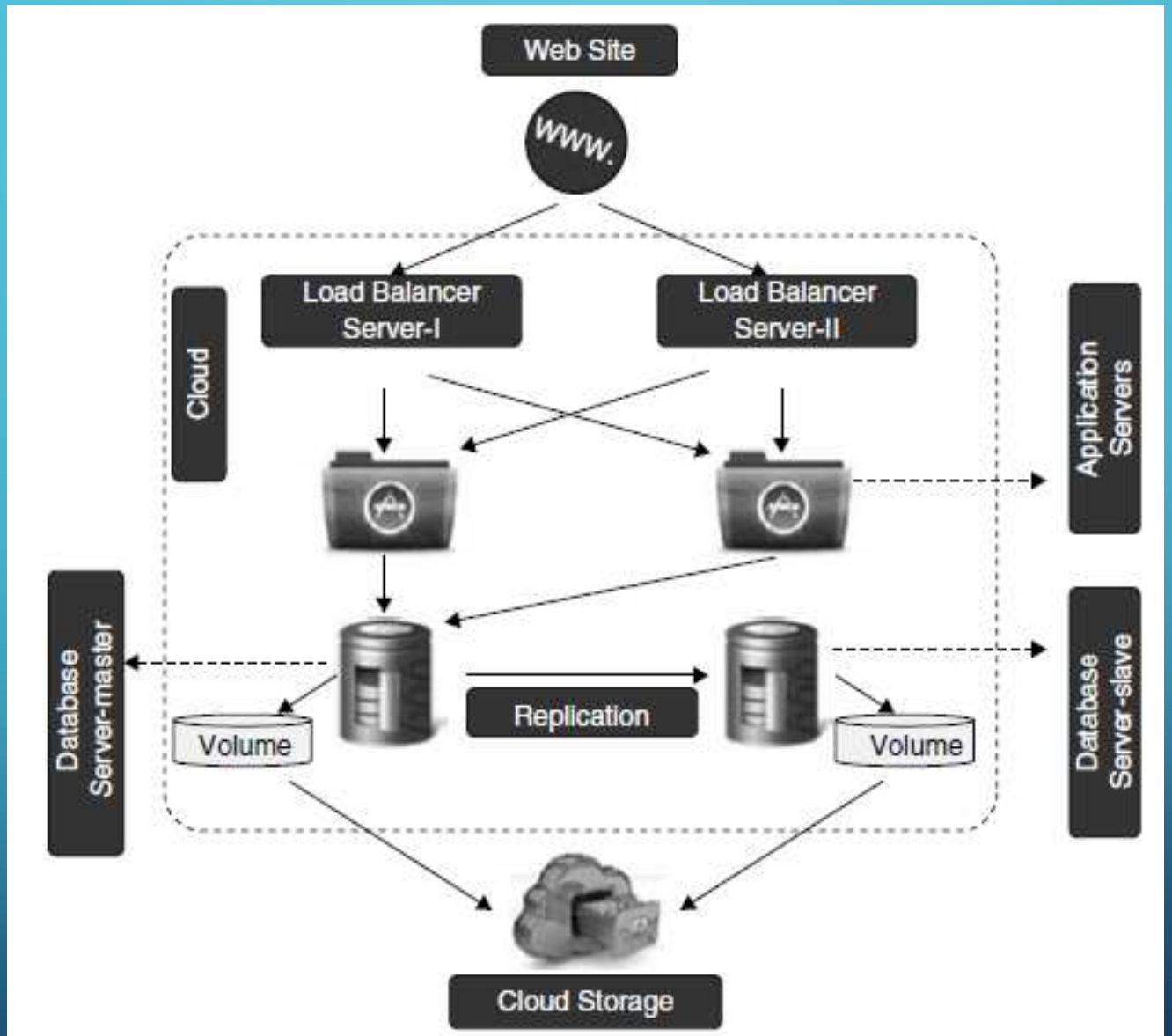


Figure 6.3 Redundant 3-Tier Architecture

Multi-datacentre Architecture

- If the cloud infrastructure has many datacentres, it is recommended to distribute the system architecture to the datacentres for redundancy and protection.
- Diagram
- The multiple datacentres in reference architecture.
- The multiple datacentre architecture has two datacentres, each having a load balancing applications, volume and master database.
- When one datacentre goes down, then automatically the other datacentre can be used.

