Cloud Computing

Unit-I

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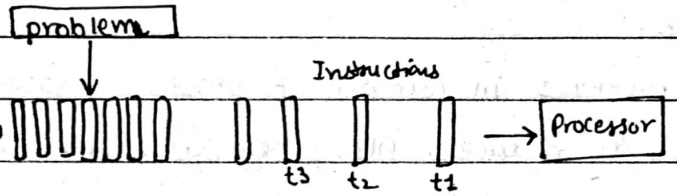
Introduction To Cloud Computing

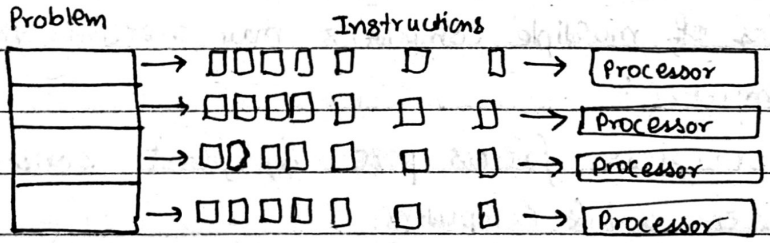
* Serial Computing

- Traditionally, software has been written for serial computation:
  - ↳ A problem is broken into a discrete series of instructions
  - ↳ Instructions are executed sequentially one after another
  - ↳ Executed on a single processor
  - ↳ only one instruction may execute at any moment in time



* Parallel Computing

- Parallel Computing is simultaneous use of multiple computational resources to solve a computational problem:
  - ↳ A problem is broken into discrete parts that can be solved concurrently
  - ↳ Each part is further broken down to a series of instructions
  - ↳ Instructions from each part execute simultaneously on different processors
  - ↳ An overall control / coordination mechanism is employed



- The computational problem should be able to:
  - ↳ Be broken apart into discrete pieces of work that can be solved simultaneously
  - ↳ Execute multiple program instructions at any moment in time
  - ↳ Be solved in less time with multiple compute resources than a single compute resource
- The compute resources are typically:
  - ↳ A single computer with multiple processors / cores
  - ↳ An arbitrary no. of such computers connected by a network.

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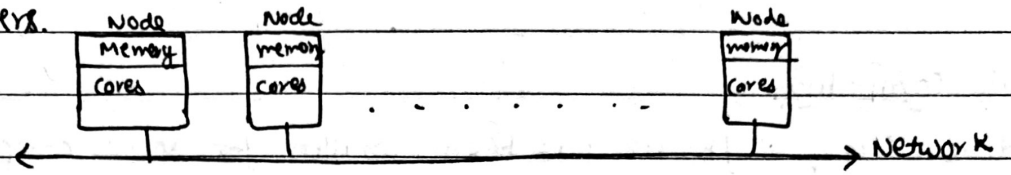
- Networks connect multiple standalone computers (node) to make larger parallel computer clusters.



* Need of Parallel Computing

① Save time and solve large problems:

- With the progress of computer science, computational speed of the processors has also increased many a time so we have to look for alternatives. The answer lies in parallel computing.
- It is obvious that with the increase in number of processors working in parallel, computation time is bound to reduce. Also they're some scientific problems that even the fastest processor to take months or even years to solve
- However, with application of parallel computing these problems may be solved in a few hours

② Cost savings:

- we can use multiple cheap computing resources instead of paying heavily for a supercomputer

③ Overcoming Memory Constraints:

- Single computers have very finite memory resources. For large problems, using the memories of multiple computers may overcome this problem.

④ Limits to Serial Computing:

- Both physical & practical factors pose significant constraints to simple building ever faster serial computers.
- Increasing speeds necessitate increasing proximity of processing elements.
- Using a large number of moderately fast commodity processors to achieve the better performance is less expensive.

* Hardware Architectures for parallel computing

(i) Single instruction, single data (SISD) systems
(ii) Single instruction, multiple data (SIMD) systems
(iii) Multiple instruction, single data (MISD) systems
(iv) Multiple instruction, multiple data (MIMD) systems

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* Approaches to parallel programming

- A variety of most prominent parallel programming approaches are:
  (i) Data parallelism (ii) Process parallelism (iii) Farmer-&-Worker model

* Levels of Parallelism

(i) Large grain (or task level) ⇒ separate & heavyweight process
(ii) Medium grain (or control level) ⇒ Function or procedure
(iii) Fine grain (or data level) ⇒ Loop or Instruction block
(iv) Very fine grain (or multiple-instruction issue) ⇒ Instruction

* Grid Computing

- Resource Sharing & coordinated problem solving in dynamic, multi-institutional virtual organizations.

Serial	Parallel	Grid
Fetch/Store	Fetch/Store	Fetch/Store
Compute	Compute/communicate	Discovery of resources
	Cooperative game	Interaction with remote applications
		Authentication/Authorization
		Security compute/communicate etc

- Web vs Grid
  → web: Uniform naming access to documents
  → Grid: Uniform high performance access to computational resources
- Why Grids?
  → Large-scale science & engineering are done through the interaction of people, heterogeneous resources, information systems, & instructions, all of which are geographically & organizationally dispersed.
  → The overall motivation for "Grids" is to facilitate the routine interactions of these resources in order to support large-scale science & engineering.
  Ex:- Data grids for high energy physics
- The Grid Opportunity: eScience & eBusiness
  → Physicists worldwide pool resources for peta-op analysis of petabytes of data
  → Civil engineers collaborate to design, execute, & analyze shake table experiments
  → An insurance company mines data from partner hospitals for fraud detection
  → An application service provider offloads excess load to a compute cycle provider

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→ An enterprise configures internal & external resources to support eBusiness workload

* Distributed System

- A distributed system is one in which components located at networked computers communicate & coordinate their actions only by passing messages.
- Characteristics of distributed systems:
  - ↳ Concurrency of components
  - ↳ Lack of a global 'clock'
  - ↳ Independendent failure of components
- Centralized vs Distributed System Features:

Centralized System	Distributed System
(i) one component with non-autonomous parts	(i) Multiple autonomous components
(ii) Component shared by users all the time	(ii) Components are not shared by all users
(iii) All resources accessible	(iii) Resources may not be accessible
(iv) Software runs in a single process	(iv) Software runs in concurrent processes on different processors
(v) Single point of control	(v) Multiple points of control
(vi) Single point of failure	(vi) Multiple points of failures

- Examples of Distributed System:
  - ↳ Local Area Network & Intranet
  - ↳ Automatic Teller Machine Network
  - ↳ Database Management System
  - ↳ Internet/world wide web
  - ↳ Mobile & Ubiquitous Computing
- Advantages of Distributed Systems
  - ↳ Shareability
  - ↳ Local ~~Autonomy~~ Autonomy
  - ↳ Improved Reliability & Availability
  - ↳ Expandability
  - ↳ Improved Performance
  - ↳ Potential cost reductions
- Disadvantages of Distributed Systems
  - ↳ Network Reliance
  - ↳ Security
  - ↳ Complexities
  - ↳ Multiple point of failure

— Grid Computing

1. Loosely coupled (decentralization)
2. Diversity & Dynamism
3. Distributed job management & scheduling

Distributed Computing

To solve single large problem by breaking it down into several tasks where each task is computed in the individual computers of the distributed systems

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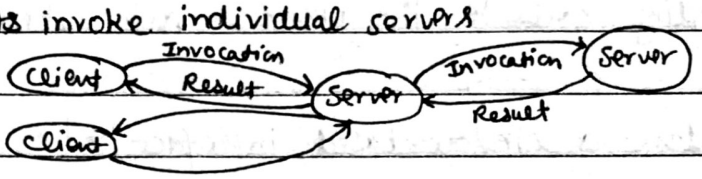
- Distributed Computing Variants:

↳ Client - Server Architecture

clients invoke individual servers



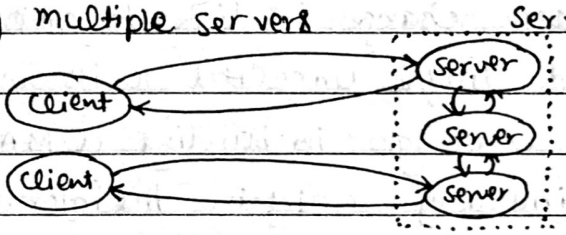
↳ Peer-To-Peer Architecture

All processes play similar roles - i.e., they interact as peers

No central component - potentially better scalability & resiliency to failures

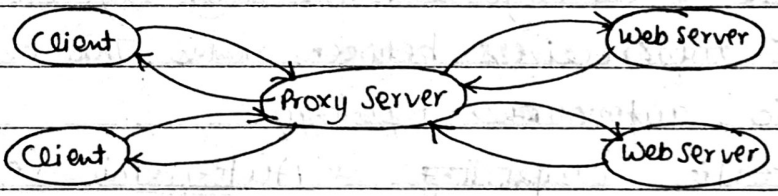
↳ Services by multiple Servers

A service provided by multiple servers



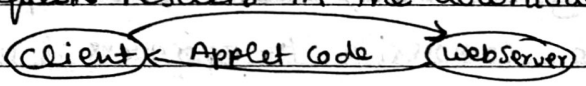
↳ Proxy Servers & Caches

web proxy server

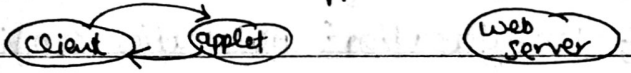


↳ Mobile Code

web applets: ⓐ client request results in the downloading of applet code



ⓑ class interacts with the applet



↳ Mobile Agents

A running program (both code & data) that travels from one computer to another.

Ex :- A worm

↳ Network Computers

Doesnot rely on locally installed software

Downloads operating system and applications from a remote computer

Applications are run locally, but files are managed on a remote server

Users can migrate from one computer to another

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↳ Thin Clients:

Similar to a network computer
Instead of downloading code to the user computer, it runs on a compute server
Software layer provides a window-based interface to the client (x windows)

↳ MANETS

A "mobile ad hoc network" (MANET) is a continuously self-configuring, infrastructure-less network of mobile devices connected wirelessly.
Each device in a MANET is free to move independently in any direction, & will therefore change its links to other devices frequently. Each must forward traffic unrelated to its own use, & therefore be a router.
The primary challenge in building a MANET is equipping each device to continuously maintain the information required to properly route traffic. Such networks may operate by themselves or may be connected to the larger Internet. They may contain one or multiple and different transreceivers between nodes. This results in a highly dynamic, autonomous topology.

* ~~Automatic Computing~~ Autonomic Computing

- It refers to the ~~self~~ self-managing characteristics of distributed computing resources, adapting to unpredictable changes while hiding intrinsic complexity to operators & users.
- Characteristics:
  - ↳ Self-configuration: Automatic configuration of components
  - ↳ Self-Healing: Automatic discovery & correction of faults
  - ↳ Self-Optimization: Automatic monitoring & control of resources to ensure the optimal functioning wrt defined requirements
  - ↳ Self-Protection: Proactive identification & protection from arbitrary attacks.
- ~~Model for Cloud Comp~~ Automatic Computing
  - ↳ A fundamental building blocks of an autonomic system is the sensing capability (sensors Si), which enables the system to observe its external operational context. Inherent to an autonomic system is

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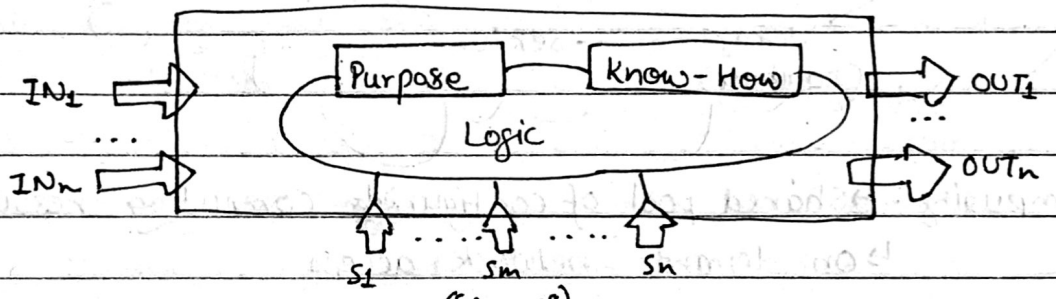
the knowledge of the purpose (intention) & know how to operate itself without external intervention.

↳ The actual operation of the autonomic system is dictated by the Logic, which is responsible for making the right decisions to serve its purpose, & influence by the observation of the operational context (based on the sensor input).

↳ This model highlights the fact that the operation of an autonomic system is purpose-driven. This includes its mission (ex- the service it is suppossed to offer), the policies (ex- that define the basic behaviour).



* Cloud Computing

- Cloud computing provides us a means by which we can access the applications as utilities, over the Internet. It allows us to create, configure and customize applications online.
- The term cloud refers to a Network or Internet. In other words, we can say that Cloud is something, which is present at remote location. Cloud can provide services over network, i.e., on public networks or on private networks, i.e., WAN, LAN or VPN. Applications such as e-mail, web conferencing, customer relationship management (CRM), all run in cloud.
- Cloud Computing is a type of parallel & distributed computing system consisting of a collection of inter-connected & virtualised computers that are dynamically provisioned & presented as one or more unified computing resources based on service-level agreements established through negotiations between the service provider & consumers.

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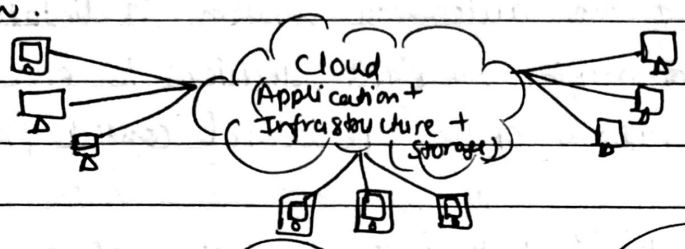
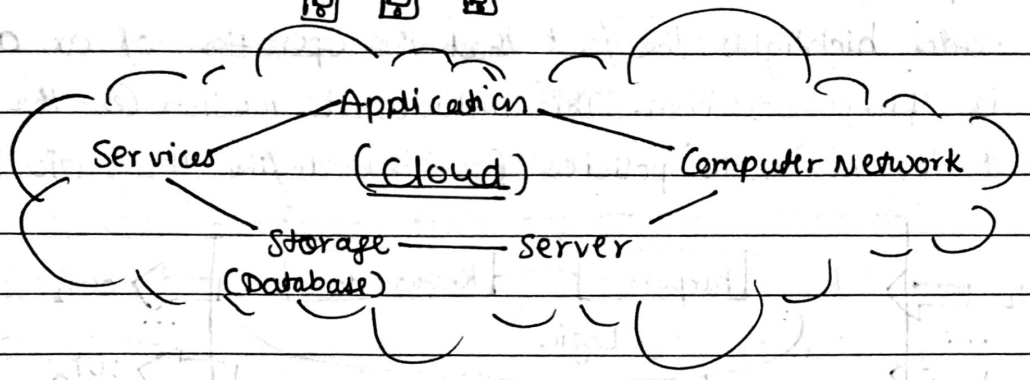
- Cloud computing refers to manipulating, configuring, & accessing the applications online. It offers online data storage, infrastructure & application.





- Cloud computing: ↳ Shared pool of configurable computing resources
  ↳ On-demand network access
  ↳ Provisioned by the Service Provider

- Evolution of Cloud Computing

↳ The concept of cloud computing came into existence in 1950 with implementation of mainframe computers, accessible via thin/static clients

↳ Since then, cloud computing has evolved from static clients to dynamic ones from software to services.

Mainframes	Rise of the PC	Client / Server Architecture	Hosted Environment	Cloud computing
# Start of automation phase # Localized Infrastructure	# Rise in demand of personal desktops # Decentralized Computing # Birth of IT services Industries	# Virtual Private Network offered # Demand for high bandwidth # Dot Com Revolution	# IT infra-structure Outsourcing # Increase use of virtualization	# Emergence of "as a service" # Delivery of Iaas, Paas, Saas, NaaS # Collaborative Computing # Utility Computing Model
1950s	1960s	1990s	2000	Beyond 2020

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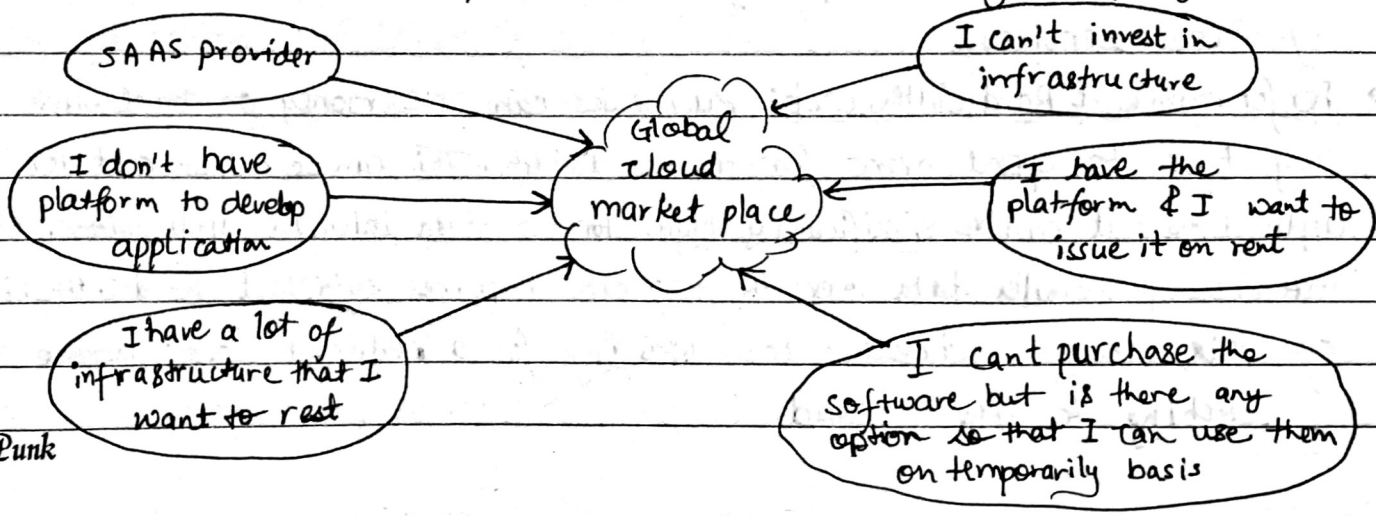
- ❀ Benefits of Cloud
  - ↳ One can access applications as utilities, over the Internet
  - ↳ Manipulate and configure the application online at any time
  - ↳ It doesnot require to install a specific piece of software to access or manipulate cloud ~~computing~~ application.
  - ↳ Cloud computing offers online development & deployment tools, programming runtime environment through Platform as a Service Model.
  - ↳ Cloud resources are available over the network in a manner that provides platform independent access to any type of clients.
  - ↳ Cloud computing offers on-demand self-service. The resources can be used without interaction with cloud service provider
  - ↳ Cloud computing is highly cost effective because it ~~offers~~ operates at higher efficiences with greater utilization. It just requires an Internet connection.
  - ↳ Cloud computing offers load balancing that makes it more reliable.
- Vision of Cloud Computing
  - ↳ Cloud computing provides the facility to provision virtual hardware, runtime environment and services to a person having money.
  - ↳ These all things can be used as long as they are needed by the user, there is no requirement for the upfront commitment.
  - ↳ The whole collection of computing system is transformed into a collection of utilities, which can be provisioned & composed together to deploy systems in hours rather than days, with no maintenance costs.
  - ↳ The long term vision of a cloud computing is that IT services are traded as utilities in an open market without technological & legal barriers.



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- Challenges of Cloud Computing

↳ Security & Privacy : The main challenge to cloud computing is how it addresses the security & privacy concerns of businesses thinking of adopting it. The fact that the valuable enterprise data will reside outside the corporate firewall raises serious concerns. Hacking & various attacks to cloud infrastructure would affect multiple clients even if only one site is attacked. These risks can be mitigated by using security applications, encrypted file systems, data loss software, & buying security hardware to track unusual behaviour across servers.

↳ Service Delivery & Billing: It is difficult to assess the costs involved due to the on-demand nature of the services. Budgeting & assessment of the cost will be very difficult unless the provider has some good and comparable benchmarks to offer. The service-level agreements (SLAs) of the provider are not adequate to guarantee the availability & scalability. Businesses will be reluctant to switch to cloud without a strong service quality guarantee.

↳ Interoperability & Portability : Businesses should have the leverage of migrating in & out of the cloud & switching providers whenever they want, and there should be no lock-in period. Cloud computing services should have the capability to integrate smoothly with the on-premise IT.

↳ Reliability & Availability : Cloud providers still lack round-the-clock service; this results in frequent outages. It is important to monitor the service being provided using internal or third-party tools. It is vital to have plans to supervise usage, SLAs, performance, robustness, & business dependency of these services.

↳ Performance & Bandwidth Cost: Businesses can save money on hardware but they have to spend more for the bandwidth. This can be a low cost for smaller applications but can be significantly high for the data-intensive applications. Delivering intensive & complex data over the network requires sufficient bandwidth. Because of this, many businesses are waiting for a reduced cost before switching to the cloud.

