UNIVERSITÀ DEGLI STUDI DI NAPOLI
FEDERICO II

La Virtualizzazione nel Dispiegamento di Sistemi Complessi

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La virtualizzazione

- La virtualizzazione è una tecnica per aumentare l’efficacia e l’efficienza di Centri Elaborazione Dati complessi
- Tecnica risalente agli anni ‘60, ma ritornata in auge una decina di anni fa, grazie all'evoluzione tecnologica delle CPU

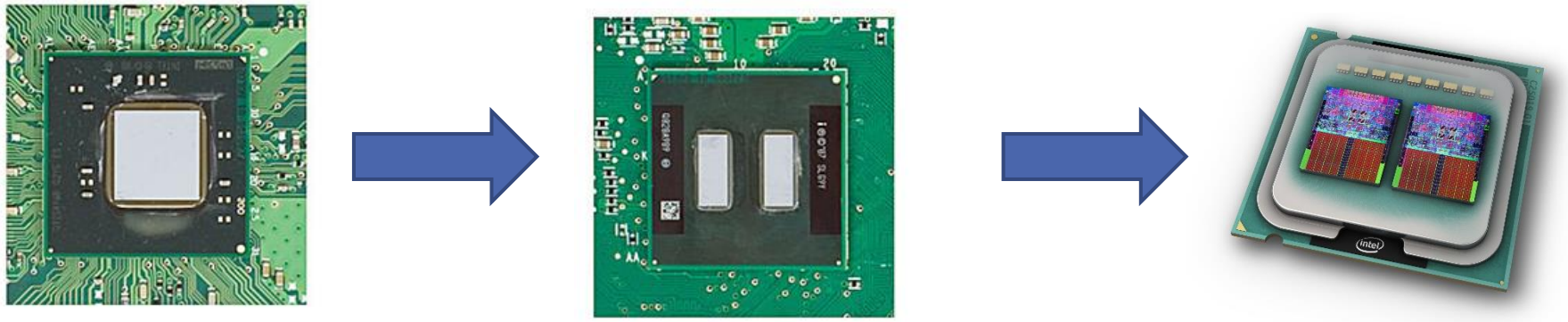
L’evoluzione delle CPU

Evoluzione delle CPU

- I microprocessori hanno da sempre avuto un rapidissimo incremento nelle prestazioni e una diminuzione dei costi.
- La strategia per migliorare le prestazione è storicamente stata quella di aumentare la "velocità" di un processore.
  - 1978: Intel 8086, 4MHz
  - 1985: Intel 386, 25 MHz (~ 6x)
  - 1995: Intel Pentium Pro, 200 MHz (~ 8x)
  - 2005: Intel Pentium P4 3,8 GHz (3800 MHz) (~ 19x)
- Questa strategia ha subito una battuta d’arresto nel 2005
  - 2020: Intel i9-10980XE 3,0 GHz

Le CPU multicore

- Raggiunti i limiti fisici del silicio, la soluzione è stata aumentare il numero di unità di processo (multi core),allo scopo di aumentare la potenza di calcolo.
  - 2020: Intel i9-10980XE 3,0 GHz → 18 unita di calcolo
  - 2020: AMD Ryzen™ Threadripper™ 3970X 3,7 GHz → 32 unita di calcolo



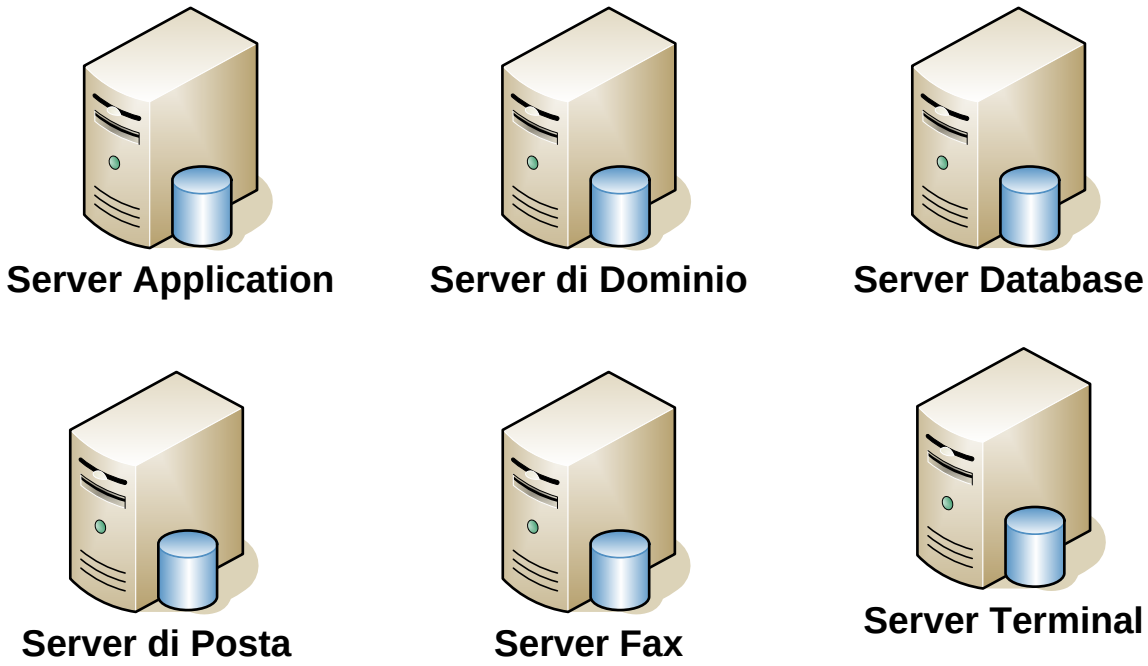
Problemi dei Multi-core

- Tradizionalmente i programmi sono stati scritti per essere eseguiti su un computer con una singola CPU.
- La stragrande maggioranza delle applicazioni sono costituite da programmi sequenziali.
- Come sfruttare più unità in parallelo?

Infrastruttura tradizionale di un CED

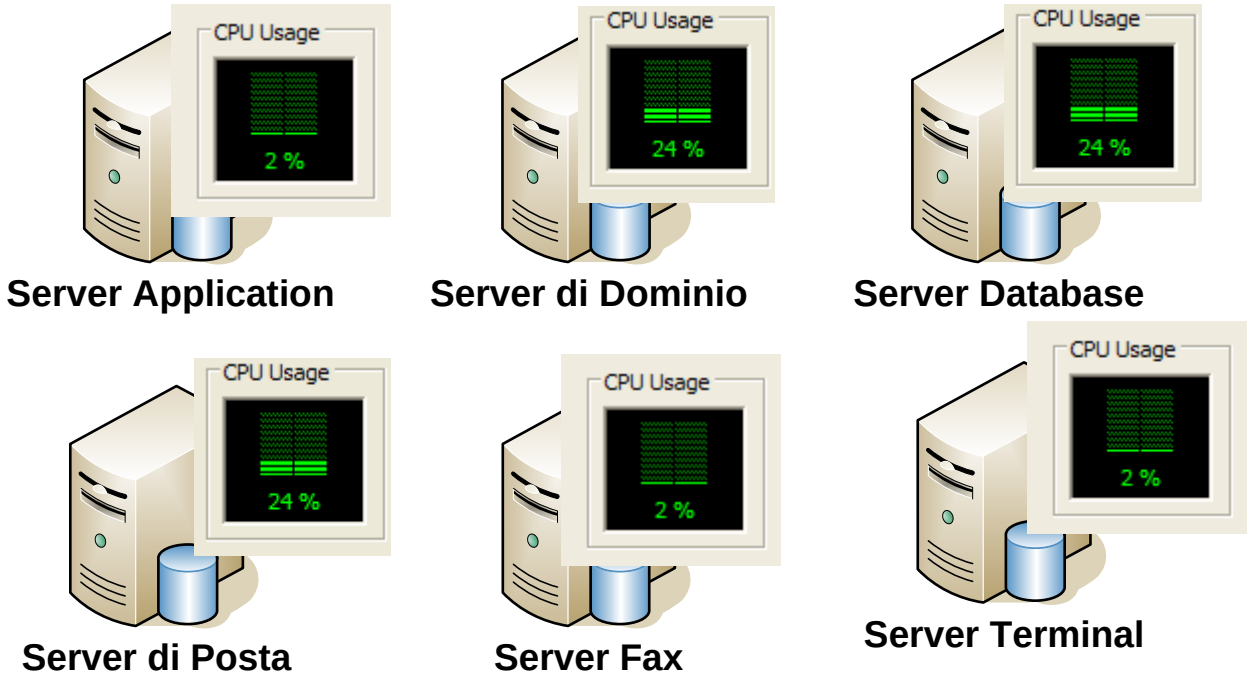
Infrastruttura Tradizionale di CED

- Singoli server che offrono singoli servizi e/o applicazioni (*one workload, one box*)
- Nuovo Servizio e/o Applicazione → Nuovo Server, con proprio Storage



Infrastruttura Tradizionale di CED

- Tutti i server, consumano (tanta) corrente, emettono calore, occupano spazio, vanno gestiti fisicamente…

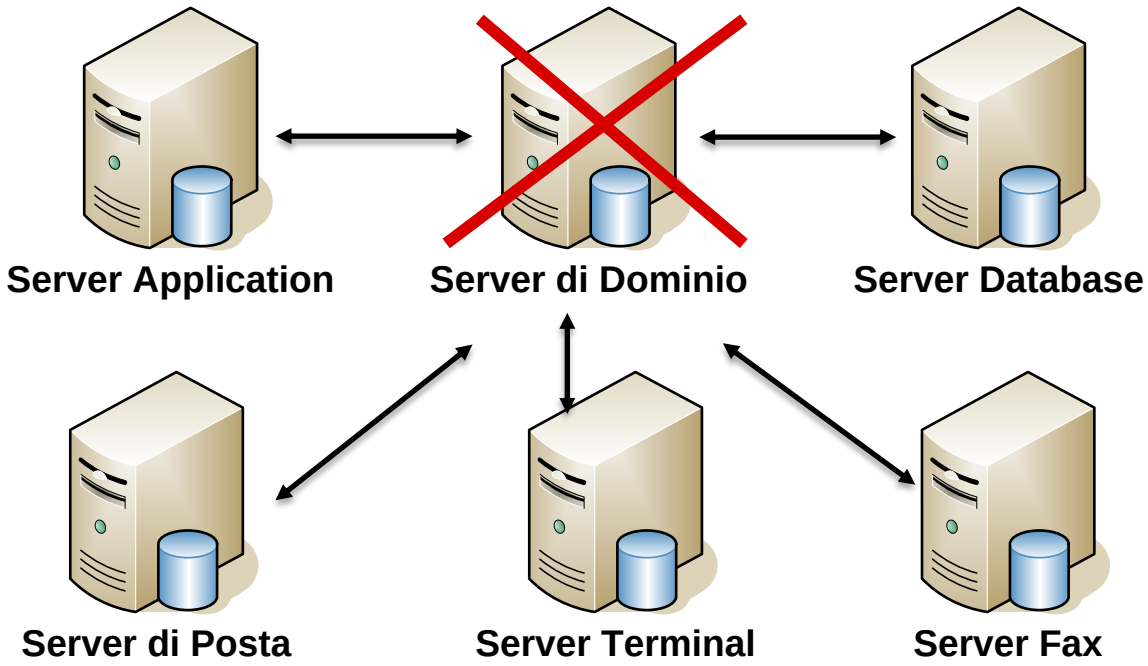


Infrastruttura Tradizionale di CED: Conseguenze

- Sottoutilizzo delle risorse
  - La maggior parte dei server sfrutta in media tra il 5% ed il 15% della propria capacità computazionale.
  - In caso di servizi critici, necessità di ridondanza (computer di riserva normalmente non usati).
- Aumento dei costi di installazione e gestione
  - Rilascio aggiornamenti su scala nazionale molto costosi
  - Back-up da effettuare su ogni macchina
  - …

Infrastruttura Tradizionale di CED : Conseguenze

- I servizi sono intrinsecamente interconnessi.
  - Es: Il server di dominio, che gestisce le autenticazioni degli utenti, viene interrogato da tutti gli altri servizi/server
  - Cosa succede se si rompe un server?