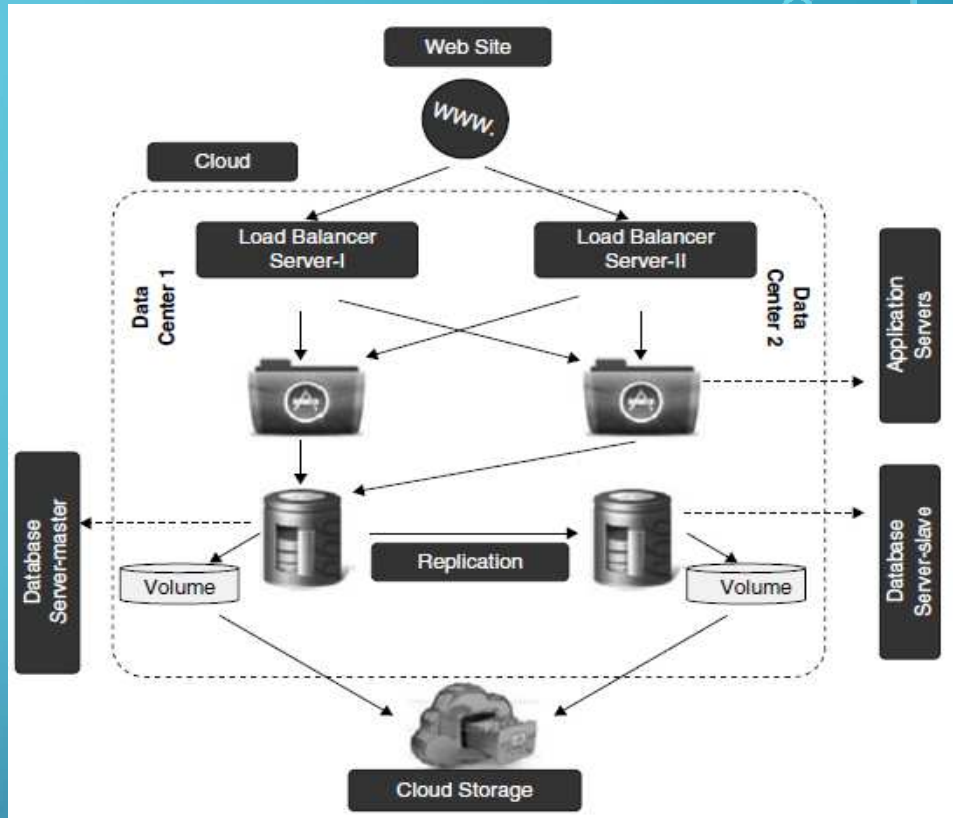


Figure 6.4 Multi-Datacentre Architecture

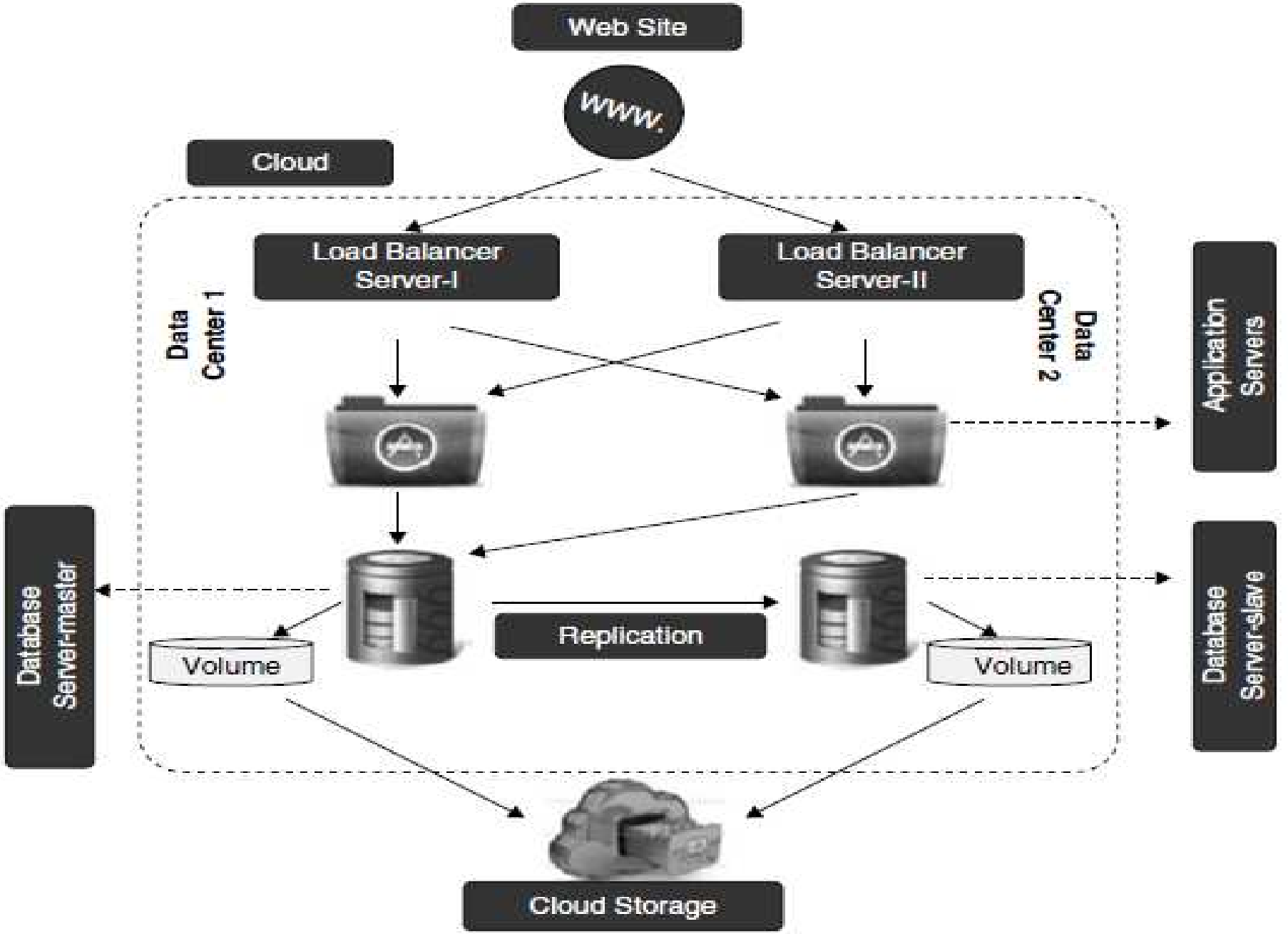


Figure 6.4 Multi-Datacentre Architecture

1.3.4 CLOUD DEPLOYMENT MODEL

- Cloud Computing Deployment Models : Private , Public, Hybrid, Community, *Combined,* Inter Clouds (Cloud of Clouds)
- Types of Cloud Deployment Model

1.Cloud Computing Deployment Models

- NIST has standardized the characteristics of cloud computing as
  - ✓ ubiquitous network access
  - ✓ on-demand self-service
  - ✓ elasticity
  - ✓ resource pooling
  - ✓ pay per use

Private Cloud

- Infrastructure is dedicated to a single organization
- NOT shared with other organizations
- Can be owned or leased
- Managed by the IT organization or a vendor, who provided the service and can exist at on-premises or off-premises
- More expensive and secure compared to the public cloud
- Flexible and service based
- Firewall protects private cloud from outsiders.
- Accessed by users within the organization via the intranet
- Diagram

