

Chapter 2 Cloud computing architecture, concepts, and characteristics

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Learning Objectives

Develop basic understanding of cloud computing

1. Concepts
2. Architecture
3. Characteristics
4. Service models
5. Types or deployment models
6. Available cloud services and open source solutions

Learning Modules

1. Cloud computing concepts
2. Cloud computing architecture
3. Characteristics of cloud computing
4. Cloud service models
5. Deployment models and cloud types
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Cloud computing concepts

- Evolution of distributed computing
- Cloud computing history
- Cloud computing concepts

Cloud computing concepts:

Evolution of distributed computing

- Mainframe computer is shared by local terminal users
- Internet improves distant computing sharing
- HPC increases the computing power that can be shared
- Grid computing improves computing sharing to a plug-and-play fashion
- Cloud computing provides virtually unlimited on demand, utility-based, and market-oriented computing services.

Cloud computing concepts: History

- The idea could be traced back to 1950s when mainframe is shared among terminal users.
- The concept was formally proposed in 1980s.
- The development started in 1990s.
- In 2006, Amazon started to provide cloud service.
- Around 2000, cloud computing became popular.
- Many industry commercial cloud services and open source cloud solutions exist today.

Cloud computing concepts

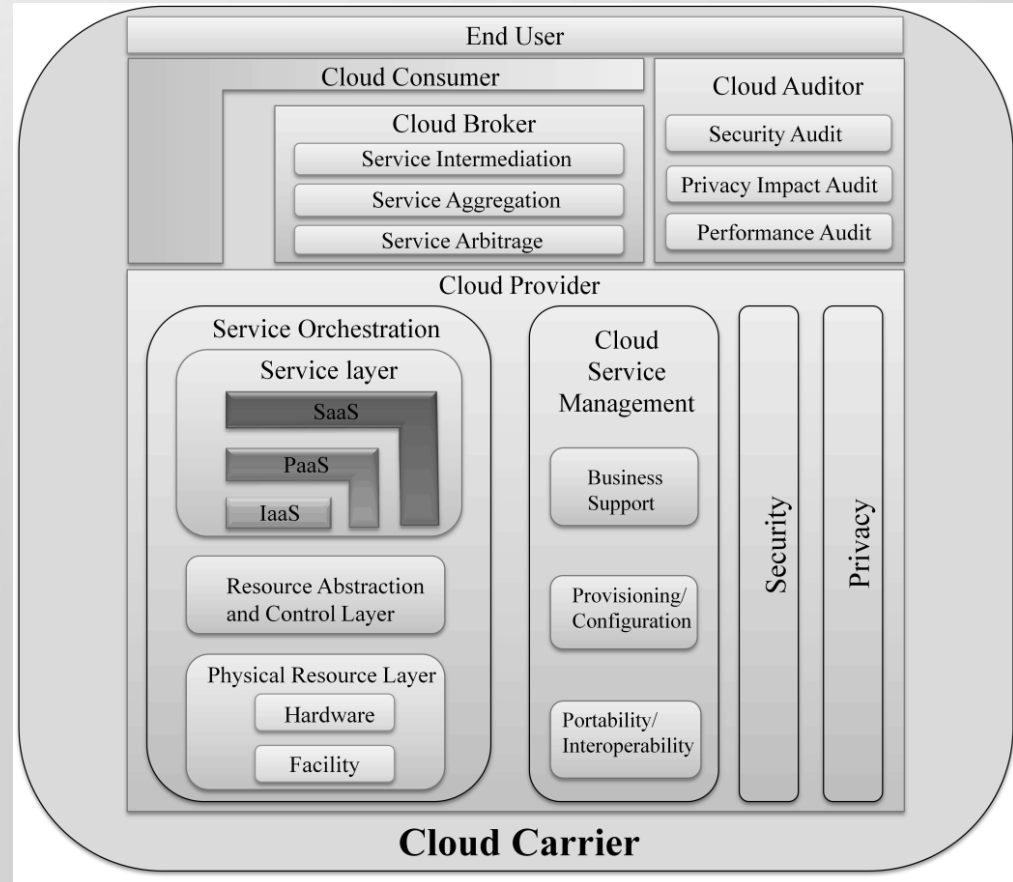
- NIST took the leadership in standardizing the cloud computing concepts.
- Mell and Grace (2009) define cloud computing as “a model for enabling ubiquitous, convenient, and on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.”
- Five characteristics
- Three service models
- Four deployment models

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Cloud Computing Architecture