Fail di un server nello scenario tradizionale

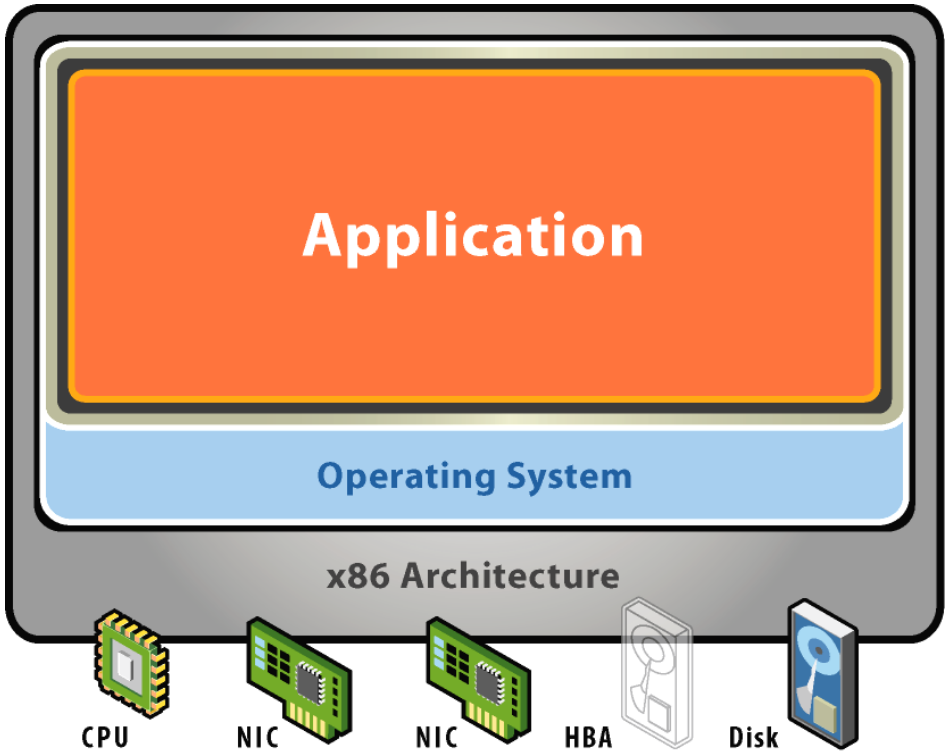
- In caso di FAIL di un server si possono bloccare i servizi di altri Server in comunicazione con esso.
- Ciò comporta:
  - Interruzione dell'operatività collegata a quel servizio
  - Nei casi più gravi interruzione dell'intera operatività aziendale
  - Aumento dei costi (costi di fermo e di ripristino)
  - Tempi di fermo non sempre prevedibili

Le Macchine virtuali

Concetti Generali

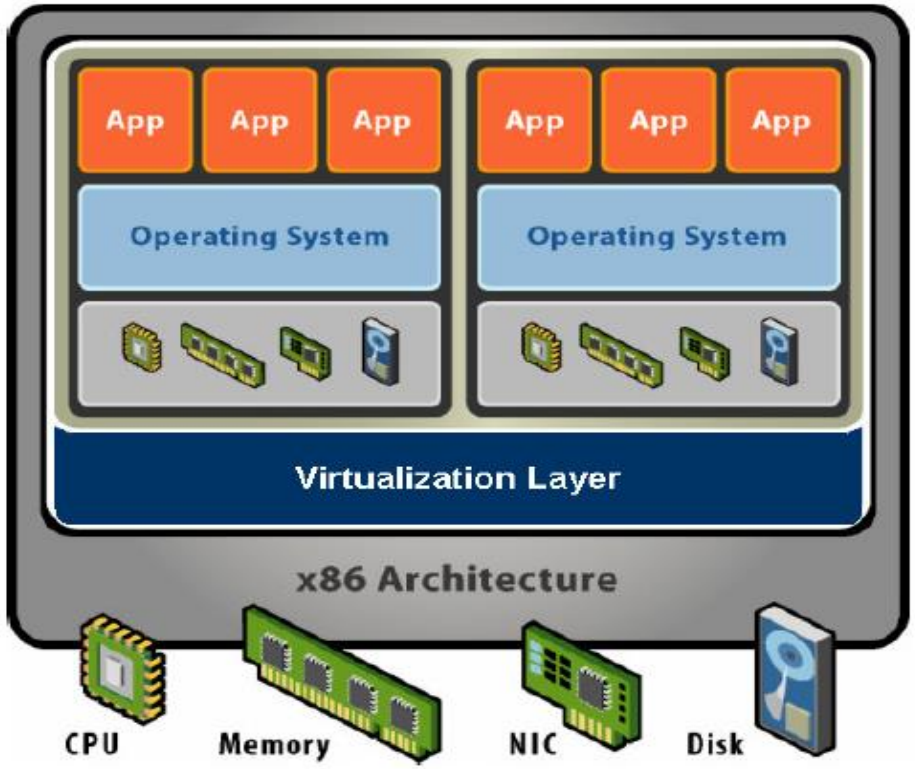
Un Server Fisico

- Un Server fisico consiste di:
  - Una serie di risorse hardware
  - Un sistema operativo
  - Uno o più software applicativi
- **Idea:** se la CPU del Server ha più unità di calcolo parallele, possiamo "simulare" l'esistenza di più computer, indipendenti dal "vero" hw sottostante?



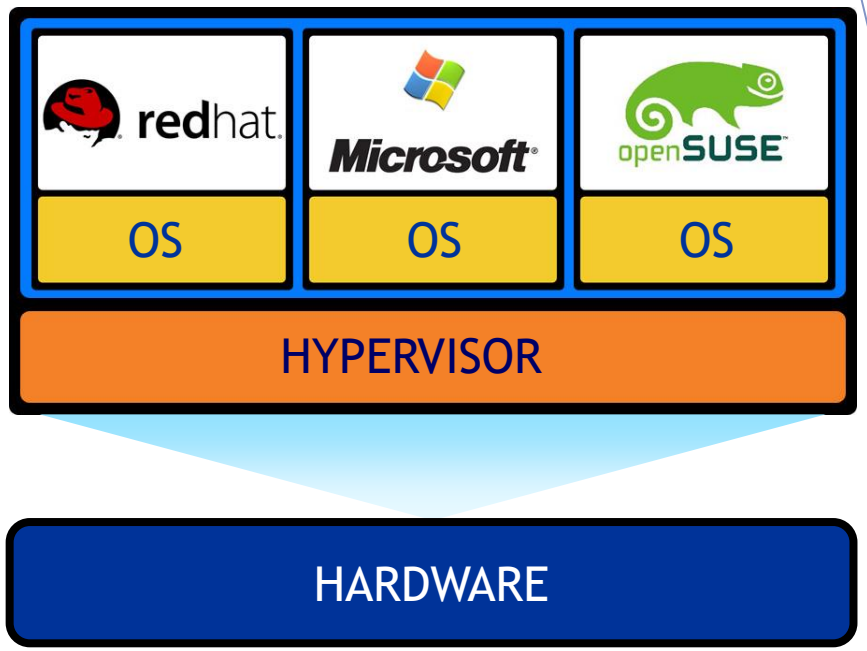
Una Macchina Virtuale

- La virtualizzazione consiste nella creazione di una versione virtuale di una risorsa normalmente fornita fisicamente e appartenente a un sistema.
  - Migliore sfruttamento delle risorse e delle unità di calcolo



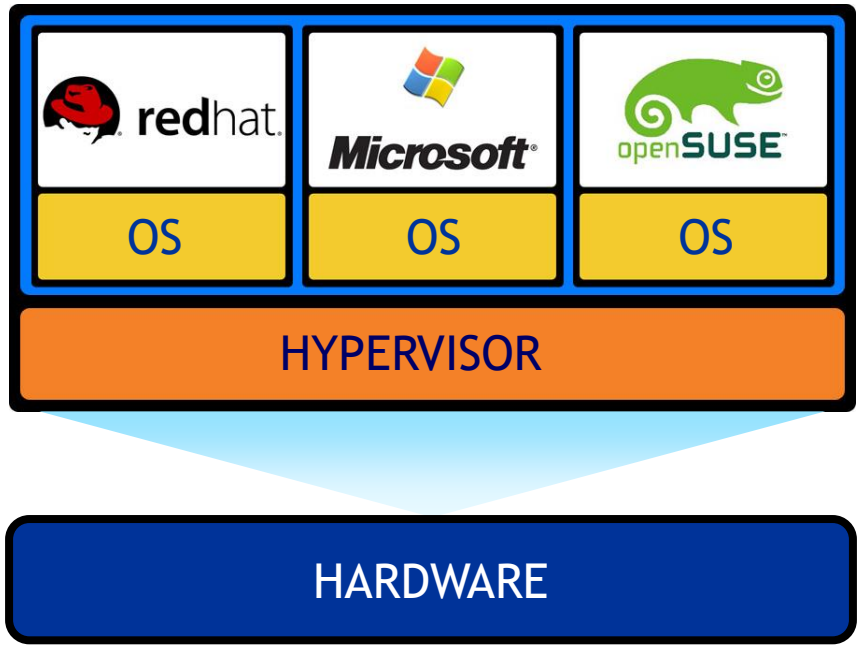
Come si ottiene la Virtualizzazione?

- Si introduce un nuovo strato che parte prima del sistema operativo, chiamato **Hypervisor.**
- L'Hypervisor simula l'esistenza di più computer "virtuali" su uno fisico



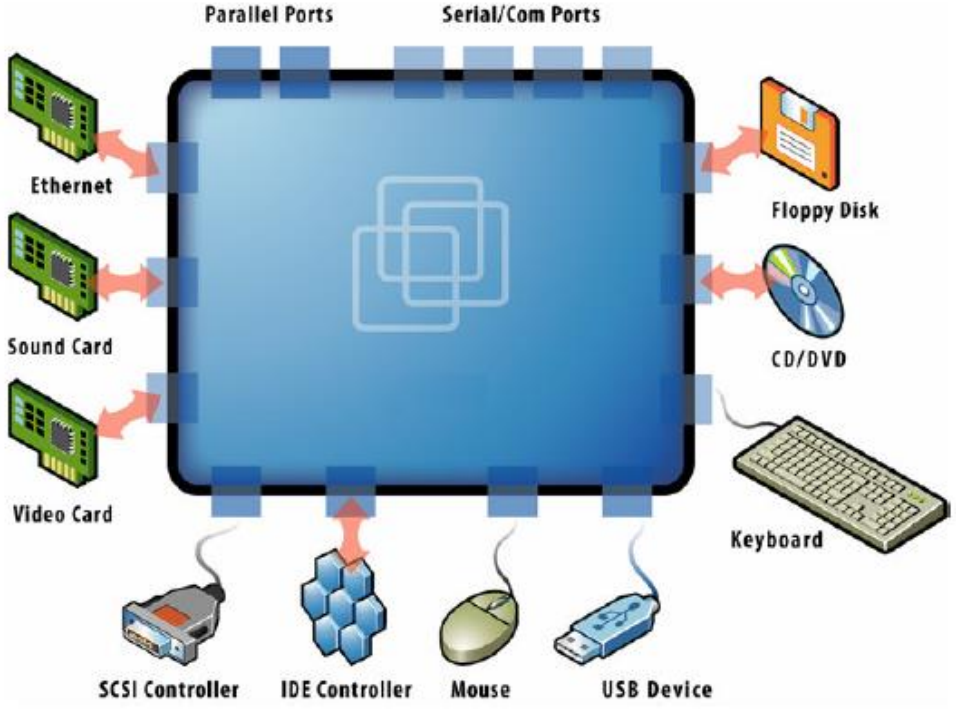
Come si ottiene la Virtualizzazione?

- L'Hypervisor offre le risorse fisiche ai computer virtualizzati, e si occupa di gestirle in modo concorrente a favore delle macchine virtuali.
- In ogni computer virtualizzato, si installa un normalissimo sistema operativo, che non ha modo di sapere se sta funzionando su un computer "reale" o virtuale.



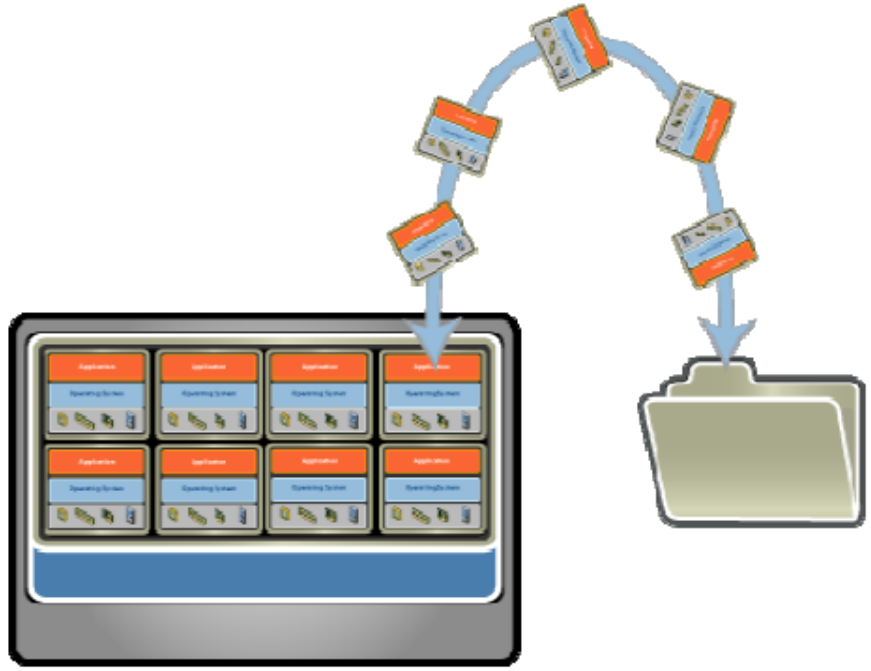
Indipendenza dall'Hardware

- L'Hypervisor simula una configurazione standard di un server, nascondendo il vero hardware fisico
- Conseguenza: Le Virtual Machines possono funzionare su server fisici diversi senza bisogno di essere configurate



Memorizzazione di una VM

- Una virtual machine è **un file**, contenente:
  - Sistema Operativo, Applicativi, Dati
  - Rappresentazione della Memoria del Server
- Un file memorizza lo stato di un server virtuale e ne permette la copia su un numero arbitrario di server fisici
- Esistono strumenti commerciali che trasformano il contenuto di un server fisico in una VM

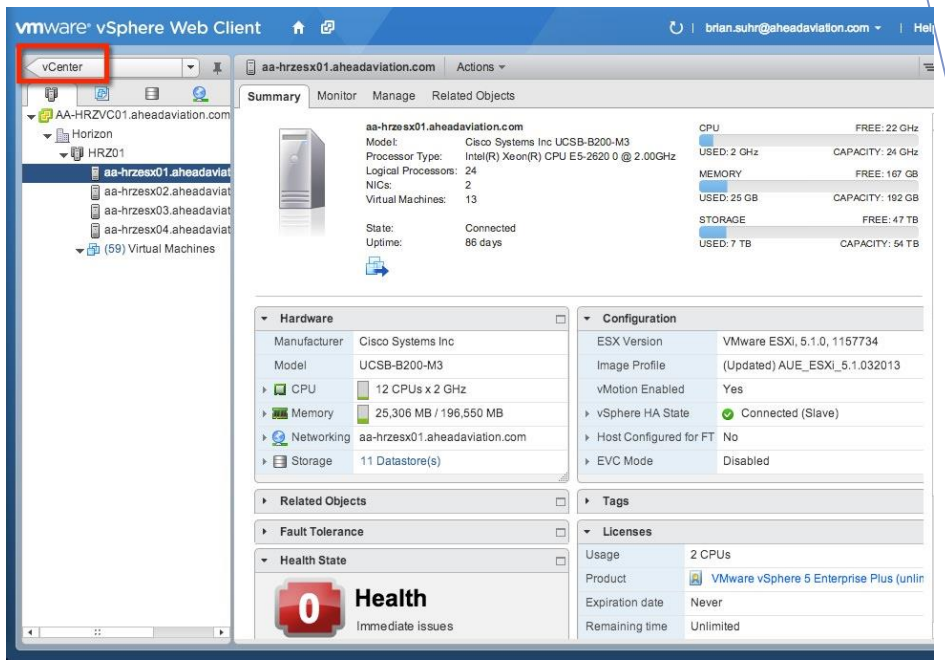


Isolamento di una VM

- Ogni VM è totalmente isolata dalle altre VM in esecuzione sullo stesso server fisico
- In caso di attacco o di crash di una VM, le altre non sono intaccate

