Cloud Computing

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Content

- Cloud computing definition
- Principles, concepts, tools, architecture and technologies applied in cloud computing
- Cloud computing main characteristics
- Cloud computing drivers, the SPI model
- Issues related to cloud computing model: Ethics, Security, Confidentiality, Migration, Dispossession

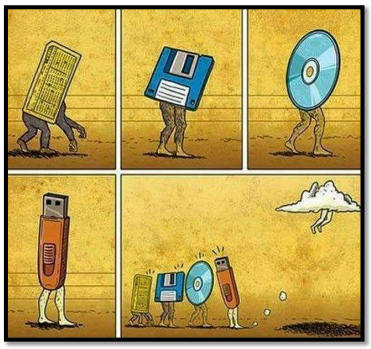
This course is partially based on the following content: book Cloud Computing: Theory and Practice of Dan Marinescu; The Cloud Computing tutorial, the USA National Institute of Standards and Technology (NIST) reports; book Cloud Computing Explained of John Rhoton

Objectifs

- Comprendre le modèle de l'Informatique dans les nuages (Cloud Computing), ansi que ses caractéristiques et technologies
  - Tout comme service : XaaS)

Connaître l'historique du Cloud Computing

- Séparer le marketing des evolutions technologiques
- Identifier le modèle de rentabilité
- Comprendre les enjeux techniques



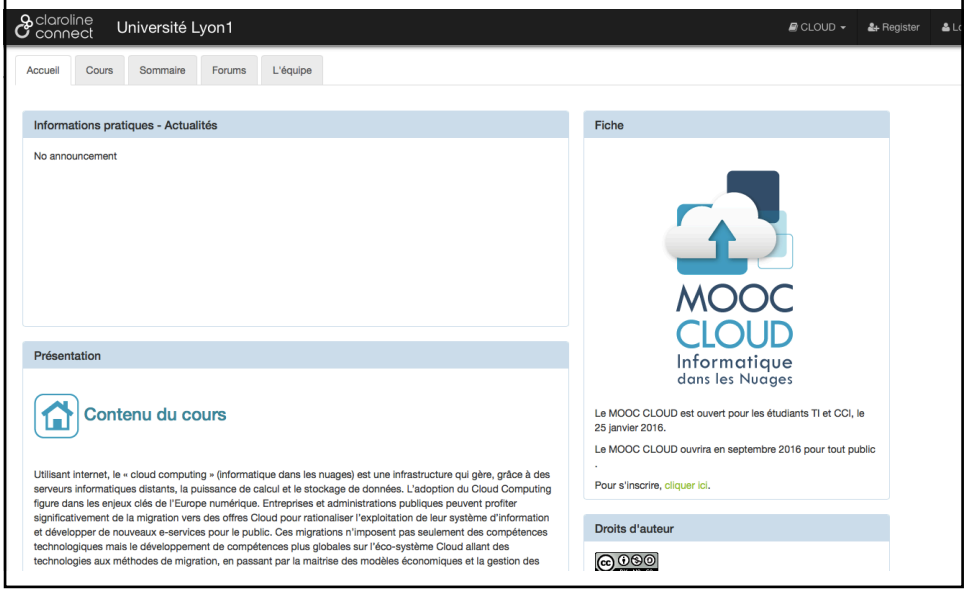
Cloud computing term

- The Cloud term represents a *black box* where interfaces are well known but the internal routing and processing is not visible to the network users
- Different other definitions

Cloud computing, in French

- Utilisant internet, le « cloud computing » (informatique dans les nuages) permet de gèrer, grâce à des serveurs informatiques distants
  - Des applications
  - De la puissance de calcul
  - Le stockage des données
  - …
- Tout comme service

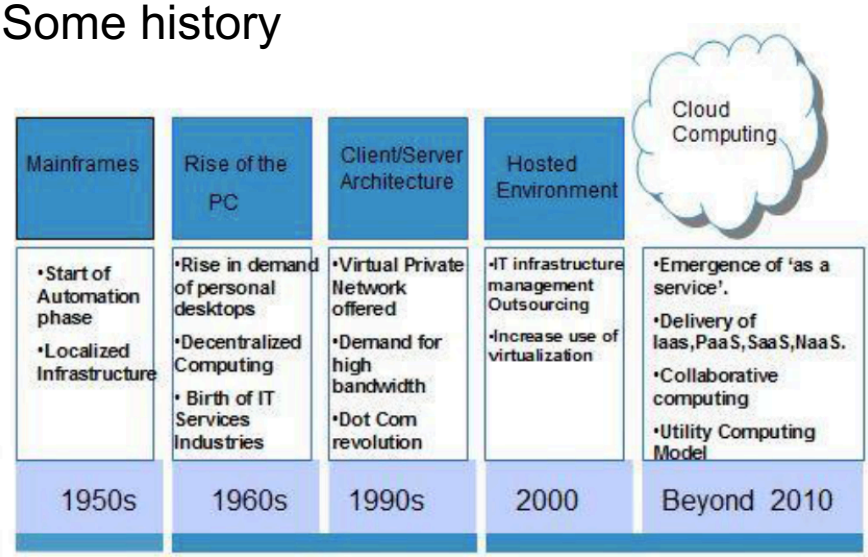
http://tinyurl.com/mooccloud



Where does Cloud computing come from

- John McCarthy, Stanford computer scientist, in the 1960s already envisioned that computing facilities will be provided to the general public like a utility
- *Pioneered by firms like IBM and ideas of computation as a utility function - which cloud computing really is, like water and electricity*
- *Cloud computing business model goes back to the old days, when companies rented computation time on large mainframe computers*
- In 2006, Google's CEO Eric Schmidt describes the Cloud business model of providing services across the Internet