- Cloud computing roles
- Responsibility of each role
 - End User
 - Cloud Consumer
 - Cloud Broker
 - Cloud Auditor
 - Cloud Provider
 - Carrier
- Service Models



Cloud Computing Architecture: Roles

- End User will consume Cloud service without knowing it's provided by a cloud computing platform. For example, Gmail users.
- Cloud Consumer will purchase cloud services to operate their applications. E.g., we can host our website in EC2.
- Cloud broker will provide brokering service for cloud computing services, similar to priceline.com for brokering flights, hotels, and car rentals.
- Cloud auditor will ensure the cloud is running in a good manner, for example, the federal IT security agency.
- Cloud provider is the company that provide cloud computing as a service and charge to the service, such as Amazon.
- Cloud carrier is the network operator that help carry cloud service to users.

Cloud Computing Architecture: End User

- Users are end users of applications running on a cloud service.
- Gmail users are using Gmail service supported by Google cloud.
- We may be a user if our dept. purchase a cloud service for us to do research and we don't worry about the negotiation in purchase.
- Web browser users, or the public maybe a cloud user if he/she uses data.gov service running on the EC2 cloud.
- Users will make not much difference about the computing service they received before only in that their computing service is more reliable.

Cloud Computing Architecture:

Cloud Consumer

- Cloud consumer finds, evaluate, and purchase cloud services for their own use.
- We may purchase a cloud service from EC2 to host our website as a cloud consumer.
- Our organization may purchase cloud services as a cloud consumer for everyone in the organization.
- Consumers will purchase and pay for cloud services.

Cloud Computing Architecture: Cloud Broker

- Cloud broker will integrate cloud services from different providers.
- Cloud broker aggregate cloud services as much as they could.
- Cloud broker build a price model and capability model.
- Cloud broker will add a service fee to the cloud.
- The U.S. Government Service Administration brokers several cloud services for agency consumers.

Cloud Computing Architecture: Cloud Auditor

- Cloud auditor is a person or organization monitors and assess the performance of a cloud provider's services.
- They assess security, privacy impact, and performance.
- Security officer may be an auditor for the security cloud service security, for example, FISMA level.
- This may also be another company or agency.
- This is an immature area that needs development in the next few years.

Cloud Computing Architecture: Cloud Provider

- Cloud provider is the person or organization that develop, maintain, and operates computing service for sell.
- Cloud provider will be responsible for security, privacy of the cloud service.
- They also responsible for service level agreement for business support, provision resources, and they own the physical infrastructure and virtualized services build upon the infrastructure.
- Cloud providers may provide one or several types of cloud services.

Cloud Computing Architecture: Service Models

- Infrastructure as a Service (IaaS) provides the capability of provisioning computation, storage, networks, and other fundamental computing resources on which the operating systems and applications can be deployed. A popular representative is Amazon EC2.
- Platform as a Service (PaaS) provides a computing platform on which consumers can develop software using the tools and libraries from the cloud provider, and deploy the software onto cloud services. Windows Azure is a typical PaaS.
- Software as a Service (SaaS) supports software and data to be hosted on the cloud and provided as services. For example, Gmail is a SaaS.
- Cloud evolution also created other types of cloud services, or the so called Everything as a Service (XaaS).

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Characteristics of cloud computing

- On-demand
- Self-service
- Broadband network and device independent access
- Resource pooling
- Rapid Elasticity
- Measured Services
- Reliability

Characteristics of cloud computing:

On-demand

- Consumers can provision cloud services as needed automatically
- Cloud computing generally has a huge computing resource pool at the back-end for users to access on demand.
 - Google cloud computing has more than one million servers across three dozen data centers worldwide (Newton 2010).
 - Amazon, Microsoft, and other public cloud providers also run thousands to millions of physical servers.
 - Private enterprise clouds also have hundreds of servers (Newton 2010).
- Therefore, clouds give users unprecedented and on-demand computing power with the large scale computing pool operated at the back-end.

Characteristics of cloud computing:

Self-service

- Consumers can purchase and use cloud services with minimum interactions with the providers.
- To the consumer, the capabilities available for provisioning and releasing cloud computing resources often appear to be unlimited
- Cloud Services can be purchased in any quantity at any time without any interactions with the cloud providers.
- Similar to our purchasing books from Amazon.com.