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- Applications of Cloud Computing: ↳ Gene Expression Data Analysis, Satellite Image Processing
  ↳ Email communication, ECG analysis in cloud, protein structure prediction
  ↳ No need of local data storage: Data stored on your home or business computer suffers from many of the same restrictions as email and, as with email, the cloud offers a solution. Storing your MP3's, video, photos & documents online instead of at home gives you the freedom to access them ~~when~~ whenever you can find the means to get online.
  ↳ Are you collaborator: Some occasion you may find yourself in need of the ~~opior~~ opinion of your peers. Downloading files onto flash memory, emailing documents to friends or family or colleagues or sending submissions by snail mail is so last century. Using google wave, you can create document & then invite others to comment, amend, offer opinion, or otherwise join in with the creation of the final draft.
  ↳ Working in virtual office
  ↳ Need extra processing: Rather than purchasing servers, software, network equipment & so on, users would buy ~~with~~ into a fully outsourced set of online services instead.

- Advantages of Cloud Computing
  ↳ Lower computer costs
  ↳ Improved performance
  ↳ Improved document format compatibility
  ↳ Increased data reliability
  ↳ Latest version availability
  ↳ Device Independence
  ↳ Reduced software costs
  ↳ Instant software updates
  ↳ Unlimited Storage capacity
  ↳ Universal document access
  ↳ Easier group collaboration

- Disadvantages of Cloud Computing
  ↳ Requires a constant Internet Connection
  ↳ Doesn't work well with low-speed connections
  ↳ Features might be limited
  ↳ Can be slow
  ↳ Stored data might not be secure
  ↳ Stored data can be lost

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↳ Are you collaborator: Some occasion you may find yourself in need of the ~~opior~~ opinion of your peers. Downloading files onto flash memory, emailing documents to friends or family or colleagues or sending submissions by snail mail is so last century. Using google wave, you can create document & then invite others to comment, amend, offer opinion, or otherwise join in with the creation of the final draft.
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↳ HPC (High Performance Computing) Systems
↳ General concerns

- The Future

↳ Many of the activities loosely grouped together under cloud computing have already been happening and centralised computing activity is not a new phenomena.
↳ Grid computing was the last research-led centralised approach
↳ However there are concerns that the mainstream adoption of cloud computing could cause many problems for users
↳ Many new open source systems appearing that you can install & run on your local ~~cluster~~ cluster.

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Cloud Computing Architecture

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* Features of Cloud:

- Five essential characteristics of cloud computing:

(i) **On-demand self-service**: A consumer can unilaterally provision computing capabilities, such as server time & network storage, as needed automatically without requiring human interaction with each service provider

(ii) **Broad Network Access**: Capabilities are available over the network and accessed through standard mechanisms that promote uses by heterogeneous thin or thick client platforms (eg:- mobile phones, tablets, laptops & workstations)

(iii) **Resource Pooling**: The provider's computing resources are pooled to serve multiple consumers using a multi-tenant model, with different physical & virtual resources dynamically assigned and reassigned acc^n to consumer demand. Examples of resources include storage, processing, memory etc.

(iv) **Rapid elasticity**: Capabilities can be elastically provisioned & released, in some cases automatically, to scale rapidly outward and inward commensurate with demand. To the consumer, the capabilities available for provisioning often appear to be unlimited & can be appropriated in any quantity of time.

(v) **Measured Service**: Cloud systems automatically control and optimize resource use by leveraging a metering capability at some level of abstraction appropriate to the ~~user~~ type of service. Resource usage can be monitored, controlled & reported, providing transparency for the provider and consumer

* Components of Cloud

- Successful implementation of cloud computing requires proper implementation of certain components. Without any of these components, cloud computing will not be possible. These components are implemented by group of persons with different expertise with the expectation of optimal performance

- **The Client - The End User**

↳ Everything ends with the client. The hardware components, the application & everything else developed for cloud computing will be used in the client.

↳ The client could come in two forms: the hardware component or the combination of software & hardware components. There are certain systems that requires pre-installed application to ensure smooth transition of cloud.

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- The hardware on the other hand will be the platform where everything has to be launced.
  - ↳ Optimization is based on two fronts; the local hardware capacity & the software security. Through optimized hardware with security, the application will launch seamlessly.

- The Service - the functions in cloud computing
  - ↳ Cloud computing is all about processes & the services launched through cloud computing always has to deal with processes with an expected output.
  - ↳ The optimization on service is based on two things: the proper development of the application & the end user.

- The Application - backbone of Service
  - ↳ It is application is through that the service is realised. This is where software developers have to focus in terms of ensuring the application will work as expected.
  - ↳ Optimization of the application is based on the actual coding of developers. Through extensive testing on load handling, security and functionality, the application could work as expected.

- Infrastructure for the Application
  - ↳ In regular websites (without cloud), the application is directly connected to server. But in cloud computing, the application is launched to another application called the platform which usually comes as the programming language such as AJAX (ASynchronous Javascript And XML) or Ruby on Rails
  - ↳ A powerful application with real time updating capability is a must for cloud computing.

- Warehouse of Cloud Computing
  - ↳ Everything that application knows & the functions that could be provided by service are possible through storage. The storage holds pertinent data & information on function on how they will be implemented.
  - ↳ Optimization on storage is based on how the storage facility protected from different attacks & availability of backup.

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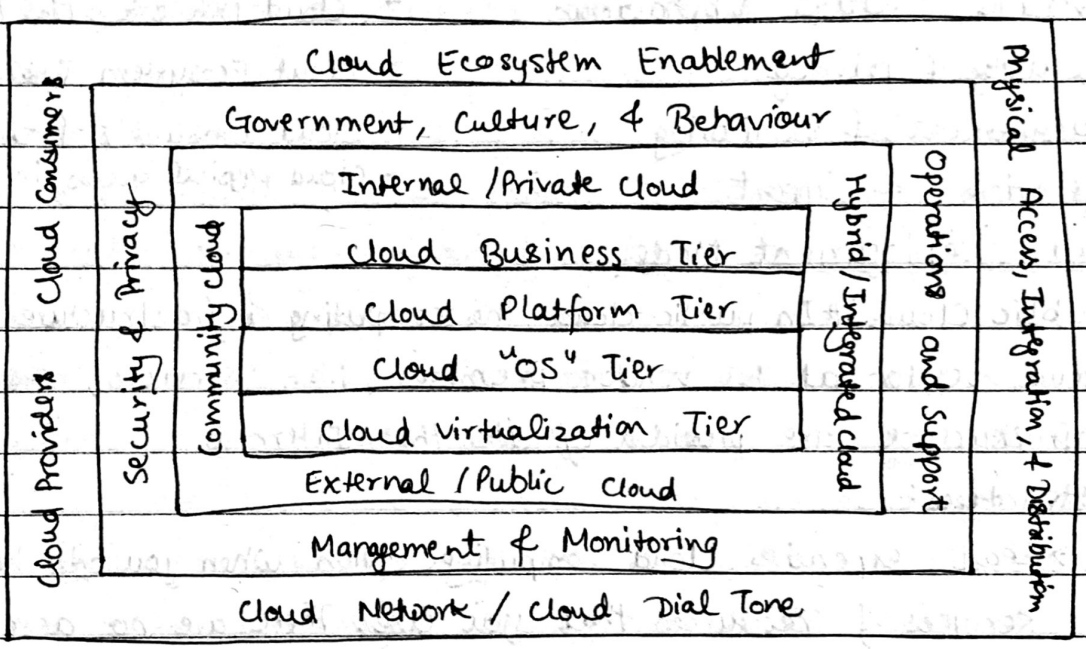
- Backbone of Cloud Computing

↳ Every func^n, service & the ability of storage to provide the needed data is only possible through optimized infrastructure. The infrastructure is a platform wherein it weights the ability of storage against no. of requests.

↳ The infrastructure has the ability to make some changes by load balancing and even management.

* Cloud Reference Model



- Comprised of four supporting models:

① Cloud Enablement Model: Describes fundamental technology tiers of cloud computing capabilities provided by cloud platform & cloud service providers to potential consumers of cloud-enabled technology and business capabilities.

② Cloud Deployment Model: Describes range of cloud deployment scenarios available to your enterprise: internal / private cloud, external / public cloud, hybrid / integrated cloud & community or vertical cloud.

③ Cloud Governance & Operations Model: Describes governance, security operations, support, management, & monitoring requirements for cloud computing to ensure you have considered all potential operational risks of adopting cloud for your enterprise.

④ Cloud Ecosystem Model: Considers the requirements of developing & sustaining a cloud ecosystem. It also includes various cloud enablement

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technologies, cloud providers & consumers.

Ⓐ Cloud Enablement Model
- Cloud virtualization tier
- Cloud OS tier
- Cloud platform tier
- Cloud business tier

Ⓑ Cloud Deployment Model
- Internal / Private Cloud
- External / Public Cloud
- Hybrid / Integrated Cloud
- Community / Vertical / Shared by Community of interest stakeholders

Ⓒ Cloud Goverance & Operations Model
- Goverance, culture & behaviour
- Security & privacy
- Management & monitoring
- Operations & Support

Ⓓ Cloud Ecosystem Model
- Cloud Network / Dial Tone
- Clout Ecosystem Enablement
- Cloud consumers & cloud providers
- Cloud physical access, integration & distribution

* Cloud Deployment Models

ⓘ Public Cloud: # In public cloud the computing infrastructure is hosted by the cloud vendor at the vendor premises, i.e., services, resources & infrastructure are provided off-site the Internet.

Advantages:
→ Least expensive cloud computing option when you only have to pay for services & resources that you use. There are no associated hardware & server maintenance costs
→ provides large scalability for your business needs by enabling you to allocate as many server & storage instances as needed.

Disadvantages:
→ Security can be a concern and there is always the risk of data being compromised
→ Outages to available resources can occur that may be completely outside your control.
→ Network latency issues can cause performance issues

Cloud infrastructure is made available to general public or a large industry group & is owned by an organization selling cloud services.

Examples: Google App Engine, Microsoft Windows Azure, IBM smart Cloud Amazon EC2

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(ii) Private Cloud : # The computing infrastructure is dedicated to a particular organization and not shared with other organizations, i.e., services, resources & infrastructure are maintained on a private network.

Advantages:

→ Hardware & cloud software are implemented on a private network, ensuring full control of security needs

→ Performance is typically better because there are minimal latency issues since the systems are communicating with end users and clients over private networks.

Disadvantages:

→ Higher costs because of hardware & software expenses & maintenance

→ Private cloud software continuously evolving & can require more IT maintenance.

Two types of private clouds:

(A) On-Site : Applies to private clouds implemented at a customer's premises.

(B) Outsourced : Applies to private clouds where server side is outsourced to a hosting company.

Ex:- Eucalyptus, Ubuntu Enterprise Cloud (UEC), Amazon VPC (Virtual Private Cloud), VMware Cloud Infrastructure Suite, Microsoft ECI data center.

(iii) Hybrid Cloud: # The usuage of both private & public clouds together is called Hybrid cloud. It includes a variety of public & private options with multiple providers.

Advantages:

→ Provides best of both clouds (private & public), providing quick access to information & applications whenever needed for public services while ensuring required security & reliability availability to data for private cloud services.

→ Innovative ideas & new technologies are rapidly emerging in this direction.

Disadvantages:

→ The security, processing & storage between private & public cloud instances can be technologically challenging today.

→ Could cost more than either private or public computing options considering technology & skills required

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Ex:- Windows Azure (capable of hybrid cloud), VMware vCloud (Hybrid Cloud services)

(iv) Community Cloud: # It involves sharing of computing infrastructure in between organizations of same community.

The cloud infrastructure is shared by several organizations & supports a specific community that has shared concerns (ex- mission, security requirements, policy, compliance considerations etc)

Government departments, universities, central banks etc find this cloud useful.

Two types of community clouds:

(A) On-site: Applies to community clouds implemented on premises of customers composing a community cloud

(B) Outsourced: Applies to community clouds where the server side is outsourced to a hosting company

Ex:- Google Apps for Goverenment, Microsoft Goverment Community Cloud

* Cloud Deployment Implications

(i) Network Dependency
(ii) Subscribers still need IT skills
(iii) Risk for multi-tenancy
(iv) Data import / export & performance limitations
(v) Workloads Locations

* Cloud Computing Service Reference Models:

- The three service models defined by NIST are essentially a hierarchy:

(i) Cloud Software as a Service (SaaS)
(ii) Cloud Platform as a Service (PaaS)
(iii) Cloud Infrastructure as a Service (IaaS)

SaaS	Highest level
PaaS	Intermediate level
IaaS	Lowest level

- Infrastructure As A Service (IaaS)

→ The capability provided to the consumer is to provision processing, storage, networks, and other fundamental computing resources where the consumer is able to deploy and run arbitrary software, which can include operating systems & applications.

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→ Leading vendors that provide IaaS are Amazon EC2, Amazon S3, Racspace Cloud Servers & Flexiscale

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→ It involves offering hardware related services using principles of cloud computing, i.e., the capability provided to the consumer is to rent processing, storage, networks & other fundamental computing resources.
→ The consumer does not manage or control the underlying cloud infrastructure but has control over operating systems, storage, deployed applications and possibly limited control of select networking components (ex- Host Firewalls).

— Platform as a Service (Paas)

→ The capability provided to the consumer in this intermediate level is to deploy onto the cloud infrastructure consumer created or acquired applications ~~deployed~~ developed using programming languages and tools supported by provider.
→ It involves offering a development platform on the cloud. Platforms provided by different vendors are ~~not~~ typically not compatible.
→ Typical vendors are Google Application Engine, Microsoft Azure, Salesforce.com, force.com

— ~~Software as a Service~~

→ The consumer does not manage or control the underlying cloud infrastructure but has control over the deployed applications and possibly application hosting environment configurations.

— Software as a Service (SaaS)

→ The capability provided to the consumer in this highest level is to use the provider's Applications running on a cloud infrastructure. The applications are accessible from various client devices through a thin client interface such as a web Browser (ex- Web based e-mail)
→ It includes a complete software offering on the cloud. Users can access a software application hosted by the cloud vendor on pay-per-use basis.
→ The consumer doesn't manage or control the underlying cloud infrastructure with the possible exception of limited user-specific application configuration settings.

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→ Examples of the vendors are Google docs, Microsoft online version of office called BPOS (Business Productivity Online Standard Suite)

→ SaaS alleviates burden of software maintenance/support

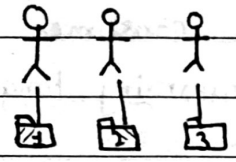
→ Three features of Mature SaaS Applications:

(i) Scalable : Handle growing amounts of data in graceful manner

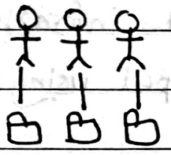
(ii) Multi-Tenancy: one application instance may be serving hundreds of companies

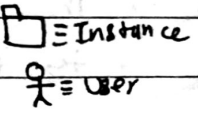
(iii) Metadata driven configurability : Instead of customizing application for a customer, one allows the user to configure application through metadata

Level 1: AdHoc/Custom
- One instance per customer
- ~~Configurable per customer~~

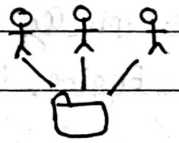


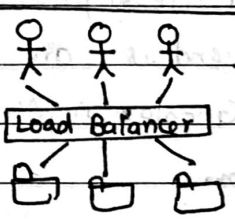
Level 2: Configurable per customer





Level 3: Configurable & multi-tenant-efficient

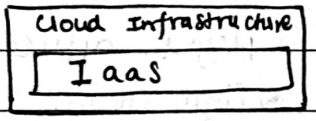




Level 4: Scalable, Configurable & Multi-Tenant-Efficient

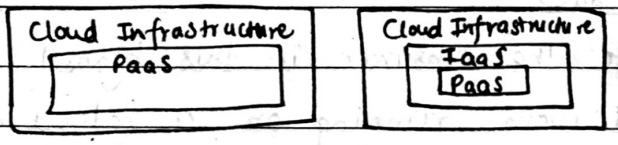
SaaS Maturity Model

(i)



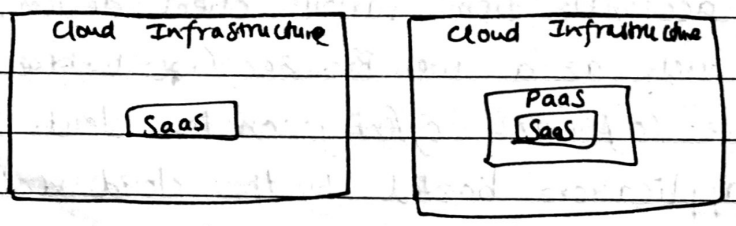
IaaS Architecture

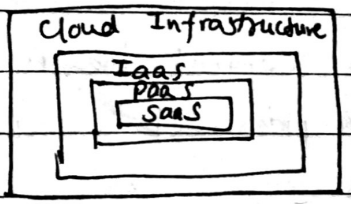
(ii)



PaaS Architectures

(iii)





SaaS Architectures

Service Model Architectures

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* Comparison of Saas, Paas & Iaas

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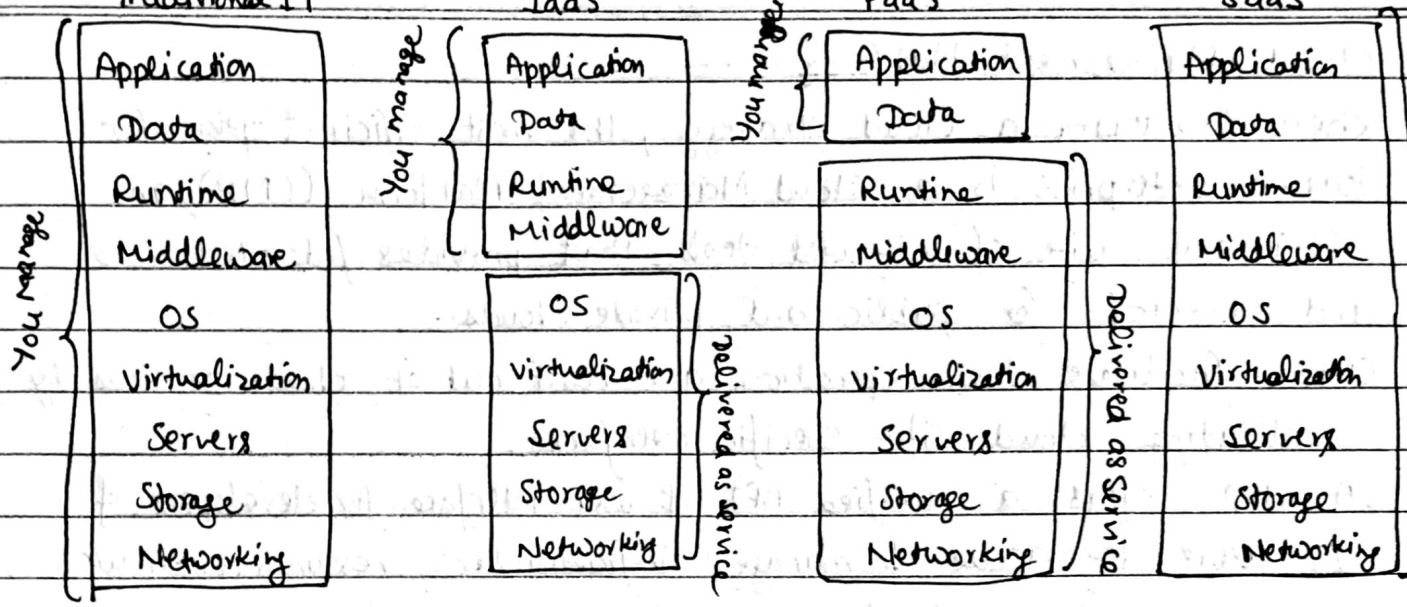

* Different Cloud Computing layers

Application Service (SaaS)	MS live / Exchange labs, IBM, Google Apps, ~~Salesforce~~ Zoho, Salesforce.com, Quicken Online, Cisco
Application Platform	Google App Engine, Mosso, Force.com, Engine Yard, Facebook, Heroku, AWS
Server Platform	3Tera, EC2, Slicehost, GoGrid, Rightscale, Linode
Storage Platform	Amazon S3, Dell, Apple, ...

* Cloud Computing Service Layers

Application Focused	Services	Complete business service such as PayPal, OpenID, OAuth, Google Maps, Alexa
	Application	Cloud based S/W that eliminates need for local installation such as Google Apps, MS Office
	Development	S/W Development platforms used to build custom cloud based applications (SaaS & PaaS) such as Salesforce
Infrastructure Focused	Platform	Cloud based platforms ~~for~~ ~~search~~ provided using virtualization, such as Amazon EC2, Sun Grid
	Storage	Data storage or cloud based NAS such as CIFRA, iDisk of ~~Cloudmo~~ CloudNAS
	Hosting	Physical data centers such as those run by IBM, HP, Navisite etc.

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* Cloud Management Platform

- when developing a cloud strategy, the most efficient option for today's enterprise is a Cloud Management Platform (CMP), an all-in-one suite of integrated tools that provides federated access and goverance for public and private-clouds
- CMPs facilitate the operation and built out of cloud services by consolidating cloud silo specific interfaces.
- A CMP offers a unified API & web interface for developers & IT users to access & manage infrastructure resources distributed across numerous public & private clouds, such as Amazon Web Services and OpenStack. An all-in-one solution delivers superior results from individual components as well, especially as information can be compared across clouds, & shared across teams.