Gestione di VM

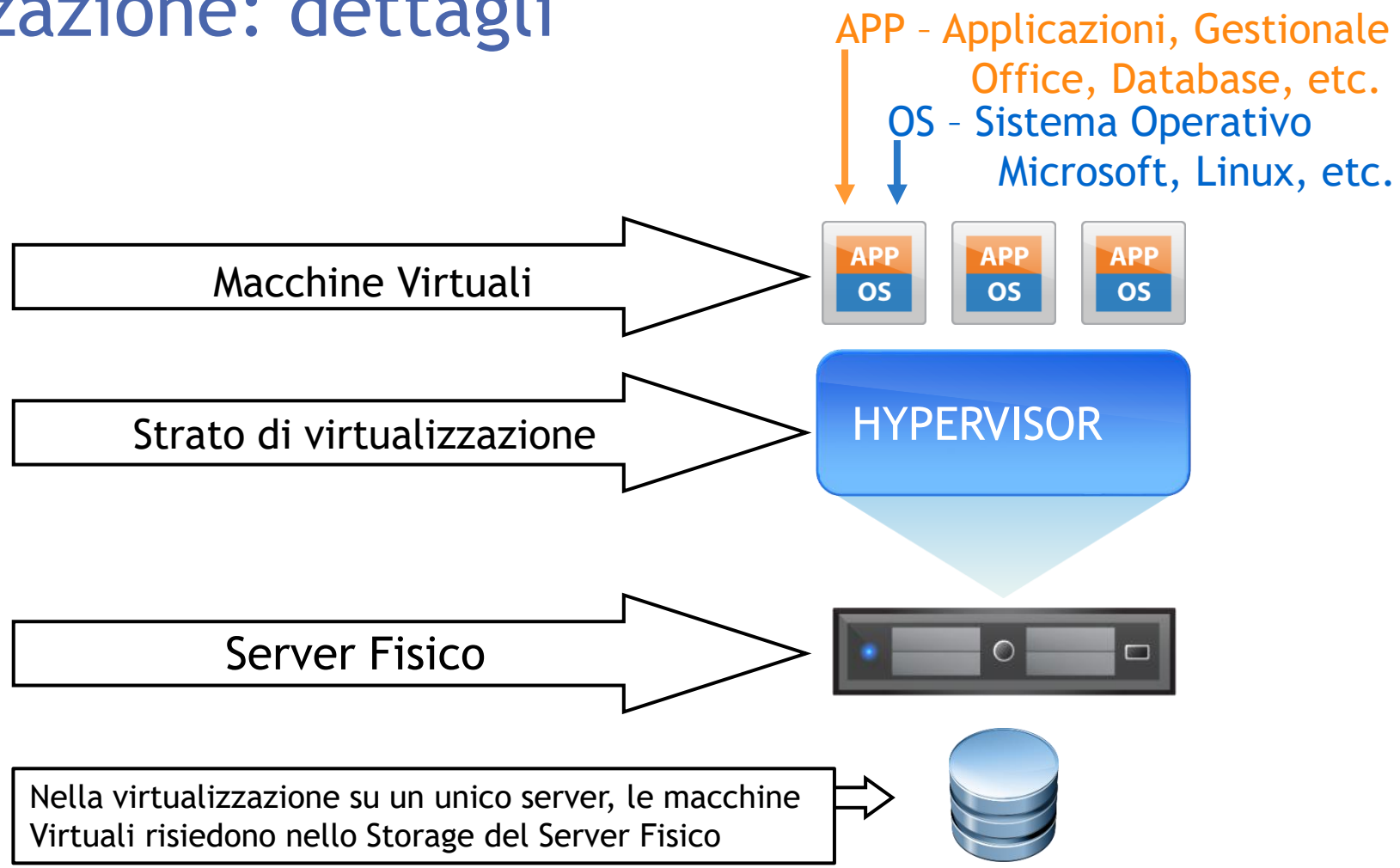
- Tutte le VM di un CED possono essere gestite attraverso un'unica finestra.
- La gestione dell'intero CED risulta centralizzata, con notevole semplificazione della gestione



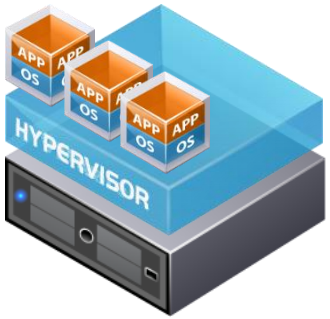
Le Macchine virtuali

Dettagli Operativi

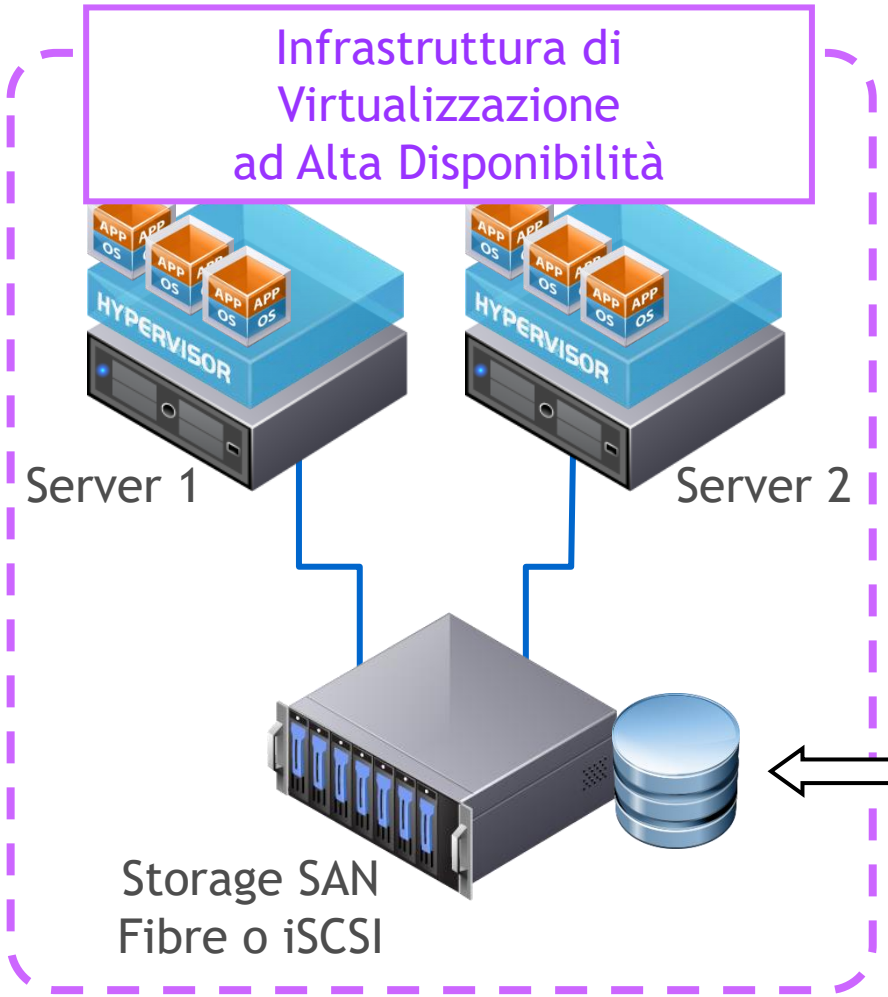
Virtualizzazione: dettagli



Virtualizzazione Enterprise ad Alta Disponibilità



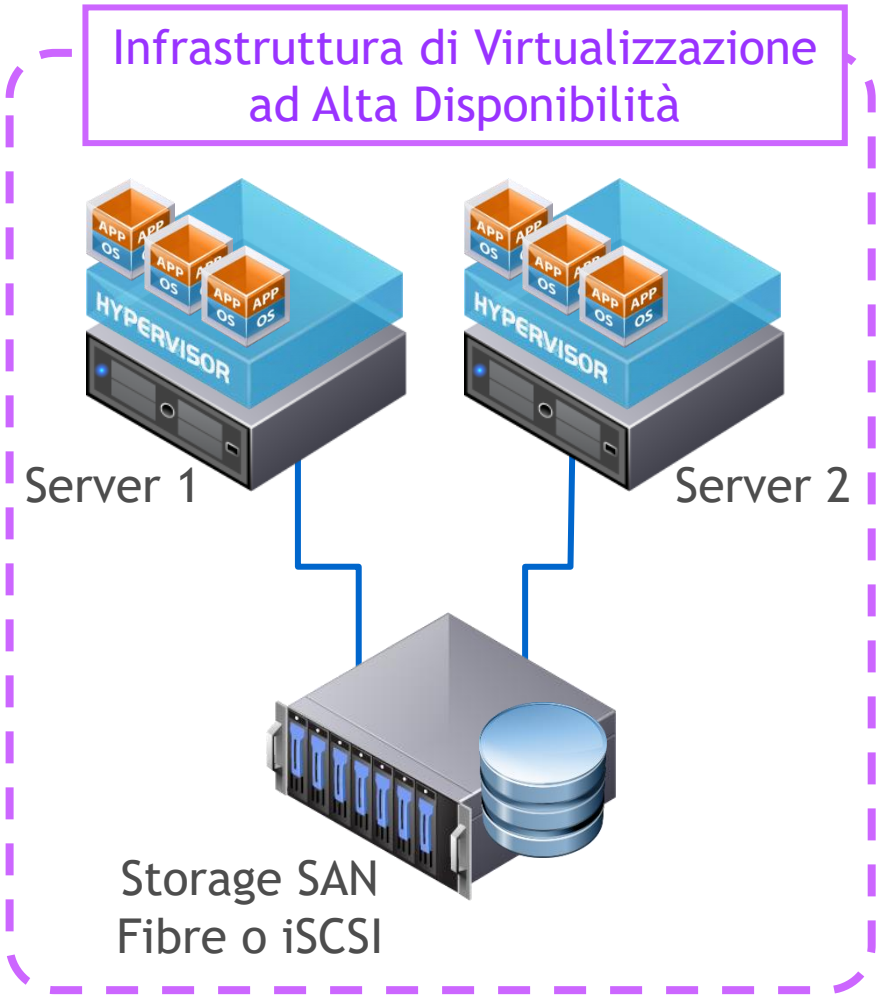
Virtualizzazione Enterprise ad Alta Disponibilità

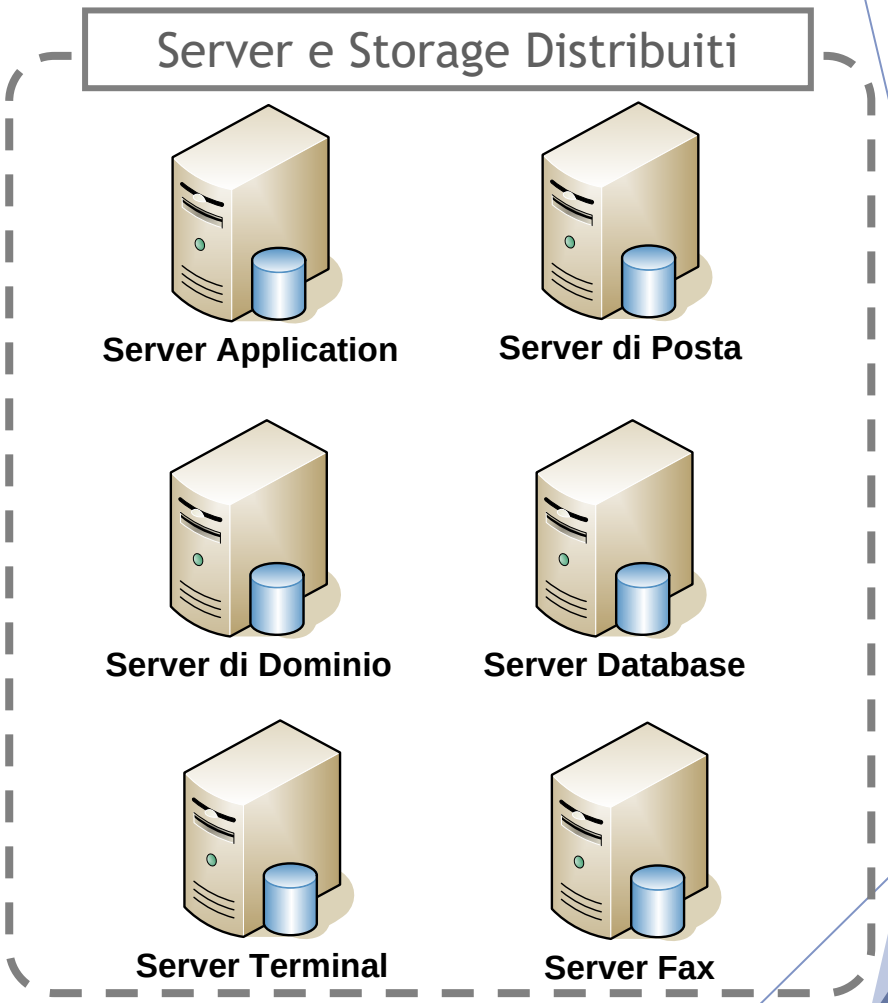


Un CED Enterprise deve disporre di almeno 2 Server Fisici e di un'unità di dischi rigidi (SAN – Storage Area Network), collegati tra loro ad altissima velocità (Fibra Ottica)