Characteristics of cloud computing:

Broadband network

- Cloud resources are available over the network and accessed through standard mechanisms/devices (e.g., mobile phones, laptops and personal digital assistants [PDAs]).
- Cloud computing makes sharing data between different devices easier with data saved as one copy or multiple copies and synchronized automatically in the "cloud" shared by all electronic devices connected to the Internet.
- For example, the Apple iCloud service enables users to synchronize software packages, email addresses, apps, media files, and phone numbers between the iPhone, iPad, and Apple Computers.

Characteristics of cloud computing:

Resource pooling

- The provider's computing resources are pooled to serve multiple consumers using a multi-tenant model (Liu et al. 2011)
- The shared resource model helps reduce the cost for enterprises to provide, and consumers to purchase, operate, and maintain the computing resources.
- Virtualization technologies can be applied to different levels of physical resources and therefore non-expensive physical resources can contribute to the cloud resource pool and therefore lowering the cost to build a cloud platform.
- Consumers are now spending only several hundred dollars and a few days, while thousands of dollars and several months were spent, to complete the task in the past.

Characteristics of cloud computing:

Rapid Elasticity

- Rapidly and elastically provisioning, allocating, and releasing computing resources.
- Applications can be configured to automatically, rapidly and elastically acquire more resources
- Spike workloads and rapidly release the resources
- Typically within several seconds to minutes, when the loads decrease (Huang et al. 2010)

Characteristics of cloud computing:

Measured Services

- Pay-as-you-go service and price models.
- Cloud resource usage can be monitored, controlled, reported, and charged transparently for both the provider and consumer of the utilized service.
- Typically, cloud vendors enable users pay for computing capacity by hour with no long-term commitments.
- Cloud providers usually offer the long-term customers the reserved cloud resources to make a low, one-time payment for the virtual servers that customers want to reserve and therefore receiving a significant discount on the hourly charge for the servers.
- Some providers (e.g., Amazon EC2) even provide the price bid (spot) option for users to bid on unused cloud resources with even lower price.

Characteristics of cloud computing:

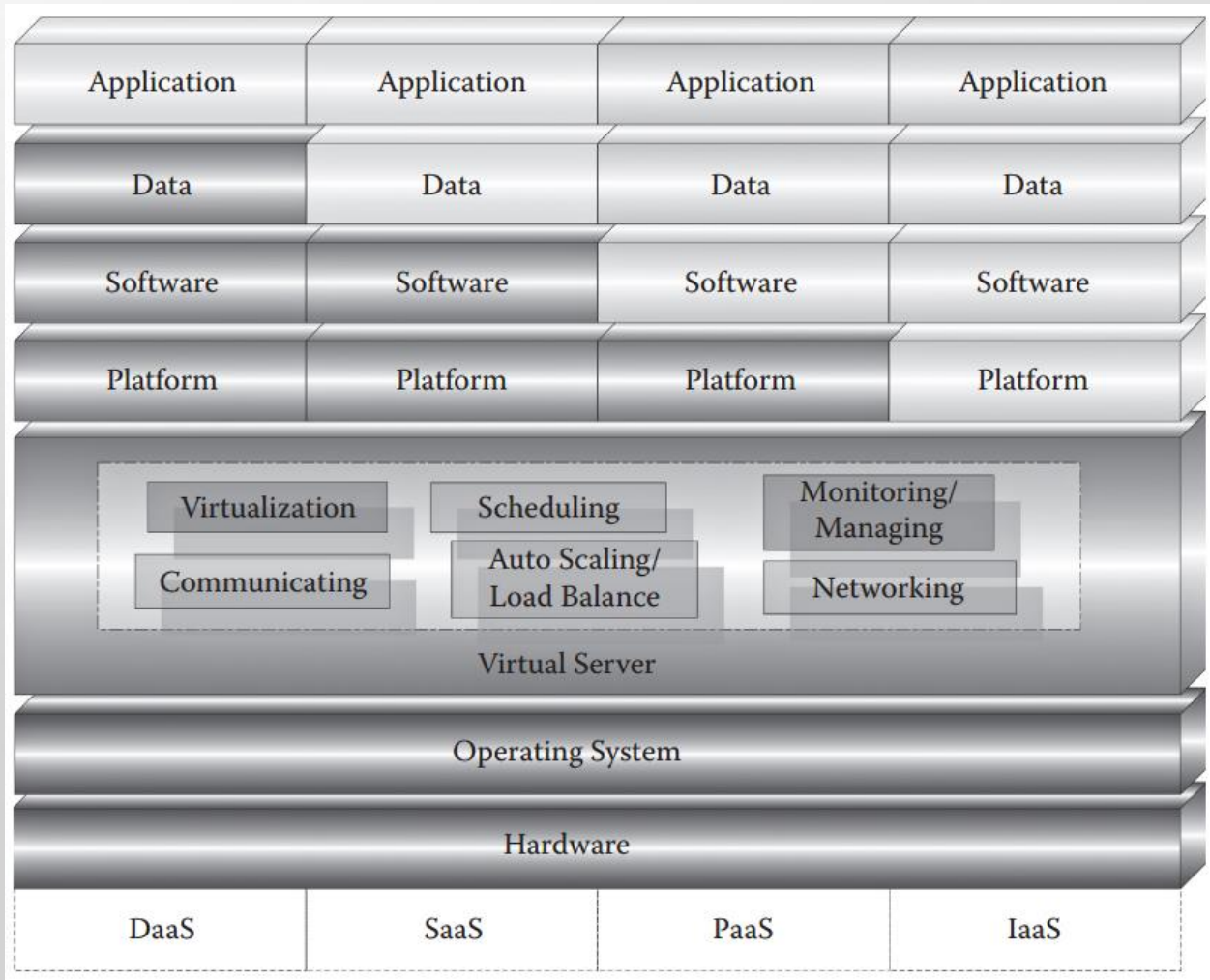
Reliability

- Individuals and enterprises using cloud computing infrastructures can always get better services
- Continual improvement with proven physical infrastructure and data centers by providers, compliance with new policies, security patches and upgrades for free.
- For example, the Amazon EC2 Service Level Agreement (SLA) commits 99.95% availability for all Amazon EC2 Regions.

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Cloud Service Models



Cloud Service Models

1. Cloud computing layered logic framework includes the hardware, operating system, virtualization service (the core of cloud computing), platform management, software management, data management and specific applications.
2. IaaS: the cloud provider supplies the cloud service a virtual computing server including the three lower layers, such as Amazon EC2.
3. PaaS: the cloud provider supplies the lower four layers for cloud service as a platform where we can develop, test, and deploy applications and software, such as Microsoft Azure with Visual Studio.
4. SaaS: the cloud provider supplies the cloud service as software including the lower five layers, such as Gmail and Google Earth.
5. DaaS: the cloud provider supplies the cloud service as a data service including all layers except applications.

Cloud Service Models

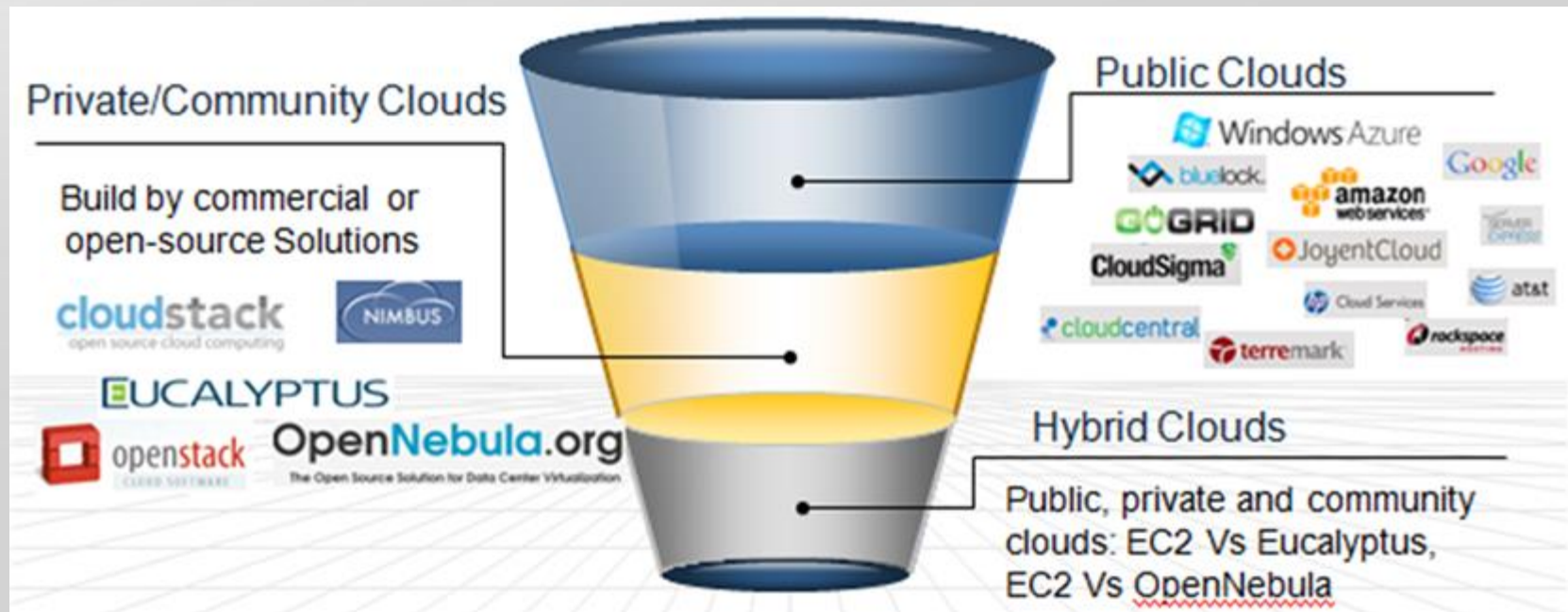
- Applications could reside on any of the services of IaaS, PaaS, SaaS, and DaaS depends on the application requirements.
- The evolution of cloud computing first provides the three services of IaaS, PaaS and SaaS.
- The big data challenge (The Whitehouse 2012) stands up the need for DaaS (such as data.gov).
- The industry also provides other computing functions as a service, for example, Network as a Service (NaaS), Security as a Service (SECaaS) and Storage as a Service (STaaS).
- Some scholars also refer to them all as everything as a Service (XaaS, such as Yang et al. 2011).

