



# Distributed & Cloud Computing

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## Outline



From [DAMAC Laboratory](#)

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## Outline

- Introduction to Cloud Computing,

From [DAMAC Laboratory](#)

2-2



## Outline

- Introduction to Cloud Computing,
- Cloud Computing Architecture,

From [DAMAC Laboratory](#)

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## Outline

- Introduction to Cloud Computing,
- Cloud Computing Architecture,
- Service Management in Cloud Computing,

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- Introduction to Cloud Computing,
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- Data Management in Cloud Computing,

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## Outline

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- Cloud Computing Architecture,
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- Data Management in Cloud Computing,
- Resource Management in Cloud,

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- Introduction to Cloud Computing,
- Cloud Computing Architecture,
- Service Management in Cloud Computing,
- Data Management in Cloud Computing,
- Resource Management in Cloud,
- Cloud Security,

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## Outline

- Introduction to Cloud Computing,
- Cloud Computing Architecture,
- Service Management in Cloud Computing,
- Data Management in Cloud Computing,
- Resource Management in Cloud,
- Cloud Security,
- Open Source and Commercial Clouds,

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- Introduction to Cloud Computing,
- Cloud Computing Architecture,
- Service Management in Cloud Computing,
- Data Management in Cloud Computing,
- Resource Management in Cloud,
- Cloud Security,
- Open Source and Commercial Clouds,
- Cloud Simulator,

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- Research trend in Cloud Computing,

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- Research trend in Cloud Computing,
- Fog Computing

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## DEFINING THE CLOUD: 3 SERVICE MODELS

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## A Simple Analogy

Say, you just moved to a city and you are looking for a place to live.



4

## What are your options ?



5-1

## What are your options ?



5-2

## What are your options ?



- Built a new house ?
- Buy an empty house ?

5-3

## What are your options ?



- Built a new house ?
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- Live in a hotel ?

5-4

## What are your options ?



- Built a new house ?
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**What is your choice ?**

5-5

## Let's built a new house !!



6-1

## **Let's built a new house !!**

You can fully control everything like your new house to have. But that is a hard work ...



6-2

## **If you buy an empty house ?**



7-1

## **If you buy an empty house ?**



You can customize some part of your house.



7-2

## **If you buy an empty house ?**



You can customize some part of your house.



But never change the original architecture.

7-3

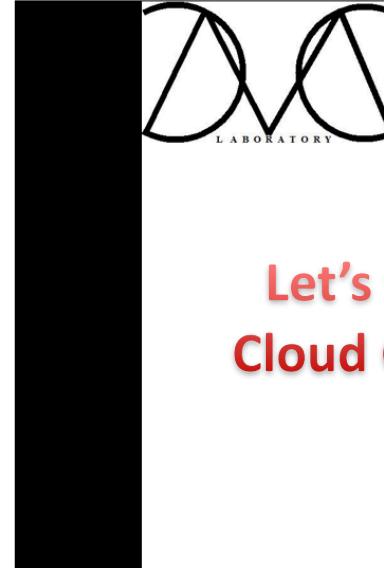
## How about live in a hotel ?

- Live in a hotel will be a good idea if the only thing you care is enjoy your life!!
- There is nothing you can do with the house except living in it.



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Let's translate to  
Cloud Computing !!



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## Service Models Overview

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## Service Models Overview

- What if you want to have an IT department ?

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## Service Models Overview

- Similar to **build a new house** in previous analogy
  - You can rent some virtualized infrastructure and build up your own IT system among those resources, which may be fully controlled.
  - Technically speaking, use the *Infrastructure as a Service (IaaS)* solution.

- **What if you want to have an IT department ?**

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10-3



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- Similar to **buy an empty house** in previous analogy
  - You can directly develop your IT system through one cloud platform, and do not care about any lower level resource management.
  - Technical speaking, use the *Platform as a Service (PaaS)* solution.

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10-4



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  - Technical speaking, use the *Platform as a Service (PaaS)* solution.
- Similar to **live in a hotel** in previous analogy
  - You can directly use some existing IT system solutions, which were provided by some cloud application service provider, without knowing any detail technique about how these services were achieved.
  - Technical speaking, use the *Software as a Service (SaaS)* solution.

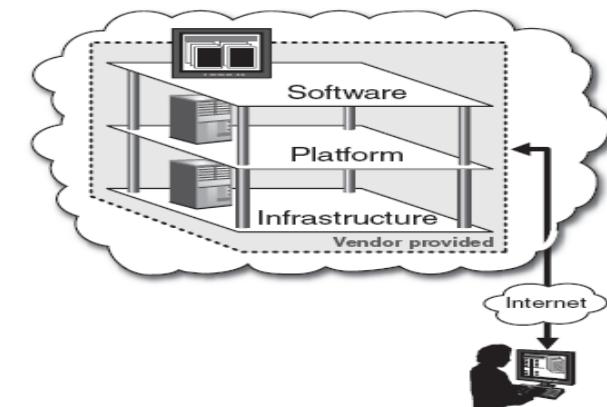
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## Cloud as a Service



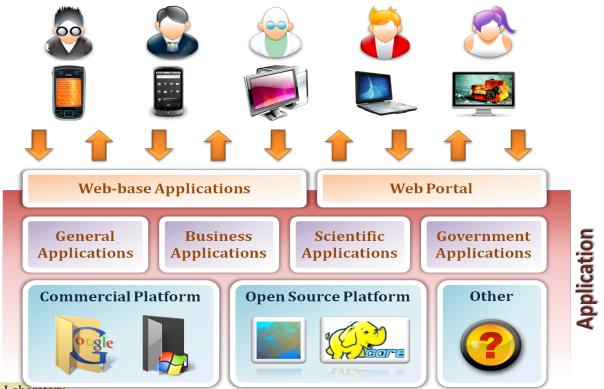
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## Software as a Service (SaaS)

- System architecture :



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## Software as a Service (SaaS)

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## Software as a Service (SaaS)

- Also referred to as “software on demand”.

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## Software as a Service (SaaS)

- Also referred to as “software on demand”.
- This service model involves outsourcing the infrastructure, platform, and software or applications.

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- The customer accesses the applications over the internet.