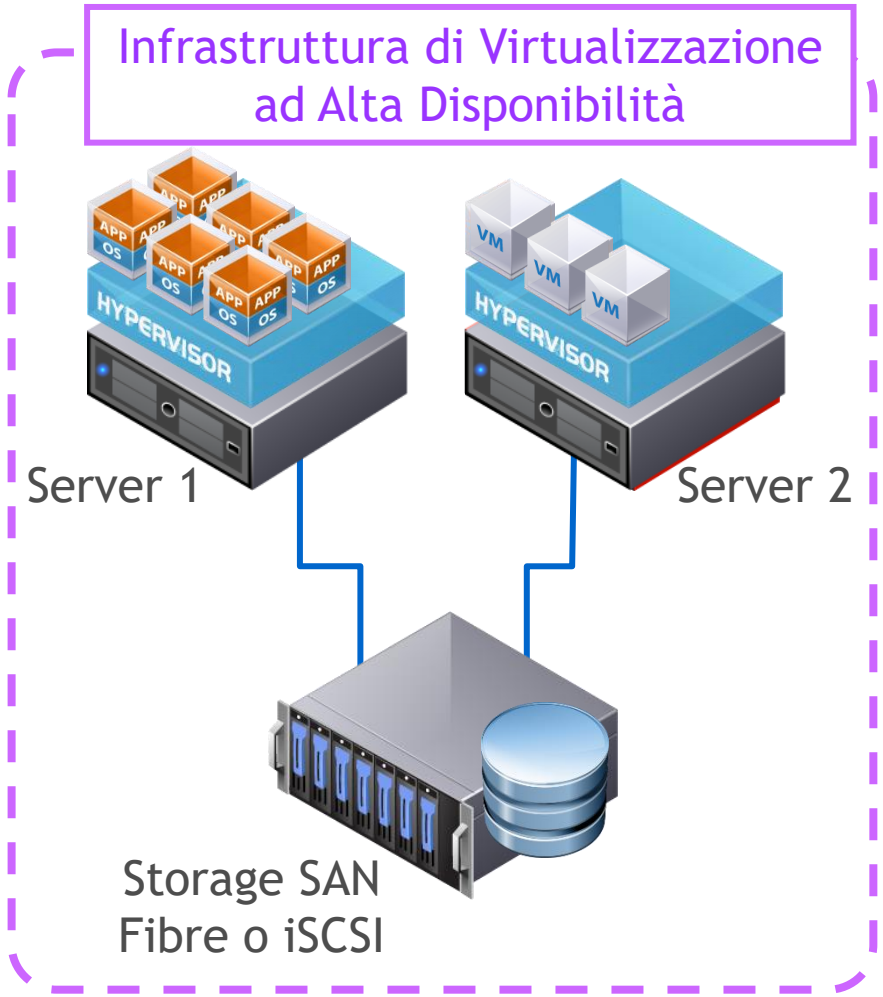
Nella Virtualizzazione Enterprise, le macchine Virtuali risiedono nello Storage SAN

Migrazione da Fisico a Virtuale





Come Funziona un sistema ad Alta Disponibilità



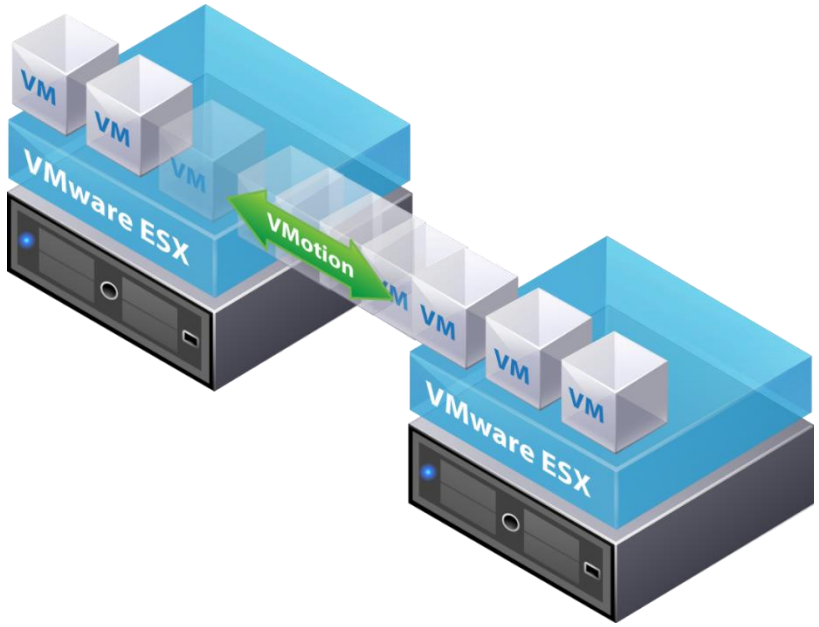
La Virtualizzazione garantisce Business Continuity tramite la funzione HA (High Availability - Alta Disponibilità).

Se un Server ha un guasto, le macchine virtuali presenti saranno istantaneamente migrate su gli altri Server disponibili e fatte ripartire, minimizzando il downtime al tempo di re-start delle macchine virtuali

Recenti tecnologie consentono di avere anche il Fault Tollerant (FT), cioè garantire la continuità di funzionamento delle VM dopo il guasto di un server, azzerando il tempo di fermo. E' al momento quanto di meglio si possa avere per la Business Continuity.

Virtualizzazione: La Migrazione Live delle VM

- La migrazione "a caldo" delle VM fra i vari Server Fisici è una delle tante funzionalità del sistema di virtualizzazione.
- Consente operazioni di manutenzione o di bilanciamento del carico mantenendo l'operatività dei server virtuali.

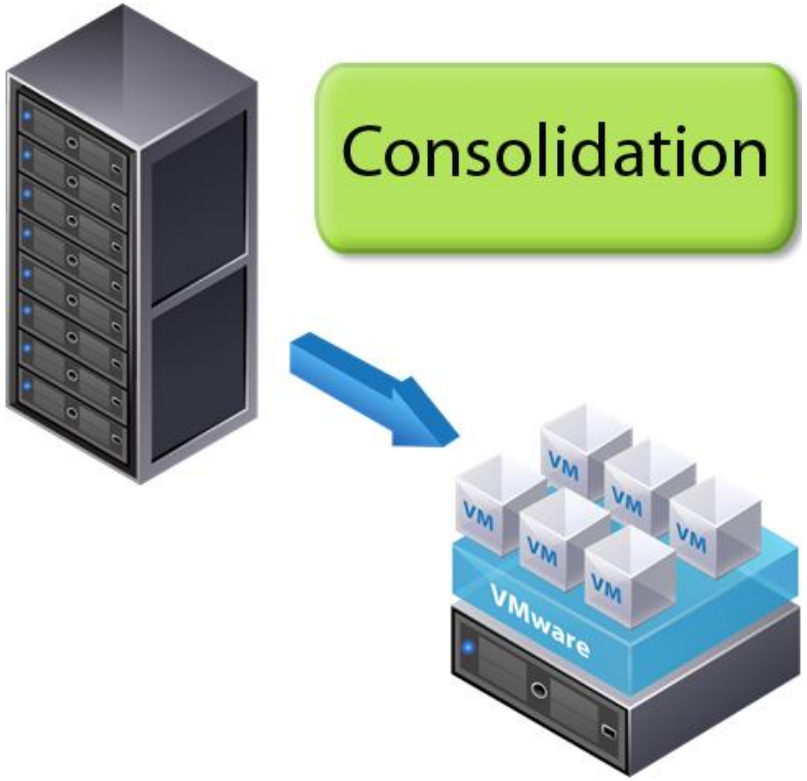


Le Macchine virtuali

Benefici

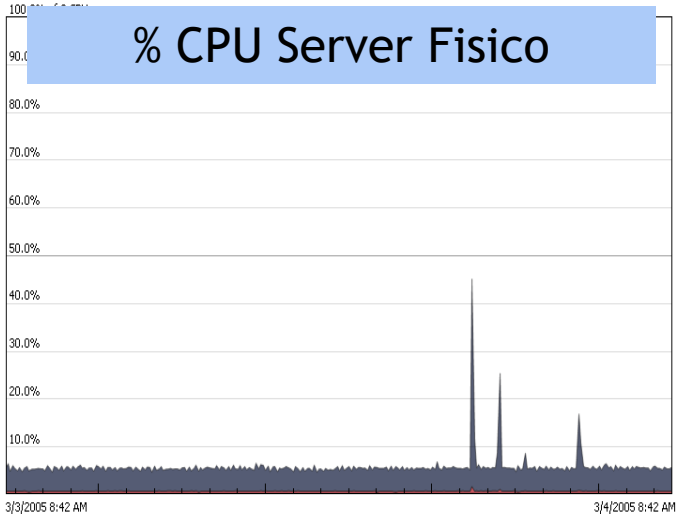
Consolidamento di un CED

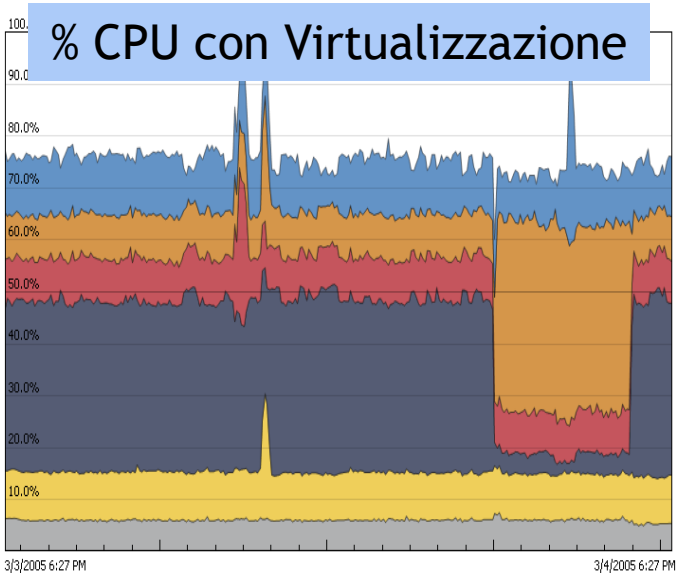
- Con l'introduzione della virtualizzazione si parla di "**consolidamento**" di un CED.
- Sfruttando al meglio le risorse di computazione parallela offerte dai nuovi processori, è possibile ridurre significativamente il numero di server necessari per erogare i servizi informatici richiesti da un ente



Benefici introdotti dalla Virtualizzazione: Ottimizzazione

- Ottimizzazione delle risorse HW - La virtualizzazione permette di eseguire distinti sistemi operativi contemporaneamente in una singola macchina
- Ottimizzazione della occupazione dello spazio disco - ad una macchina virtuale viene assegnato lo spazio disco strettamente necessario.
  - Il resto del volume resta disponibile per nuove macchine virtuali





Benefici introdotti dalla Virtualizzazione: Semplificazione

- Backup e disaster recovery
  - L'intero server (SO, applicazioni, dati, dispositivi e stato) non è altro che un file, più facile creare copie di backup per il disaster recovery
- Indipendenza dall'hardware
- Rilasci semplificati
  - Possibilità di clonare "LIVE" le macchine virtuali per test e aggiornamenti, senza compromettere l'integrità di quella originale.

Benefici introdotti dalla Virtualizzazione: Costi

- Riduzione dei costi di IT
  - Riduzione del numero dei server necessari, con conseguente risparmio sui costi energetici, di condizionamento e dimensione degli spazi fisici richiesti dal CED.
- Riduzione dei costi di personale IT
  - Gestione centralizzata: Incremento di produttività del reparto IT, dovuto alla gestione centralizzata delle macchine attraverso un'unica interfaccia di amministrazione

La Virtualizzazione Al Ministero di Giustizia

Virtualizzazione e Giustizia

- Al momento la maggior parte dei CED del Ministero di Giustizia sfrutta i vantaggi della virtualizzazione
- Il Ministero ha una Enterprise Licence Agreement con VMWare, leader di mercato per la fornitura di soluzioni virtuali a livello mondiale
- I contratti con le aziende fornitrici prevedono il rilascio degli applicativi per Giustizia principalmente sotto forma di Macchine Virtuali

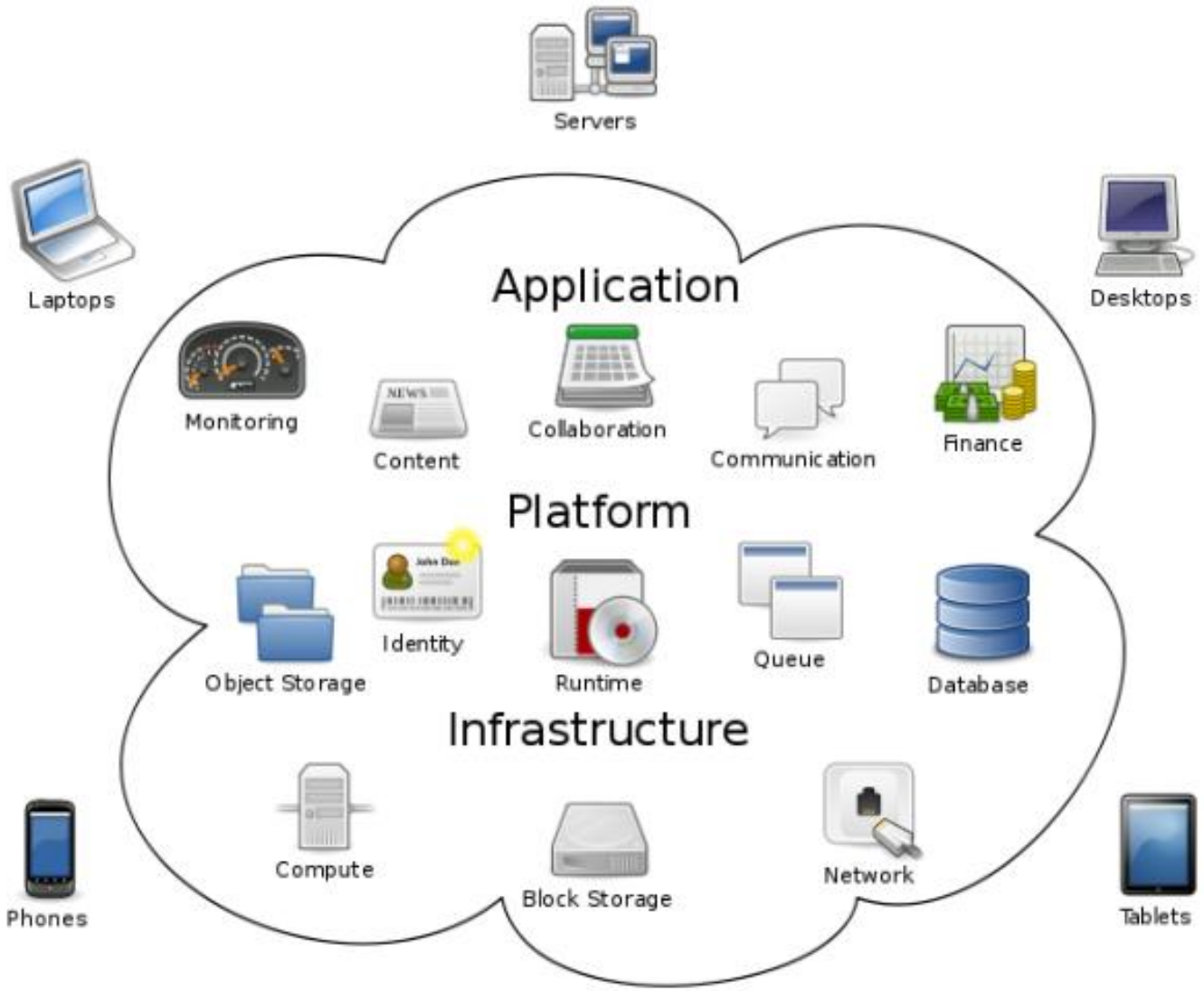
Esempio del CISIA di Napoli

- Centro Elaborazione Dati per Civile (interdistrettuale) e Penale.
- Circa 800 macchine virtuali in esecuzione in parallelo, con bilanciamento del carico.
- Circa 30 server fisici.
- 2 Storage Area Network, con circa 500 TB di spazio.
- Gestione di 800 macchine da 2 console di amministrazione.