Some history

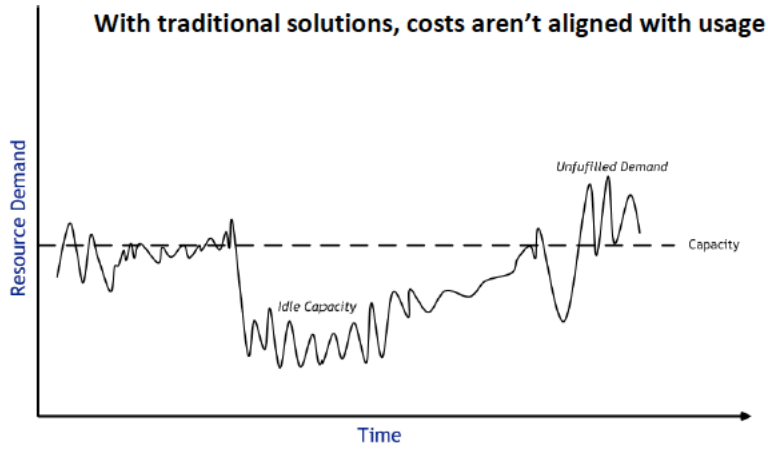


From Cloud Computing Tutorial

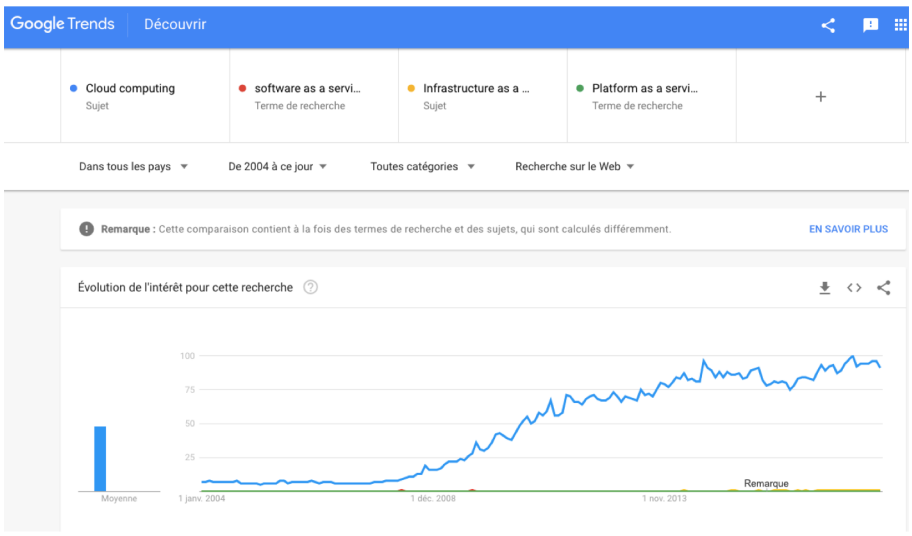
Cloud Computing early adopters

- Amazon Web Services, 2002
  - Way to minimize its IT costs
  - Sell idle capacity to other companies
- Google App Engine and Google Apps, 2009
  - G. App Engine: online development tool, basic run-time env. to deploy code, monitoring and automatic scaling
  - G. Apps: software service office-like tools, such as docs, wiki sites, gmail…

In the cloud, the user does not pay for idle capacity



Cloud computing google trends



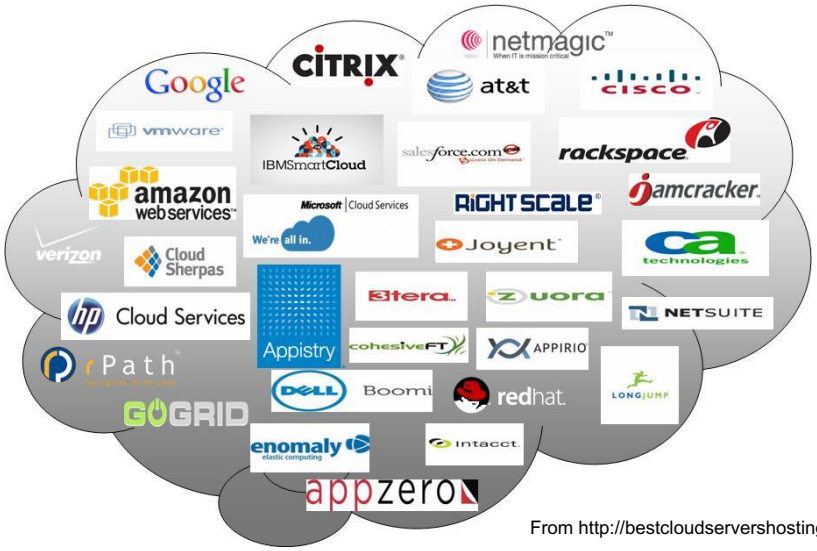
Cloud Computing: different definitions

1. Using all kind of informatics services (eg. for storage, management and processing of data), through the Internet, over a network of remote servers hosted by suppliers rather than on a local server or a personal computer
2. Provision of Internet resources, shared data processing and services, which are available on customer request through Internet

Une définition possible

- Le cloud computing, c'est
  - Un ensemble de technologies et services informatiques
- Permettant
  - De **dématérialiser** (virtualiser) un SI
  - D'affecter des **ressources partagés**
    - CPU, stockage, réseau, services, applications,…
- **Dynamiquement**
  - Notions de service à la demande et d'élasticité des ressources
- A travers un ensemble d'outils
  - Permettant un **accès distant par Internet/Web**

Example of Cloud Providers



From http://bestcloudservershosting.com/

Different perceptions of cloud computing

- Brings together a set of existing technologies to run business in a different way
  - Grid computing, virtualisation, utility-based pricing
- To meet the technological and economic requirements of today's demand for information technology
- Intends to provide
  - **Scalabitility of ressources**
  - **Multi-tenancy resource sharing**
  - **Fine-grain metering and billing**