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Deployment models and cloud types

- Public cloud
- Private cloud
- Community cloud
- Hybrid cloud



Deployment models and cloud types:

Public cloud

- Open access and use by the general public.
- A public cloud system is usually provided, managed, and operated by a company, and the cloud resources are charged when consumed by consumer.
- The public cloud is also known as commercial cloud.
- Among the four cloud types, the public cloud is probably the most popular and mature in cloud offerings.

Deployment models and cloud types:

Private cloud

- The cloud is provisioned for exclusive use by a single organization comprising multiple consumers (e.g. business units).
- It may be owned, managed, and operated by a business, academic, or government organization, or some combination of them.
- The private clouds offer many of the same economic and operational benefits as the public cloud while allowing companies or organizations to retain absolute control over their IT environment.
- HP is one company to have made the shift to private cloud computing by consolidating what used to be 85 data centers staffed by 19,000 IT workers to six cloud data centers with half the IT staff (Newton 2010).
- Open-source solutions are normally used to transform the private physical infrastructure into private cloud (Chapter 13).

Deployment models and cloud types:

Community cloud

- Usually, a community cloud is initiated to serve a specific community with common concerns, such as mission, security, compliance, jurisdiction, and others.
- They may be provided solely for a single organization or several organizations, and operated and managed internally or by a third party.

Deployment models and cloud types:

Hybrid cloud

- The combination of two or more public, community and private clouds.
- Hybrid clouds are usually built to meet specific concerns or needs. For example, IT software enterprises may construct a hybrid cloud with two private cloud systems where one acting as official product system, and one serving for developing and testing platform.
- Sometimes, public and private clouds are bound to achieve both cost-efficiency and on-demand computing power.
- Under most circumstances, the enterprises can utilize the internal private cloud resources without paying for the third party cloud providers, and are able to provision massive computing power from outside public resources when need.
- There are several products and services capable of managing and accessing different private and public clouds. For example, enStratus delivers brokerage for more than 10 cloud platforms, and OpenNebula can be used to build private cloud and access public cloud Amazon EC2 as well.

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Available cloud services and open source solutions

- Commercial Clouds
- Open-source Cloud Solutions

Available cloud services and open source solutions:

Commercial Clouds

- Amazon EC2 and Microsoft Azure
- Google App Engine (GAE)
- Salesforce
- Joyent
- Rackspace
- GoGrid
- Verizon's CaaS
- IBM

Available cloud services and open source solutions:

Open-source Cloud Solutions

- Amazon Elastic MapReduce (EMR)
- Xen Cloud Platform (XCP)
- Tplatform
- Apache VCL
- Open Nebula
- Eucalyptus
- Nimbus, etc.

Discussion Questions

1. What other cloud services have you heard about? What's the cloud service model and deployment type?
2. Does your organization offer cloud services or brokering cloud services?
3. What's the different between public and private clouds?
4. If you are going to design a cloud service for your organization, what cloud services will be considered and why?
5. What's your immediate next question for cloud computing?

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