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- Viewing the Internet as a computing platform

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- Running interactive applications through a web browser
- Leveraging interconnectivity and mobility of devices
- Enhanced effectiveness with greater human participation

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## Software as a Service (SaaS)

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## Software as a Service (SaaS)

- Consumer does not manage or control the cloud infrastructure
  - network, servers, operating systems, storage, or even individual application capabilities

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- Examples :
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  - SalesForce.com
  - EyeOS
  - Etc....

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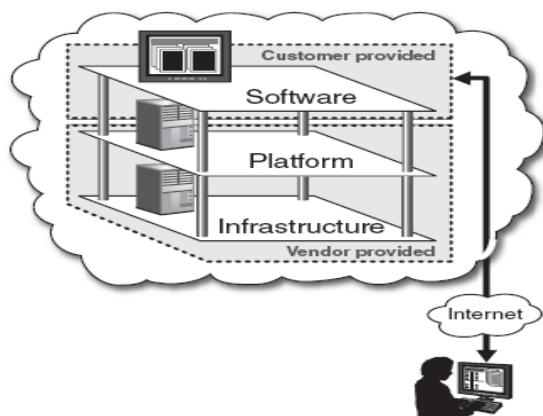
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- SaaS users subscribe to an application rather than purchasing it once and installing it.
- Users can log into and use a SaaS application from any compatible device over the Internet.

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## Platform as a Service (PaaS)



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## Applications of Software as a Service

- **General Applications** – Applications which are designed for general purpose, such as *office suit*, *multimedia* and *instant message*, ...etc.
- **Business Applications** – Application which are designed for business purpose, such as *ERP*, *CRM* and *market trading system*, ...etc.
- **Scientific Applications** – Application which are designed for scientific purpose, such as *aerospace simulation* and *biochemistry simulation*, ...etc.
- **Government Applications** – Applications which are designed for government purpose, such as *national medical system* and *public transportation system service*, ...etc.

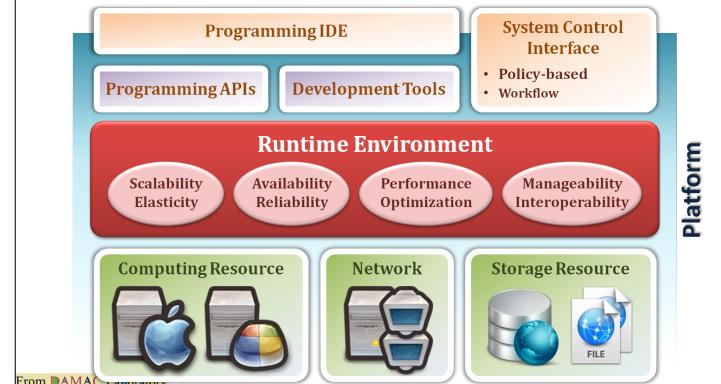
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## Platform as a Service (PaaS)

- **System architecture :**



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# Platform as a Service (PaaS)

- 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



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# Platform as a Service (PaaS)

- Provide service – **Programming IDE**
  - Users make use of programming IDE to develop their service among PaaS.
    - This IDE should integrate the full functionalities which are supported from the underlying 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

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# Platform as a Service (PaaS)

- Provide service – **System Control Interface**
  - Policy-Based Control**
    - Typically described as a principle or rule to guide decisions and achieve rational outcome(s)
    - Make the decision according to some requirements
  - Workflow Control**
    - Describe the flow of installation and configuration of resources
    - Workflow processing daemon delivers speedy and efficient construction and management of cloud resources

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# Platform as a Service (PaaS)

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## Platform as a Service (PaaS)

- A service model that involves outsourcing the basic infrastructure and platform (Windows, Unix)

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- Examples :
  - Microsoft Windows Azure
  - Google App Engine
  - Hadoop
  - ... etc

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## Platform as a Service (PaaS)

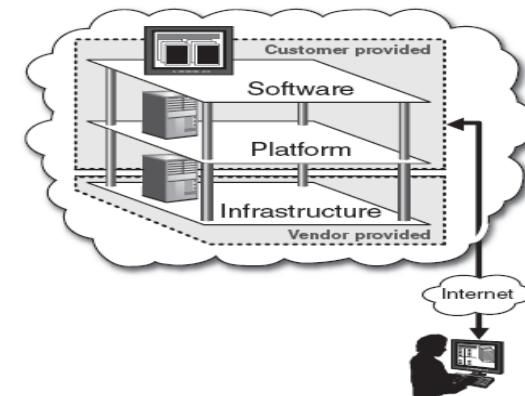
- The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, or storage,
- It has control over the deployed applications and possibly application hosting environment configurations.

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## Infrastructure as a Service (IaaS)



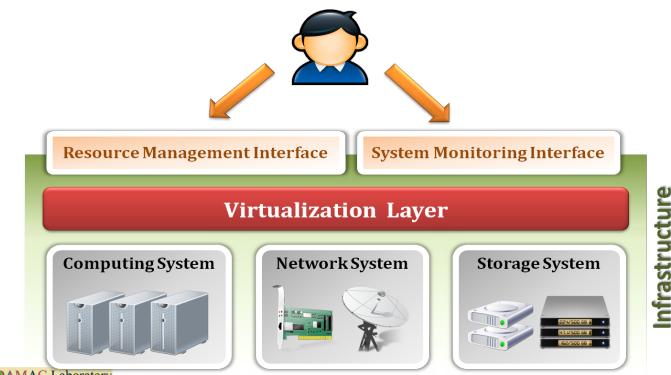
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## Infrastructure as a Service (IaaS)

- System architecture :



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## Infrastructure as a Service (IaaS)

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## Infrastructure as a Service (IaaS)

- A service model that involves outsourcing the basic infrastructure used to support operations
  - Including storage, hardware, servers, and networking components.

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## Infrastructure as a Service (IaaS)

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- Examples :
  - Amazon EC2
  - Eucalyptus
  - OpenNebula
  - ... etc

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## Infrastructure as a Service (IaaS)

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## Infrastructure as a Service (IaaS)



Traditional Stack

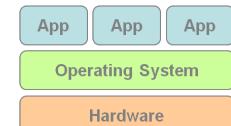
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## Infrastructure as a Service (IaaS)

- 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.