Unit-III

Virtualization of Clouds

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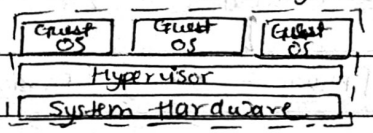
Introduction

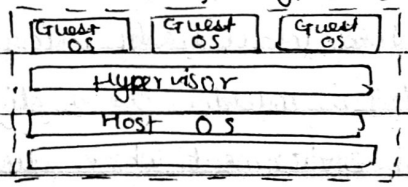
- Virtualization is a technique which allows to share single physical instance of an application or resource among multiple organizations or tenants customers. It does so by assigning a logical name to a physical resource and providing a pointer to that physical resource on demand.
- Creating a virtual machine over existing OS & hardware is referred as Hardware virtualization. Virtual machines provide an environment that is logically separated from underlying hardware.
- The machine on which the virtual machine is created is known as host machine and virtual machine is referred as a guest machine. This virtual machine is managed by a software or firmware, which is known as hypervisor.
- Hypervisor : The hypervisor is a firmware or low-level program that acts as a Virtual Machine Manager. There are two types:

(a) Type 1 Hypervisor executes on bare system. Ex:- Oracle VM, Sun xVM server, LynxSecure etc.



(b) Type 1 hypervisor doesnot have any host OS.

(b) Type 2 Hypervisor is a s/w interface that emulates the devices with which a system normally interacts. Ex:- Microsoft Hyper V, VMware Fusion, VMware workstation 6.0 etc.



- Types of Hardware virtualization:
  - Full virtualization: The underlying h/w is completely simulated. Guest s/w doesn't require any modification to run.
  - Emulation Virtualization: The virtual machine simulates the h/w & hence becomes independent of it. In this, guest OS doesn't require modification.
  - Paravirtualization: The h/w is not simulated. The guest OS run their own isolated domains.
- VMware vSphere is highly developed infrastructure that offers a management infrastructure framework for virtualization. It virtualizes the system, storage and networking hardware.

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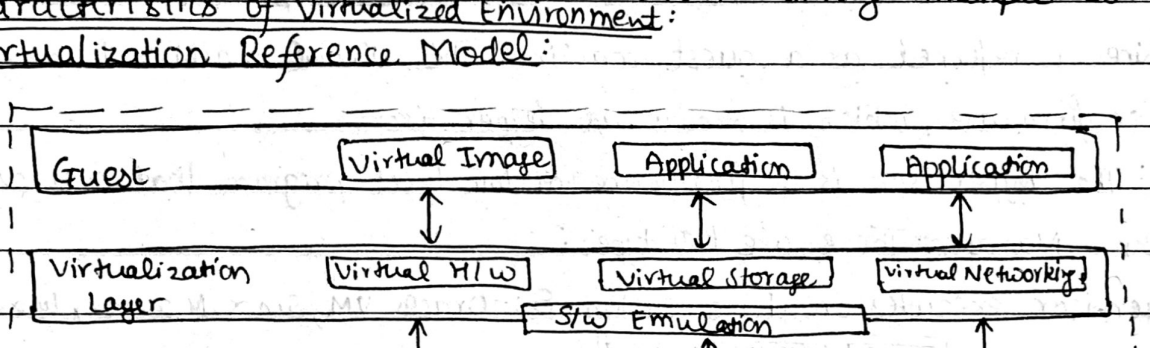
- Need of Virtualization
  - Enhanced performance
  - Limited use of resources
  - Shortage of space
  - Eco-friendly initiatives
  - Administrative Costs

- Benefits of Virtualization
  - More flexible & efficient allocation of resources
  - Enhance developement productivity
  - Lowers cost of IT infrastructure
  - Remote access & rapid scalability
  - High availability and Disaster Recovery
  - Pay per use of the IT infrastructure on demand
  - Enables running multiple OS.

* Characteristics of Virtualized Environment:

- Virtualization Reference Model:



Reference Model of virtualization

① Guest: The guest represents the system component that interacts with virtualization layer rather than host. It usually consists of one or more virtual disk files, and a VM definition file. Virtual Machines are centrally managed by a host application that sees and manages each virtual machine as a different application.

② Host: It represents the original environment where guest is supposed to be managed. Each guest runs on the host using shared resources donated to it by the host. The OS, works as the host & manages the physical resource management, & the device support.

③ Virtualization Layer: It is responsible for recreating the same or a different environment where the guest will operate. It is an additional abstraction layer b/w a network & storage h/w, computing, and the application running on it. Usually it helps to run a single OS per machine which can be very inflexible compared to usage of virtualization.

- Virtualized Environment Characteristics

① Increased Security

- The ability to control the execution of guest programs in a completely

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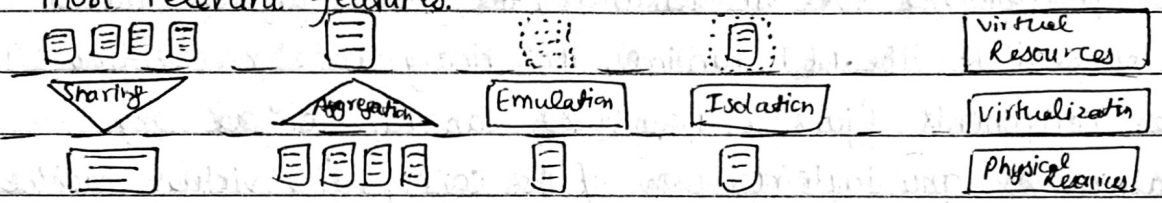
transparent manner opens new possibilities for delivering a secure, controlled execution environment. All the operations of the guest programs are generally performed against the virtual machine, which then translates and applies them to the host programs.

- A virtual machine manager can control and filter the activity of the guest programs, thus preventing some harmful operations from being performed. Resources exposed by the host can then be hidden or simply protected from the guest. Increased security is a requirement when dealing with untrusted code.

  Ex:- Untrusted code can be analyzed in Cuckoo sandboxes environment.

② Managed Execution: In particular, sharing, aggregation, emulation and isolation are the most relevant features.



- Sharing: Virtualization allows the creation of a separate computing environments within the same host. This basic feature is used to reduce the no. of active servers and limit power consumption.
- Aggregation: Virtualization allows a group of separate hosts to be tied together & represented to guests as a single virtual host. This functionality is implemented with cluster management s/w, which harnesses the physical resources of a homogeneous group of machines and represents them as a single resource.
- Emulation: ~~Virtual~~ Guest programs are executed within an environment that is controlled by the virtualization layer, which ultimately is a program. Also a completely different environment wrt host can be emulated, thus allowing the execution of guest programs requiring specific characteristics that are not present in the physical host.
- Isolation: Virtualization allows providing guests - whether they are OS, applications or other entities - with a completely separate environment, in which they are executed. The guest program performs its activity by interacting with an abstraction layer, which provides access to the underlying resources. The virtual machine can filter the activity of the guest and prevent harmful operations against the host.
- Besides these characteristics, another important feature enabled by virtualization is

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performance tuning. It becomes easier to control the performance of the guest by finely tuning the properties of the resources exposed through virtual environment. This capability provides a means to effectively implement a QOS infrastructure.

③ Portability

- The concept of portability applies in different ways according to the specific type of virtualization considered.

(i) In the case of h/w virtualization soln, the guest is packaged into a virtual image that, in most cases, can be safely moved and executed on the top of different virtual machines.

(ii) In case of programming-level virtualization, as implemented by the JVM or ~~the guest is packaged into a virtual image that~~ the .NET runtime, the binary code representing application components (jars or assemblies) can run without any recompilation on any implementation of the corresponding virtual machine.

* Types of Virtualization

(i) Application Virtualization

It helps user to have a remote access of an application from a server. The server stores all personal info & other characteristics of application but can still run on a local workstation through internet. Example of this would be a user who needs to run two different versions of the same software. Technologies that use application virtualization are hosted applications and packaged applications.

(ii) Network Virtualization

The ability to run multiple virtual networks that each has a separate control & data plan. It co-exist together on top of one physical network. It can be managed by individual parties that potentially confidential to each other.

Network virtualization provides a facility to create & provision virtual networks - logical switches, routers, firewalls, load balancer, virtual private networks (VPN), and workload ~~securi~~ security within days or even in weeks.

(iii) Desktop Virtualization

Desktop virtualization allows the users OS to be remotely stored on a server in the data center. It allows the user to access their desktop virtually, from any location by different machine. Users who want

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spaific OS other than windows server will need to have a virtual desktop. Main benefits of desktop virtualization are user mobility, portability, easy management of s/w installation, updates and patches.

(iv) ~~Software Virtualization~~ Storage Virtualization

Storage virtualization is an array of servers that are managed by a virtual storage system. The servers aren't aware of exactly where their data is stored and instead func" more like worker bees in a hive. It makes managing storage from multiple sources to be managed and utilized as a single repository. Storage virtualization maintains smooth operations, consistent performance and a continuous suite of advanced functions despite changes, break down and differences in underlying equipments.

* ~~Hardware~~ Server Virtualization

- Server virtualization is the masking of server resources, including the no and identity of individual physical servers, processors & OS, from server users. The server administrator uses a s/w applications to divide one physical server into multiple isolated virtual environments. The virtual environments are sometimes called virtual private servers, but they are also known as guests, instances, containers or emulations.

OR

- Server virtualization is the partitioning of a physical server into no of small virtual servers, each running its own OS. These OS are known as guest OS. These are running on another OS known as host OS. Each guest running in this manner is unaware of any other guests running on the same host.

- Why use Server Virtualization?
  - Consolidation to conserve spaces
  - Isolated independent guest OS
  - Redudancy
  - Support Legacy Systems
  - Supports migration

- There are three ways to create virtual servers: full virtualization, para-virtualization & OS Level virtualization. The physical server is called host. The virtual servers are called guests. Each system uses a different approach to allocate physical server resources to virtual server

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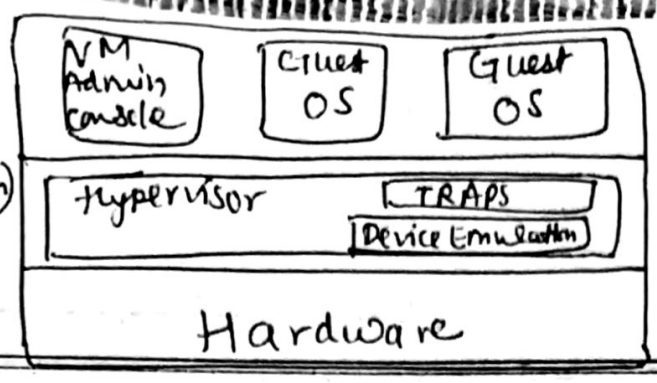
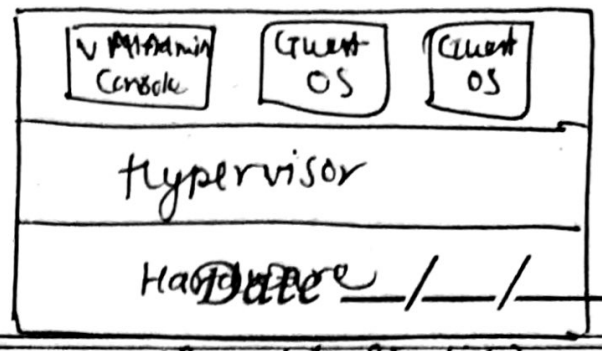


(Full virtualization)



(Para virtualization)

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- Full virtualization

- Each guest runs on a virtual limitation of h/w layer. This approach allows the guest OS to run without modifications. It also allows admin to create guests that use different OS.
- Full virtualization uses a special kind of software called a hypervisor (also known as Virtual Machine Monitor (VMM)). The hypervisor interacts directly with the physical server's CPU & disk space.
- Hypervisor serves as a platform for the virtual servers OS. It keeps each virtual server completely independent and unaware of the other virtual servers running on the physical machine. Each guest server runs on its own OS.
- The hypervisor monitors the physical server's resources. As virtual servers run applications, the hypervisor relays resources from physical machine to the appropriate virtual server.
- Advantages:

→ No modification to Guest OS required

- Disadvantages:

→ Complex → Slower due to emulation → Installation of new device driver difficult

- Paravirtualization / Paravirtual Machine (PVM)

- Guest servers are aware of one another. A paravirtualization hypervisor doesn't need as much processing power to manage the guest OS, because each OS is already aware of demands the other OS are placing on physical server. The entire system works together as a cohesive unit.
- The hypervisor actually modifies the guest OS code. This modification is called porting. Porting supports the VMM so it can utilize privileged system calls sparingly.
- Advantages:

→ Easier → Enhanced Performance → No emulation overhead

- Limitations:

→ Requires modification to guest OS.

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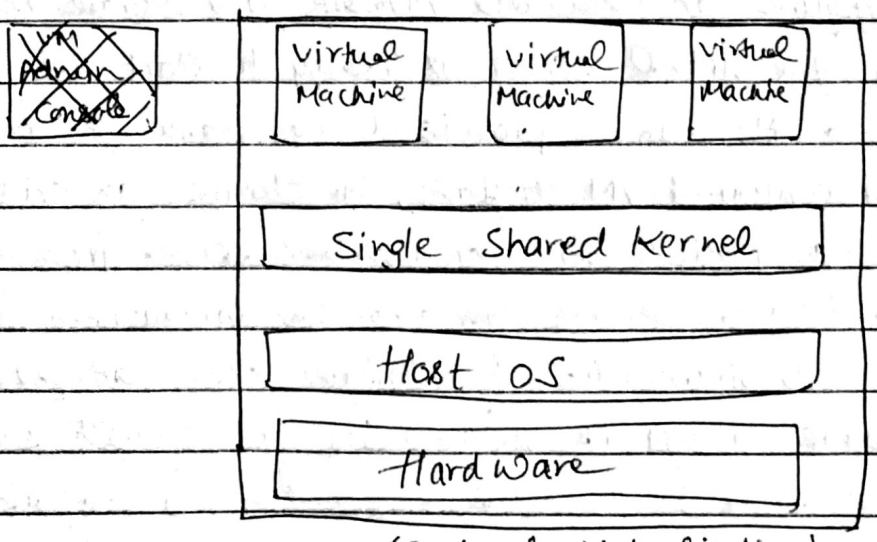
- OS Level Virtualization

- The OS level virtualization approach doesn't use a hypervisor at all. Instead, the virtualization capability is a part of host OS, which performs all the functions of a fully virtualized hypervisor.
- The host runs a single OS kernel as its core & export OS functionality to each of the guests. Guests must use same OS as host, although different distributions of the same system are allowed.
- This distributed architecture eliminates system calls between layers, which reduces CPU usage overhead. It also requires that each partition remain strictly isolated from its neighbours so that a failure or security breach in one partition isn't able to affect any other partitions.
- Common binaries and libraries on the same physical machine can be shared, allowing an OS level virtual server to host thousands of guest at the same time.
- Because of all guest OS must be same, this is called a homogenous environment.
- Advantages:
  → Significantly light weight than complete machines (including a kernel)
  → Can host many more virtual servers
  → Enhanced Security & Isolation
- Limitations:
  → Kernel or driver problem can take down all virtual servers



OS Level Virtualization)

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Virtualization

Hardware	Network	Storage	Memory	Software	Data	Desktop
• Full • Partial • Para	• Internal Network Virtualization • External Network Virtualization	• Block Virtualization • File Virtualization	• Application Level Integration • OS Level Integration	• OS Level • Application • Service	• Database	• Virtual Desktop Infrastructure • Hosted Virtual Desktop

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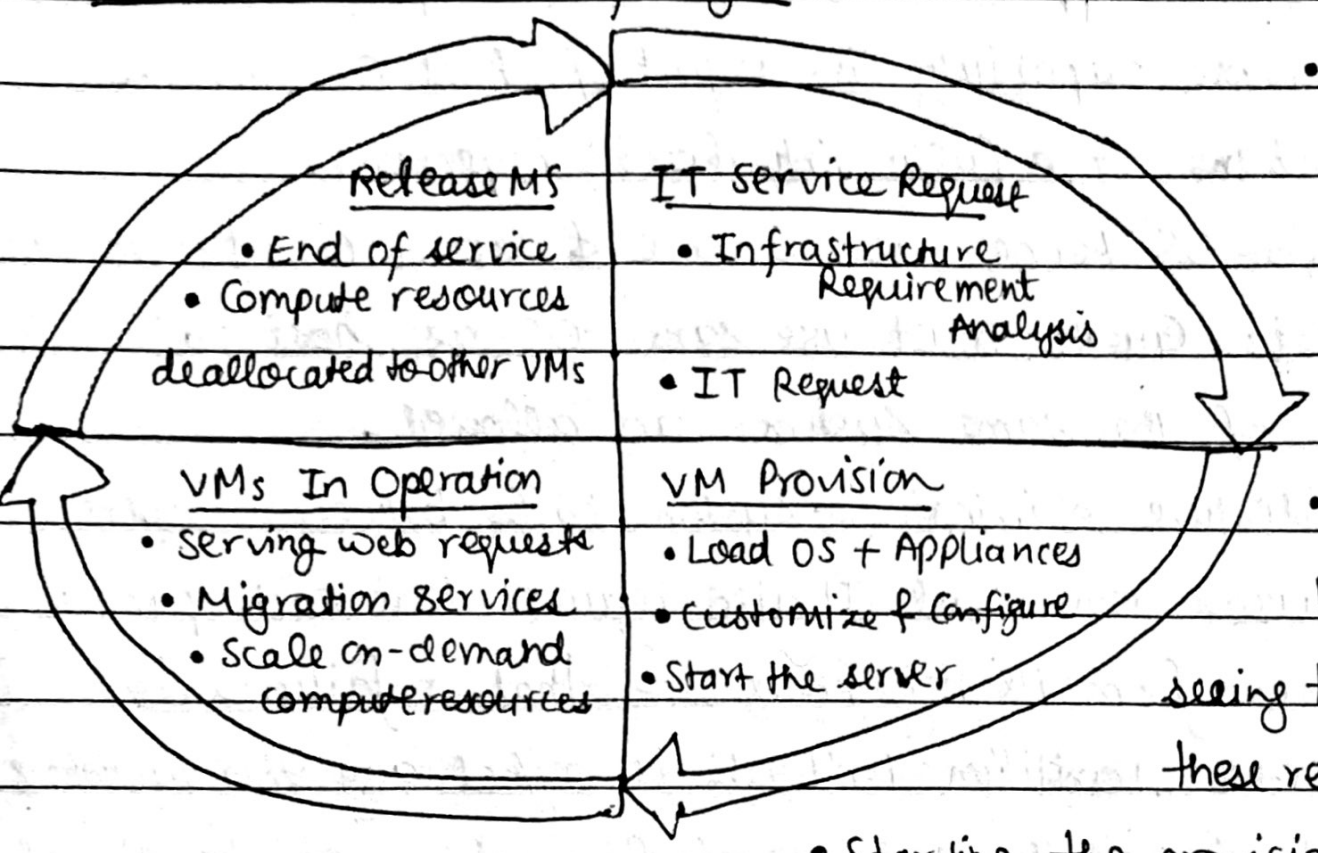
* Virtual Machine Provisioning and Manageability

- Virtual Machine Life Cycle



- The cycle starts by a request delivered to IP dept., stating requirement for creating a new server for a particular service.
- This request is being processed by IT administration to start seeing the servers' resource pool, matching these resources with requirements
- Starting the provision of the needed virtual machine
- Once it is provisioned & started, it is ready to provide the required service acc^n to an SLA.
- Virtual is being released; & free resources.

- VM Provisioning Process

- The common and normal steps of provisioning a virtual server are as follows
- (i) Firstly, you need to select a server from a pool of available servers along with appropriate as template you need to provision VM.
- (ii) Secondly, you need to load appropriate S/w (OS, drivers, middleware & needed applications for service required)
- (iii) Thirdly, you need to customize and configure the machine (ex. IP address, gateway) to configure an associated network and storage resources.
- (iv) Finally, the virtual server is ready to start with its newly loaded S/w.
- Normally, VMs can be provisioned by manually installing an OS, by using a preconfigured VM template, by cloning an existing VM, or by importing a physical server or a virtual server from another hosting platform. Physical servers can also be virtualized & provisioned using P2V (Physical To Virtual) tools & techniques (ex:- virt-p2v)
- After creating a VM by virtualizing a physical server, or by building a new virtual server in the virtual environment, a template can be created out of its.

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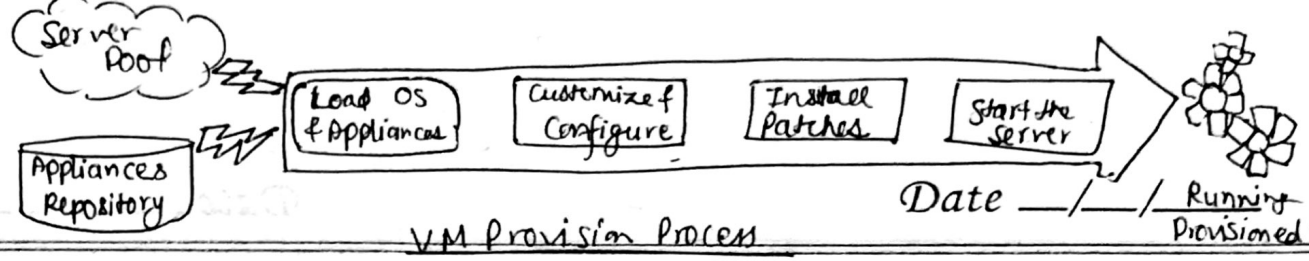

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VM Provision Process

- Most virtualization management vendors (VMware, XenServer, etc.) provide the data center's administration with ability to do such tasks in an easy way.
- Provisioning from a template is an invaluable feature, because it reduces the time required to create a new VM. Admins can create different templates for different purposes. For ex, you can create a Windows 2003 server template for the finance dept, or a Red Hat Linux template for the engineering dept. This enables the admin to quickly provision a correctly configured virtual server on demand.