Cloud Computing

Cloud Computing

- IT resources provided as a service
  - Compute, storage, databases, queues
- Clouds leverage economies of scale of commodity hardware
  - Cheap storage, high bandwidth networks & multicore processors
  - Geographically distributed data centers
- Offerings from Microsoft, Amazon, Google, …


Servers
Laptops
Desktops
Application
Monitoring
Content
Collaboration
Communication
Finance
Platform
Identity
Object Storage
Runtime
Queue
Database
Infrastructure
Compute
Block Storage
Network
Phones
Tablets
Cloud Computing

Cloud Scalability & Elasticity

Scalability & Elasticity

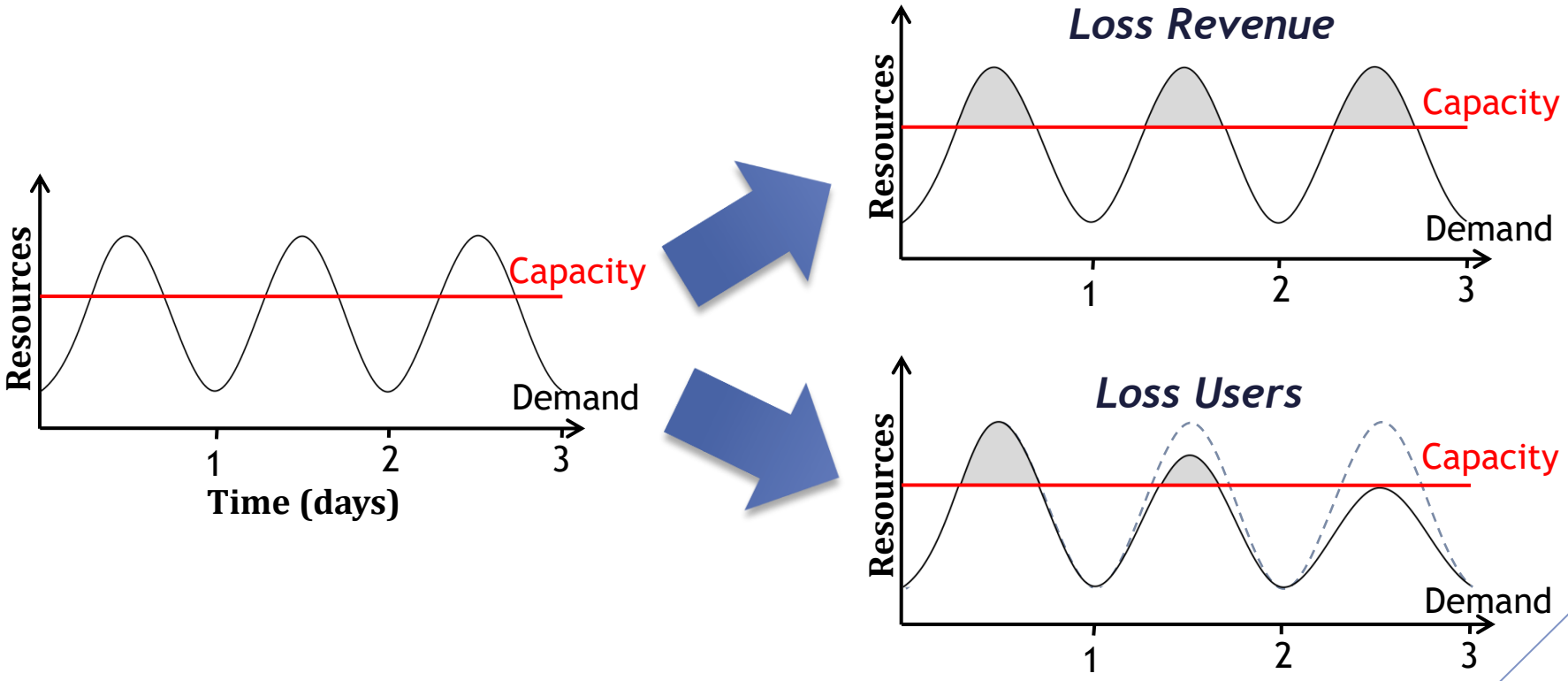
- What is scalability ?
  - A desirable property of a system, a network, or a process, which indicates its ability to either handle growing amounts of work in a graceful manner or to be readily enlarged.
- What is elasticity ?
  - The ability to grow or shrink infrastructure resources dynamically as needed to adapt to workload changes in an autonomic manner, maximizing the use of resources..
- But how to achieve these properties ?
  - Dynamic provisioning
  - Multi-tenant design

Dynamic Provisioning

- Dynamic Provisioning is a simplified way to explain a complex networked server computing environment where server computing instances are provisioned or deployed from a administrative console or client application by the server administrator, network administrator, or any other enabled user.

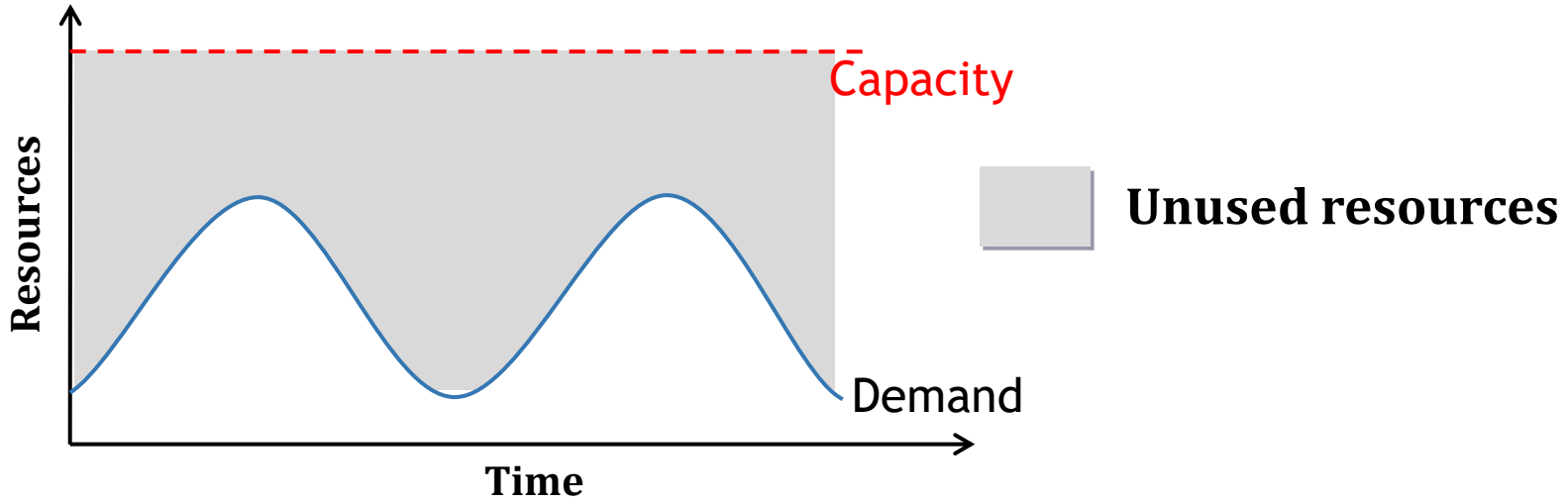
Dynamic Provisioning

- In traditional computing model, two common problems :
  - Underestimate system utilization which result in under provision



Dynamic Provisioning

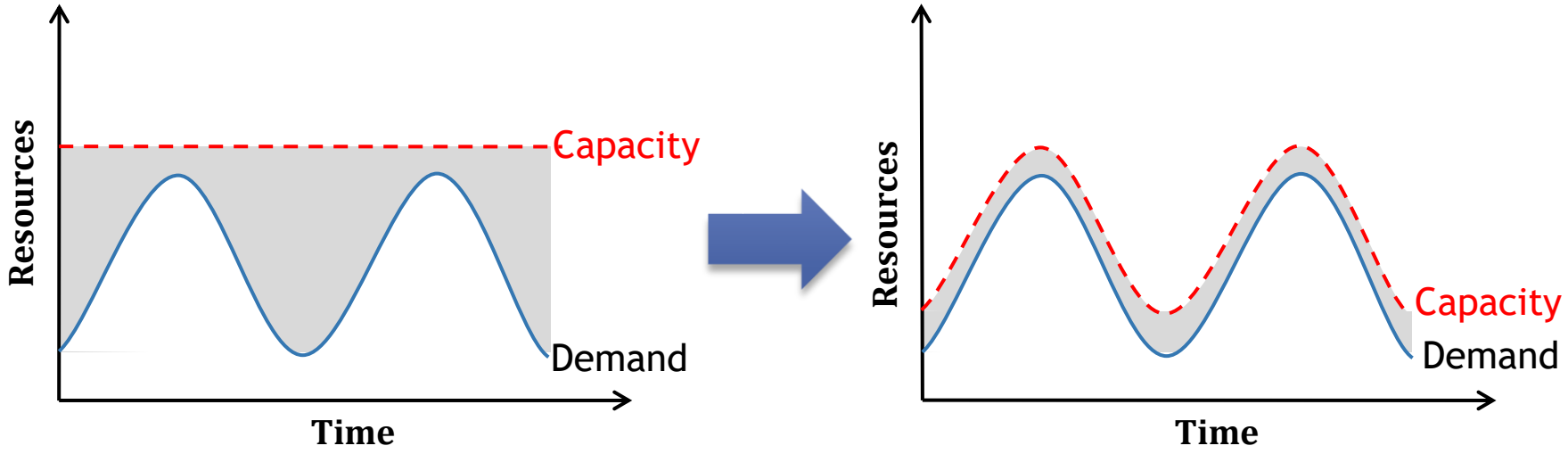
- Overestimate system utilization which result in low utilization



- How to solve this problem ??
  - Dynamically provision resources

Dynamic Provisioning

- Cloud resources should be provisioned dynamically
  - Meet seasonal demand variations
  - Meet demand variations between different industries
  - Meet burst demand for some extraordinary events



Multi-tenant Design

- Multi-tenant refers to a principle in software architecture where a single instance of the software runs on a server, serving multiple client organizations.
  - With a multi-tenant architecture, a software application is designed to virtually partition its data and configuration thus each client organization works with a customized virtual application instance.

- Client oriented requirements :
  - Customization
    - Multi-tenant applications are typically required to provide a high degree of customization to support each target organization's needs.
  - Quality of service
    - Multi-tenant applications are expected to provide adequate levels of security and robustness.

Availability & Reliability

- What is availability ?
  - The degree to which a system, subsystem, or equipment is in a specified operable and committable state at the start of a mission, when the mission is called for at an unknown time.
  - Cloud system usually require high availability
    - Ex. “Five Nines” system would statistically provide 99.999% availability
- What is reliability ?
  - The ability of a system or component to perform its required functions under stated conditions for a specified period of time.
- But how to achieve these properties ?
  - Fault tolerance system
  - Require system resilience
  - Reliable system security

Fault Tolerance

- Fault-tolerance is the property that enables a system to continue operating properly in the event of the failure of some of its components.
  - If its operating quality decreases at all, the decrease is proportional to the severity of the failure, as compared to a naively-designed system in which even a small failure can cause total breakdown.

- Four basic characteristics :
  - No single point of failure
  - Fault detection and isolation to the failing component
  - Fault containment to prevent propagation of the failure
  - Availability of reversion modes

System Resilience

- Resilience is the ability to provide and maintain an acceptable level of service in the face of faults and challenges to normal operation.
  - Resiliency pertains to the system's ability to return to its original state after encountering trouble. In other words, if a risk event knocks a system offline, a highly resilient system will return back to work and function as planned as soon as possible.

- Some risk events
  - If power is lost at a plant for two days, can our system recover ?
  - If a key service is lost because a database corruption, can the business recover ?

System Security

- Security issue in Cloud Computing :
  - Cloud security is an evolving sub-domain of computer security, network security, and, more broadly, information security.
  - It refers to a broad set of policies, technologies, and controls deployed to protect data, applications, and the associated infrastructure of cloud computing.

Manageability & Interoperability

Manageability & Interoperability

- What is manageability ?
  - Enterprise-wide administration of cloud computing systems. Systems manageability is strongly influenced by network management initiatives in telecommunications.
- What is interoperability ?
  - Interoperability is a property of a product or system, whose interfaces are completely understood, to work with other products or systems, present or future, without any restricted access or implementation.
- But how to achieve these properties ?
  - System control automation
  - System state monitoring

Control Automation

- What is Autonomic Computing ?
  - Its ultimate aim is to develop computer systems capable of self-management, to overcome the rapidly growing complexity of computing systems management, and to reduce the barrier that complexity poses to further growth.
- Architectural framework :
  - Composed by Autonomic Components (AC) which will interact with each other.
  - An AC can be modeled in terms of two main control loops (local and global) with sensors (for self-monitoring), effectors (for self-adjustment), knowledge and planer/adapter for exploiting policies based on self- and environment awareness.