Traditional Stack

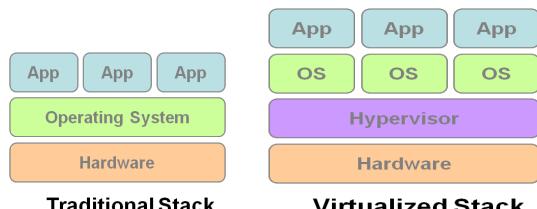
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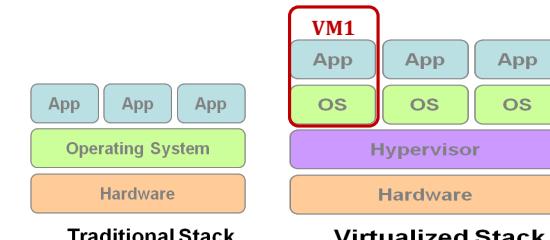
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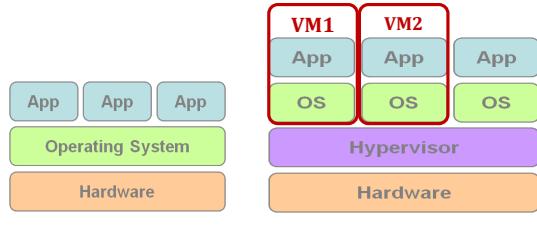
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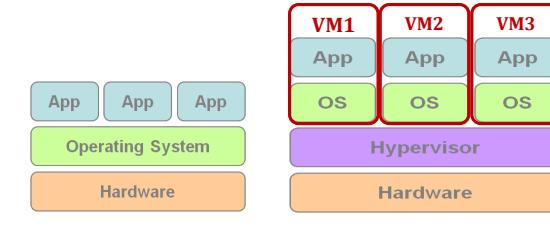
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## Infrastructure as a Service (IaaS)

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## Infrastructure as a Service (IaaS)

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## Infrastructure as a Service (IaaS)

- **Virtual Machine –**

- As an IaaS provider, we should be able to provide the basic virtual machine operations, such as **creation**, **suspension**, **resumption** and **termination**, ...etc.

- **Virtual Storage –**

- As an IaaS provider, we should be able to provide the basic virtual storage operations, such as **space allocation**, **space release**, **data writing** and **data reading**, ...etc.

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- **Virtual Network –**

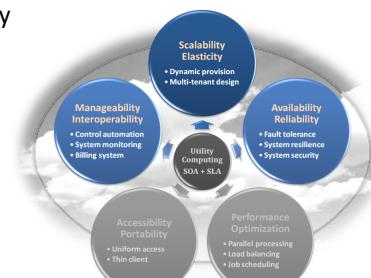
- As an IaaS provider, we should be able to provide the basic virtual network operations, such as **IP address allocation**, **domain name register**, **connection establishment** and **bandwidth provision**, ... etc.

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## Infrastructure as a Service (IaaS)

- Properties supported by virtualization technique :
  - Manageability and Interoperability
  - Availability and Reliability
  - Scalability and Elasticity

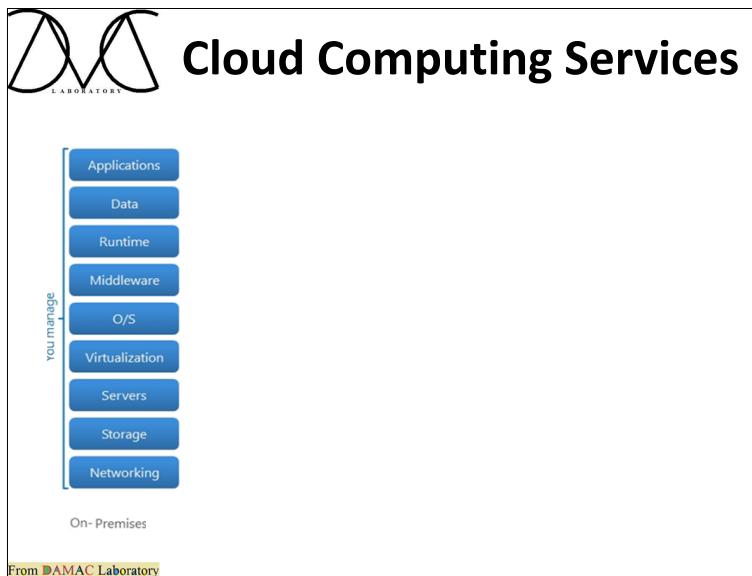


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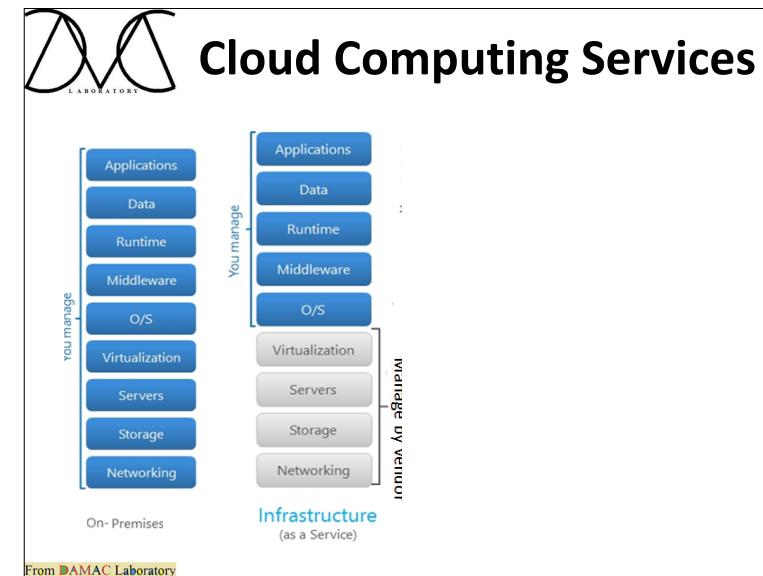
## Infrastructure as a Service (IaaS)

- Provide service – **System Monitoring Interface**
  - Several types of monitoring metrics :
    - Virtual Machine** – As an IaaS provider, we should be able to monitor some system states of each virtual machine, such as *CPU loading*, *memory utilization*, *IO loading* and *internal network loading*, ...etc.
    - Virtual Storage** – As an IaaS provider, we should be able to monitor some storage states of each virtual storage, such as *virtual space utilization*, *data duplication* and *storage device access bandwidth*, ...etc.
    - Virtual Network** – As an IaaS provider, we should be able to monitor some network states of each virtual network, such as *virtual network bandwidth*, *network connectivity* and *network load balancing*, ...etc.