* VM Migration Services

– Live Migration & High Availability

- Live Migration (Also called Hot or Real-Time Migration) can be defined as the movement of a VM from one physical host to another while being powered on. When it is properly carried out, this process takes place without any noticeable effect from user end point of view. It facilitates proactive maintenance in case of failure.
- Live migration can also be used for load balancing in which work is shared among computers in order to optimize the utilization of available CPU resources.

– Live Migration Anatomy, Xen Hypervisor Algorithm

- How to live migration's mechanism & memory & virtual machine states are being transferred through network from Host A to B, the XEN hypervisor is an example of this mechanism. The migration process can be viewed as a transactional interaction b/w two hosts involved.

– The logical steps that are executed when migrating an OS.

(Live Migration Stages)

Stage 0: Pre-Migration: An active virtual machine exists on physical host A.

Stage 1: Reservation: A request is issued to migrate an OS from Host A to Host B (a precondition is that the necessary resources exist on B and VM container of the size

Stage 2: Iterative Pre-Copy: During 1st iteration, all pages are transferred from A to B. Subsequent Iterations copy only those pages dirtied during previous transfer Phase.

Stage 3: Stop-and-Copy: Running OS instance at A is suspended, & its network traffic is redirected to B. CPU states and any remaining

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inconsistent memory pages are then transferred. At the end of this stage, there is a consistent suspended copy of VM at both A & B. The copy of A is considered primary & is resumed in case of failure.

Stage 4: Commitment: Host B indicates to A that it has successfully received a consistent OS image. Host A acknowledges this msg as a commitment of migration transaction.

Stage 5: Activation: The migrated VM on B is now activated. Post-migration code runs to reattach the device's drivers to new machine & advertise moved IP addresses.

This approach of failure management ensures that at least one host has a consistent VM image at all times during migration.

— Live Migration Vendor Implementation Example

- There are lots of VM management & provisioning tools that provide the live migration of VM facility, two of which are VMware VMotion & Citrix Xenserver "Xen Motion".
- VMware VMotion
  - (a) Automatically optimize & allocate an entire pool of resources for maximum hardware utilization, flexibility, & availability.
  - (b) Perform h/w maintenance without scheduled downtime along with migrating VM away from failing or underperforming servers.
- Citrix Xenserver "XenMotion"

  Based on Xenlive migrate utility, it provides the IT admin the facility to move a running VM from one Xenserver to another in the same pool without interrupting the service, making it a highly available service & also good feature to balance workloads on the virtualized environments.

— Regular / Cold Migration

- Cold migration is the migration of a powered-off VM. With cold migration:
  - → you have options of moving the associated disks from one data store to another.
  - → The VM are not required to be on a shared storage.
- Live migrations needs to have a shared storage for VM in server's pool but cold migration doesn't. In live migration for a VM b/w two hosts, there should be certain CPU compatibility checks, but in cold migration this check doesn't apply.
- Cold migration (VMware product) is easy to implement:
  - → The config files, including NVRAM file (BIOS Setting), log files, & the disks

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of the VM, are moved from the source host to the destination host's associated storage area.

→ The virtual machine is registered with new host.

→ After migration is completed, the old version of VM is deleted from source host.

- Live Storage Migration of VM: This kind of migration constitutes moving the virtual disks or the configuration file of a running VM to a new data store without any interruption in the availability of VM's service.

* Provisioning in the Cloud Context

- In cloud context, systems that provide VM provisioning & migration services.
- Amazon EC2 is a widely known example for vendors that provide public cloud services. Also Eucalyptus & Open Nebula are two complementary & enabling technologies for open-source cloud tools in building private, public & hybrid cloud infrastructure.
- Amazon Elastic Compute Cloud

• It is a web service that allows users to provision new machines into Amazon's virtualized infrastructure in a matter of minutes; using a publicly available API, it reduces time required to obtain & boot a new server.

• Users get full root access & can install almost any OS or application in their AMIs (Amazon Manager Images). Web services API allow users to reboot their instances remotely, scale capacity quickly & use on-demand service when needed.

• Setting up an EC2 is quite easy. Once you create your AWS account, you can use the on-line AWS console, or simply download offline cmd tools to start provisioning their instances.

• Amazon EC2 provides its customers with three flexible purchasing models to make it easy for the cost optimization:

→ On-demand instances

→ Reserved instances

→ Spot instances

- Eucalyptus

• It is an open-source infrastructure for the implementation of cloud

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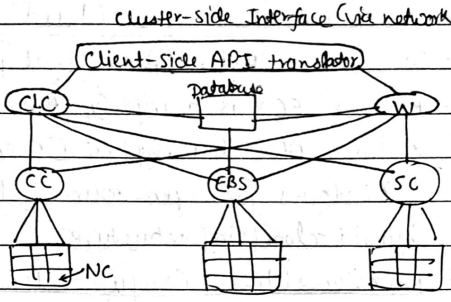
computing on computer clusters.

- Some of the Eucalyptus features are:
  → Interface compatibility with EC2 & S3 → Simple installation & Deployment
  → Support for most Linux distributions → Secure internal communication using SOAP
  → Support for running VMs that run atop Xen hypervisor or KVM.
- Eucalyptus aims at fostering the ~~research~~ research in models for service's provisioning, scheduling, SLA formulation & hypervisor' portability.
- Eucalyptus architecture:



→ Node Controller (NC) controls execution, inspection & termination of VM instances on the host where it runs.
→ ~~Cloud~~ Cluster Controller (CC) gathers info about & schedules VM execution on specific node controller, as well as manages virtual instance network.
→ Storage Controller (SC) is a put/get storage service that implements Amazon S3 interface & provides a way for storing and accessing VM images & user data.
→ Cloud Controller (CLC) is the entry point into cloud for users & admins. It queries node managers for info about resources, makes high-level scheduling decisions, & implements them by making requests to cluster controllers.
→ Walrus (W) is the controller component that manages access to the storage services within Eucalyptus. Requests are communicated to walrus using SOAP or REST based interface

— Open Nebula

- OpenNebula is an open & flexible tool that fits into existing data center's environments to build any type of cloud ~~management~~ deployment. It supports hybrid and public clouds.
- It can be primarily used as a virtualization tool to manage your virtual infrastructure.
- It is an open-source alternative to commercial tools for dynamic management of VMs on distributed resources. This tool is supporting several research lines in advance reservation of capacity, probabilistic admission control, placement optimization, resource models for efficient management of groups of VM, elasticity support & so on.

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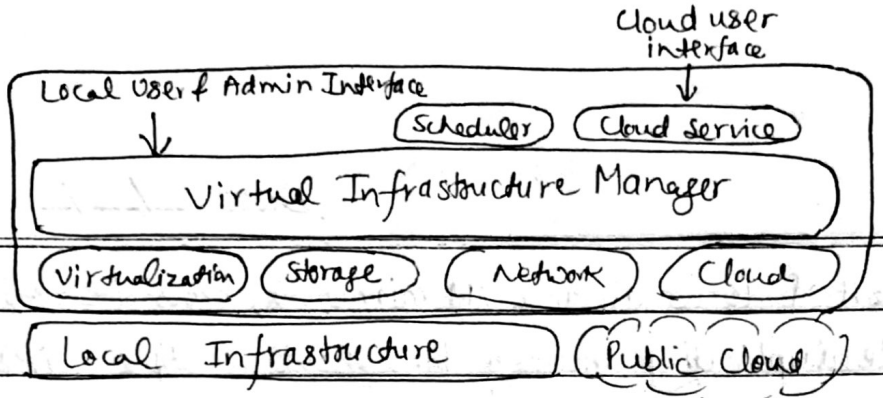

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Open Nebula High Level Architecture

- Haizea

- ~~It is an opensource provisioning abstraction & implements leases~~
- It is an opensource virtual machine-based lease management architecture developed by Sotomayor et al. It can be used as a scheduling backend for OpenNebula.
- Haizea uses leases as a fundamental resource provisioning abstraction & implements those leases as VMs, taking into account the overhead of using VMs when scheduling leases. It also provides advanced functionality such as
  → Advance reservation of capacity.
  → Best effort scheduling with backfilling.
  → Resource Preemption (Using VM suspend / resume / migrate)
  → Policy engine, allowing developers to write pluggable scheduling policies in Python.

* Future Research Directions

- Virtual machine provision & migration services take their place in research to achieve the best out of its objectives & here is list of potential areas for research:
  - Self-adaptive and dynamic data center
  - Study of performance in this dynamic environment
  - Common workload model & methodology for virtualized systems for performance evaluation & workload characterization of virtual workloads.
  - Implementing systems that are capable of scaling data with the same pace as scaling the infrastructure, or to integrate current infrastructure elastic ~~provising~~ provisioning systems with existing systems that are designed to scale out the applications & data layers.
  - Performance & high availability in clustered VMs through live migration:
    → VM scheduling algorithms
    → Accelerating VMs live migration time
    → Cloud wide VM migration & memory ~~de-dup~~ de-duplication

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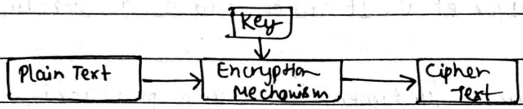
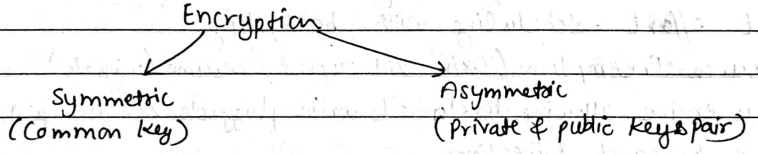
- Setup that can enable faster & longer distance VM migrations, cross-site load balancing, power management, & de-duplicating memory throughout multiple sites.
- Live migration security:
  → Extend migration algorithms to allow for priorities
  → Dynamic just-in-time provisioning of VMs & increase of business agility.

* Cloud Security Mechanisms (Encryption, PKI, SSO, IAM)

(i) Encryption



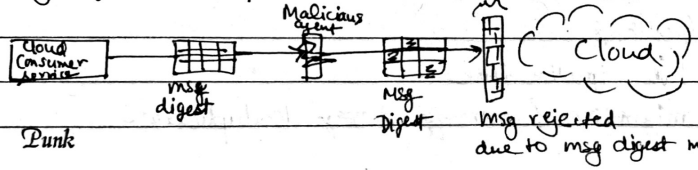
- A malicious agent is unable to retrieve data from encrypted msg or cipher text. The retrieval attempt may furthermore be revealed to the cloud service consumer.



- The encryption mechanism is added to the communication channel b/w outside users & user portal. This safeguards msg confidentiality via use of HTTPS.

(ii) Hashing

- It is used when a one-way, non-reversible form of data protection is required.
- A common application is storage of passwords. Hashing technology is used to derive a hashing code or msg digest from a msg.
- The msg sender can utilize hashing mechanism to attach msg digest to msg. The recipient applies same hash func^n to message to verify msg.
- A hashing func^n is applied to protect integrity of msg that is intercepted & altered by a malicious service agent, before it is forwarded. The fire wall can be configured to determine that msg has been altered thereby enabling it to reject the msg before it can proceed to cloud service.



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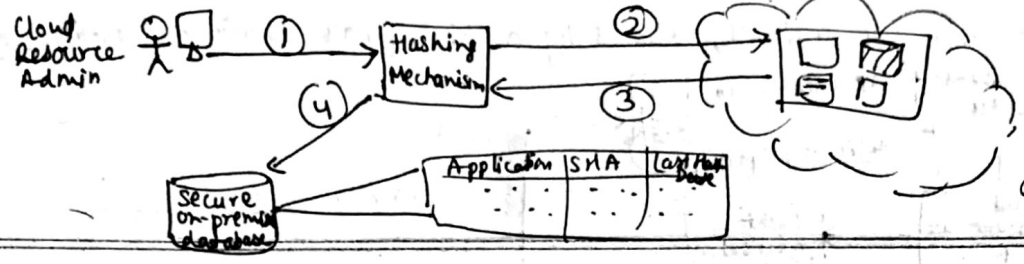

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- A hashing procedure is invoked when PaaS environment is accessed:
  ① The applications that were ported to this environment is checked
  ② & their msg digests are calculated
  ③ The msg digests are stored in a secure on-premise database
  ④ & a notification is issued if any of their values are not identical to ones in storage

(iii) Digital Signature

- It is a means of providing data ~~auth~~ authenticity and integrity through authentication & non-repudiation. A msg is assigned a digital signature prior to transmission which is then rendered invalid if msg experiences any subsequent unauthorized modifications.
- It provides evidence that the msg received is same as one created by its rightful sender. Both hashing & asymmetrical encryption are involved in creation of a digital signature, which essentially exists as a msg digest that was encrypted by a private key & appended to original msg. The recipient verifies the sign validity & uses corresponding public key to decrypt sign, which produces msg digest.
- Cloud service consumer B sends a msg digitally signed but was altered by consumer A. Virtual server B verify the digital sign before processing incoming msg even if they are within its trust boundary. The msg is then revealed as illegitimate due to invalid sign & is therefore rejected by Virtual Server B.
- Whenever a cloud consumer performs a management action that is related to IT resources, the cloud service consumer program must include a digital sign in the msg request to prove the legitimacy of its user.

(iv) Public Key Infrastructure (PKI)

- A common approach for managing the issuance of asymmetric keys is based on the PKI mechanism, which exists as a system of protocols, data formats, rules and practices that enable large-scale systems to securely use public key cryptography.
- This system is used to associate public keys with their corresponding key owners (known as public key identification) while enabling verification of key validity.
- PKIs rely on the use of digital certificates, which are digitally signed data structures that bind public keys to certificate owner identities as well as to related info, such as validity periods.

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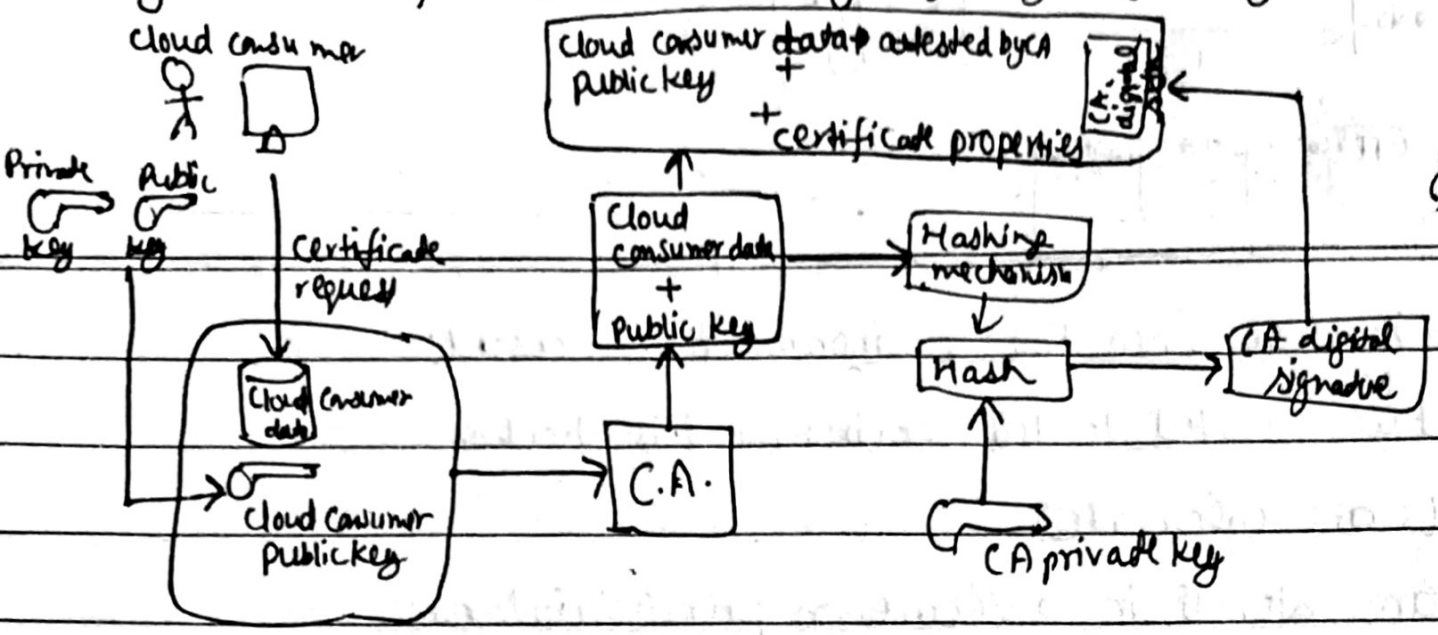
- Digital Certificates are usually digitally signed by a third-party certificate authority (CA)



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- The PRT is primarily used to counter insufficient authorization threat. An external cloud resource uses a digital certificate signed by trusted CA to access web-based management environment.

(v) Identity and Access Management (IAM)

- The IAM mechanism encompasses the components & policies necessary to control & track user identities & access privileges for IT resources, environments & systems.
- Specifically, IAM mechanisms exist as systems comprised of four main components:
  (a) Authentication (username + password)
  (b) Authorization (Correct Access Controls)
  (c) User management (Creating & deleting users)
  (d) Credential management (Password check, Account Recovery)
- The IAM mechanism is primarily used to counter the insufficient authorization, denial of service, & overlapping trust boundaries threats.

(vi) Single Sign-On (SSO)

- Propagating the authentication & authorization info for a cloud service consumer across multiple cloud services can be a challenge. The SSO mechanism enables one cloud service consumer to be authenticated by a security broker, which establishes a security context that is persisted while the cloud service consumer accesses other cloud services or cloud based IT resources.
- Otherwise, the cloud service consumer would need to re-authenticate itself within every subsequent request.
- The SSO mechanism essentially enables mutually independent cloud services & IT resources to generate & circulate runtime authentication & authorization credentials.
- A cloud service consumer provides the security broker with login credentials:

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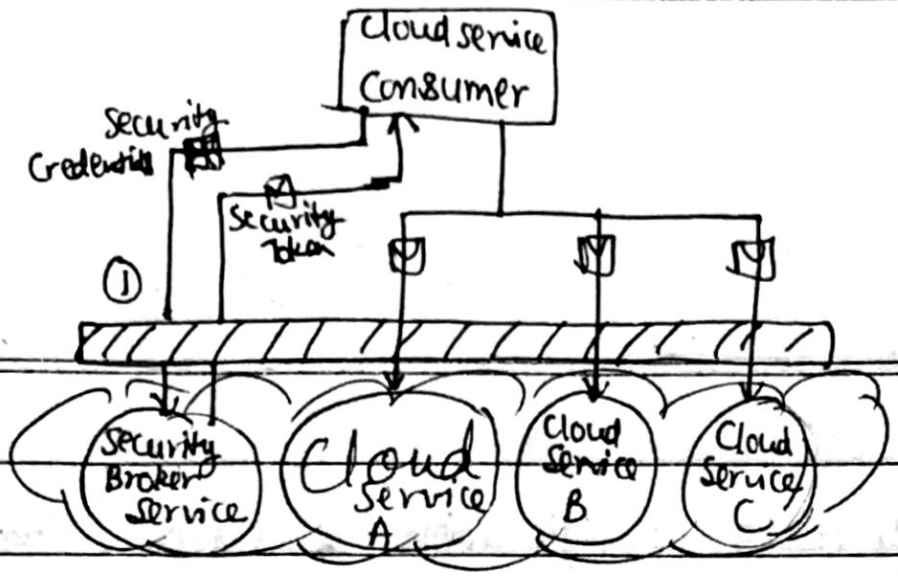
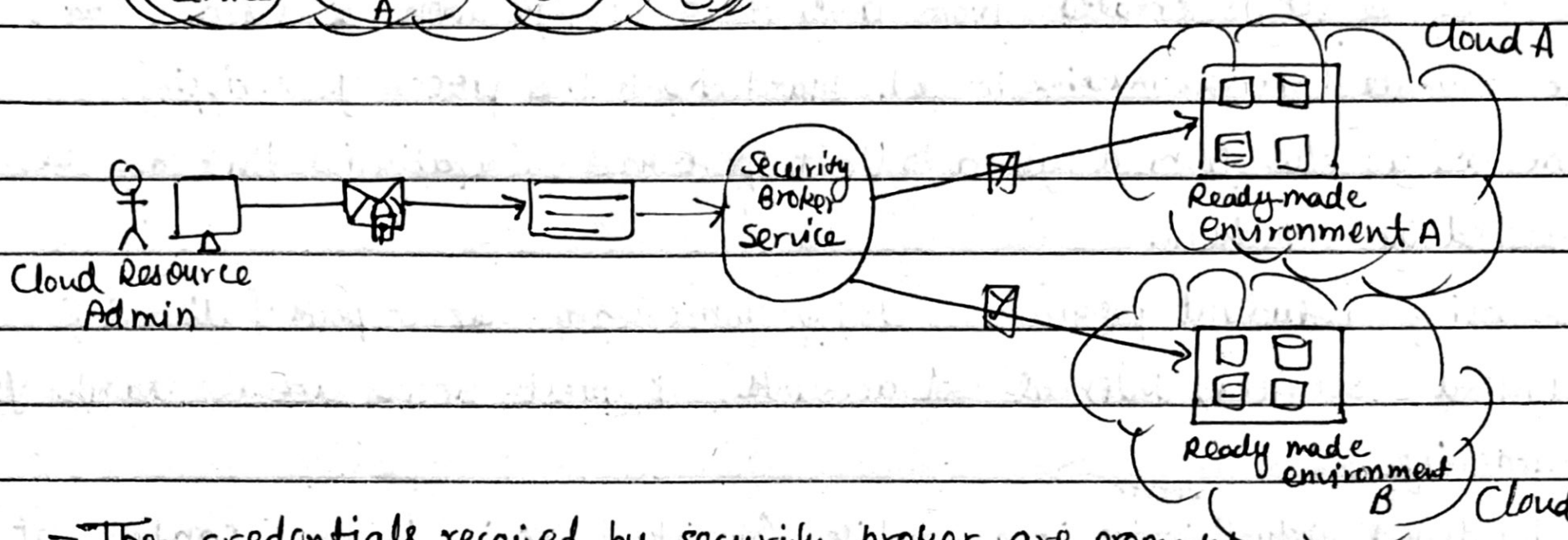


① The security broker responds with an authentication token upon successful authentication, which contains cloud service consumer identity info.