System Monitoring

- What is system monitor ?
  - A System Monitor in systems engineering is a process within a distributed system for collecting and storing state data.
- What should be monitored in the Cloud ?
  - Physical and virtual hardware state
  - Resource performance metrics
  - Network access patterns
  - System logs
  - … etc
- Anything more ?
  - Billing system

Billing System

- Users pay as many as they used.
  - Cloud provider must first determine the list of service usage price.
  - Cloud provider have to record the resource or service usage of each user, and then charge users by these records.
- How can cloud provider know users' usage ?
  - Get those information by means of monitoring system.
  - Automatically calculate the total amount of money which user should pay. And automatically request money from use's banking account.

Acce ty & Portability

Accessibility
Portability
- Uniform access
- Thin client

Anyone !
Anytime !
Anywhere !

Accessibility & Portability

- What is accessibility ?
  - Accessibility is a general term used to describe the degree to which a product, device, service, or environment is accessible by as many people as possible.
- What is service portability ?
  - Service portability is the ability to access services using any devices, anywhere, continuously with mobility support and dynamic adaptation to resource variations.
- But how to achieve these properties ?
  - Uniform access
  - Thin client

Uniform Access

- How do users access cloud services ?
  - Cloud provider should provide their cloud service by means of widespread accessing media. In other word, users from different operating systems or other accessing platforms should be able to directly be served.
  - Nowadays, web browser technique is one of the most widespread platform in almost any intelligent electronic devices. Cloud service take this into concern, and delivery their services with web-based interface through the Internet.

Thin Client

- What is thin client ?
  - Thin client is a computer or a computer program which depends heavily on some other computer to fulfill its traditional computational roles. This stands in contrast to the traditional fat client, a computer designed to take on these roles by itself.
- Characteristics :
  - Cheap client hardware
    - While the cloud providers handle several client sessions at once, the clients can be made out of much cheaper hardware.
  - Diversity of end devices
    - End user can access cloud service via plenty of various electronic devices, which include mobile phones and smart TV.
  - Client simplicity
    - Client local system do not need complete operational functionalities.

Benefits of Cloud Computing

Reduce Initial Investment

- Traditional process of enterprises to initiate business :
  - Survey and analysis the industry and market
  - Estimate the quantity of supply and demand
  - Purchase and deploy IT infrastructure
  - Install and test the software system
  - Design and develop enterprise specific business service
  - Announce the business service to clients
- Some drawbacks :
  - The survey, analysis and estimation may not 100% correct
  - Infrastructure deployment is time consuming
  - Enterprises should take the risk of wrong investment

Reduce Initial Investment

- Initiate business with Cloud Computing services :
  - Survey and analysis the industry and market
  - Chose one cloud provider for enterprise deployment
  - Design and develop business service upon cloud environment
  - Announce the business service to clients
- Some benefits :
  - Enterprise do not need to own the infrastructure
  - Enterprise can develop and deploy business service in short time
  - Enterprise can reduce the business loss of wrong investment

Reduce Initial Investment

- What dose cloud computing achieve ?

	Traditional	With Cloud Computing
Investment Risk	*Enterprise takes the risk*	*Cloud reduces the risk*
Infrastructure	*Enterprise owns the infrastructure*	*Cloud provider owns the infrastructure*
Time duration	*Long deployment time*	*Fast to business ready*

Reduce Capital Expenditure

- Traditional capital expenditure of enterprises :
  - Each enterprise should establish its own IT department
  - IT department should handle the listing jobs
    - Manage and administrate hardware and software
    - Apply regular data backup and check point process
    - Purchase new infrastructure and eliminate outdated one
    - Always standby for any unexpected IT problems
- Some drawbacks :
  - Enterprise pays for IT investment which is not its business focus
  - Enterprise should take the risk of hardware/software malfunction
  - Replacing and updating infrastructure is time consuming and risky

Reduce Capital Expenditure

- Capital expenditure with Cloud Computing service :
  - Enterprise can almost dismiss its IT department
  - The jobs of IT department can be achieved by cloud provider
    - Dynamically update and upgrade hardware or software
    - Dynamically provision and deploy infrastructure for enterprise
    - Automatically backup data and check consistency
    - Self-recover from disaster or system malfunction
- Some benefits :
  - Enterprise can shift effort to its business focus
  - Enterprise can reconfigure its IT services in short time
  - Enterprise pays to cloud provider as many as the service used

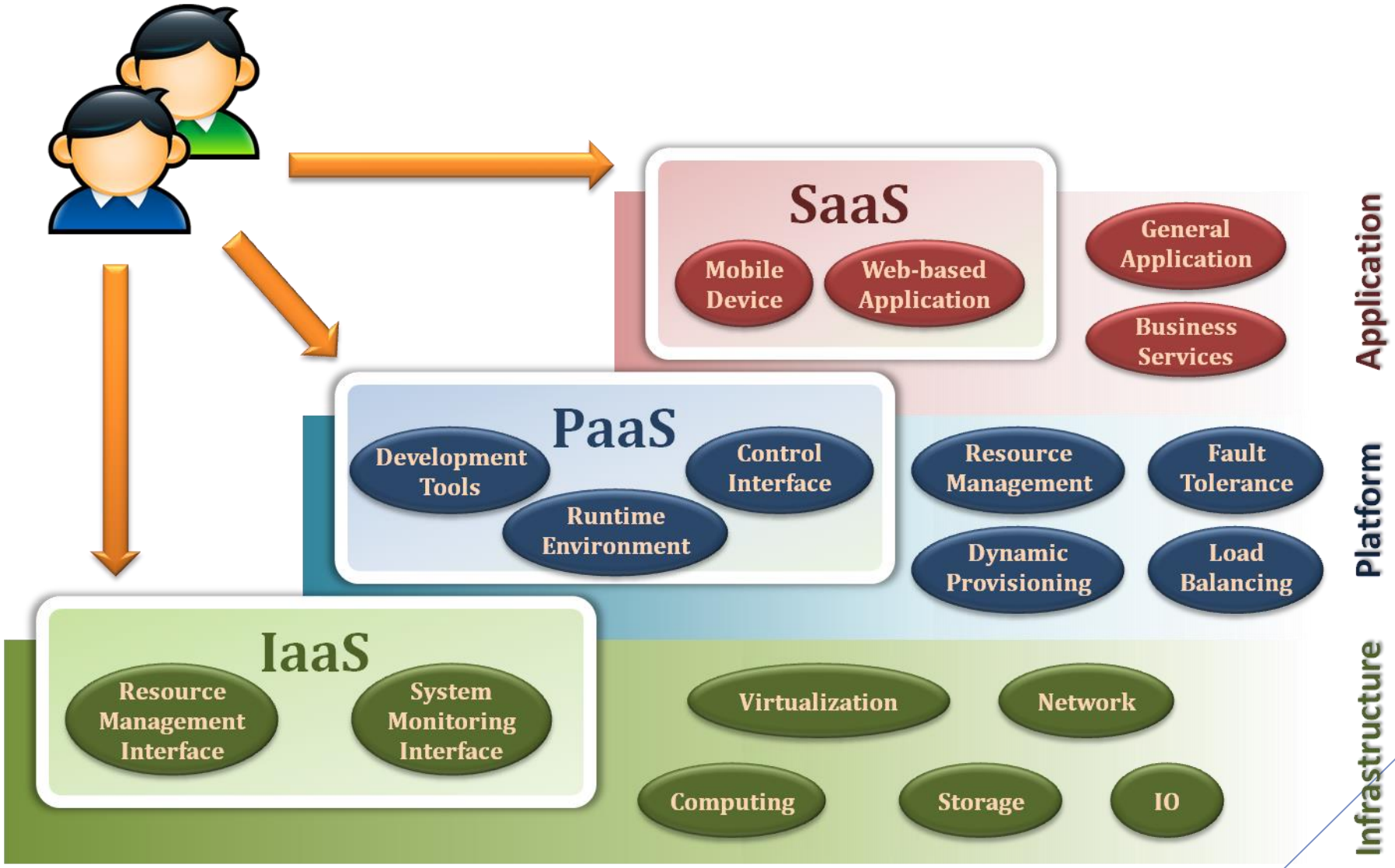
Reduce Capital Expenditure

- What dose cloud computing achieve ?

	Traditional	With Cloud Computing
Business focus	*Need to own its IT department*	*Cloud provider takes care everything*
Payment	*Pay for all investment and human resource*	*Enterprise pays as the service used*
Time duration	*Long establish time*	*Fast to business ready*

Service Models

Service Model Overview

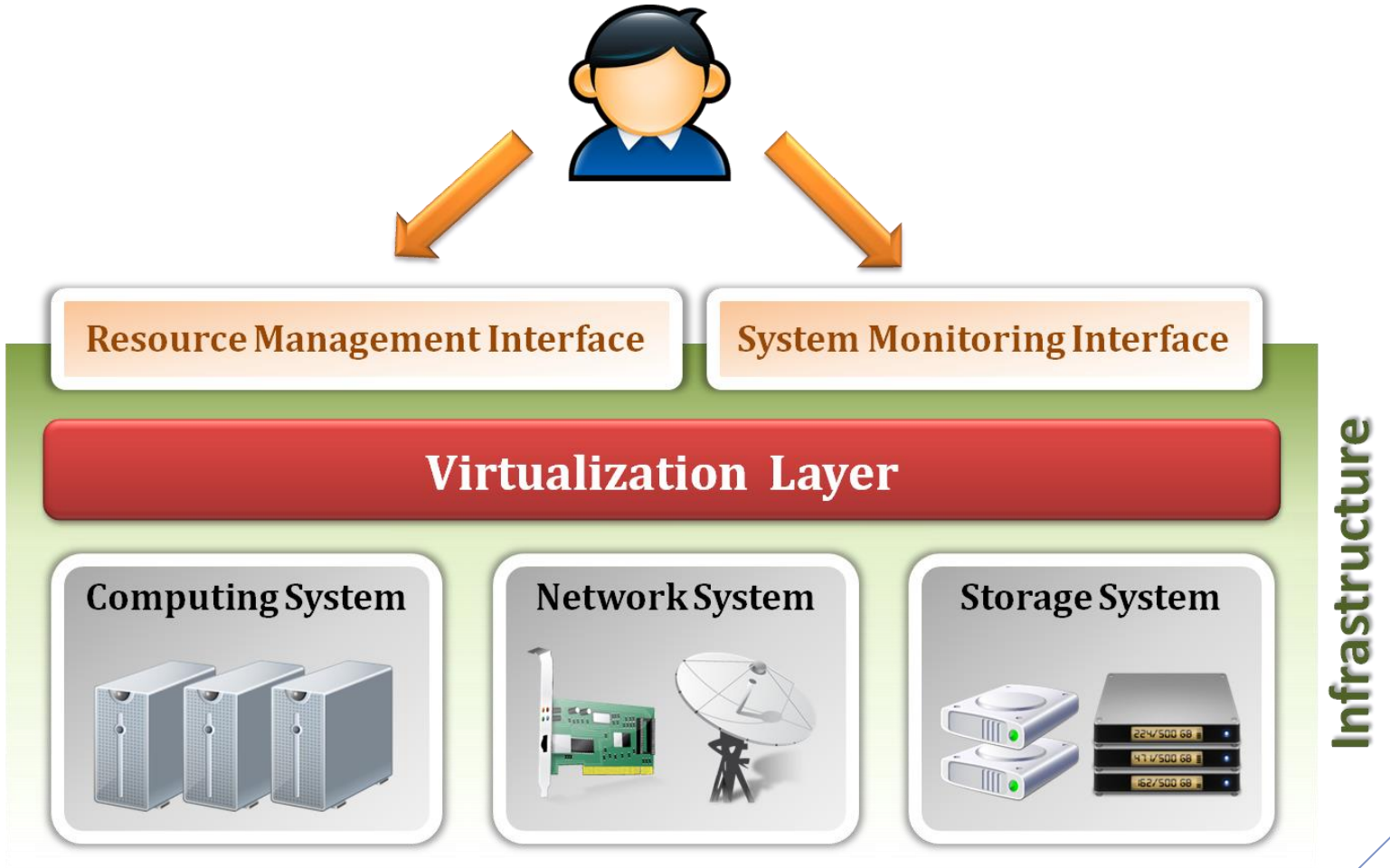


Infrastructure as a Service - IaaS

- 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 and applications.
  - 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 .
- Examples :
  - Amazon EC2
  - Eucalyputs
  - OpenNebula
  - … etc

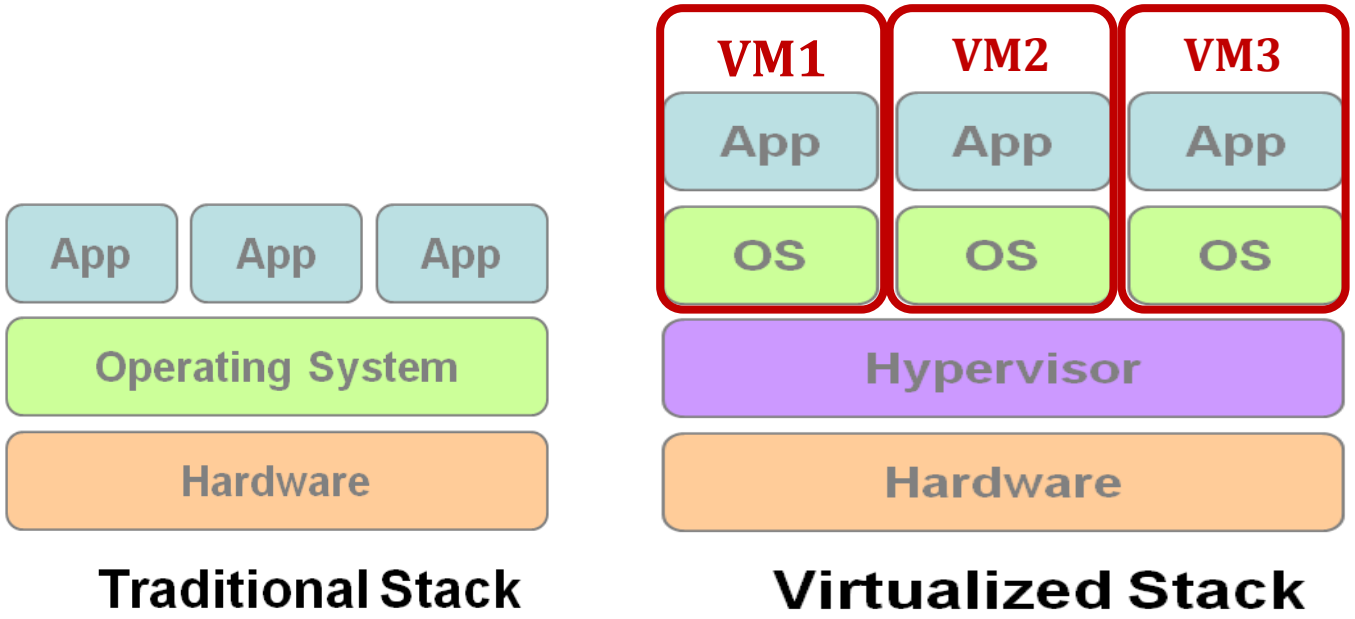
Infrastructure as a Service

- System architecture :



Infrastructure as a Service

- Enabling technique - ***Virtualization***
  - Virtualization is an abstraction of logical resources away from underlying physical resources.
    - Virtualization technique shift OS onto hypervisor.
    - Multiple OS share the physical hardware and provide different services.
    - Improve utilization, availability, security and convenience.