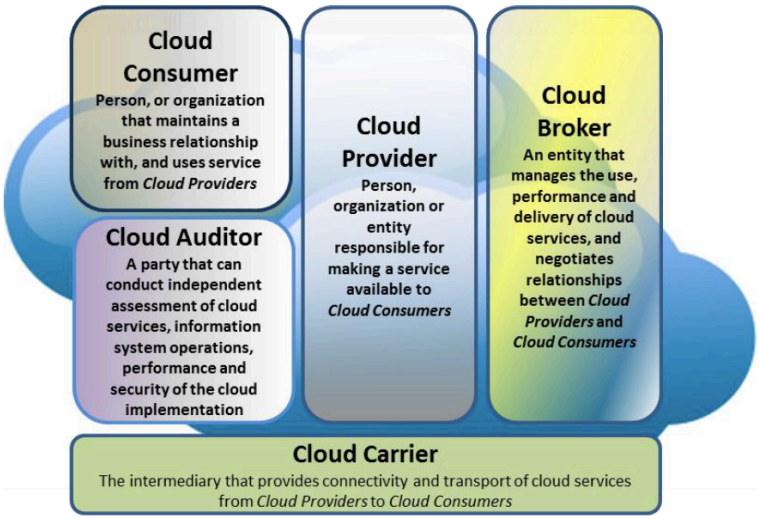
What is Cloud Computing (1/2)

- It is the online provision of services, such as data storage, infrastructure or application, which are available at remote location
- Provides us means by which we can **access** the applications as utilities, over the Internet
- Allows us to **create, utilize, manipulate, configure, and customize** online application services at different degrees depending on the (SPI) Software-Platform-Infrastructure as a Service model level

What is Cloud Computing (2/2)

- There are certain services and **models working behind the scene** making the cloud computing feasible and accessible to end users
- The **Cloud** needs a **Network** or **Internet**
- Cloud can provide services over network, i.e., on public networks or on private networks
- We need not to install a piece of software on our local PC and this is how the cloud computing overcomes **platform dependency issues**
- It is making the applications **mobile** and **collaborative**

Cloud Actors



From NIST Cloud Computing Standards Roadmap

Cloud Computing NIST definition

- A model for enabling
  - Ubiquitous, Convenient, On-demand
  - Network access
  - To a shared pool of configurable computing resources
    - e.g., networks, servers, storage, applications, and services
  - Resources can be rapidly provisioned and rapidly released
  - With minimal management effort for the client
  - The Client ha no direct interaction with the service provider

Cloud Computing NIST 5 essential characteristics

1. *On-demand self-service*
2. *Broad network access*
3. *Resource pooling:* multi-tenant model
4. *Rapid elasticity*
5. *Measured service*

Detail of the cloud essential characteristics

- *On-demand self-service*
  - A consumer can unilaterally provision computing capabilities, such as server time and network storage, as needed automatically without requiring human interaction with each service provider or its intervention
- *Broad network access*
  - Capabilities are available over the network and accessed through standard mechanisms that promote use by heterogeneous thin or thick client platforms (e.g., mobile phones, tablets, laptops, and workstations)

Essential characteristics (cont'd)

- *Resource pooling*
  - The provider's computing resources are pooled/shared to serve multiple consumers using a multi-tenant model, with different physical and virtual resources dynamically assigned and reassigned according to consumer demand
  - Examples of resources include storage, processing, memory, and network bandwidth
- *Rapid elasticity*
  - Capabilities can be elastically provisioned and released, in some cases automatically, to scale rapidly outward and inward commensurate with demand
  - To the consumer, the capabilities available for provisioning often appear to be unlimited and can be appropriated in any quantity at any time

Essential characteristics (cont'd)

- *Measured service*
  - Cloud systems automatically control and optimize resources use by leveraging a metering capability at some level of abstraction appropriate to the type of service (e.g., storage, processing, bandwidth, and active user accounts)
  - Resource usage can be monitored, controlled, and reported, providing transparency for both the provider and consumer of the utilized service

Inheritance between service of the SPI model

Examples of provider tools:

SugarCRM, SalesForce, Drupal Gardens (CMS), WordPress (OpenSaaS), Dropbox, Google Apps, My Yahoo!, Zoho.com

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Amazon Elastic Beanstalk, Google App Engine, Microsoft Azure (SQL servers, Web Apps servers, …), Heroku, OpenShift, Digital Ocean, AppDynamics, Scout, OpTier, MongoDB, Cassandra

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Openstack, Nebula, Amazon EC2, Amazon S3, Microsoft Azure IaaS, IBM IaaS, CloudStack, CloudIaaS, Rackspace Cloud