② that is used to automatically authenticate cloud service consumer across cloud services A, B & C ③



- The credentials received by security broker are propagated to ready-made environments across two different clouds. The security broker is responsible for selecting the appropriate security procedure with which to contact each cloud.

(vii) Cloud-Based Security Groups

- Cloud resource segmentation is a process by which separate physical & virtual IT environments are created for different users & groups. Ex:- One network can be established with resilient firewall for external Internet access, while a second is deployed without a firewall because its users are internal & unable to access Internet.
- Resource segmentation is used to enable virtualization by allocating a variety of physical IT resources to virtual machines.
- The cloud-based resource segmentation process creates cloud-based security group mechanisms that are determined through security policies. Networks are segmented into logical cloud-based security groups that form logical network perimeters.
- Multiple virtual servers running on the same physical server can become members of different logical cloud-based security groups. Virtual servers can further be separated into public-private groups, development-production groups or any other designation configured by the cloud resource admin.
- When an external cloud resource admin accesses the web portal to allocate a virtual server, the requested security credentials are assessed & mapped to an internal security policy that assigns a corresponding cloud-based security group to new virtual server.

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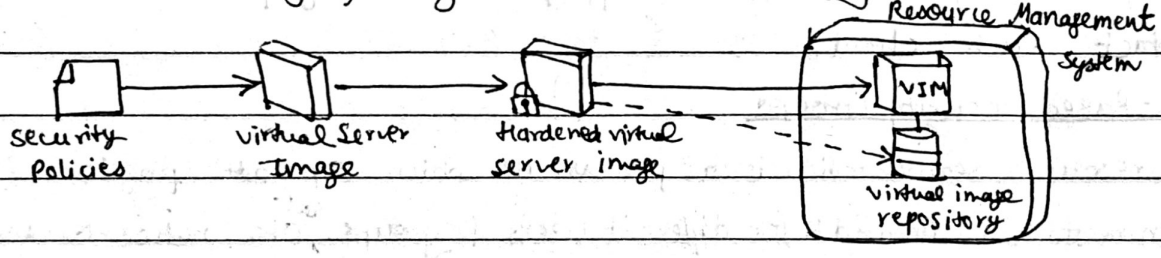
(viii) Hardening Virtual Server Images

- A virtual server is created from a template configuration called a virtual server image (or virtual machine image). Hardening is the process of stripping unnecessary s/w from a system to limit potential vulnerabilities that can be exploited by attackers.
- Removing redudant programs, closing unnecessary server ports & disabling unused services, internal root accounts, & guest access are all examples of hardening.
- A hardened virtual server image is a template for virtual service instance creation that has been subjected to a hardening process. This generally results in a virtual server template that is significantly more secure than original standard image.



- A cloud provider applies its security policies to harden its standard virtual server images. The hardened image template is saved in the VM images repository as part of a resource management system.
- Hardened virtual server images help counter the DOS, insufficient authorization, & overlapping trust boundaries threat.

* Service Management in Cloud Computing (SLA, Billing & Accounting etc.)

- Service Management → A system integral of supply chain management that connects actual company sales & the customer.
  → The goal of service management is to maximize service supply chains
  → The purpose of service management is to reduce high costs by integrating products & services & keep inventory levels smaller.
- Cloud Service Management
  - Cloud monitoring & cloud service management tools allow cloud providers to ensure optimal performance, continuity & efficiency in virtualized, on-demand environments. The delivery of dynamic, cloud-based infrastructure, platform & application services doesn't occur in a vacuum.

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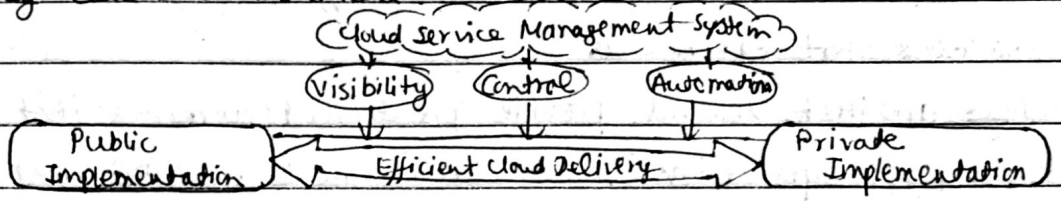
- In addition to best practices for effective administration of all the elements associated with cloud service delivery, cloud service management & cloud monitoring tools enable providers to keep up with the continually shifting capacity demands of a highly-elastic environment.



- The service management provides the visibility, control & automation needed for efficient cloud delivery in both public & private implementations.
- Simplify user interaction with IT: The user friendly self service accelerates time to value. Service catalogue enables standards which drives consistent service delivery.
- Enable policies to lower cost with provisioning: Automatic allocating & de-allocating of resources will make delivery of services fast. Provisioning policies allow reuse & release & reuse of assets.
- Increase system admin productivity: Providing the benefits of to broker will probably become a critical success factor in cloud computing. Due to growth of service brokage business will increase the ability of cloud consumers to use services in a trustworthy manner. These cloud mediators will help companies to choose the right platform, deploy apps across multiple clouds.
- Following are opportunities for cloud brokers:

→ Cloud service intermediation: The broker must need to manage the additional securities or management capabilities over the cloud.

→ Cloud aggregation: It includes deployment of services over multiple cloud platforms

- The ability to group an application across multiple clouds will become important, i.e, if one service goes down another can be started.
- Key Cloud Sol^{n} Characteristics: The cloud architect should maintain an index of resources for enabling the scalability to scale across tens & thousands of machines across multiple geographies.

→ High availability: The cloud architect must need to act as boss for availability & disaster recovery.

→ Application Lifecycle: The cloud architect should support for creation of infrastructure to installation, configuration & launching an application to deletion or expiration.

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→ Role based administration: It allows fine grained control of what each person can or can't do in cloud features.

→ Policies: The cloud architect should provide a rich set of policies which can be modified or new policies can be created to take effect at global level. ~~This frees up resources that can be us~~

→ Alarms: The cloud architect should provide pre defined alarms that can be set at global level for applications. These alarms can be ~~modified~~ used to notify individual users or application owners regarding the application thresholds being reached.

→ Application awareness & policy based allocation.

– SLA (Service-level Agreement)

- A SLA is a contract b/w a service provider & its internal or external customers that documents what services the provider will furnish & defines the service standards the provider is obligated to meet.
- Service providers need SLAs to help them manage customers' expectations & define circumstances under which they are not liable for outages or performance issues.
- Customers also benefits from SLAs in that they describe the performance characteristics of the service, which can be compared with other vendors' SLAs, & also set forth means of redressing service issues – via service credits, for ex.
- An SLA will typically include a statement of objectives, a list of services to be covered by the agreement & will also define the responsibilities of the service provider & customer under SLA.
- SLA performance metrics may include following:
  → Availability & uptime percentage → Specific ~~Per~~ Performance Benchmarks
  → Server provider response time → Resolution time → Usage statistics, etc.
- In addition to establishing performance metrics, SLA may include a plan for addressing downtime & documentation for how service provider will compensate customers in event of contract breach. ~~SLAs~~
- SLAs tend to be broad agreements intended to cover all of a service provider's customers.

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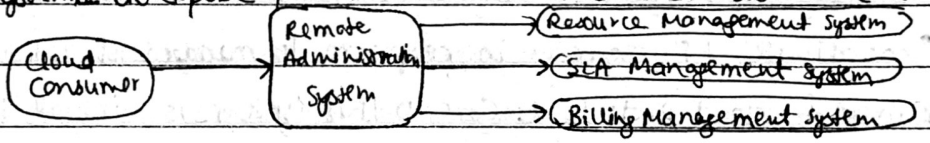
* Service Management in Cloud

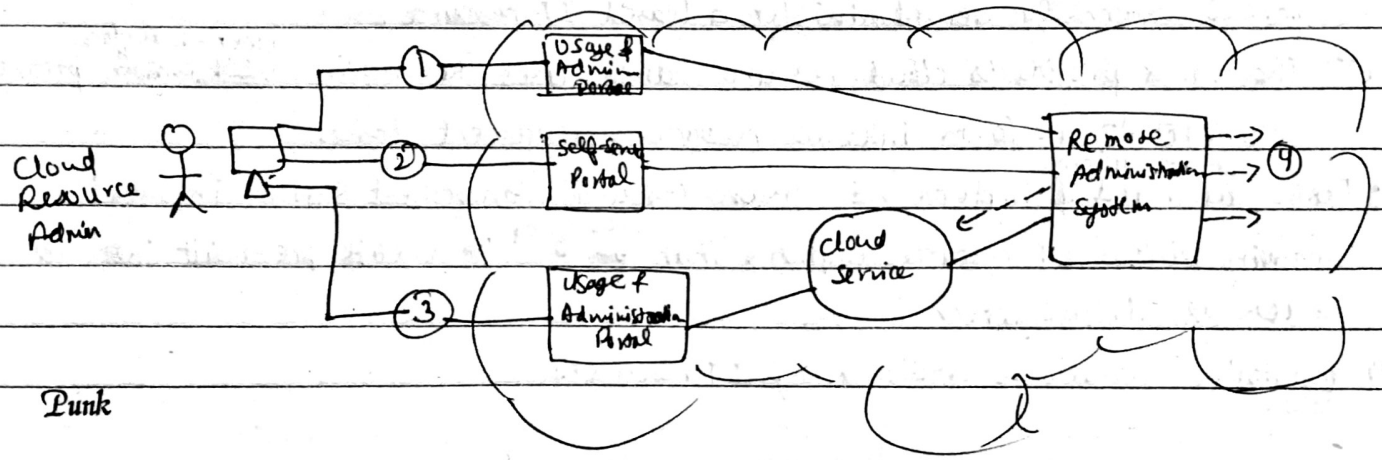
- The following management related mechanisms / systems typically provide integrated APIs & can be offered as individual products, custom applications, or combined into various product suites or multi-functn applications:
  - Remote Administration System
  - Resource Management System
  - SLA Management System
  - Billing Management system

- Remote Administration System

- The Remote Administration System mechanism provides tools and user-interfaces for external cloud resources administrators to configure and administer cloud-based IT resources.
- It can establish a portal for access to administration and management features of various underlying systems to expose & centralize administration controls to external resource admins.



- The system provides a user console while programming interfacing with underlying management systems via their APIs.
- The following are two types of portals that are created with this system:
  - → Usage and Administration Portal: A general purpose portal that centralizes management controls to different cloud-based IT resources and can further provide IT resource usage reports.
  - → Self-Service Portal: This is essentially a shopping portal that allows cloud consumers to search an up-to-date list of cloud services & IT resources that are available from a cloud provider. The cloud consumers submits its chosen items to cloud provider for provisioning. This portal is primarily associated with rapid provisioning architecture.



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① A cloud resource admin uses usage & administration portal to configure an already leased virtual server to prepare it for hosting.
② The cloud resource admin then uses self-service portal to select & request the provisioning of a new cloud service.
③ The cloud resource admin then accesses the usage & administration portal again to configure the newly provisioned cloud service that is hosted on virtual server
④ Throughout these steps, the remote administration system interacts with necessary management systems to perform the requested actions.

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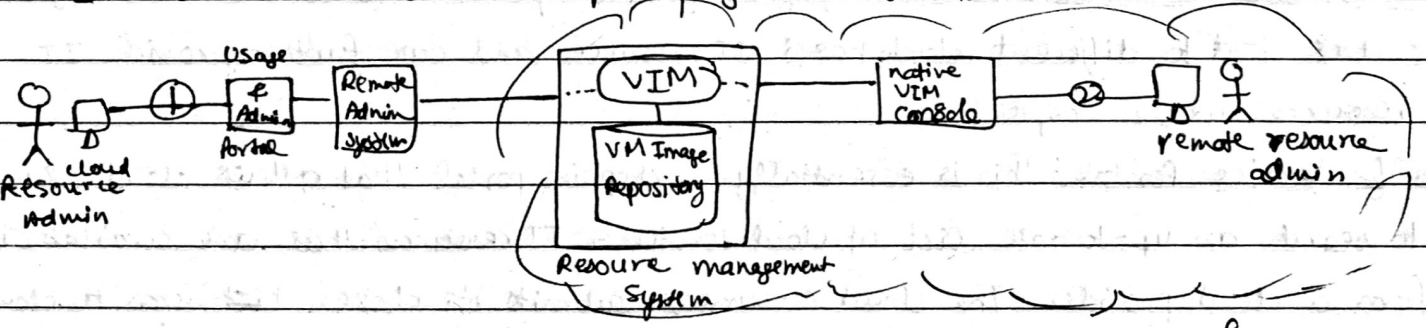
- Depending on type of cloud product, access control level & underlying management system, tasks that can commonly be performed by cloud consumers via remote administration console include:
→ configuring & setting up cloud services → provisioning & releasing IT resource for on-demand services
→ monitoring cloud service status, usage, & performance → monitoring QOS & SLA fulfilment
→ managing leasing costs & usage fees → tracking internal & external access to leased services
→ planning & assessing IT resource provisioning → capacity planning
→ managing user accounts, security credentials, authorization & access control.

— Resource Management System

- It helps coordinate IT resources in response to management actions performed by both cloud consumers & cloud providers. Core to this system is virtual infrastructure manger (VIM) that coordinates server hlw so that virtual server instances can be created from the most expedient underlying physical system server.
- A VIM is a commercial product that can be used to manage a range of virtual IT resources across multiple physical servers.



① The cloud consumer's cloud resource admin accesses a usage & administration portal externally to administer a leased IT resource.
② The cloud provider's cloud resource admin uses the native user-interface VIM console provided by VIM to perform internal resource management tasks.

- Tasks that are typically automated & implemented through resource management System include:
→ managing virtual IT resource templates that are used to create pre-built instances, such as virtual server images
→ monitoring operational conditions of IT resources

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→ allocating & releasing virtual IT resources into available infrastructure
→ coordinating IT resources & enforcing usage & security policies throughout lifecycle of cloud service instances.

— SLA management System

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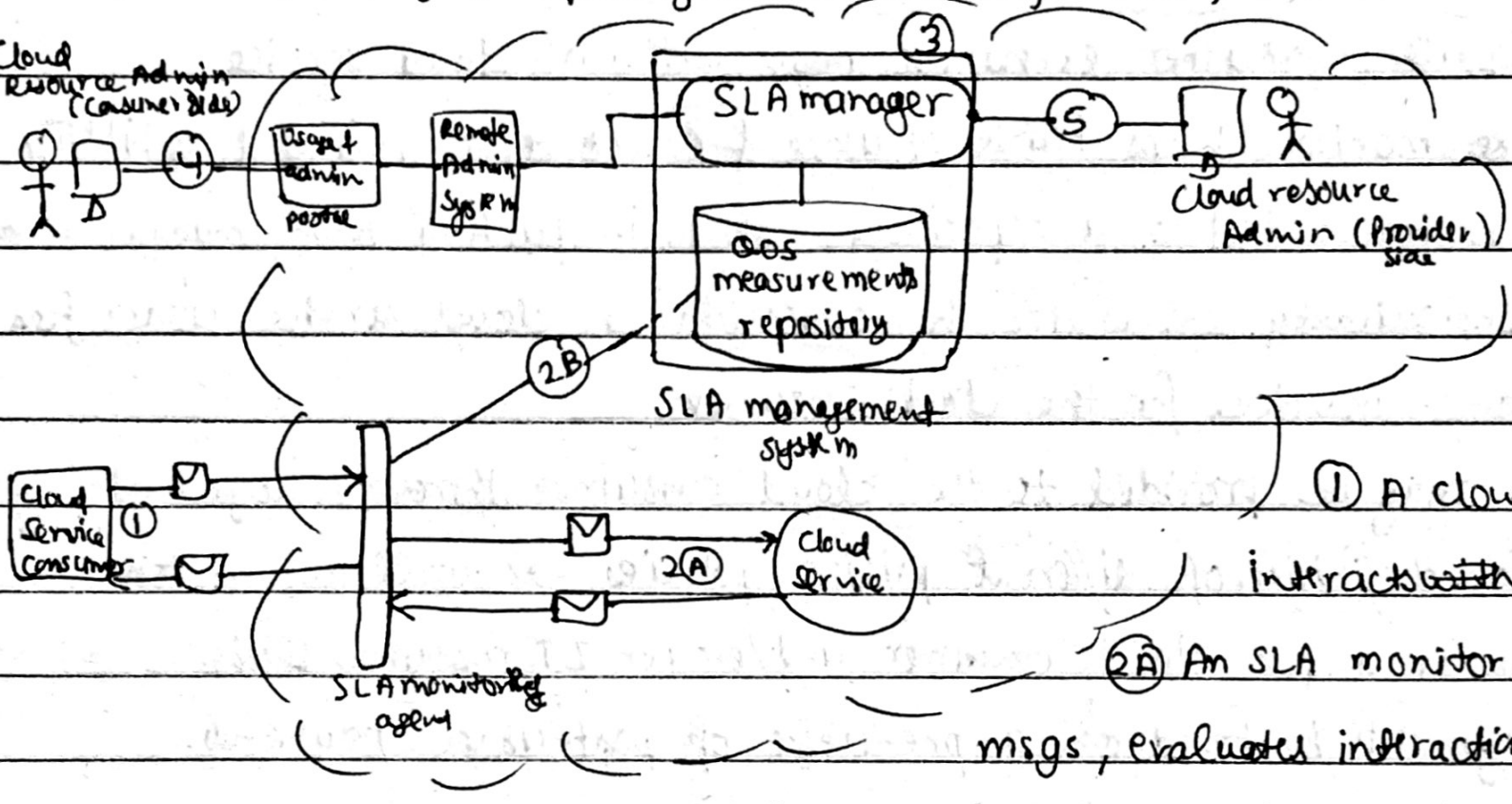
• The SLA management system mechanism represents a range of commercially available cloud management products that provide features pertaining to the administration, collection, storage, reporting & runtime notification of SLA data.



① A cloud service consumer interacts with a cloud service

② An SLA monitor intercepts exchanged msgs, evaluates interaction & collects relevant runtime data in relation to QOS guarantees defined in cloud service SLA

(2B) The data collected is stored in repository ③ that is part of the SLA management system

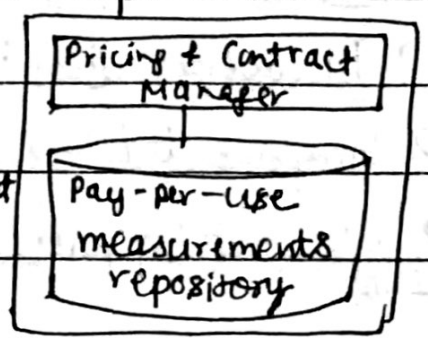
④ Queries can be issued & reports can be generated for an external cloud resource admin via usage & administration portal ⑤ or for an internal cloud resource administrator via SLA management system's native user-interface.

• An SLA management system deployment will generally include a repository used to store & retrieve collected SLA data based on pre-defined metrics & reporting parameters. It will further rely on one or more SLA monitor mechanisms to collect SLA data that can then be made available in near-real time to usage & administration portals to provide on-going feedback regarding active cloud services. The metrics monitored for individual cloud services are aligned with SLA guarantees in corresponding cloud provisioning contracts.

— Billing Management System

• The Billing management system mechanism is dedicated to the collection & processing of usage data as it pertains to cloud provider accounting & cloud consumer billing.