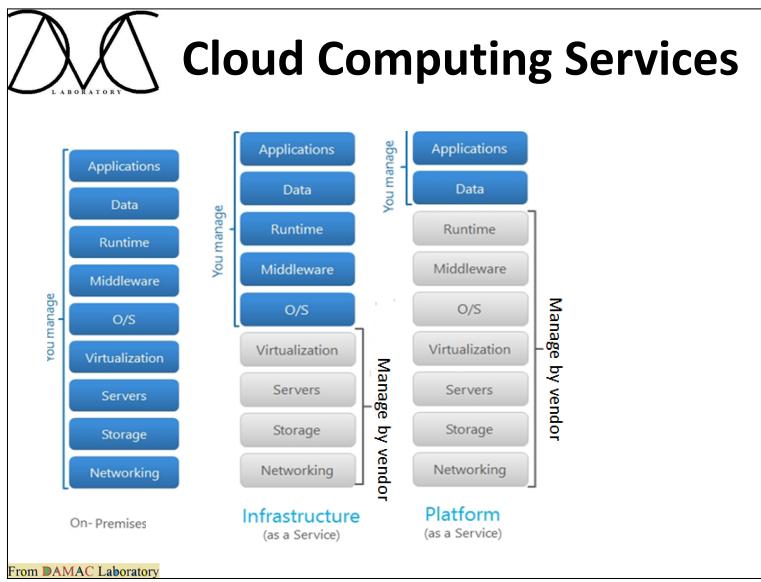
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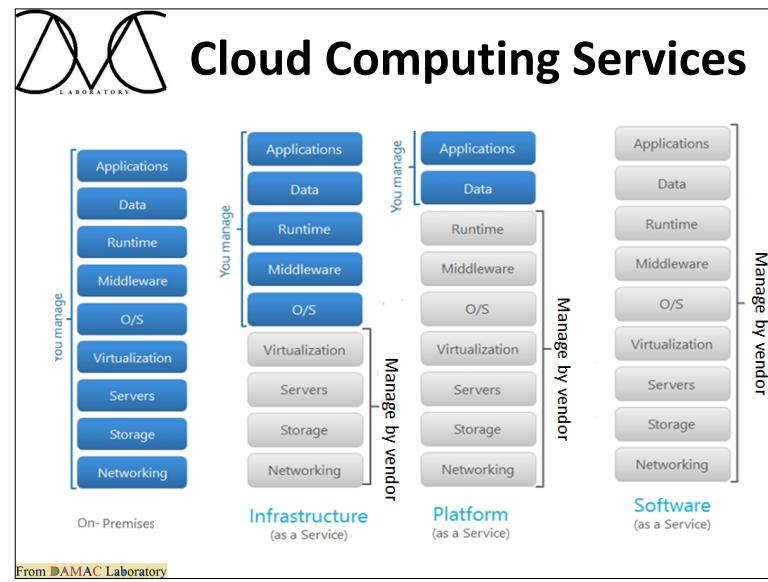
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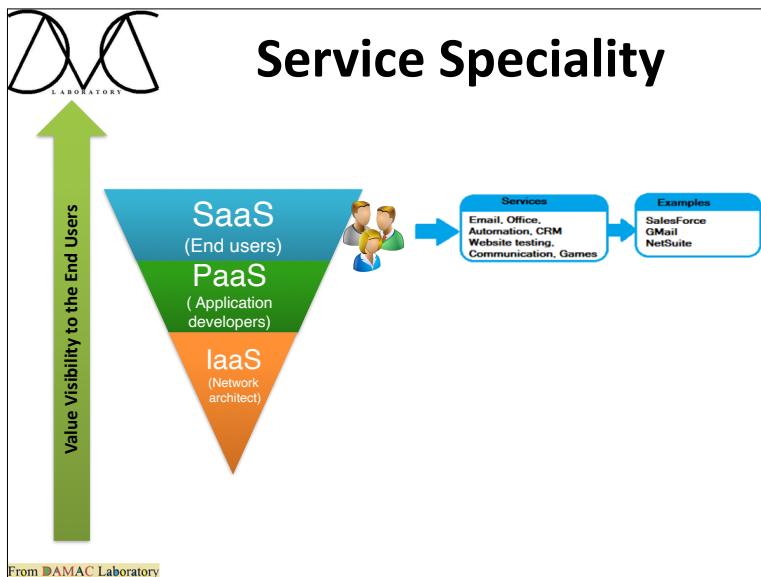
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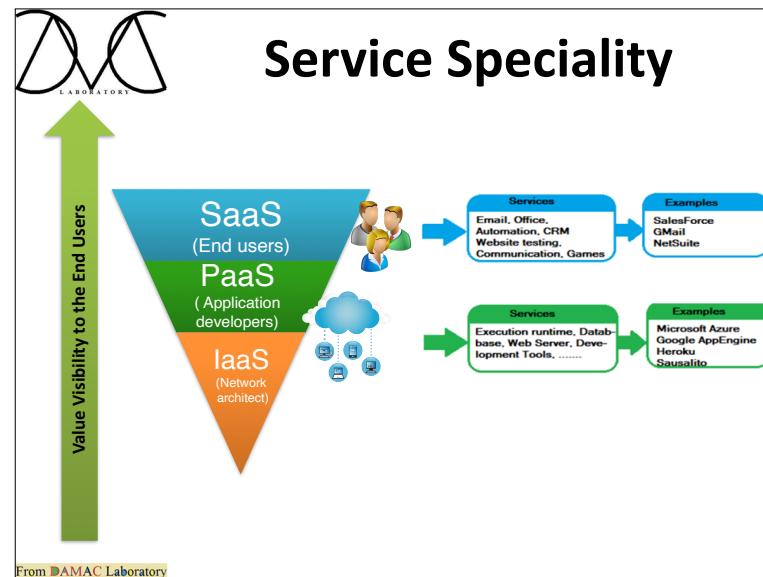
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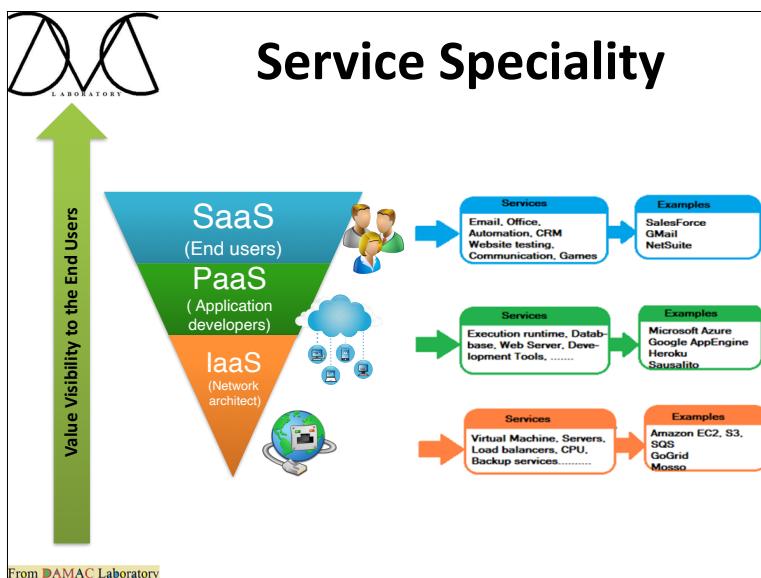
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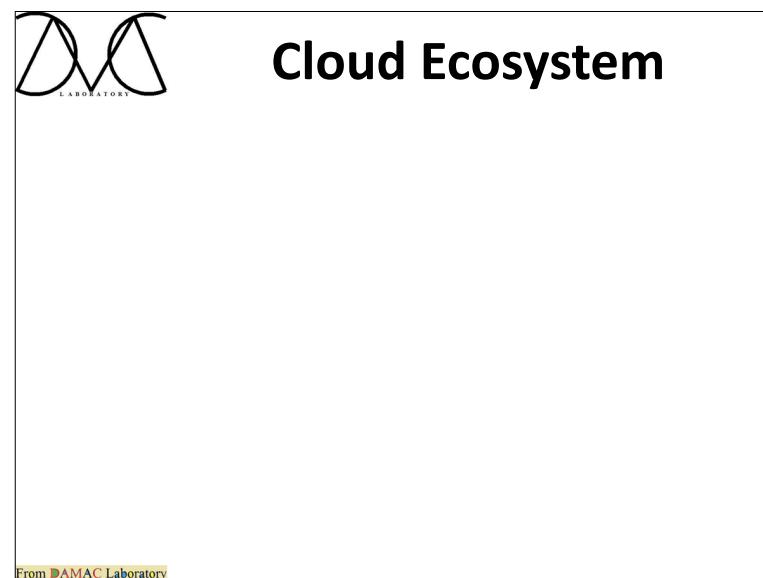