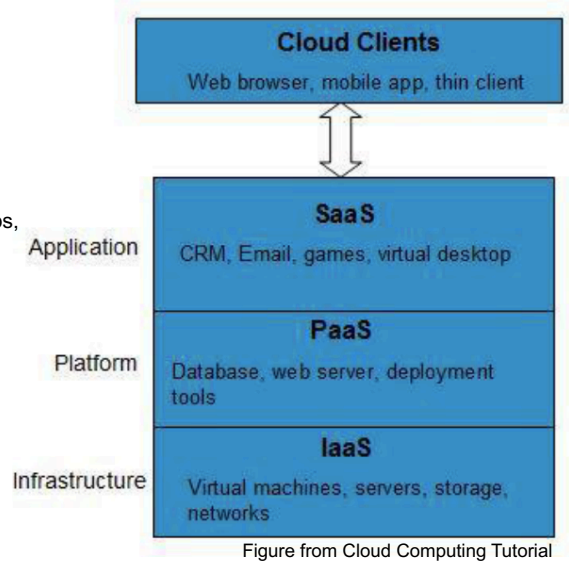
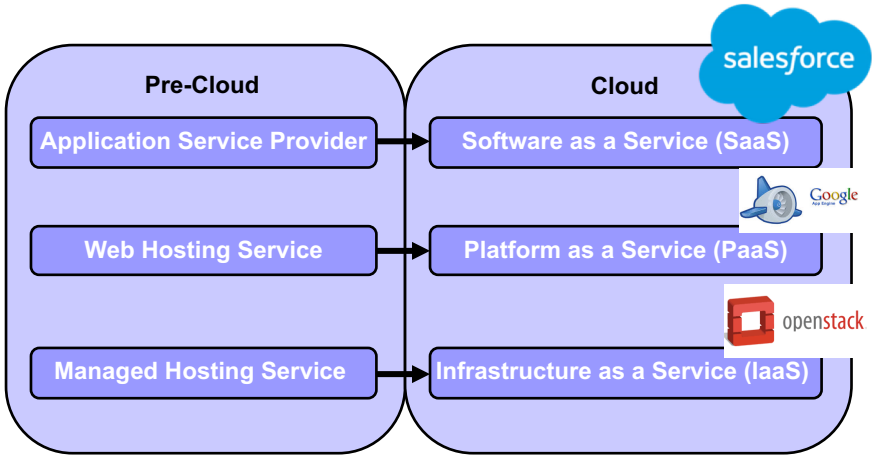


Figure from Cloud Computing Tutorial

The SPI model and its origins

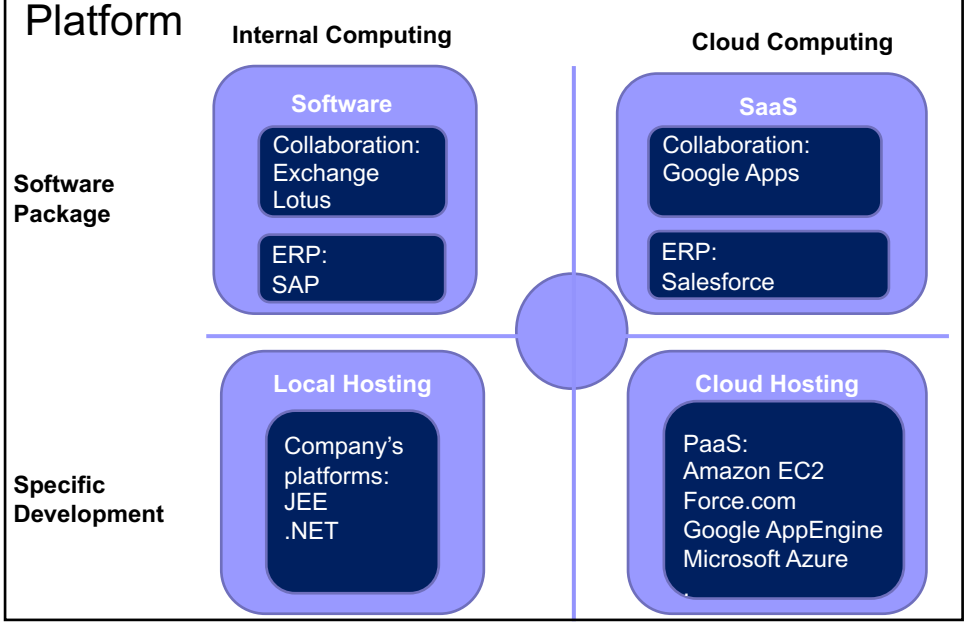


Adapted from *Cloud Computing Explained, John Rhoton, 2010, Recursive Press*

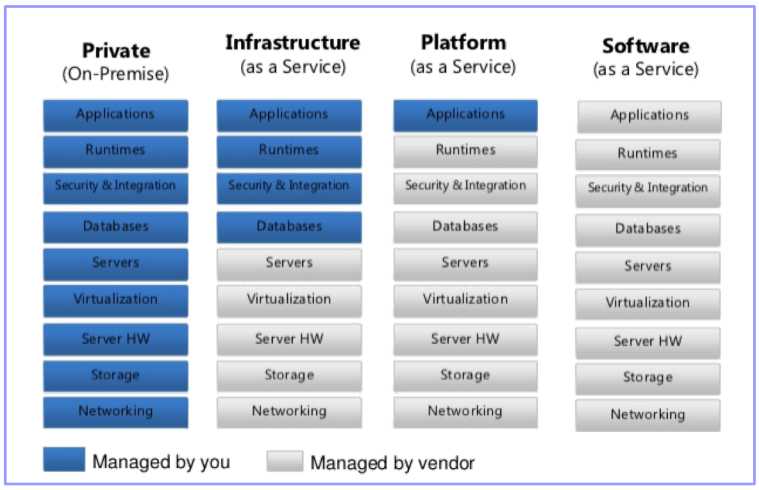
ASP versus SaaS

- SaaS are the successors of Application Service Providers (ASP). SaaS differ from the latter by
  - Usage of Rich Internet Application (RIA) Interfaces
  - Multi-tenants architecture dedicated and optimized for online usage
  - Highlighting collaborative functions
  - Providing Application Programming Interface (API)

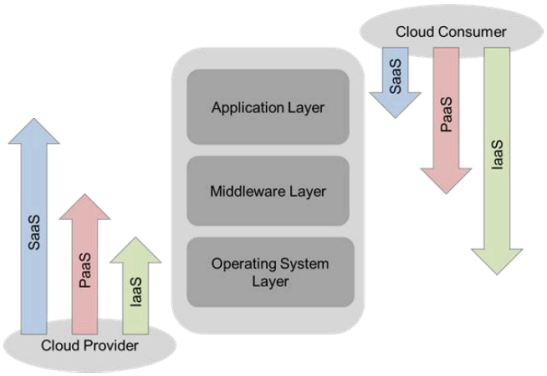
Cloud Computing versus on premises Company's Platform