• Specifically, it relies on pay-per-use monitors to gather runtime usage data that is stored in a repository that system components then draws from for billing, reporting & invoicing purposes



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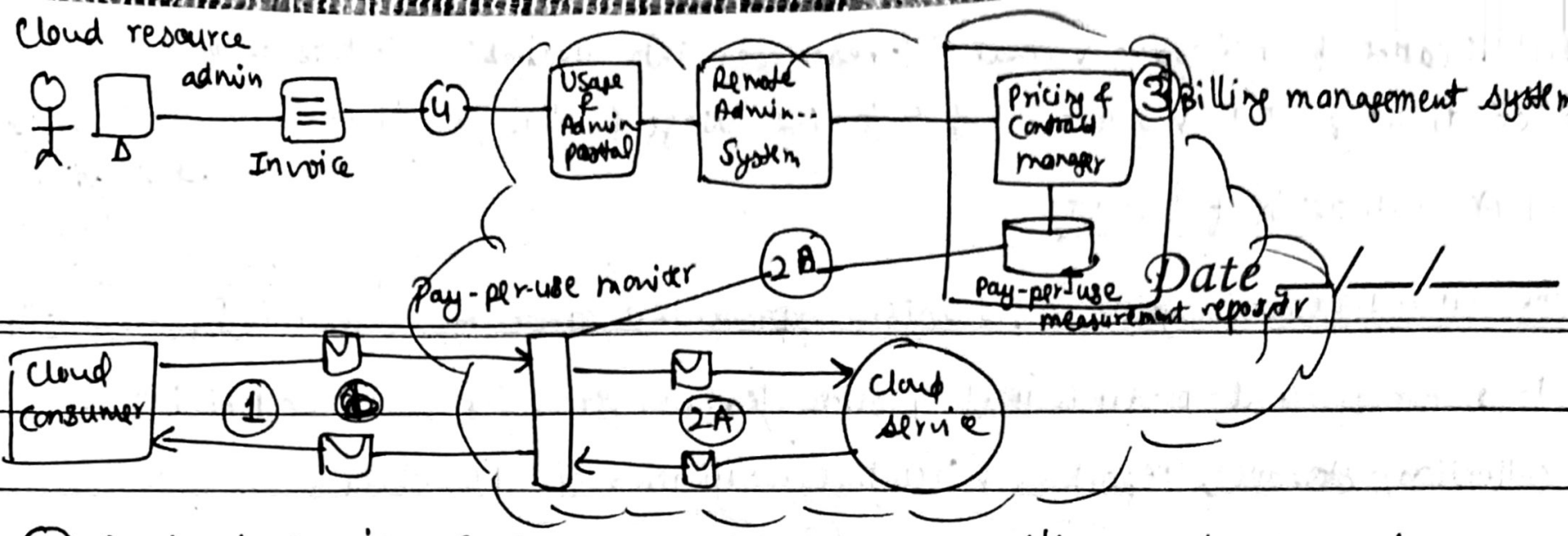

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(1) A cloud service consumer exchanges msgs with a cloud service.

(2A) A pay-per-use monitor keeps track of usage & collects data relevant to billing,

(2B) which is forwarded to a repository that is part of billing management system.

(3) The system periodically calculates the consolidated cloud service usage fees & generates an invoice for the cloud consumer

(4) The invoice may be provided to the cloud consumer through usage & administration portal.

- It allows for definition of different pricing policies as well as custom pricing models on a per cloud consumer and/or per IT resource basis.
- Billing arrangements be based on a pre-usage of post-usage payments.

* Provisioning

- Bare Metal Provisioning Architecture

- Access to conventional remote mangement programs in unavailable for bare-metal servers - physical servers that do not have pre-installed OS or any other S/w.
- It establishes a system that utilizes specialized service agents, which are used to discover & effectively provision entire OS remotely. The remote management system that is integrated with server's ROM becomes available upon server start-up.
- A web-based or proprietary user-interface is usally used to connect to physical server's remote management interface. IP address of remote management interface through default IP can be configured manually, or through configuration of DHCP service.
- The bare-metal provisioning system addresses "vulnerability to inadvertent human & configuration errors when manual deployment on multiple servers" & "Time-intensive & significant runtime processing required in remote mangement S/w" by using following components:

→ Discovery agent: Search & find available physical servers to be assigned to consumer

→ Deployment agent: Client for bare-metal provisioning system

→ Discovery section: Scans & locates available physical server with which to connect.

→ Management Loader: Connects to physical server & loads management options for consumer

→ Deployment Component: Responsible for installing OS on selected physical servers.

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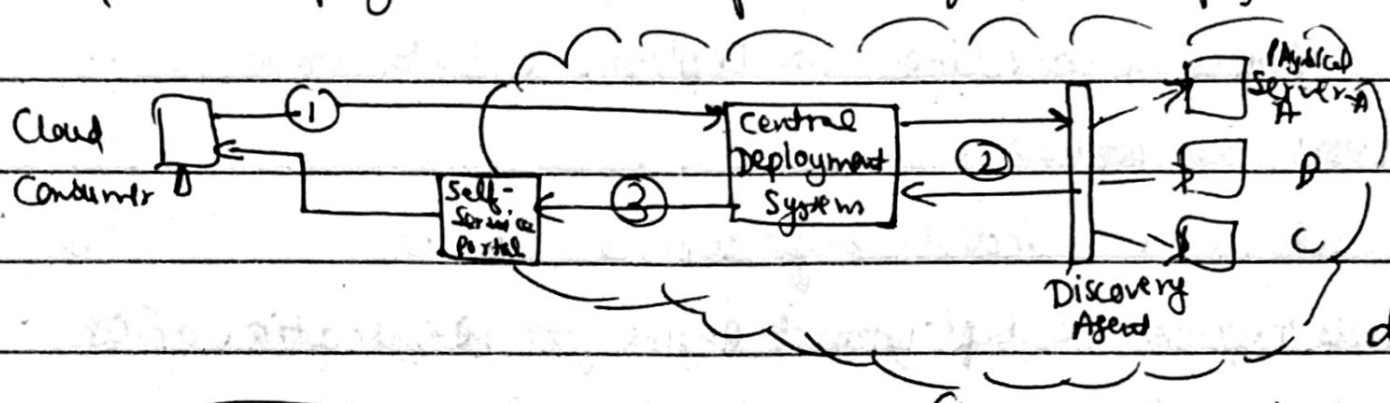
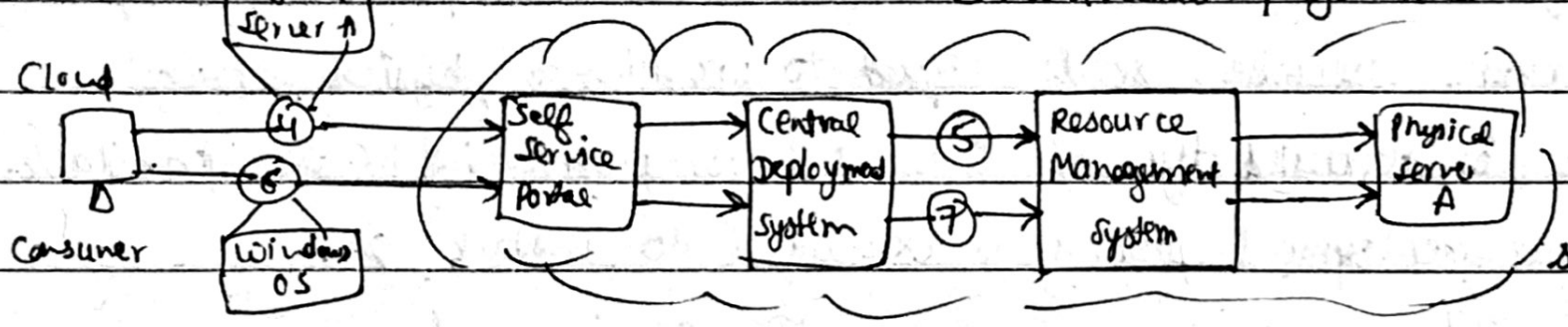
- The bare-metal provisioning system provides an auto deployment feature that allows consumers to connect to deployment server & provision more than one server or OS at same time.
- The central deployment system connects to servers via ~~their~~ Data management interfaces & uses same protocol to upload & operate as an agent in physical server's RAM.
- The bare metal server then becomes a raw client with a management agent installed, & the deployment sw uploads required setup files to deploy the OS.



① Cloud consumer connects to deployment soln ② to perform a search using discovery agent. ③

③ The available physical servers are shown to consumer



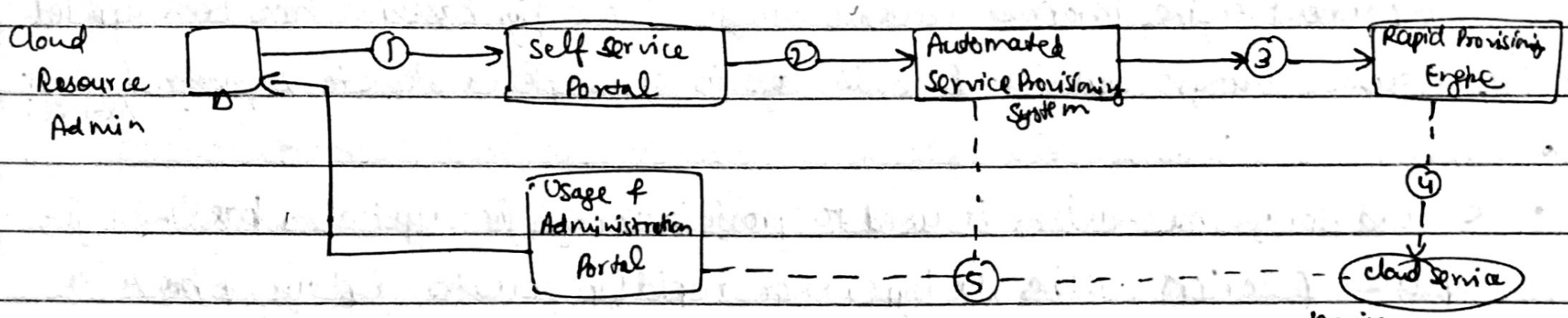
④ The cloud consumer selects a physical server to provision.

⑤ The deployment agent is loaded to the physical server's RAM via Remote management system. ⑥ The consumer selects an OS & method of config. via deployment soln. ⑦ The OS is installed & server becomes operational.

- The following additional mechanisms can be part of this architecture:
  - → Cloud storage Device: Stores OS templates & installation files
  - → Hypervisor
  - → SLA Management System
  - → Resource Replication: For replication of IT resources
  - → Logical Network Perimeter

- Rapid Provisioning Architecture

- It establishes a system that automates the provisioning of wide range of IT resources, either individually or as a collective.



① A cloud resource admin requests a new cloud service through self-service portal ② The self-service portal passes the request to automated service provisioning program installed on virtual server ③ which passes necessary tasks to be performed to rapid provisioning engine, ④ which announces when new cloud service is ready. ⑤

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(5) The automated service provisioning program finalizes & publishes cloud service on usage & administration portal for cloud consumer access.

- Beyond components displayed, many additional architectural artifacts are available to coordinate & automate different aspects of IT resource provisioning, such as:

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→ Server templates → Server Images → Application packages → Application package
→ Custom scripts → Sequence Manager → Sequence Logger → OS Baseline
→ Application Configuration Baseline → Deployment Data store

- Steps using the above components:

(i) Consumer requests a new server through self-service portal
(ii) Sequence Manager forwards request to deployment engine for preparation of OS.
(iii) Deployment engine uses virtual server templates for provisioning if request is for virtual server. Otherwise, sends request to provision a physical server
(iv) Pre-defined image for requested type of OS is used for provisioning of OS, if available. Otherwise, regular deployment process is executed to install OS.
(v) Deployment engine informs sequence manager when OS is ready.
(vi) Sequence manager updates & sends logs to sequence logger for storage.
(vii) sequence manager requests that deployment engine apply OS baseline to provisioned OS.
(viii) Deployment engine applies requested OS baseline.
(ix) Deployment engine informs sequence manager that OS baseline has been applied.
(x) Sequence manager updates & sends logs of completed steps to sequence logger for storage.
(xi) Sequencer manager requests that deployment engine install applications.
(xii) Deployment engine deploys the applications on provisioned server.
(xiii) Deployment engine informs sequence manager that applications have been installed.
(xiv) Sequence manager updates & sends logs of completed steps to sequence logger for storage.
(xv) Sequence manager requests that deployment engine apply application's configuration baseline.
(xvi) Deployment engine applies config. baseline.
(xvii) Deployment engine informs sequence manager that config. baseline have been applied.
(xviii) Sequence manager updates & sends logs of completed steps to sequence logger for storage.

- The cloud storage mechanism is used to provide storage for application baseline info, templates & scripts, while the hypervisor rapidly creates, deploys, & hosts the virtual servers that are either provisioned themselves or host provisioned IT resources.
- The resource replication mechanism is usally used to generate replicated instance of IT resources in response to rapid provisioning requirements.

Unit-IV

Advanced Cloud Applications

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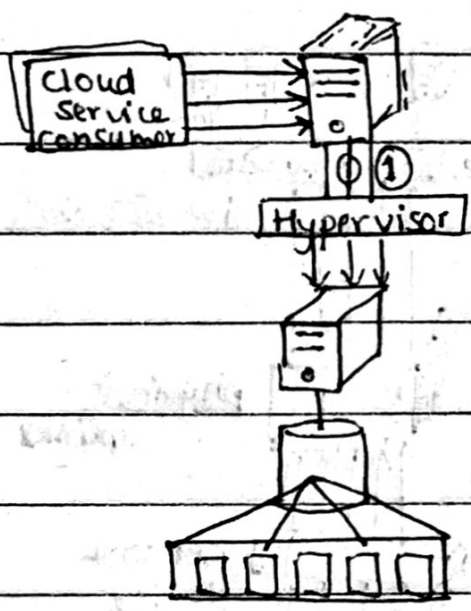
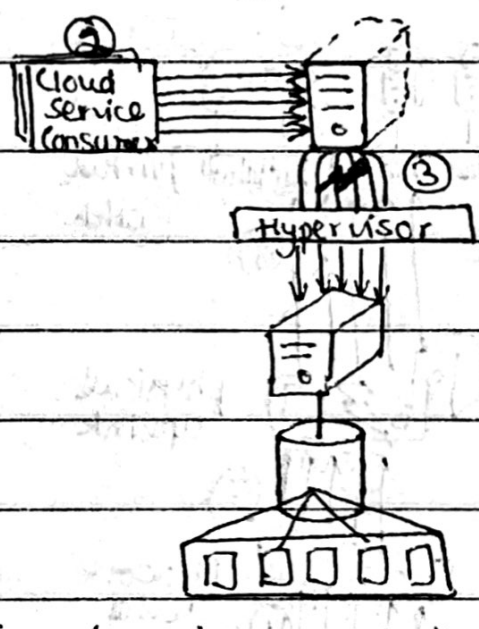
* Specialized Cloud Architecture

- Direct I/O Access Architecture

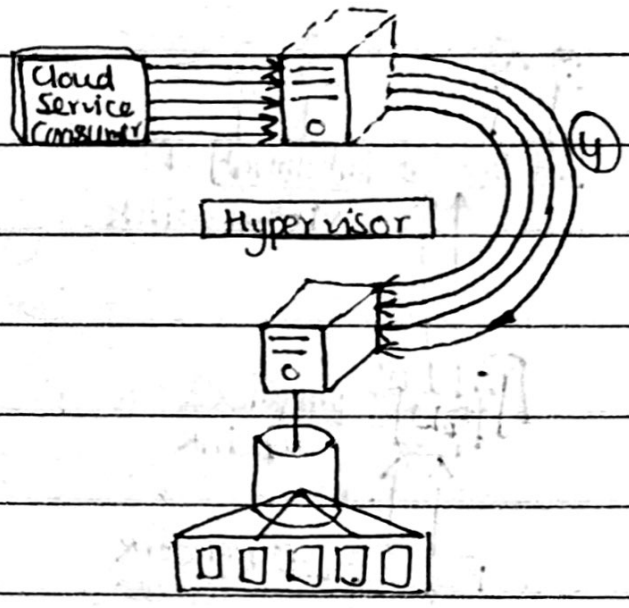
- Access to physical I/O cards that are installed on a physical server is usually provided to host virtual servers via a hypervisor-based layer of processing called I/O virtualization. However, virtual servers sometimes need to connect to & use I/O cards without any hypervisor interaction or emulation.
- With the direct I/O access architecture, virtual servers are allowed to circumvent the hypervisor and directly access the physical server's I/O card as an alternative to emulating a connection via the hypervisor.



① Cloud service consumers access a virtual server, which accesses a database on a SAN storage LUN. Connectivity from virtual server to the database occurs via a virtual switch.



② There is an increase in the amount of cloud service consumer requests,
③ causing the bandwidth & performance of the virtual switch to become inadequate.



④ The virtual server bypasses the hypervisor to connect to the database server via a direct link to the physical server. The increased workload can now be properly handled.

- To achieve this sol^{n} & access the physical I/O card without hypervisor interaction, host CPU needs to support this type of access with the appropriate drivers installed on the virtual server. The virtual server can then recognize the I/O card as a hardware installed after the drivers are installed.
- Other mechanisms that can be involved in this architecture in addition to the virtual server & hypervisor include:
  - → Cloud Usage Monitor - The cloud service usage data that is collected by runtime monitors can include & separately classify direct I/O access.
  - → Logical Network Perimeter - The logical network perimeter ensures that the allocated physical I/O card does not allow cloud consumers to access other cloud consumers' IT resources.

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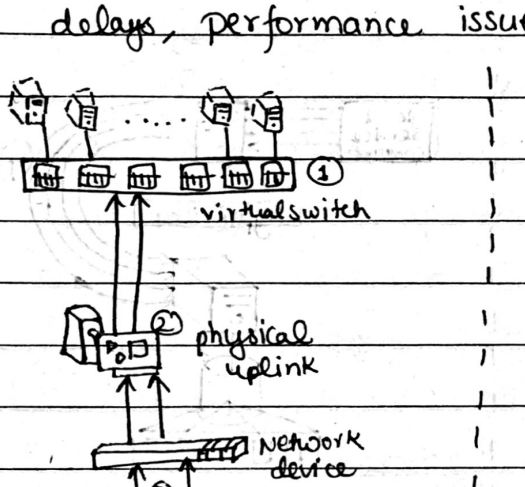
→ Pay-Per-Use Monitor :- This monitor collects usage cost information for allocated physical I/O card.

→ Resource Replication - Replication technology is used to replace virtual I/O cards with physical I/O cards.

- Load Balanced Virtual Switches Architecture

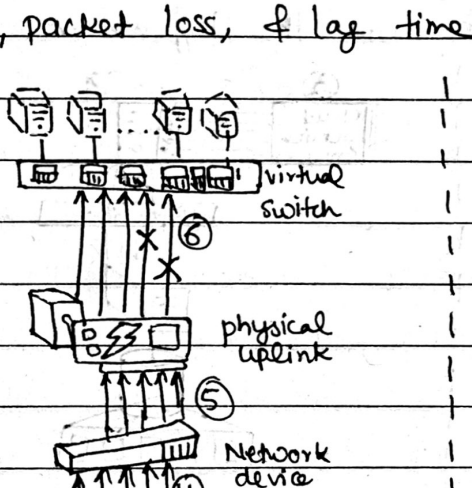
• virtual servers are connected to the outside world via virtual switches, which send & receive traffic with the same uplink. Bandwidth bottlenecks form when the network traffic on the uplink's port increases to a point that it causes transmission delays, performance issues, packet loss, & lag time.



① A virtual switch is interconnecting virtual servers

② A physical network adapter has been attached to the virtual switch to be used as an uplink to the physical (external) network, connecting the virtual servers to cloud consumers

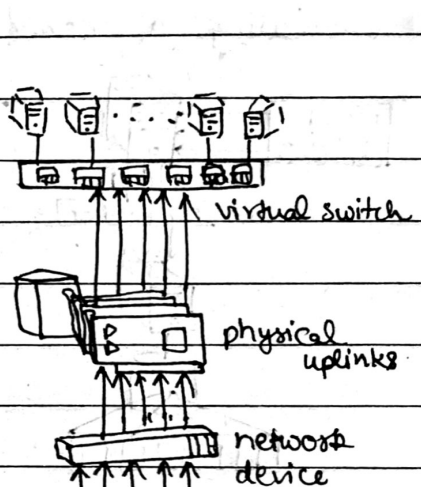
③ Cloud service consumers send requests via physical uplink



④ The amount of traffic passing through physical uplink grows in parallel with increasing no. of requests. The no. of packets that need to be processed & forwarded by the physical network adapter also increases.

⑤ The physical adapter can't handle the workload, now that the network traffic has exceeded its capacity

⑥ The network forms a bottleneck that results in performance degradation & loss of delay-sensitive data packets



Additional physical uplinks are added to distribute & balance network traffic

- The load balanced virtual switches architecture establishes a load balancing system where multiple uplinks are provided to balance network traffic workloads across multiple uplinks or redudant paths which can help avoid slow transfers & data loss.
- Link aggregation can be executed to balance the traffic, which allows the workload to be distributed across multiple uplinks at the same time so that none of the network cards are overloaded.
- The virtual switch needs to be configured to support multiple physical uplinks,

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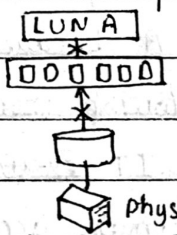
which are usually configured as an NIC team that has defined traffic-shaping policies

- The following mechanisms can be incorporated into this architecture:
  - → Cloud Monitor Usage Monitor – They are used to monitor network traffic & bandwidth usage.
  - → Hypervisor – This mechanism hosts & provides virtual servers with access to both the virtual switches & external network.
  - → Load Balancer – It distributes the network workload across different uplinks.
  - → Logical Network Perimeter – It creates boundaries that protect & limit bandwidth usage for each cloud consumer.
  - → Resource Replication – This mechanism is used to generate additional uplinks to virtual switches
  - → Virtual Server – Virtual servers host the IT resources that benefit from the additional uplinks & bandwidth via virtual switches.