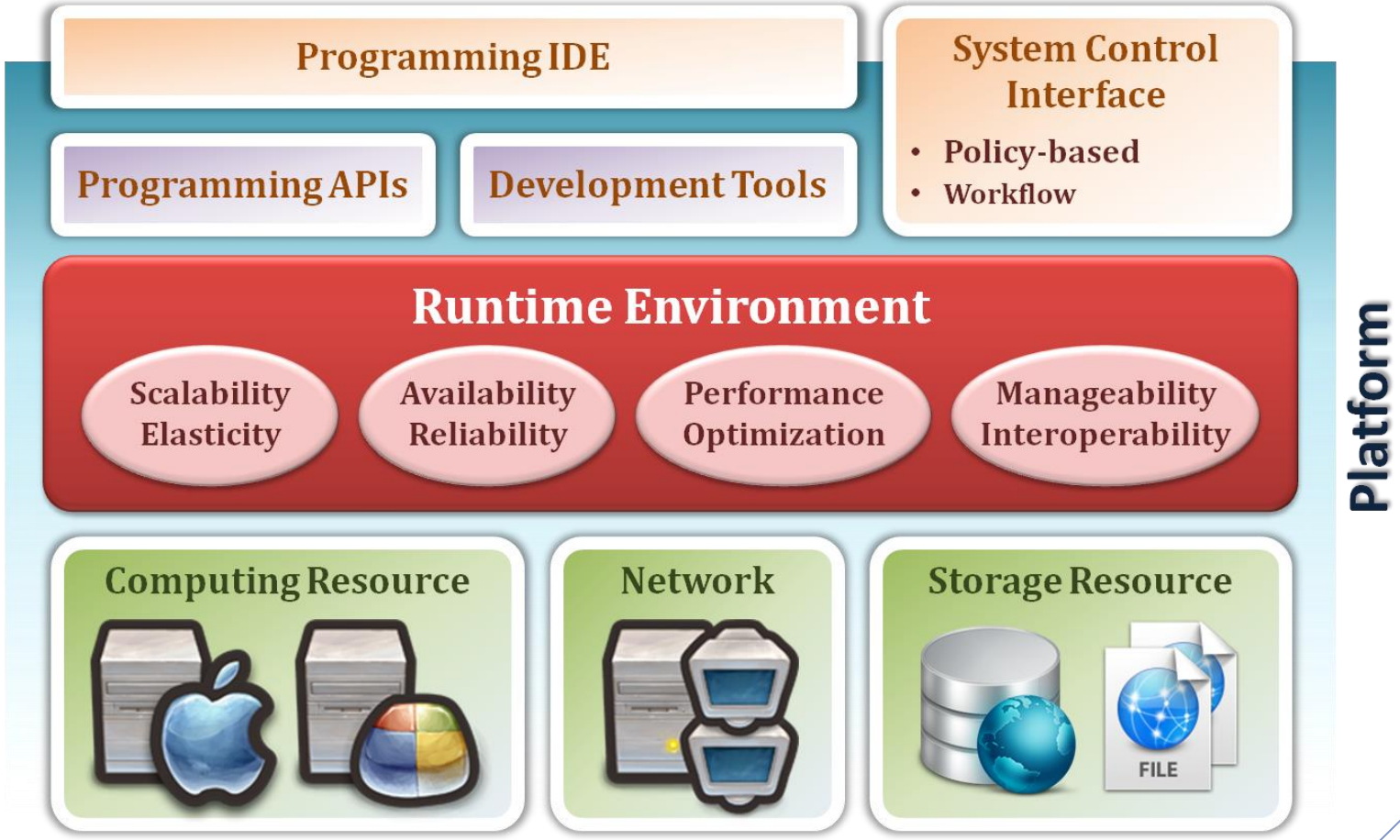


Platform as a Service - PaaS

- The capability provided to the consumer is to deploy onto the cloud infrastructure consumer-created or acquired applications created using programming languages and tools supported by the provider.
  - The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, or storage, but has control over the deployed applications and possibly application hosting environment configurations.
- Examples :
  - Microsoft Windows Azure
  - Google App Engine
  - Hadoop
  - … etc

Platform as a Service

- System architecture :



Platform as a Service

- Enabling technique – **Runtime Environment Design**
  - Runtime environment refers to collection of software services available. Usually implemented by a collection of program libraries.
- Common properties in Runtime Environment :
  - Manageability and Interoperability
  - Performance and Optimization
  - Availability and Reliability
  - Scalability and Elasticity

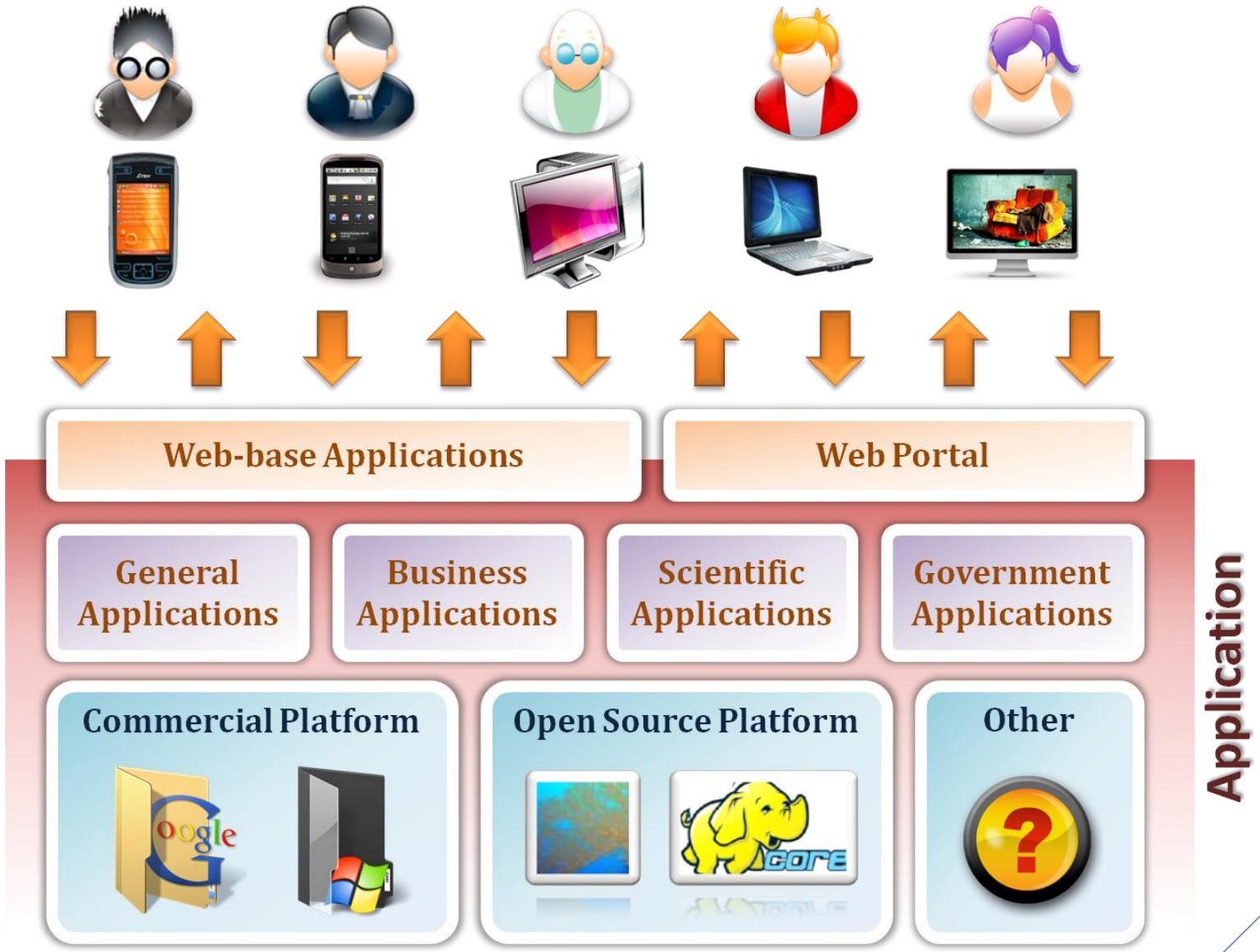
Platform as a Service

- Provide service – **Programming IDE**
  - Users make use of programming IDE to develop their service among PaaS.
    - This IDE should integrate the full functionalities which supported from the underling runtime environment.
    - This IDE should also provide some development tools, such as profiler, debugger and testing environment.
  - The programming APIs supported from runtime environment may be various between different cloud providers, but there are still some common operating functions.
    - Computation, storage and communication resource operation

Software as a Service - SaaS

- The capability provided to the consumer 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 (e.g., web-based email).
  - The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, storage, or even individual application capabilities, with the possible exception of limited user-specific application configuration settings.
- Examples :
  - Google Apps (e.g., Gmail, Google Docs, Google sites, …etc)
  - SalesForce.com
  - EyeOS
  - … etc

Software as a Service



Software as a Service

- Provide service – Web-based Applications
  - Conventional applications should translate their access interface onto web-based platform.
  - Applications in different domains
    - General Applications – Applications which are designed for general propose, such as office suit, multimedia and instant message, …etc.
    - Business Applications – Application which are designed for business propose, such as ERP, CRM and market trading system, …etc.
    - Scientific Applications – Application which are designed for scientific propose, such as aerospace simulation and biochemistry simulation, …etc.
    - Government Applications – Applications which are designed for government propose, such as national medical system and public transportation system service, …etc.

Deployment models

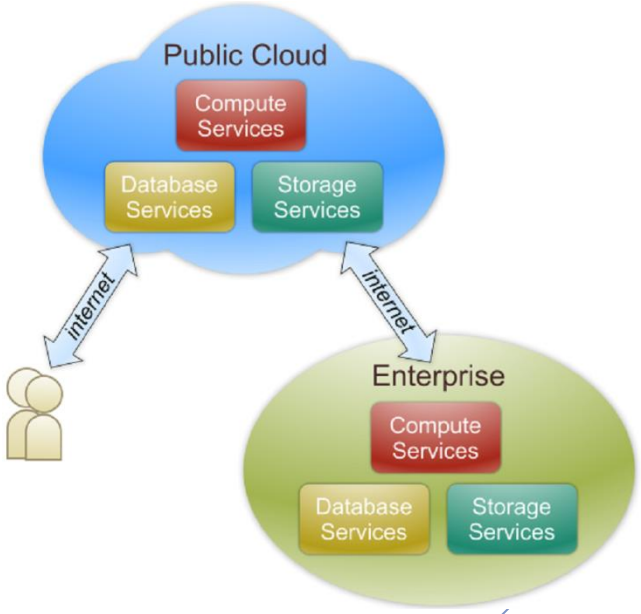
How to deploy a cloud system ?

Deployment Model

- There are four primary cloud deployment models :
  - Public Cloud
  - Private Cloud
  - Community Cloud
  - Hybrid Cloud
- Each can exhibit the previously discussed characteristics; their differences lie primarily in the scope and access of published cloud services, as they are made available to service consumers.