Cloud Service Model

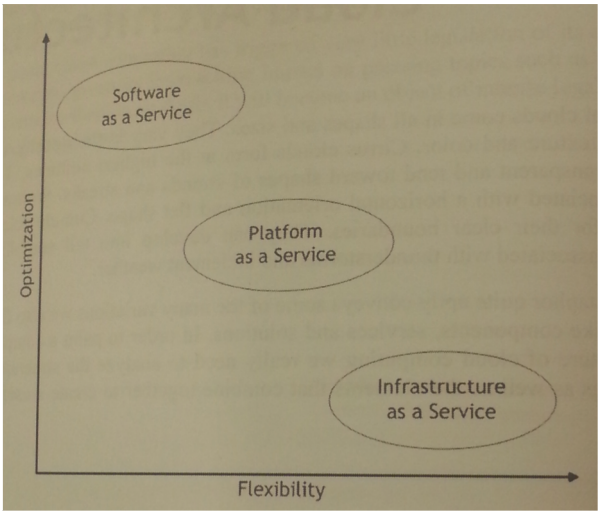


Scope of Controls between Provider and Consumer

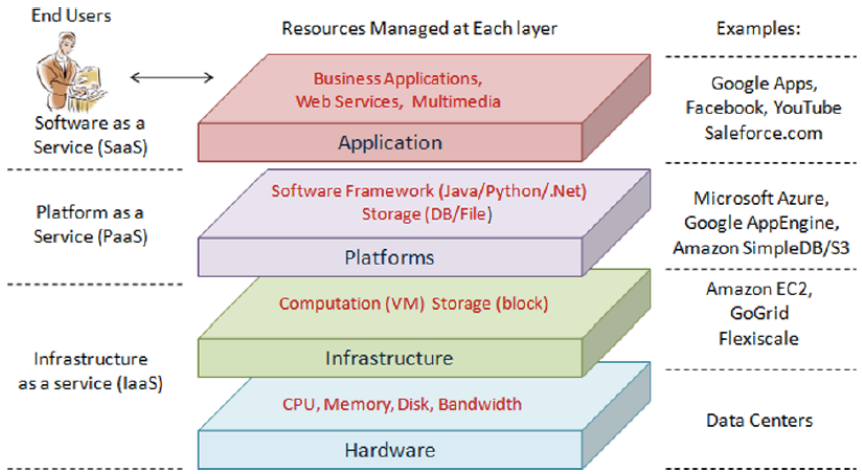


Adapted from *NIST Cloud Computing Reference Architecture*

Optimization VS Flexibility



Cloud computing architecture



From *Cloud computing: state-of-the-art and research challenges, Zhang, Chen, Boutafa, J Internet Serv Appl (2010) 1: 7–18 DOI 10.1007/s13174-010-0007-6*

Cloud computing drivers

- *No up-front investment*
  - Pay-as-you-go pricing model
- *Lowering operating cost*
  - No longer need to provision capacities according to the peak load
- *Highly scalable*
  - Pool of resources rapidly allocated and de-allocated on demand
- *Easy access*
  - Variety of devices with Internet connections
- *Reducing business risks and maintenance expenses*
  - Outsourcing the service infrastructure
  - Cut down the hardware maintenance and the staff training costs

Main cloud computing characteristics

- Network-centric
- Utility model
- Virtualization
- Autonomic computing
- Multi-tenancy

Network-centric grid computing

- Information processing can be done more efficiently on large farms of computing and storage systems accessible via the Internet
  - Grid computing
    - Is a distributed computing system that coordinates networked resources to achieve a common computational objective
    - Initiated by USA National Labs in the early 1990s; targeted initially at scientific computing which are computation-intensive
- Cloud computing takes one step further by leveraging virtualization technologies at multiple levels (hardware, application platform and application service) to realize resource sharing and dynamic resource provisioning

Network-centric content

- The "Future Internet" will be content-centric
  - Content: any type or volume of media, be it static or dynamic, monolithic or modular, live or stored, produced by aggregation, or mixed
- The creation and consumption of audio and visual content transforms the Internet to support increased quality in terms of resolution, color depth, frame rate, …
- Data-intensive: large scale simulations in science and engineering require large volumes of data
- Multimedia streaming transfers large volume of data

Network-centric computing and content

- Network-intensive: transferring large volumes of data requires high bandwidth networks
- Low-latency networks for data streaming, parallel computing
- Cloud systems are accessed using *thin clients* running on systems with limited resources, e.g., wireless devices such as smart phones and tablets
- The cloud infrastructure should support some form of workflow management

Utility aspect of cloud computing

- A model of providing resources on-demand and charging customers based on usage rather than a flat rate
- The focus of utility computing is on the business model for providing computing services
- Adoption of a utility-based pricing scheme for economic reasons
- With on-demand resource provisioning and utility based pricing, service providers can truly maximize resource utilization and minimize their operating cost
- IT companies started to apply it in 2005-2006
- Embraced by major IT companies including Amazon, Google, HP, IBM, Microsoft, Oracle, and many others

Virtualization aspect of cloud computing

- Is a technology that abstracts away the details of physical hardware or other resources
- Provides virtualized resources for high-level applications
- Forms the foundation of cloud computing
  - It provides the capability of pooling computing resources from clusters of servers
  - Dynamically assigning or reassigning virtual resources to applications on-demand

Autonomic aspect of cloud computing

- *Autonomic Computing* was originally coined by IBM in 2001
- Aims at building computing systems capable of self-management, i.e. reacting to internal and external observations without human intervention
- The goal is to overcome the management complexity of today's computer systems
- Cloud computing exhibits autonomic features such as automatic resource provisioning