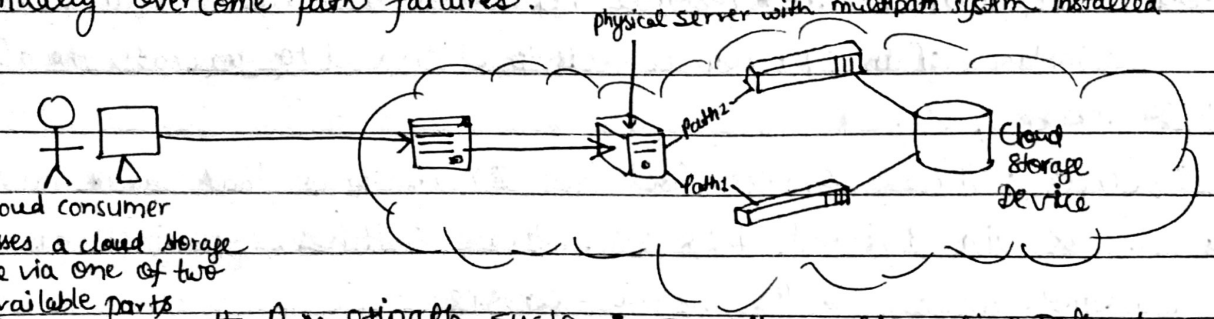
– Multipath Resource Access Architecture

- Certain IT resources can only be accessed using an assigned path (or hyperlink) that leads to their exact location. This path can be lost or incorrectly defined by the cloud provider. An IT resource whose hyperlink is no longer in the possession of the cloud consumer becomes inaccessible & unavailable. Exception conditions that result from IT resource unavailability can compromise the stability of larger cloud sol"s that depend on the IT resource.



Physical server A is connected to LUN A via a single fiber channel, & uses the LUN to store different types of data. The fiber channel connection becomes unavailable due to HBA card failure & invalidates the path used by Physical server A, which has now lost access to LUN A & all of its stored data

- The multipath resource access architecture establishes a multipathing system with alternative paths to IT resources, so that cloud consumers have the means to programatically or manually overcome path failures.



A multipath system is providing alternative paths to a cloud storage device

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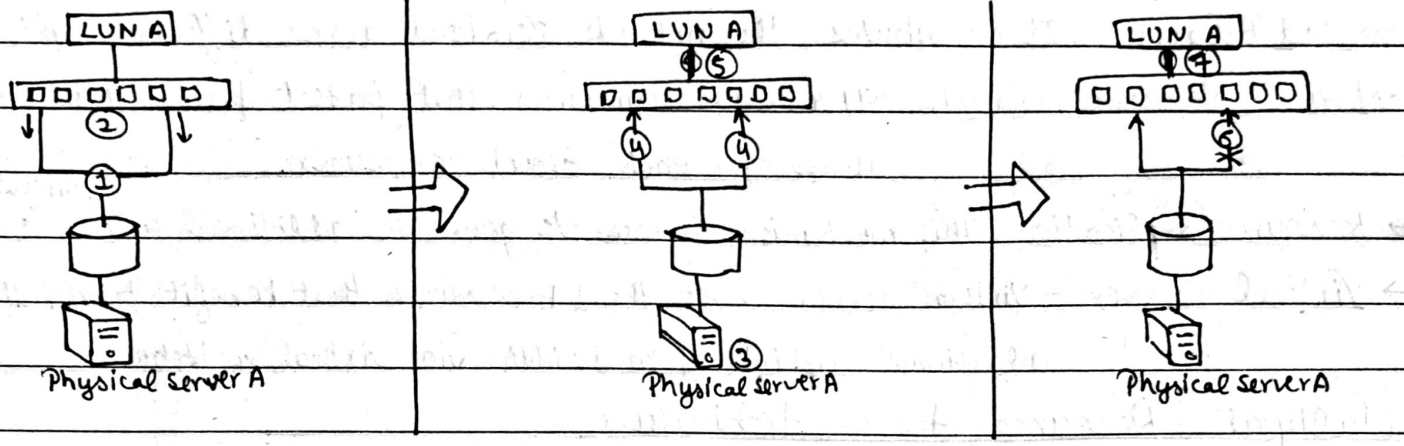
- This technology architecture requires use of a multipathing system & the creation of alternative physical or virtual hyperlinks that are assigned to specific IT resources. The multipath system resides on the server or hypervisor, & ensures that each IT resource can be seen via each alternative path identically.



① Physical server A is connected to LUN A cloud storage device via two different paths.
② LUN A is seen as different LUNs from each of the two paths
③ The multipath system is configured
④ LUN A is seen as one identical LUN from both paths, ⑤ and physical server A has access to LUN A from two different paths
⑥ A link failure occurs & one of the paths becomes unavailable
⑦ Physical server A can still use LUN A because the other link remains active.

- The architecture can involve the following mechanisms:
  - → Cloud Storage Device - It is a common IT resource that requires the creation of alternative paths in order to remain accessible to sol^{n}s that rely on data access.
  - → Hypervisor - Alternative paths to a hypervisor are required in order to have redundant links to the hosted virtual servers.
  - → Logical Network Perimeter - It guarantees the maintenance of cloud consumer privacy, even when multiple paths to the same IT resources are created.
  - → Resource Replication - The resource replication mechanism is required when a new instance of an IT resource needs to be created to generate the alternative path.
  - ~~→ Virtual Server~~
  - → Virtual Server - These servers host the IT resources that have multipath access via different links or virtual switches. Hypervisor can provide multipath access to the virtual servers

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* Federated Clouds

- A federation cloud (also called cloud federation) is the deployment & management of multiple external & internal cloud computing services to match business needs. A federation is the union of several smaller parts that perform a common action.
- Cloud federation manages consistency and access controls when two or more independent geographically distinct clouds share either authentication, files, computing resources, command & control or access to storage ~~services~~ resources.
- The primary difference between "Intercloud" & "Federation" is that the Intercloud is based on future standards & open interfaces, while federation uses a vendor version of the control plane. With the Intercloud vision, all clouds will have a common understanding of how applications should be deployed. Eventually workloads submitted to a cloud will include enough of a definition (resources, security, service level, geo-location, etc.) that the cloud is able to process the request & deploy the application. This will create the true utility model, where all the requirements are met by the definition & the application can execute "as is" in any cloud with the resources to support it.
- Cloud Federation Stack
  - Creating a cloud federation involves research & development at different levels: conceptual, logical & operational, & infrastructural.
  - Each cloud federation level presents different challenges and operates at different layer of the IT stack.
  - Conceptual Level
    → It addresses challenges in presenting a cloud federation as a favourable soln wrt use of services leased by single cloud providers.
    → Elements of concern at this level are:
    # Motivations for cloud providers to join a federation
    # Motivations for service consumers to leverage a federation
    # Advantages for providers in leasing their services to other providers
    # Obligations of providers once they have joined ~~to~~ the federation.
    # Trust agreements between providers
    # Transparency versus consumers

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→ The functional requirements include:

Supplying a low-latency access to customers, regardless of their location.

Handling Bursts in Demand

Scaling Existing Applications & services beyond capabilities of owned infrastructure

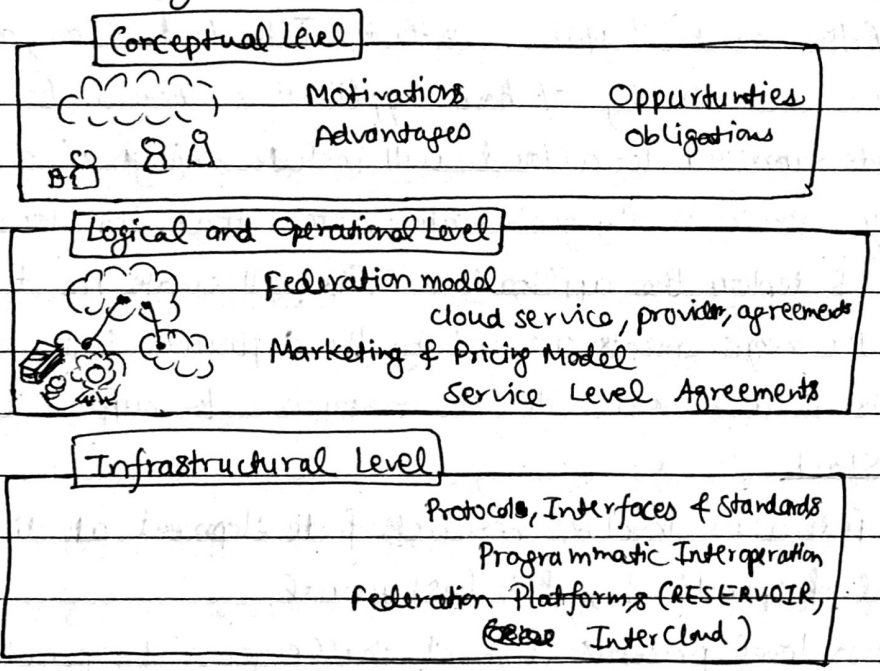
Make revenue from unused capacity.

→ The nonfunctional requirements are:

Meeting compulsory regulations about the location of data.

Containing transient spikes in operational costs

Disaster Recovery



Cloud Federation Reference Stack

- **Logical and Operational Level**

→ It identifies & addresses the challenges in devising a framework that enables the aggregation of providers that belong to different administrative domains within a context of single overlay infrastructure, which is cloud federation.

→ The following challenges are addressed at this level:

How should a federation be ~~operated~~ represented?

How should we model & represent a cloud service, a cloud provider or an agreement?

How should we define rules & policies that allow providers to join a federation?

What are the mechanisms in place for settling agreements among providers?

What are providers responsibilities with respect to each other?

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When should providers & consumers take advantage of the federation?
What kinds of services are more likely to be leased or bought?
How should we price resources that are leased, & which fraction of resources should be leased?

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→ Particular attention on this level has been put on necessity for SLAs & their definition. An implementation of SLA should specify

Purpose # Restrictions # Validity Period # Scope # Parties
Service-level objectives (SLOs) # Penalties # Optional Services # Administration

→ SLA life cycle:

(1.) Discover service provider (2.) Define SLA (3) Establish agreement
(4.) Monitor SLA violation (5.) Terminate SLA (6) Enforce penalties for SLA violation

• Infrastructural Level

→ It addresses the technical challenges involved in enabling heterogenous cloud computing systems to interoperate seamlessly.

→ It is important to address the following issues:

What kind of standards should be used?
How should design interfaces & protocols be designed for interoperation?
What technologies are the technologies to use for interoperation?
How can we realize a s/w system, design platform components, & services enabling interoperability?

→ Interoperation & composition among different cloud computing vendors is possible only by means of open standards & interfaces.

→ At IAAS layer, almost every Iaas provider exposes web Interfaces for packaging VM templates, launching, monitoring & terminating virtual instances. The use of common technology simplifies the interoperation among vendors, since a minimum amount of code is required to enable such interoperation. These APIs allow for defining an abstraction layer that uniformly accesses the services of several Iaas vendors. The possibility of dynamically moving VM instances among different providers is essential to supporting dynamic load balancing among different Iaas vendors. In this direction, the Open Virtualization Format (OVF) aims to be a soln for this problem.

→ At Paas layer, interoperations become harder. Currently, there is no sign of interoperation at this level & no proposed standards simplifying the interoperations among vendors.

→ Regarding the Saas layer, variety of services offered makes the operation less crucial. For interoperability at the Saas layer is provided by online

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office automation sol^{n}s such as Google Documents, Zoho Office, & others; several of them provide the capability to export & import documents to & from different formats, thus simplifying the exchange of data.

— Technologies for Cloud Federations

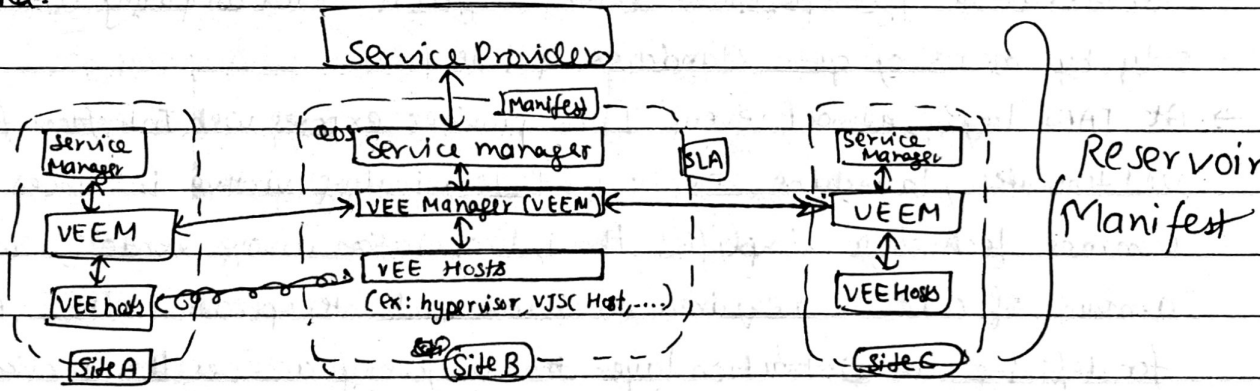
• RESERVOIR (Resources and Services Virtualization without Barriers)

→ It is an European research project focused on developing an architecture that supports providers of cloud infrastructures to dynamically partner with each other to extend their capabilities while preserving their administrative autonomy.

→ It defines a s/w stack enabling interoperation at IaaS layer & providing support for SLA-based execution of applications on top of infrastructure overlay that results from federation of infrastructure providers.

→ The role of RESERVOIR is to orchestrate the process of leasing resources wrt SLA & to minimize barriers obstructing interoperation among different administrative domains.

→ Each site runs the RESERVOIR s/w stack & provides an on-demand execution environment in which components of a service application can be deployed & executed.



→ Service Manifest specifies the structure of the service applications in terms of deployment component types that can be deployed as virtual execution environment (VEE).

→ The Reservoir stack consists of three major components:

Service manager: It is the highest level of abstraction & constitutes the front-end applications used by service providers to submit service manifests, negotiate pricing & monitor applications

Virtual Execution Environment (VEE) Manager: It is the core of Reservoir middleware & is responsible for the optimal placement of VEEs into VEE hosts acc^n to the constraints expressed by the Service manager.

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#VEE Host (VEEH): This is the lowest level of abstraction & interacts with VEEM to put into practice the IT management decisions regarding heterogenous sets of virtualization platforms.

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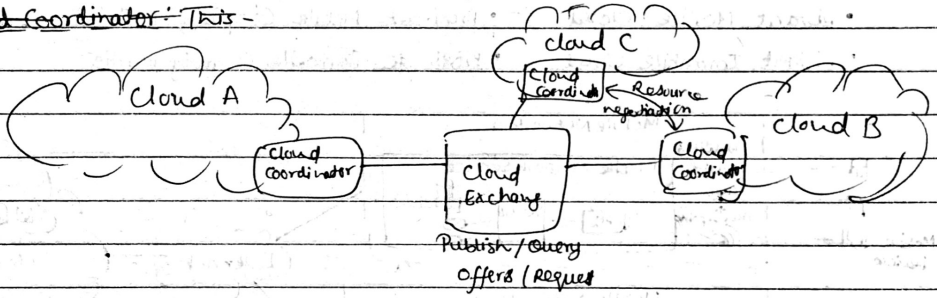
- InterCloud

→ It is a service-oriented architectural framework for cloud federation that supports utility-driven interconnection of clouds. It is composed of a set of decoupled elements that interact via a market-oriented system to enable trading of cloud assets such as computing power, storage & execution of applications.

→ The InterCloud model comprises of two main elements:

#Cloud Exchange: This is the market-making component of the architecture. It offers services that allow providers to find each other in order to directly trade cloud assets, as well as allowing parties to register & run auctions.

#~~Cloud Coordinator~~: This -



InterCloud Architecture

#Cloud Coordinator: This component manages domain-specific issues related to the federation. This component is presented on each party that wants to join the federation. It has front-end components (,i.e., elements that interacts with the federation) as well as back-end components (, i.e., components that interact with the associated data center).

* Mobile Cloud Computing (MCC) / Basics of Cloud Mobility

- Cloud Computing offers such smartphones that have rich Internet media support, require less processing and consume less power. In terms of MCC, processing is done in cloud, data is stored in cloud & mobile devices serve as media for display.
- Today smartphones are employed with rich cloud services by integrating applications that consume web services. These web services are deployed in cloud.
- MCC is an infrastructure where both data storage & data processing happen outside of mobile device. It brings not just smartphone users but the rest of mobile subscribers.

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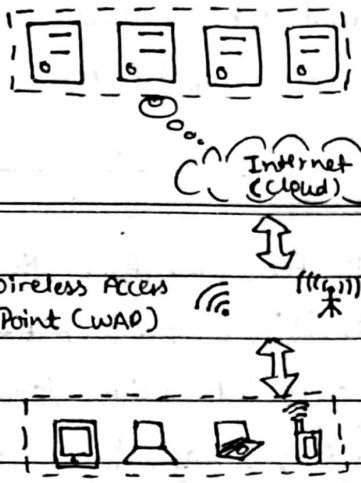

MCC Environment

- NIST: "A model for enabling convinent, on-demand network access to a shared pool of configurable computing resources (ex:- N/w, Servers, Storage, Apps & Services) that can be rapidly provisioned & released with minimal management effort or service provider interaction"

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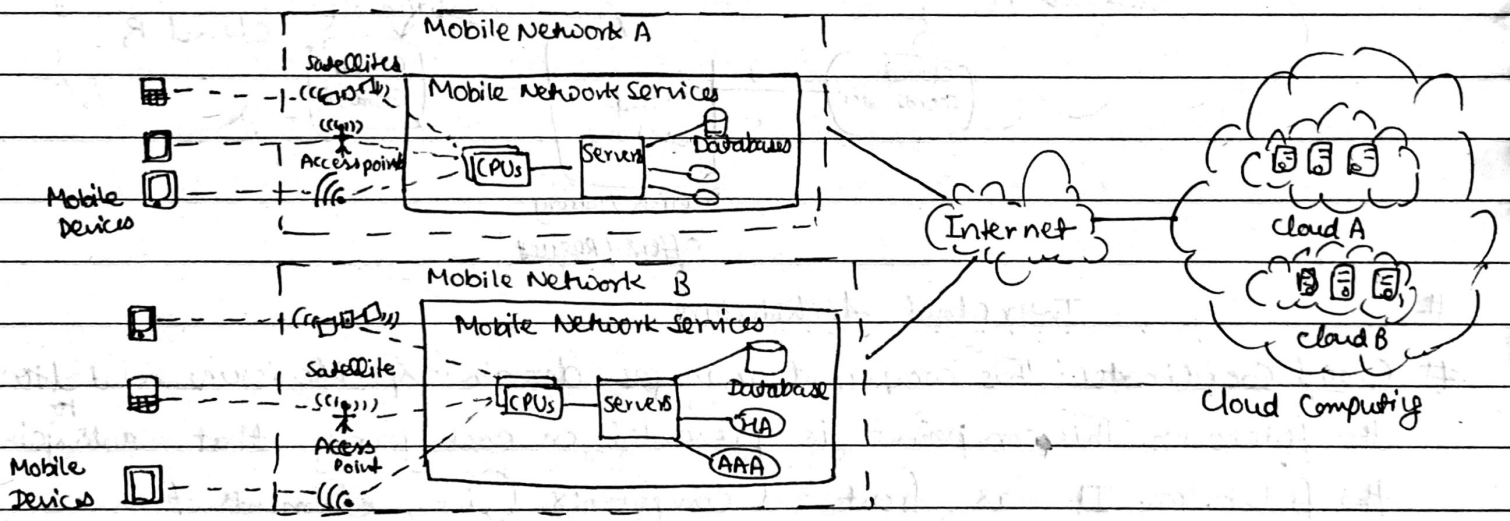
- Cloud users access apps via WEB browser or by a thin client connected wirelessly.
- MCC = Web Computing + Cloud Computing
- VMs & Servers on cloud are accessed via Internet by mobile users who need of any specialized hardware.
- Architecture: MCC includes four types of cloud resources:
  - Distant Mobile Cloud
  - Distant Immobile Cloud
  - Proximate Mobile Computing Entities
  - Proximate Immobile Computing Entities
  - Hybrid



Framework of MCC Architecture

- Issues:

(i) Emergency Efficient Transmission - There should be a frequent transmission of information b/w cloud & mobile devices

(ii) Architectural Issues - MCC is required to make architectural neutral because of heterogenous environment.

(iii) Live VM Migration - It is challenging to migrate an application, which is resource-intensive to cloud & to execute it via Virtual machine.

(iv) Mobile Communication Congestion - Due to continuous increase in demand for mobile cloud services, the workload to enable smooth communication b/w cloud & mobile devices has been increased.

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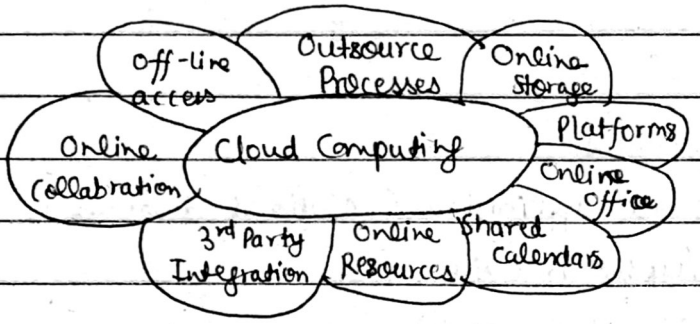
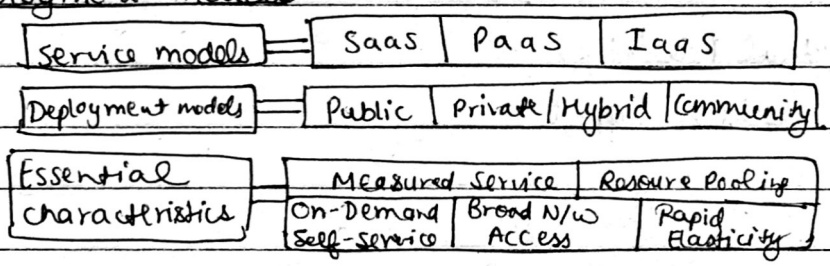
⑥ Security & Privacy: This is one of the major issues because mobile users share their personal information over the cloud.