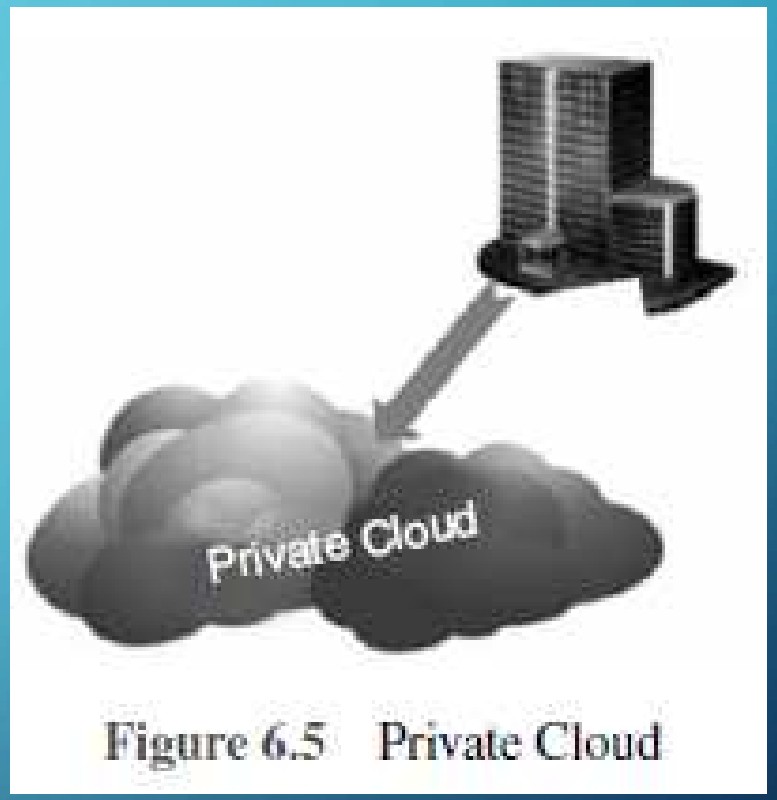


Figure 6.5 Private Cloud

Public Cloud

- Adopting public cloud type has an advantage in terms of cost, deploy time.
- Infrastructure offered via web applications and also as web services over the Internet to the public
- Diagram
- Example : CRM, Messaging and Microsoft Office products
- In this environment the service provider have control over their clients.

Figure 6.6 Public Cloud

Hybrid Cloud

- Deployment model exists due to varied needs of an organization
- A combination of private, public and community cloud service deployment models
- Diagram
- Security is given more important in private cloud than in public cloud.
- A combination of a public and a private cloud is put together for the purpose of keeping business-critical data and services in their control on private cloud and outsourcing less-critical processing to the public cloud.