Multi-tenancy aspect of Cloud computing

- Software architecture in which a single instance of software runs on a server and serves **multiple tenants**
- A **tenant** is a group of users who share a common access with specific privileges to the software instance
- The tenants use a common pool of resources
- Each tenant's data should be isolated and remain invisible to other tenants
- Resources' optimization
- Economy of scale

Degrees of multi-tenancy

- For public clouds, IT managers need to understand the degree of multi-tenancy supported by whichever vendor they are looking at
- For workloads that are meant for private clouds, the responsibility of designing a multi-tenant architecture rests with the IT managers
  - For these workloads there is a large list of fast-maturing technologies from both established and start-up vendors
  - IT managers have to evaluate these vendors and build their own custom IaaS, PaaS and SaaS layers, including support for building shared services and shared database schema

Examples of multi-tenancy

- Salesforce.com
  - For 72.500 customers, supported by 8 to 12 multi-tenant instances (meaning IaaS/PaaS instances): a 1:5000 ratio
  - Each multi-tenant instance supports 5.000 tenants who share the same database schema
- Intacct, a SaaS financial system
  - More than 2.500 customers who share 10 instances in a 1:250 ratio

From http://www.computerworld.com

So, Cloud Computing

- Uses Internet technologies to offer scalable and elastic services
- The term "elastic computing" refers to the ability of *dynamically acquiring computing resources* and supporting a variable workload
  - Resilience of computing resources
- The resources used for these services can be metered and the *users should be charged only for the resources they used*
- The maintenance and security are ensured by the service providers

Cloud computing (cont' d)

- The service providers can operate more efficiently due to specialization on their core services
- Lower costs for the cloud service provider are past to the cloud users
  - Customer responsibilities and the tasks which are permitted him differ depending on the service used
- Data is stored closer to the site where it is used
- Cloud data storage strategies provide external backups, and can lower client investment costs

Cloud business service delivery models

- Reference models on which the Cloud Computing is based
- These can be categorized into the SPI basic service model
  - Infrastructure as a Service (IaaS)
    - **IaaS** provides access to fundamental resources such as physical machines, virtual machines, virtual storage
  - Platform as a Service (PaaS)
    - **PaaS** provides the runtime environment for applications, development & deployment tools, database management, APIs, dev. languages
  - Software as a Service (SaaS)
    - **SaaS** model allows to use software applications as a service to end users

Software-as-a-Service (SaaS)

- Applications are supplied by service providers
- Users may be given the ability to customize some parts of the application, such as color of the user interface (UI) or business rules, but they cannot customize the application's code
- The user does not manage or control the underlying cloud infrastructure or individual application capabilities
- Services offered include
  - Enterprise services such as workflow management, group-ware and collaborative, supply chain, communications, digital signature, customer relationship management (CRM), desktop software, financial management, geo-spatial, and search
  - Web 2.0 applications such as metadata management, social networking, blogs, wiki services, and portal services
- Examples: Gmail, Google search engine, GoogleDocs, Salesforce.com, Dropbox, OwnCloud, Microsoft Online

Platform-as-a-Service (PaaS)

- Allows a cloud user to deploy consumer-created or acquired applications using programming languages and tools supported by the service provider
- Provides specific programming languages support, operating systems, APIs, development environments, database instances, computation instances, application server instances
- The user
  - Has control over the deployed applications and, possibly, application hosting environment configurations
  - Does not manage or control the underlying cloud infrastructure including network, servers, operating systems, or storage
- Not particularly useful when
  - Proprietary programming languages are used
  - The hardware and software must be customized to improve the performance of the application

Infrastructure-as-a-Service (IaaS)

- The user is able to deploy and run arbitrary software, which can include operating systems and applications
- The user does not manage or control the underlying cloud infrastructure but
- She has control over operating systems, storage, deployed applications, and possibly limited control of some networking components, e.g., host firewalls
- Services offered by this delivery model include: server hosting, Web servers, storage, computing hardware, operating systems, virtual instances, load balancing, Internet access, and bandwidth provisioning

Clouds deployment models

- Public Cloud - is made available to the general public or a large industry group and is owned by the organization selling cloud services
- Private Cloud – is operated solely for an organization
  - E.g.: Openstack at the UCBL
- Hybrid Cloud - composition of two or more clouds (public, private, or community) as unique entities but bound by standardized technology that enables data and application interoperability

The benefits of cloud computing

- One can access applications as utilities, over the Internet
- Manipulate and configure the application online at any time
- It does not require to install a specific piece of software to access or manipulate cloud application
- Offers online development and deployment tools, programming runtime environment through PaaS model
- Cloud resources are available over the network in a manner that provides platform independent access to any type of clients
- Offers on-demand self-service: the resources can be used without interaction with cloud service provider

More benefits of cloud computing

- Is highly cost effective because it operates at higher efficiencies with greater utilization
- It just requires an Internet connection
- Resource usage optimization: CPU cycles, storage, network bandwidth, can be shared by different users
- Resources can be aggregated to support data-intensive applications
- Data sharing facilitates collaborative activities
  - Many applications require multiple types of analysis of shared data sets and multiple decisions carried out by groups scattered around the globe