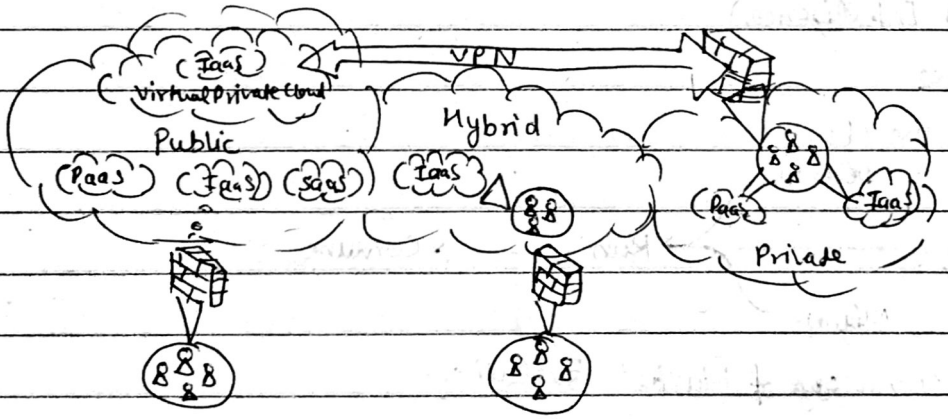
* Enterprise Cloud Computing

- ECC Paradigm



- Deployment models





- Adoption Strategy

- Scalability-Driven: Use of cloud resources to support additional load or as backup
- Availability-Driven: Use of load balanced & localised cloud resources to increase availability & reduce response time.
- Market-Driven: Users & providers of cloud resources make decisions based on the potential saving and profit?
- Convinience-Driven: Use cloud resources so that there is no need to maintain local resources.

- Consumption Strategy

(i) Software-Provision: Cloud provides instances of S/W but data is maintained within user's data center.

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② Storage Provision: Cloud provides data management & s/w accesses data remotely from user's data center.

③ Solution Provision: s/w & storage are maintained in cloud & user doesn't maintain data center.

④ Redudancy Services: Cloud is used as an alternative or extension of user's data center for s/w & storage

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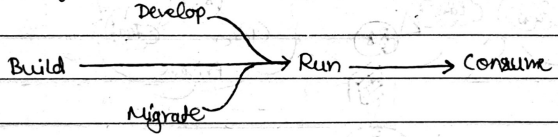
- Issues for Enterprise Applications in Cloud
  - ERP
  - Capabilities of ERP
    - → Transactional Capabilities
      - # OLTP (Online Transaction Processing)
      - # Manage transaction oriented applications (relational databases)
      - # ACID properties, write/update-intensive
      - # CRM (Customer Relationship Management)
    - → Analytical Capabilities
      - # OLAP (online Analytical Processing)
      - # Analysis, reporting, decision support
      - # Read only
      - # Data-intensive
      - # BI (Business Intelligence)

- Transition Challenges (ERP)
  - Five stages of the cloud



- Enterprise Cloud Technology & Market Evolution
  - Standard: #vendor lock-in #OGF OCCI for Computer Cloud
    #SNIA CDMI for storage & data management
    #DMTF Virtualization Management (VMAN) #DMTF Cloud Incubator
    #Drives adoption, Drives the market, Third party vendor
  - SLA: #Lack of Control #Primitive vs Sophisticated
  - Cloud Service Brokerage (CSB): #Cloud Service Intermediation #Aggregation
    #Cloud Service Arbitrage

- Marketplace
  - Industry-specific characteristics: #Rivalry #Comparable Products ⇒ Market share
    #Federation ⇒ Small Companies #Switching Cost ⇒ Standardization

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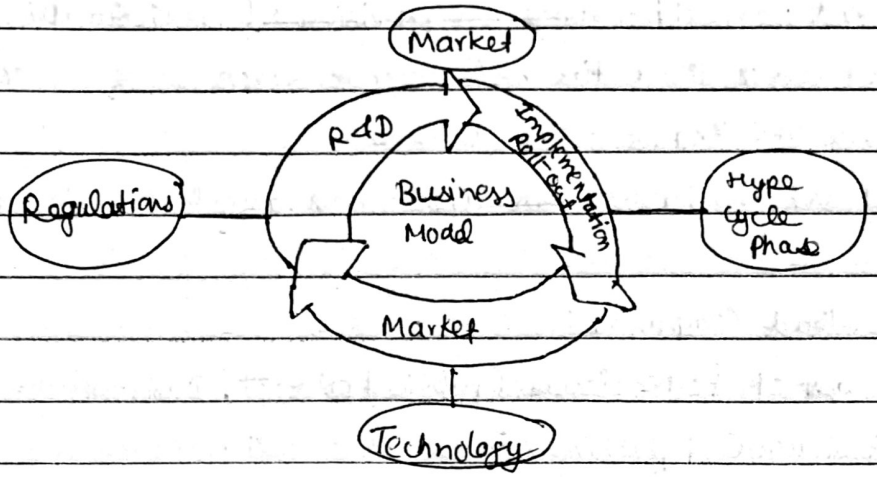
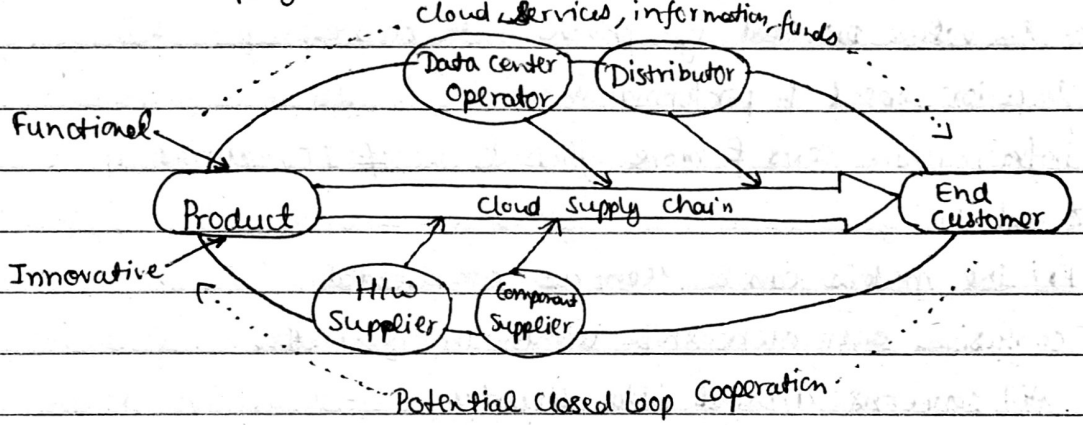
- Dynamic Business Model



- Cloud Supply Chain



- Enterprise cloud computing is a collection of characteristics of the public & private cloud, tailored to ~~be~~ needs of business. Companies get a choice of where to run workloads, as well as infrastructure that is flexible & agile.
- Enterprise clouds are built with similar web-scale technologies that enable the same durability, reliability & availability as the public cloud. This is different from public clouds as for most parts with these clouds, the data sits outside your data centre & the applications have to conform to their providers' processes & architectures.
- There are five key components of to enterprise cloud computing:
  - Full-stack infrastructure & platform services that deliver turnkey infrastructure for any app at any scale, anywhere, delivered through a combination of on-premises data centres & public cloud services
  - Zero-click operations & machine intelligence that deliver operational simplicity through automation

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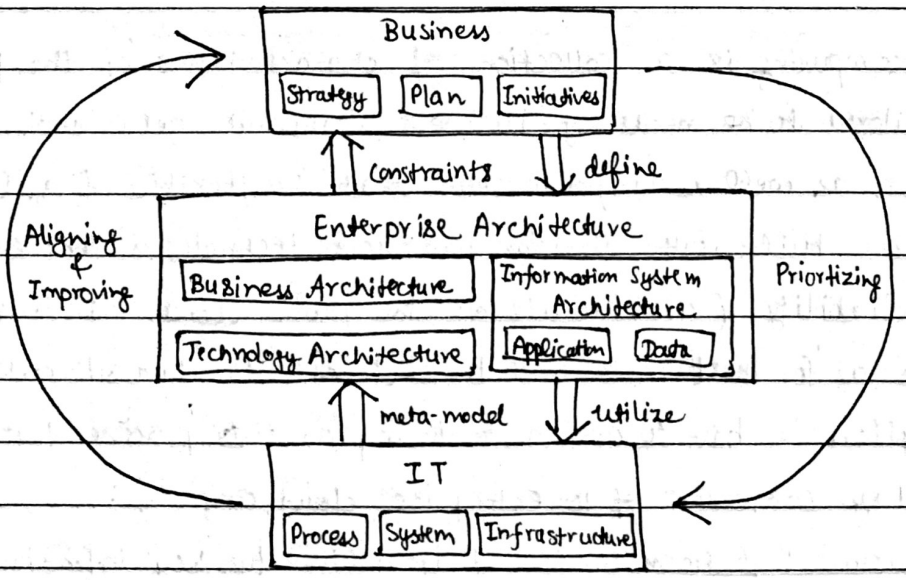
- Instance Elastic consumption that allows businesses to ~~buy~~ buy & use only the IT resources they need, when they need them, eliminating overprovisioning & prediction risk.
- Integrated security & control that covers the entire infrastructure stack, make use of automation, & simplifies security maintenance using automation.
- Application-centric mobility that lets businesses run applications anywhere with no infrastructure ~~for~~ lock-in

– Pros & Cons of Enterprise Cloud Computing:

- Advantages: (i) able to have best of both clouds (public & private), Businesses are able to use IT infrastructure & platform services that deliver the advantage of public cloud services for enterprise applications but without compromising on the value provided by private data centres.
  (ii) offers superior speed & performance
  (iii) lower infrastructure costs & more efficient use of IT resources
  (iv) presents cost savings
- Disadvantages: (i) Pricing models can be seen as complicated
  (ii) confusion over ownership within an organisation
  (iii) still concerns around data security



Enterprise Cloud Computing Architecture

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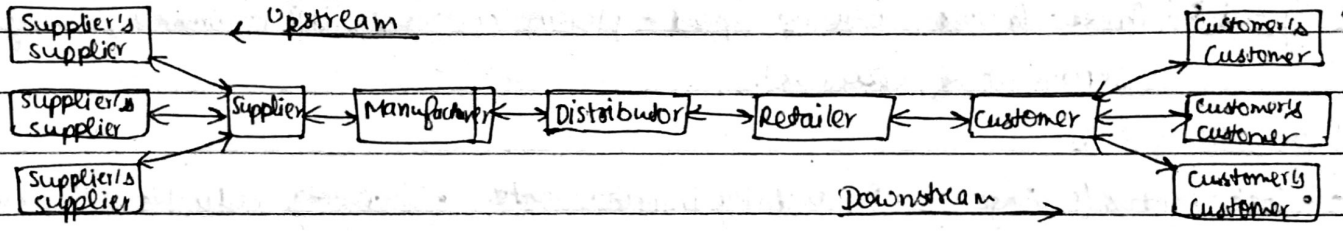
* Enterprise Software (ERP, SCM, CRM)

- ERP (Enterprise Resource Planning) is a category of business-management S/W - typically a suite of integrated applications - that an organization can use to collect, store, manage & interpret data from many business activities, including: product planning, cost, manufacturing or service delivery.
- SCM ~~Service~~ (Supply Chain Management) is the oversight of materials, information, & finances as they move in a process from supplier to manufacturer to wholesaler to retailer to consumer. SCM involves coordinating & integrating these flows both within & among companies.
- CRM (Customer Relationship Management) is an approach to managing a company's interaction with current & future customers. It often involves using technology to organize, automate, & synchronize sales, marketing, customer service, and technical support.

* Supply Chain Management (SCM)

- Supply chain consists of all parties involved, directly or indirectly, in the procurement of a product or raw material. SCM involves the management of information flows between & among stages in a supply chain to maximize total supply chain effectiveness & profitability.
- In the past, companies focused primarily on manufacturing and quality improvements within their own 4 walls. Now companies extend their effort to influence the entire SCM to include customers & suppliers
- The supply chain has three main links:-
  1. Materials flow from suppliers & their "upstream" suppliers at all levels
  2. Transformation of materials into semi-finished & finished products through the organization's own production process
  3. Distribution of products to customers and their "downstream" customers at all levels



Supply Chain

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- 5 basic SCM components:

- Find reliable suppliers - deal with pricing, delivery, & payments with suppliers
- Use metrics to meet demand
- Manufacture product or service - metric intensive
- Logistics - deals with processes & controls for efficient & effective transport & storage of supplies from supplier to customer
- Process for allowing customers to return defective & excess products

- IT's primary role is to create integrations or tight process & information linkage b/w func^{n}s within a firm.

Planning and Control Supply Chain Integration
Information Integration
Business Process Integration

Strategic Impact ↕ Operational Impact

Plan → Source → Make → Deliver → Return

- Factors Driving SCM:

- Visibility: Supply chain visibility - the ability to view all areas up & down the supply chain
- Consumer behaviour: Consumers are demanding more today. Companies can respond faster & more effectively to consumer demands through supply chain enhances. "Demand planning S/W" generates demand forecasts using statistical tools & forecasting techniques
- Competition: Having a efficient SCM means having a competitive advantage over competitors. "Supply chain Planning (SCP) S/W" - uses advanced mathematical algorithms to improve flow & efficiency of the supply chain. "Supply chain Execution (SCE) S/W" - automates the different steps & stages of the supply chain.
- Speed: Three factors fostering speed - pleasing customers, HR (Human Resource) requirement, Strategy & Deployment of Resources).

- Benefits of SCM:

- Cost control/savings • Productivity improvements • Inventory reductions/improvements
- Improved visibility into demand/supply • Quality improvements • Maintain/gain competitive advantage

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- Drivers of SCM

① Facilities: Addresses the process or transformation of inventory into another products or stores inventory before it moves to the next facility. Factors to consider are location, capacity & operational design.

② Inventory: Addresses the strategy employed to maintain low inventories but also maintain a rapid turnover time to meet demand. Management & control software helps address this.

③ Transportation: A major cost in the SCM category. S/w again is providing sol^n's for organizations through global inventory management systems, transportation planning S/w & distribution management S/w.

④ Information: An organization must decide what information is most valuable in effectively reducing costs or improving effectiveness. SCM strategies then consider information sharing & pull vs push information strategy. In a push technology environment, organizations send information. In a pull technology environment, organizations receive or request information.

* Customer Relationship Management (CRM)

- Organizations can use the RFM (Recency, Frequency, Monetary value) formula to determine who is its MVC's (Most valuable customers).
- CRM involves managing all aspects of a customer's rel^n ship with an organization to increase customer loyalty, retention, & an organization's profitability.
- CRM acknowledges industries that they are migrating from the traditional product-focused organization toward customer-driven organizations.
- Elements of CRM:
  - Sales force automation
  - Customer service/call center management
  - Marketing Automation
- CRM supporting technologies:
  - Self-service
  - 24x7 support
  - AVR's (Automated voice Response phone systems)
  - Password Resets via Email
- CRM solutions:
  - web based applets
  - Intra/Extranet - Sharepoint & Office Online
  - Business Contact Manager
  - Shared Calendars Open Source

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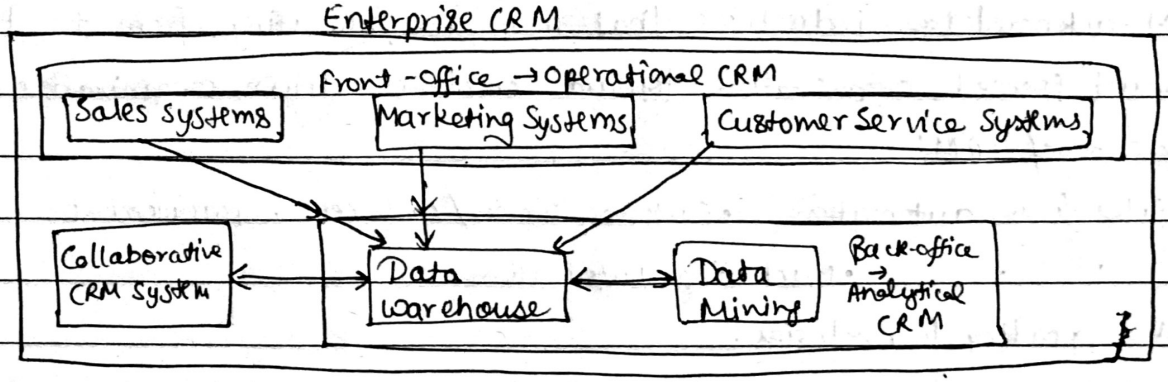
- Because businesses recognize that customers have more choices & often already come with a considerable amount of product knowledge. Businesses need to do everything they can to acknowledge customer demand, preferences, demographic info, etc.... to ensure that customers are satisfied.
- CRM enables an organization to:
  - provide better customer service
  - make call centers more efficient
  - cross sell products more effectively
  - Helps sales staff close deals faster
  - Simplify marketing & sales processes
  - Discover new customers
  - Increase customer revenues
- CRM is a business philosphy based on the premise that those organizations that understand the needs of the individual customers are best positioned to achieve sustainable advantage in the future. CRM in many cases is about shifting through information to reveal trends, explain outcomes, and predict results so that businesses can increase response rates & identify profitable customers.
- Operational and Analytical CRM
  - Operational CRM supports traditional transactional processing for day-to-day front-office operations or systems that deal directly with the customers.
  - Analytical CRM supports back-office operations & strategic analysis & includes all systems that donot deal directly with the customers.



- Sales & Operational CRM Technologies
  - # Sales Management CRM system
  - # Contact Management CRM system
  - # Opportunity Management CRM system

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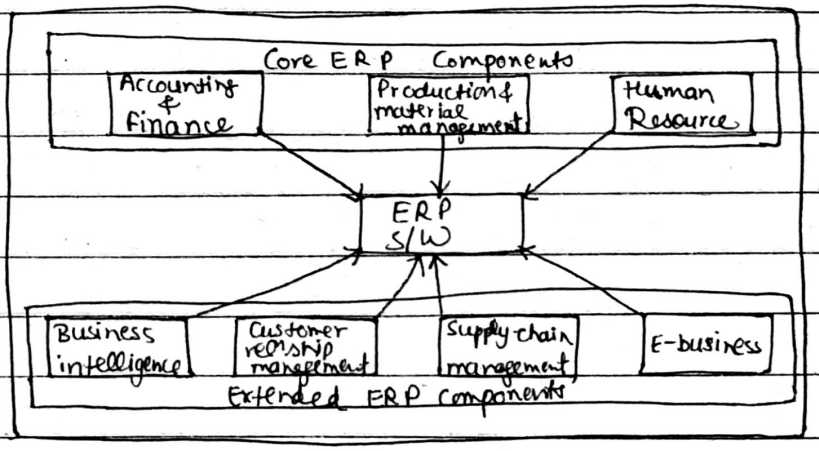
- CRM pointers for gaining prospective customer
  ① Get their attention ② Value their time ③ Over deliver
  ④ Contact Frequently ⑤ Generate a trustworthy mailing list ⑥ Follow up
- Analytical CRM has the ability to provide an organization with information about their customers that was previously impossible to locate, & the resulting payback can be tremendous.
- Analytical CRM relies heavily on data warehousing technologies & business intelligence to glean insights into customer behaviour. These systems quickly aggregate, analyze, & disseminate customer information throughout an organization
- Current trends include:
  #supplier rel^{n}ship management (SRM) #Partner rel^{n}ship management (PRM)
  #Employee rel^{n}ship management (ERM)

* Enterprise Resource Planning (ERP)

- It integrates all departments & functions throughout an organization into a single IT system or integrated set of IT systems so that employees can make decisions by viewing enterprise wide information on all business operations.
- Reasons ERP systems are Powerful Organizational Tools
  - ERP is a logical soln to the mess of incompatible applications that had sprung up most business
  - ERP addresses the need for global information sharing & reporting
  - ERP is used to avoid the pain & expense of fixing legacy systems
- Core & Extended Components
  - Core: Traditional components included in most ERP systems & they primarily focus of internal ~~applications~~ operations
  - Extended: Extra components that meet organizational needs that focus primarily on external operations.



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- Applications such as SCM, CRM, & ERP are backbone of e-business. Integration of these applications allow unlocking of information to make it available to any user, anywhere, anytime.

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- Risk & ERP
  - Costs is a major $ risk to implementing ERP.
    - # Can easily start in millions of dollars, which includes h/w, S/w, professional services & internal staff costs
    - # Implementation can take an average of 23 months
  - Associated ERP risk (cost)
    - # S/w cost # Consulting Fees # Process Rework # Training
    - # Customization # Integration & Testing # Data warehouse integration & data conversion
  - Additional risks lie in the integration layer of joining different types of application systems. Integration at enterprise level is achieved through web services. web services is defined by the W3C as "a S/w system designed to Support interoperable machine-to-machine interaction over a network" ~~with HTTP Established connection~~ Establishes connection with HTTP & uses XML sol^n^s.

* The Connected Corporation
- Many companies purchase modules from an ERP vendor, an SCM vendor, & a CRM vendor & must integrate the different modules together
- Middleware: Several different types of S/w which sit in the middle of & provide connectivity b/w two or more applications.
- Enterprise application integration (EAI) middleware: packages together commonly used functionality which reduced the time necessary to develop sol^n^s that integrate applications from multiple vendors.

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