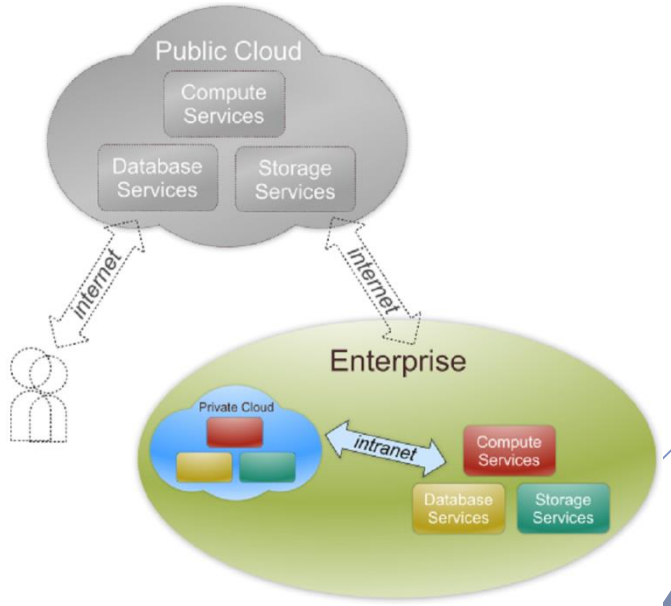
Public Cloud

- The cloud infrastructure is made available to the general public or a large industry group and is owned by an organization selling cloud services.
  - Also known as external cloud or multi-tenant cloud, this model essentially represents a cloud environment that is openly accessible.
  - Basic characteristics :
    - Homogeneous infrastructure
    - Common policies
    - Shared resources and multi-tenant
    - Leased or rented infrastructure
    - Economies of scale



Private Cloud

- The cloud infrastructure is operated solely for an organization. It may be managed by the organization or a third party and may exist on premise or off premise.
  - Also referred to as internal cloud or on-premise cloud, a private cloud intentionally limits access to its resources to service consumers that belong to the same organization that owns the cloud.
  - Basic characteristics :
    - Heterogeneous infrastructure
    - Customized and tailored policies
    - Dedicated resources
    - In-house infrastructure
    - End-to-end control



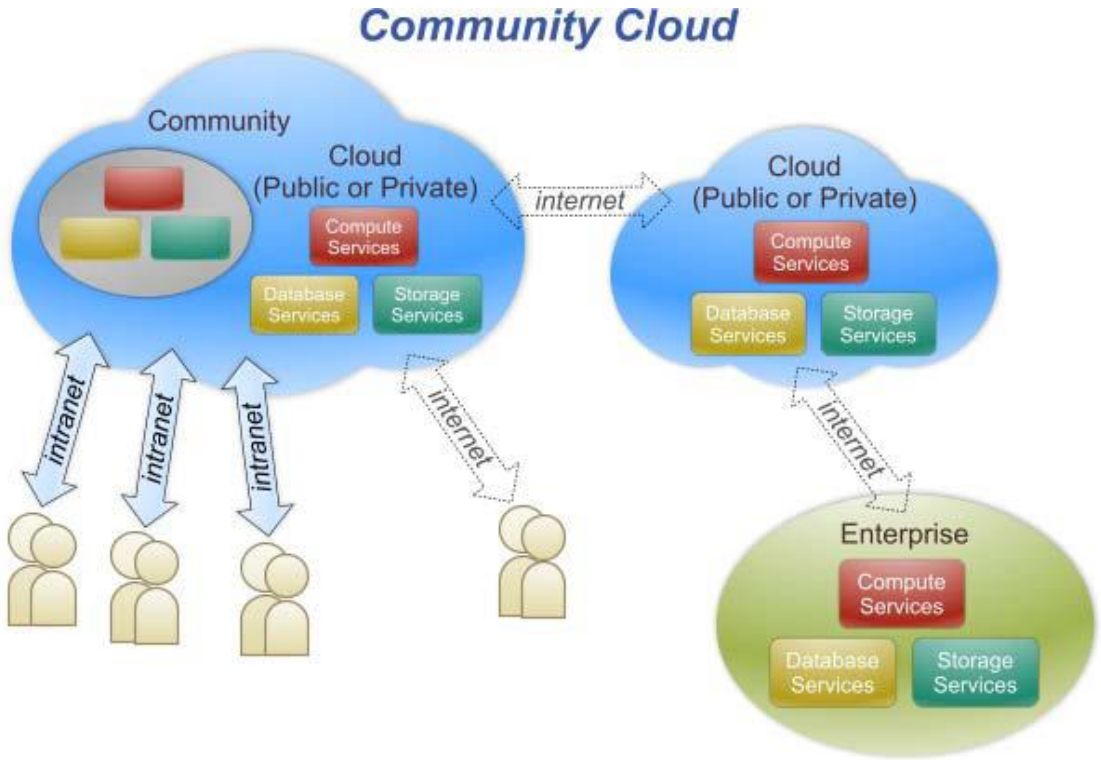
Public vs. Private

- Comparison :

	Public Cloud	Private Cloud
Infrastructure	*Homogeneous*	*Heterogeneous*
Policy Model	*Common defined*	*Customized & Tailored*
Resource Model	*Shared & Multi-tenant*	*Dedicated*
Cost Model	*Operational expenditure*	*Capital expenditure*
Economy Model	*Large economy of scale*	*End-to-end control*

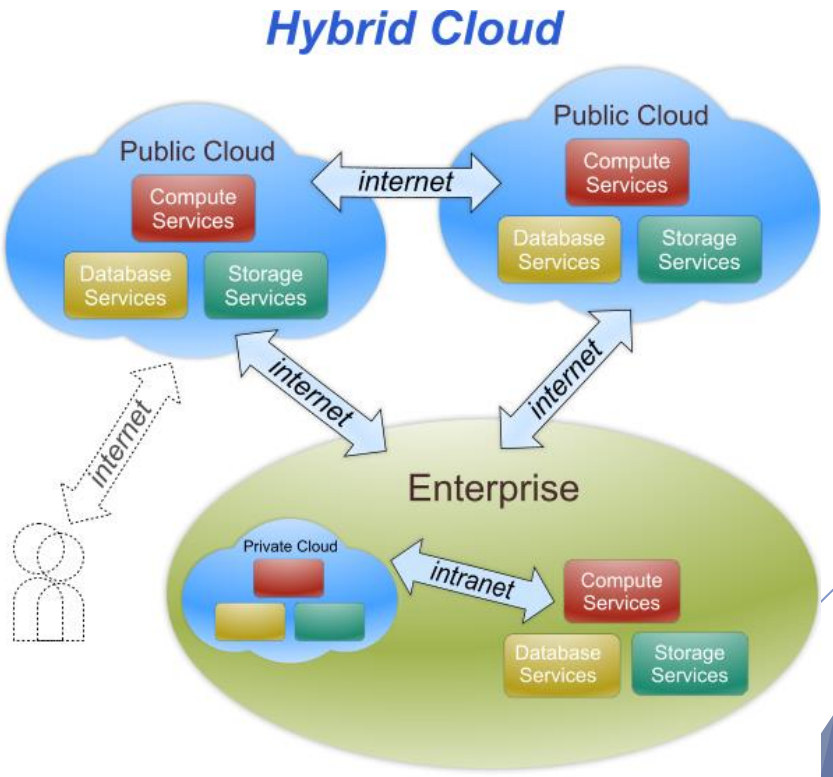
Community Cloud

- The cloud infrastructure is shared by several organizations and supports a specific community that has shared concerns (e.g., mission, security requirements, policy, and compliance considerations).

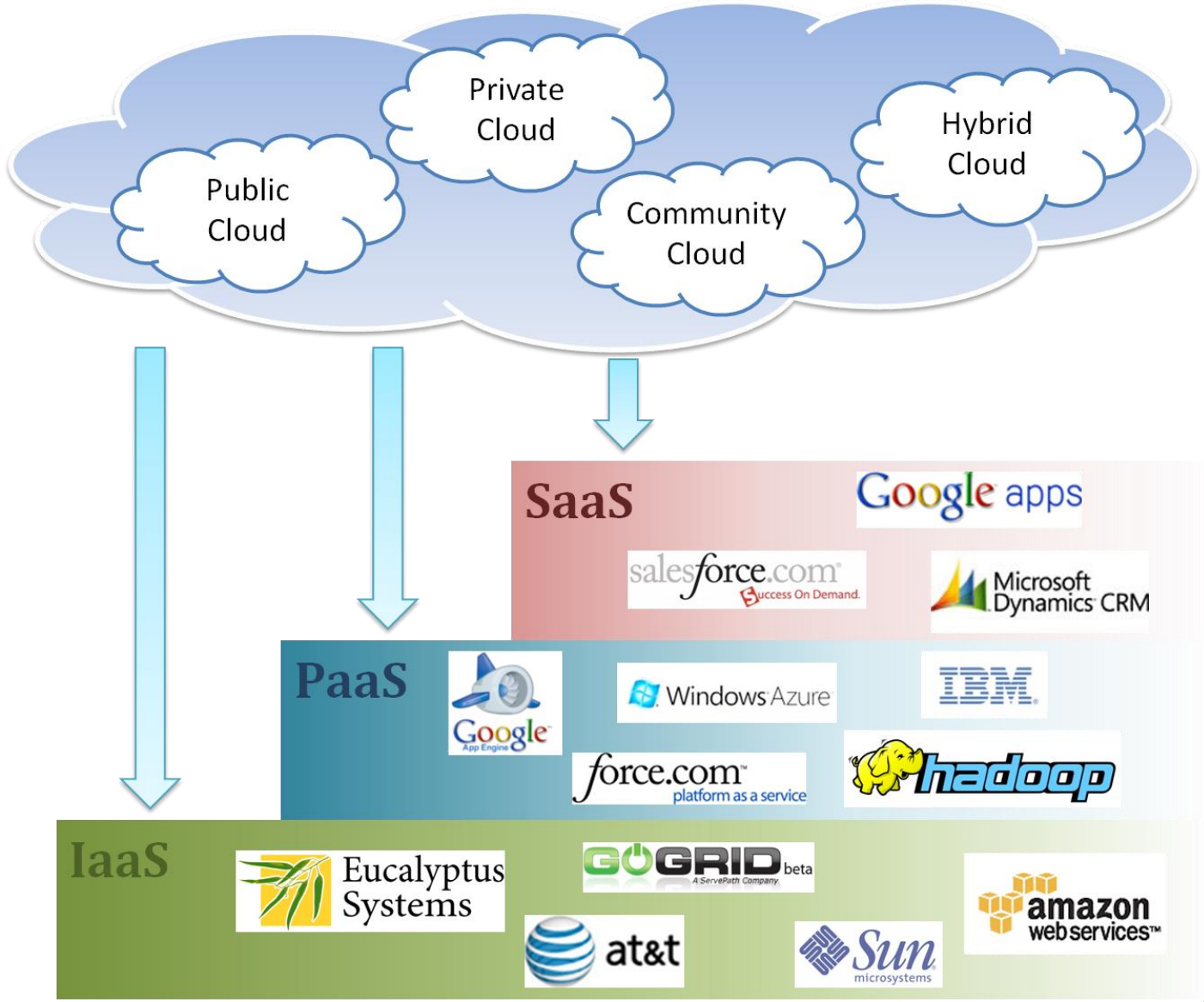


Hybrid Cloud

- The cloud infrastructure is a composition of two or more clouds (private, community, or public) that remain unique entities but are bound together by standardized or proprietary technology that enables data and application portability (e.g., cloud bursting for load-balancing between clouds).



Cloud Ecosystem

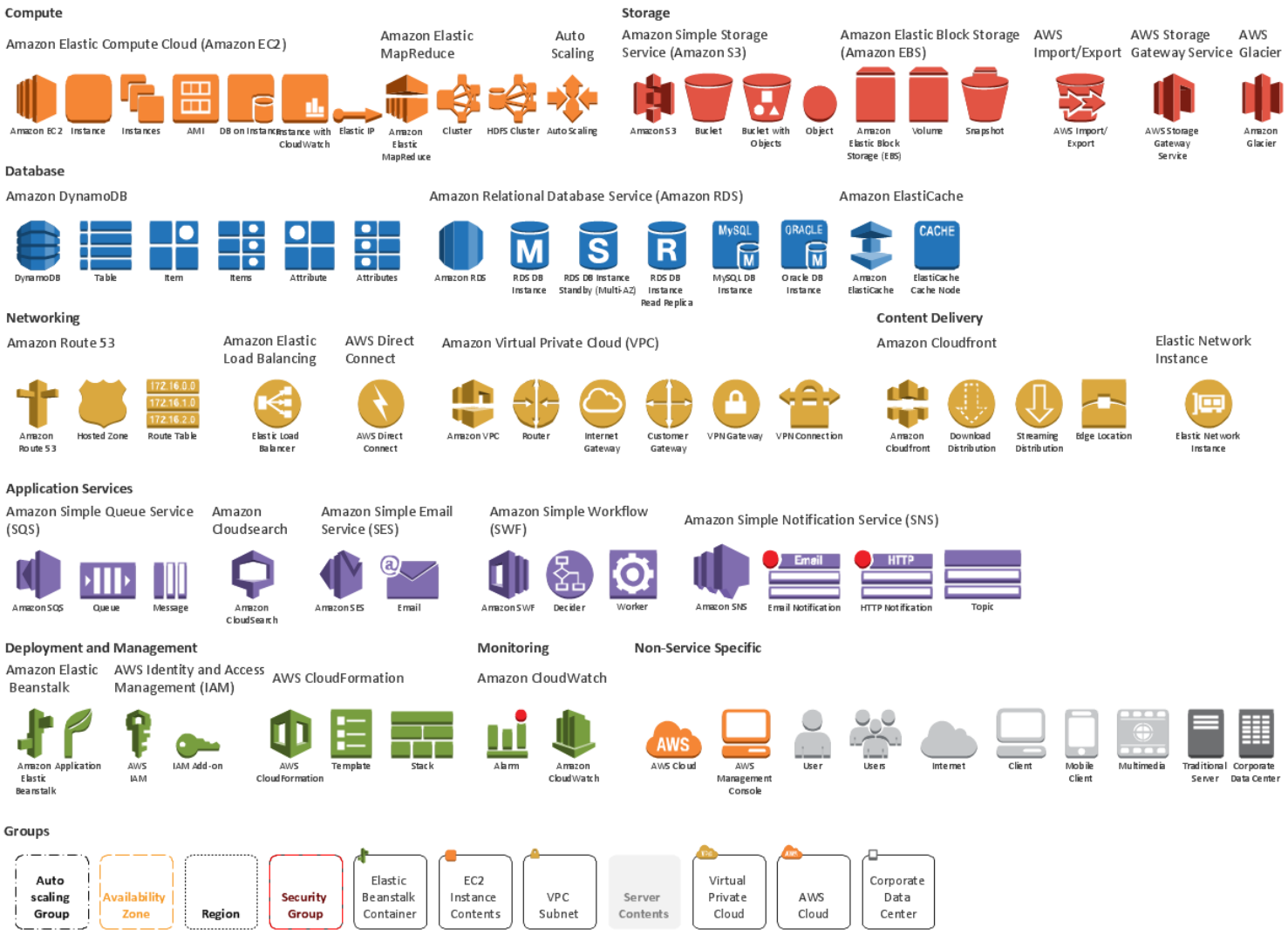


Cloud Providers

AWS

- Elastic Compute Cloud – EC2 (IaaS)
- Simple Storage Service – S3 (IaaS)
- Elastic Block Storage – EBS (IaaS)
- SimpleDB (SDB) (PaaS)
- Simple Queue Service – SQS (PaaS)
- CloudFront (S3 based Content Delivery Network – PaaS)
- Consistent AWS Web Services API

AWS Ecosystem



What does Azure platform offer to developers?