More benefits of cloud computing

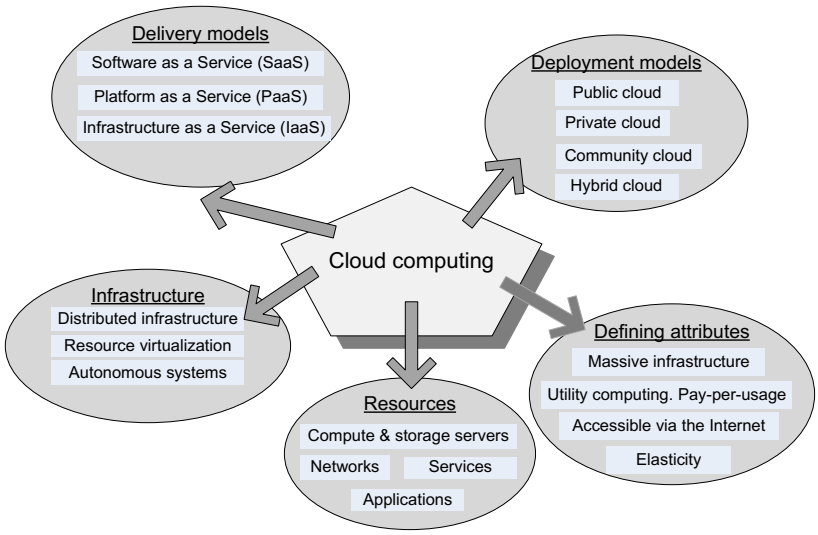
- Cost reduction
  - Eliminates the initial investment costs for a private computing infrastructure and the maintenance and operation costs
  - Concentration of resources creates the opportunity to pay as you go for computing
- Elasticity
  - The ability to accommodate workloads
- User convenience
  - Virtualization allows users to operate in familiar environments rather than in unusual ones
- Cloud Computing offers load balancing that makes it more reliable

Challenges/risks for cloud computing

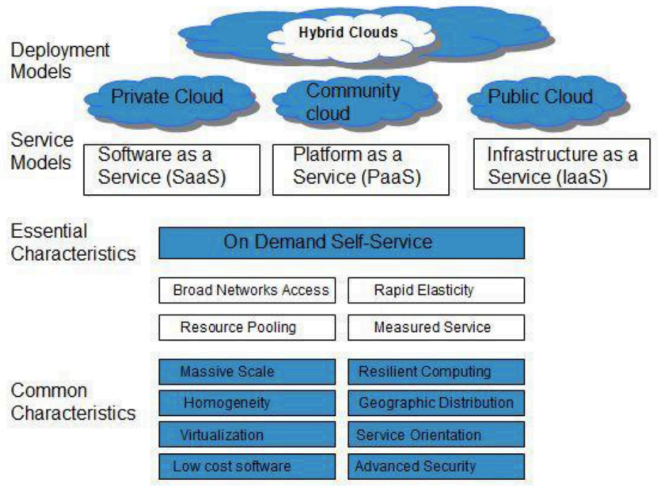
- Availability of service
  - What happens when the service provider cannot deliver?
  - Define a Risk Assessment Plan (RAP) and Service Level Agreement (SLA)
- Diversity of services, data organization, user interfaces available at different service providers limit user mobility
  - Once a customer is hooked to one provider it is hard to move to another
  - Standardization efforts, namely at NIST, *Open Cloud Computing Interface*,…
- Vendor lock-in
  - It is very difficult for the customers to switch from one **Cloud Service Provider (CSP)** to another
  - It results in dependency on a particular CSP
- Isolation failure: involves the failure of isolation mechanism that separates storage, memory, routing between the different tenants
- Data confidentiality and auditability

More challenges - research opportunities

- Data transfer bottleneck
  - Many applications are data-intensive
- Since data management and infrastructure management in cloud is provided by third-party, it is always a risk to handover the sensitive information to such providers
- Performance unpredictability, one of the consequences of resource sharing
  - How to use resource virtualization and performance isolation for Quality of Service (QoS) guarantees?
  - How to support elasticity, the ability to scale up and down quickly?
- It is possible that the data requested for deletion may not get deleted
  - It happens either because extra copies of data are stored but are not available or data to destroy also stores data from other tenants
- Addressing these challenges provides interesting research opportunities!



Key aspects of Cloud Computing



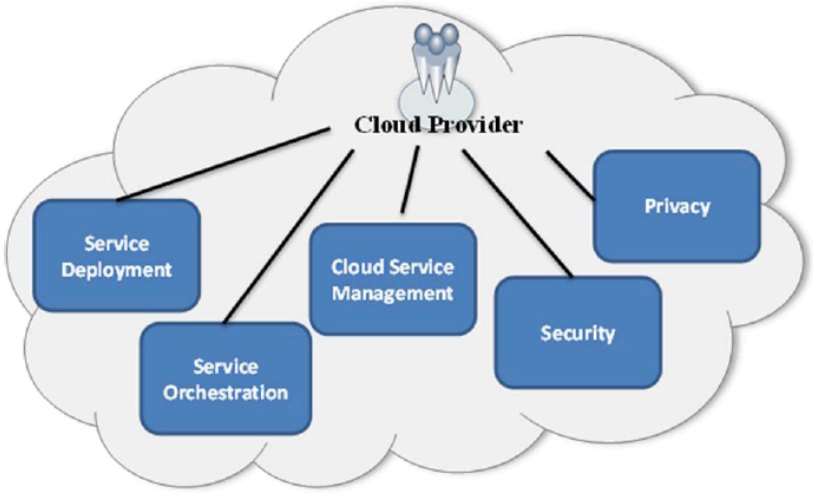
From Cloud Computing Tutorial

Consumer and Provider Activities

Service Models	Consumer Activities	Provider Activities
SaaS	Uses application/service for business process operations.	Installs, manages, maintains, and supports the software application on a cloud infrastructure.
PaaS	Develops, tests, deploys, and manages applications hosted in a cloud system.	Provisions and manages cloud infrastructure and middleware for the platform consumers; provides development, deployment, and administration tools to platform consumers.
IaaS	Creates/installs, manages, and monitors services for IT infrastructure operations.	Provisions and manages the physical processing, storage, networking, and the hosting environment and cloud infrastructure for IaaS consumers.