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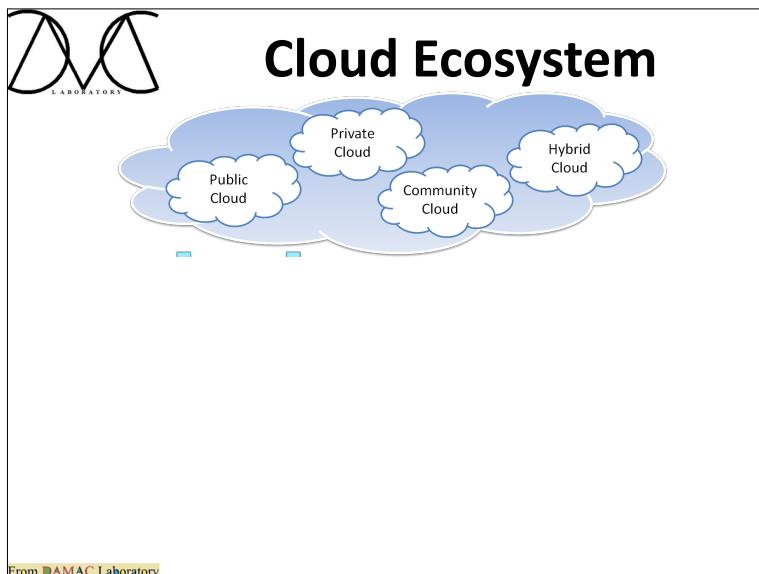
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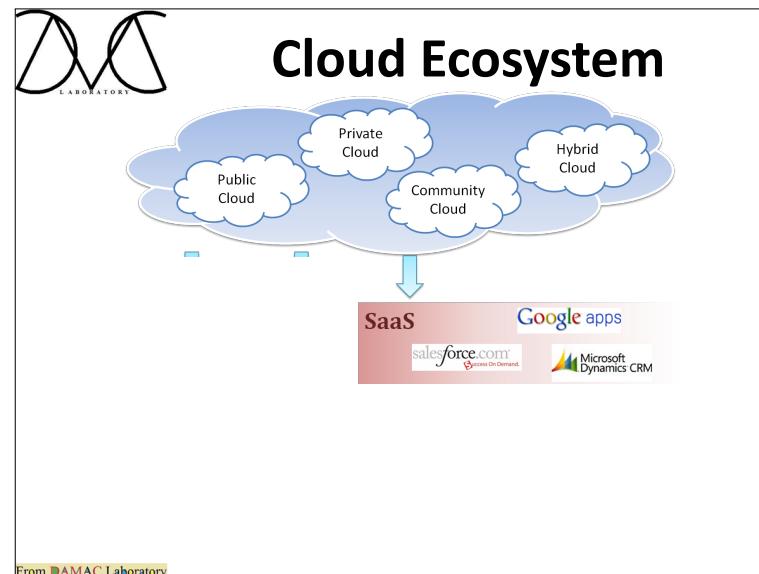
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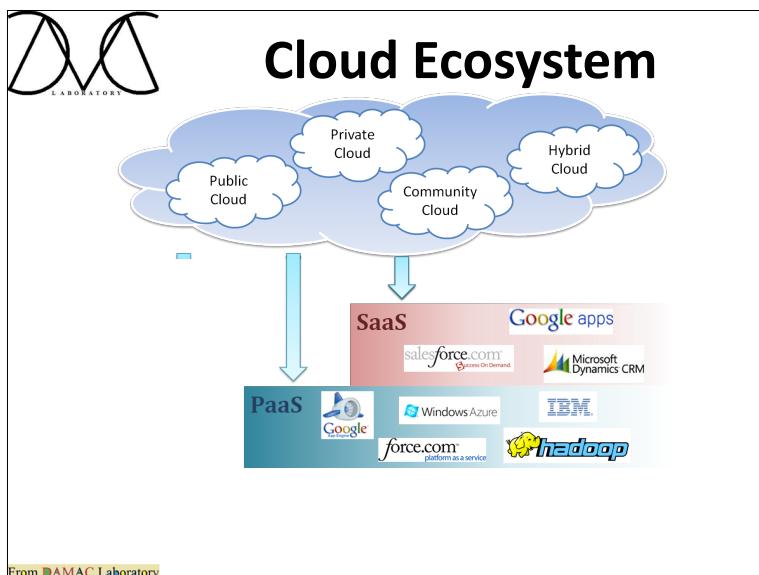
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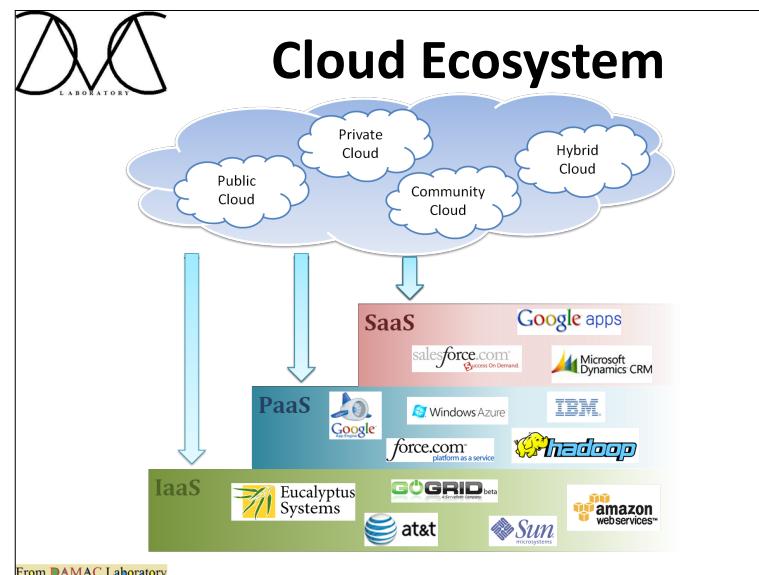
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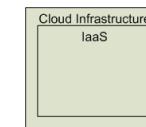
## Cloud Service Models