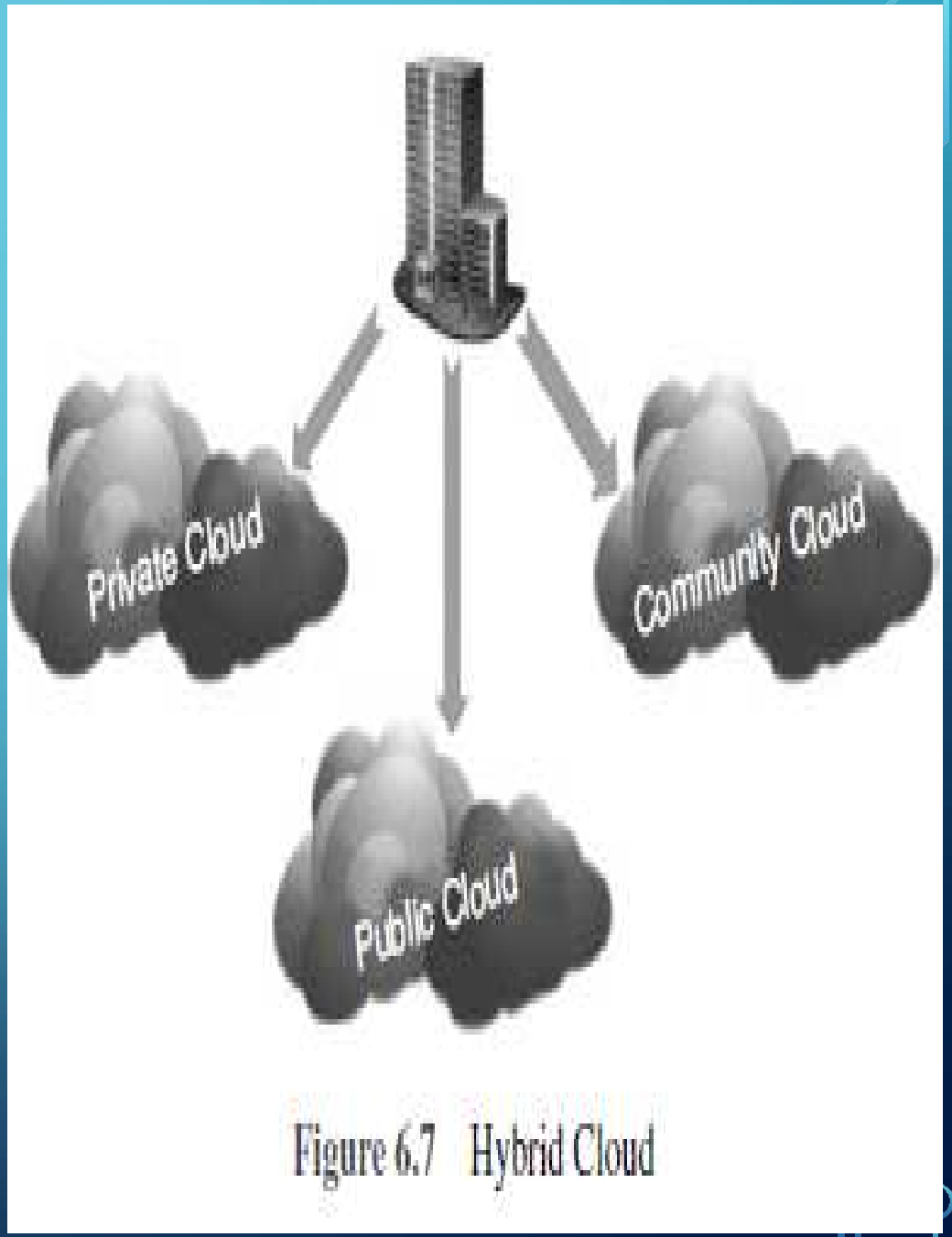


Figure 6.7 Hybrid Cloud

Community Cloud

- IT organizations share the infrastructure using community cloud
- Diagram
- Supports a particular community, that has common issues such as security requirements, missions, compliances, considerations and policies

Figure 6.8 Community Cloud

Combined Cloud

- Combining internal and external providers termed as combined cloud.
- By integrating multiple cloud services, consumers can ease the transition to public cloud services.

Inter Cloud (Cloud of Clouds)

- Mesh of cloud is called as inter cloud, which is interconnected using open standards to provide a universal acceptance.

2. Types of Cloud Deployment Model

- Three types of cloud deployment models
- Yet another type of cloud deployment model known as community cloud, which is being used in some instances
- Table : Various cloud deployment models and highlights its characteristics

Table 6.1 Cloud Deployment Models

Public Cloud	Private Cloud	Hybrid Cloud
• Provider owned and managed • Access by subscription • Economic benefits • Reduced IT service • Delivery cost • Reduced HW, systems, software, management and application costs	• Client dedicated • Access defined by client • Data governance rules/regulations • More secure • Economic benefits • Reduced capex • Reduced opex • Service level discipline	• Consume more resource in peak hours • Economic benefits • Scale private cloud for BAU • Maintain service levels by scaling externally • Share cost with vertical with charge back options
Key Patterns		
• Users initiate the amount of use of resources • Scalability for compute resource is automated • Pay per use metering and billing	• Resource-driven provisioning of development, test and production systems, managing E2E lifecycle • Ease of deploying applications	• SLA exists and policies are driven based on SLA • Consumption of resources (storage, compute) are done automatically

Course Objective:

To study fundamental concepts of cloud computing

Course Outcome:

CO1: Learners is able to ***Understand*** the different Cloud Computing environment