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## Cloud Service Models

Infrastructure as a Service (IaaS)



Infrastructure as a Service (IaaS)

Rent Processing, storage, N/W capacity & computing resources

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33-2

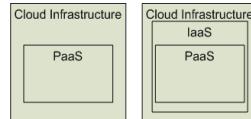
## Cloud Service Models

Platform as a Service (PaaS)

Infrastructure as a Service (IaaS)



Google App Engine  
Windows Azure  
The Future Made Familiar

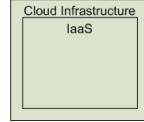


Platform as a Service (PaaS)

Deploy customer created Applications



amazon web services



Infrastructure as a Service (IaaS)

Rent Processing, storage, N/W capacity & computing resources

27

33-3

## Cloud Service Models

Software as a Service (SaaS)

Platform as a Service (PaaS)

Infrastructure as a Service (IaaS)

SalesForce CRM

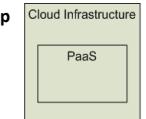
LotusLive



Windows Azure  
The Future Made Familiar

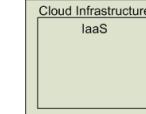


Software as a Service (SaaS)  
Providers Applications



Platform as a Service (PaaS)

Deploy customer created Applications



Infrastructure as a Service (IaaS)

Rent Processing, storage, N/W capacity & computing resources

27

33-4

## Examples of Different Cloud Service Providers

<b>Application Service (SaaS)</b>	MS Live/ExchangeLabs, IBM, Google Apps; Salesforce.com Quicken Online, Zoho, Cisco
<b>Application Platform</b>	Google App Engine, Mosso, Force.com, Engine Yard, Facebook, Heroku, AWS
<b>Server Platform</b>	3Tera, EC2, SliceHost, GoGrid, RightScale, Linode
<b>Storage Platform</b>	Amazon S3, Dell, Apple, ...

28

34

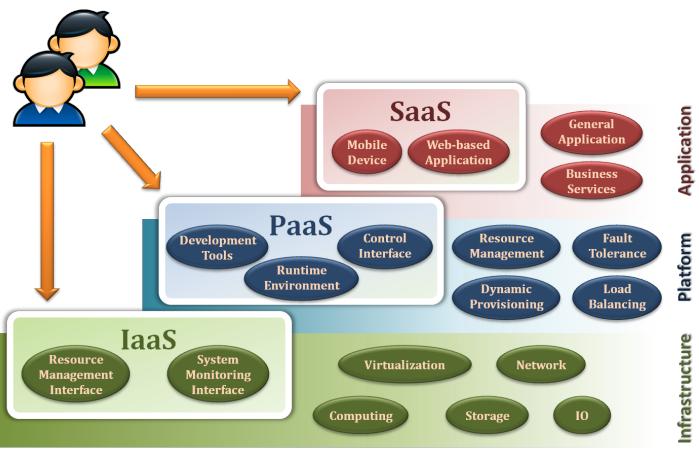
## Cloud Computing Service Layers

Services	Description
<b>Services</b>	Services – Complete business services such as PayPal, OpenID, OAuth, Google Maps, Alexa
<b>Application</b>	Application – Cloud based software that eliminates the need for local installation such as Google Apps, Microsoft Online
<b>Development</b>	Development – Software development platforms used to build custom cloud based applications (PaaS & SaaS) such as SalesForce
<b>Platform</b>	Platform – Cloud based platforms, typically provided using virtualization, such as Amazon ECC, Sun Grid
<b>Storage</b>	Storage – Data storage or cloud based NAS such as CTERA, iDisk, CloudNAS
<b>Hosting</b>	Hosting – Physical data centers such as those run by IBM, HP, NaviSite, etc.

x

35

## Service Speciality



36

Scalability & Elasticity,  
Availability and Reliability,  
Manageability and Interoperability,  
Performance & Optimization,  
Accessibility & Portability

## SERVICE SPECIALIES



37



## Service Specialties

From DAMAC Laboratory

38-1



## Service Specialties

- Scalability & Elasticity

From DAMAC Laboratory

38-2



## Service Specialties

- Scalability & Elasticity

- Dynamic Provisioning
- Multi-tenant Design

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38-3



## Service Specialties

- Scalability & Elasticity
- Availability & Reliability

From DAMAC Laboratory

38-4



## Service Specialties

- Scalability & Elasticity
  - Fault Tolerance
- Availability & Reliability
  - System Resilience
  - System Security

From DAMAC Laboratory

38-5



## Service Specialties

- Scalability & Elasticity
- Availability & Reliability
- Manageability & Interoperability

From DAMAC Laboratory

38-6



## Service Specialties

- Scalability & Elasticity
- Availability & Reliability
- Manageability & Interoperability
  - Control Automation
  - System Monitoring
  - Billing System

From DAMAC Laboratory

38-7



## Service Specialties

- Scalability & Elasticity
- Availability & Reliability
- Manageability & Interoperability
- Performance & Optimization

From DAMAC Laboratory

38-8



## Service Specialties

- Scalability & Elasticity
- Availability & Reliability
- Manageability & Interoperability
  - Parallel Processing
- Performance & Optimization
  - Load Balancing
  - Job Scheduling

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38-9



## Service Specialties

- Scalability & Elasticity
- Availability & Reliability
- Manageability & Interoperability
- Performance & Optimization
- Accessibility & Portability

From DAMAC Laboratory

38-10



## Service Specialties

- Scalability & Elasticity
- Availability & Reliability
- Manageability & Interoperability
- Performance & Optimization
- Accessibility & Portability
  - Uniform Access
  - Thin Client

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38-11



## Scalability & Elasticity

Give me the world  
without limitation!!

39

# Scalability & Elasticity

40-1

# Scalability & Elasticity

Give me the world  
without limitation!!

40-2

# Scalability & Elasticity

Give me the world  
without limitation!!

- 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.



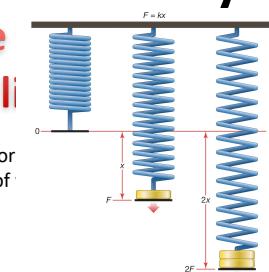
Set Amazon's Servers on Fire, Not Yours

40-3

# Scalability & Elasticity

Give me  
without li

- What is scalability ?
  - A desirable property of a system, a network, or its ability to either handle growing amounts of or to be readily enlarged.
- What is elasticity ?
  - The ability to apply a quantifiable methodology that allows for the basis of an adaptive introspection within a real time infrastructure.



40-4



## Scalability & Elasticity

### Give me the world without limitation!!

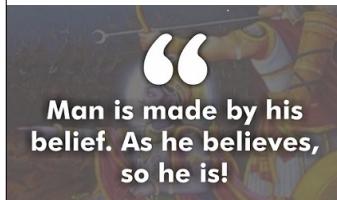
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- What is elasticity ?
  - The ability to apply a quantifiable methodology that allows for the basis of an adaptive introspection within a real time infrastructure.
- But how to achieve these properties ?
  - Dynamic provisioning
  - Multi-tenant design

40-5

## Dynamic Provisioning



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

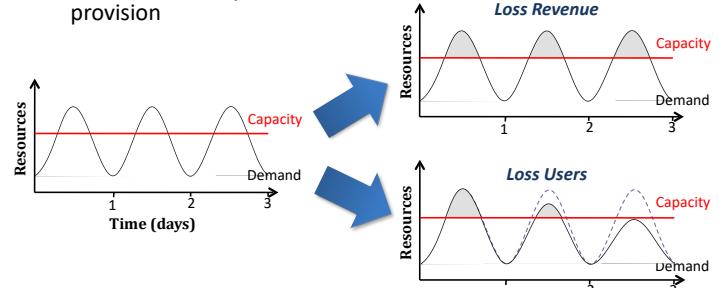


41



## Dynamic Provisioning

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

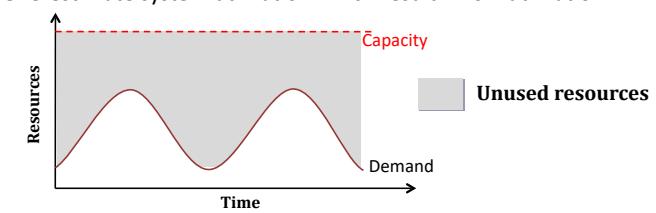


42



## Dynamic Provisioning

- Overestimate system utilization which result in low utilization



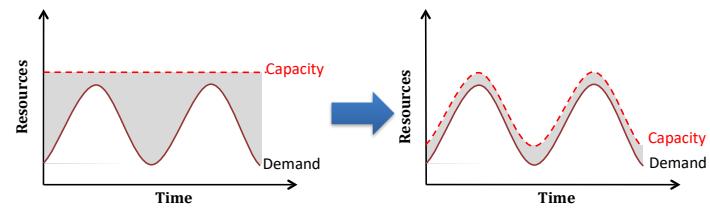
- How to solve this problem??
  - Dynamically provision resources

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## 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



44



## Multi-tenant Design

- It is principle in software architecture where a single instance of the software runs on a server, serving multiple client organizations.



45-2



## Multi-tenant Design

- It is principle in software architecture where a single instance of the software runs on a server, serving multiple client organizations.



45-1



## Multi-tenant Design

- 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.



## Multi-tenant Design

- 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.

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## Availability & Reliability



**Data Never Loss  
Machine Never Fail**

47

## Availability & Reliability

**Availability & Reliability  
Machine Never Fail  
Data Never Loss**

48-1

48-2

## Availability & Reliability

### Machine Never Fail

#### Data Never Loss

- 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



48-3

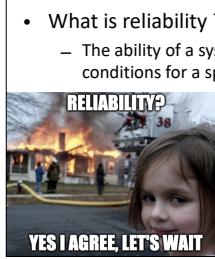
## Availability & Reliability

### Machine Never Fail

#### Data Never Loss

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48-4

## Availability & Reliability

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#### Data Never Loss

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- 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

48-5

49-1



# Fault Tolerance

- It is the property that enables a system to continue operating properly in the event of the failure of some of its components.



49-2



# Fault Tolerance

- It 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

49-4



# Fault Tolerance

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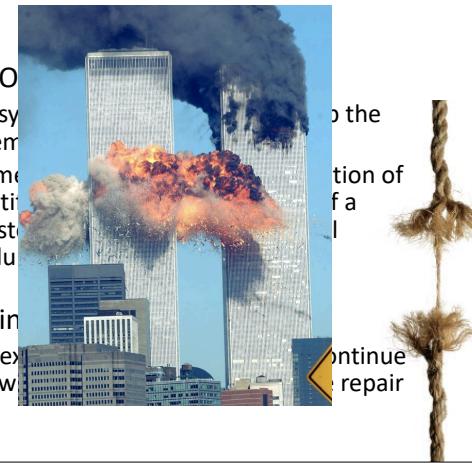


49-3



# Fault Tolerance

- Single Point Of Failure
  - A part of a system that, if failed, causes the entire system to fail
  - The assessment of potential failure identifies the critical components of complex systems that are most likely to cause systems failure
- Preventing single points of failure
  - If a system experiences a failure, it continues to operate without stopping the repair process.



50-1



# Fault Tolerance

- Single Point Of Failure (SPOF)
  - A part of a system which, if it fails, will stop the entire system from working.
  - The assessment of a potentially single location of failure identifies the critical components of a complex system that would provoke a total systems failure in case of malfunction.
- Preventing single point of failure
  - If a system experiences a failure, it must continue to operate without interruption during the repair process.



50-2



# Fault Tolerance

- Fault Detection and Isolation (FDI)
  - A subfield of control engineering concerns with monitoring a system
  - Identifying when a fault has occurred and pinpoint the type of fault and its location.
- Isolate failing component
  - When a failure occurs, the system must be able to isolate the failure to the offending component.



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# Fault Tolerance



# Fault Tolerance

- Fault Containment
  - Some failure mechanisms can cause a system to fail by propagating the failure to the rest of the system.
  - Mechanisms that isolate a rogue transmitter or failing component to protect the system are required.



52-1

52-2



# Fault Tolerance

- Fault Containment
  - Some failure mechanisms can cause a system to fail by propagating the failure to the rest of the system.
  - Mechanisms that isolate a rogue transmitter or failing component to protect the system are required.
- Available of reversion modes
  - System should be able to maintain some check points which can be used in managing the state changes.

52-3

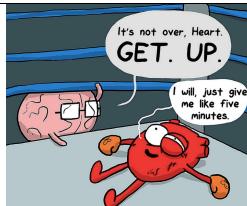
# System Resilience



53-1



# System Resilience

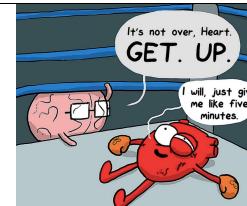


- Resilience is the ability to provide and maintain an acceptable level of service in the face of faults and challenges to normal operation.

53-2



# System Resilience

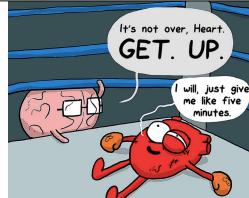


- Resilience is the ability to provide and maintain an acceptable level of service in the face of faults and challenges to normal operation.
- Resiliency pertains to the system's ability to return to its original state after encountering trouble.

53-3



## System Resilience



- Resilience is the ability to provide and maintain an acceptable

Windows

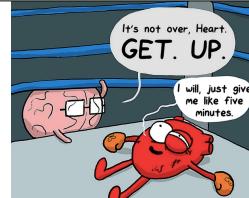
A fatal exception 0E has occurred at 0028:C0034B23. The current application will be terminated.

- \* Press any key to terminate the current application.
- \* Press CTRL+ALT+DEL again to restart your computer. You will lose any unsaved information in all applications.

Press any key to continue ...

53-4

## System Resilience

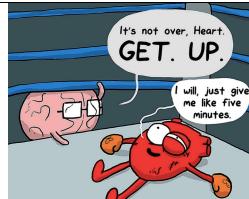


- Resilience is the ability to provide and maintain an acceptable level of service in the face of faults and challenges to normal operation.
- Resiliency pertains to the system's ability to return to its original state after encountering trouble.
- If a risk event knocks a system offline, a highly resilient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

53-5



## 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.
- 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 ?

53-6



## System Resilience

- Disaster Recovery
  - Disaster recovery is the process, policies and procedures related to preparing for recovery or continuation of technology infrastructure critical to an organization after a natural or human-induced disaster.
- Some common strategies :
  - Backup
    - Make data off-site at regular interval
    - Replicate data to an off-site location
    - Replicate whole system
  - Preparing
    - Local mirror systems
    - Surge protector
    - Uninterruptible Power Supply (UPS)



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# 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.



55



# System Security

- Important security and privacy issues :
  - Data Protection
    - To be considered protected, data from one customer must be properly segregated from that of another.
  - Identity Management
    - Every enterprise will have its own identity management system to control access to information and computing resources.
  - Application Security
    - Cloud providers should ensure that applications available as a service via the cloud are secure.
  - Privacy
    - Providers ensure that all critical data are masked and that only authorized users have access to data in its entirety.

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