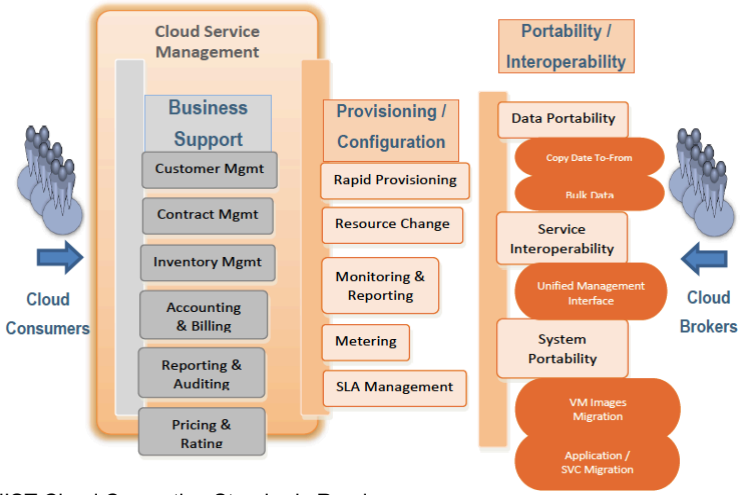
From NIST Cloud Computing Standards Roadmap

Cloud Provider Major Activities



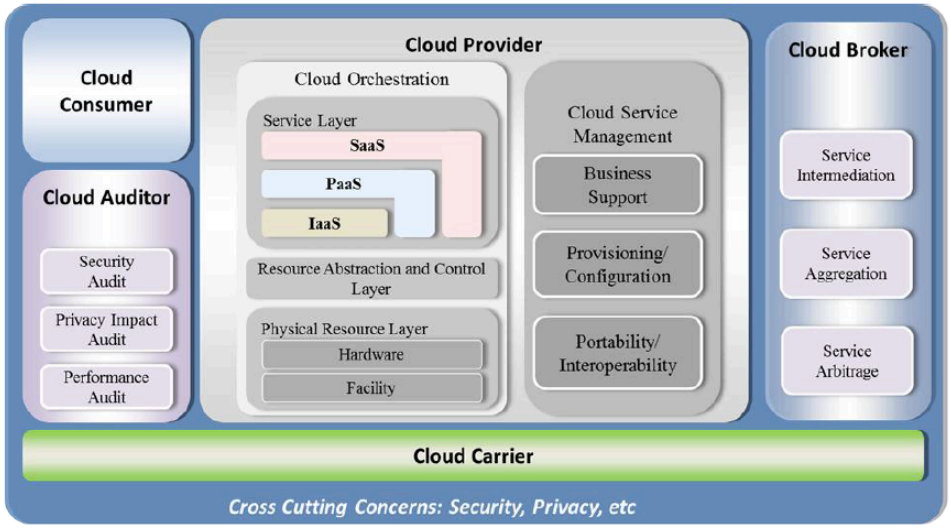
From NIST Cloud Computing Standards Roadmap

Cloud provider service management



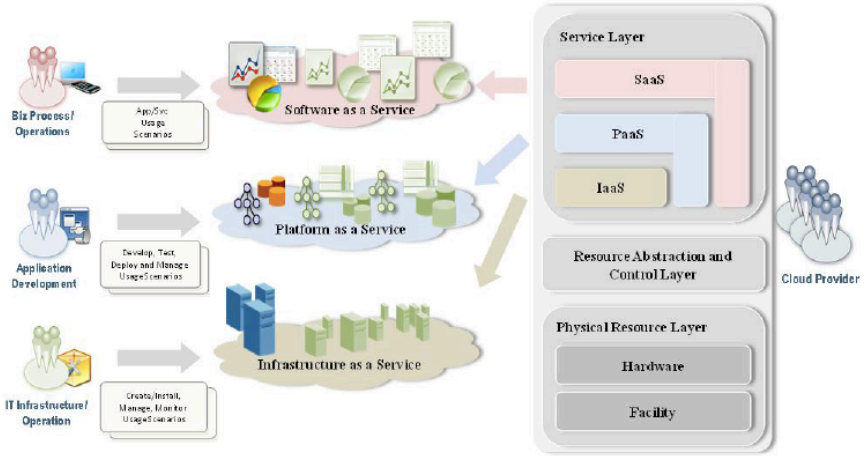
From NIST Cloud Computing Standards Roadmap

NIST cloud reference model



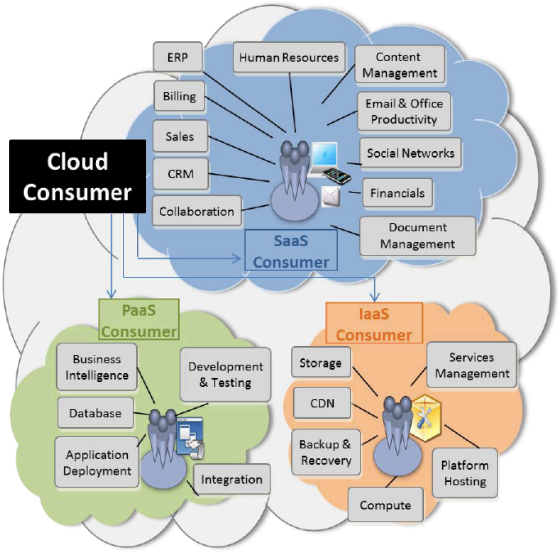
From NIST Cloud Computing Standards Roadmap

Cloud Provider Activites in Each Layer



From NIST Cloud Computing Standards Roadmap

Examples of Services Available to a Cloud Consumer



From NIST Cloud Computing Standards Roadmap

Ethical issues

- Paradigm shift with implications on computing ethics
  - The control is relinquished to third party services
  - Different laws in different countries
    - The data is stored on multiple sites administered by several organizations
    - Multiple services interoperate across the network
  - Privacy and data confidentiality
- Possible implications
  - Unauthorized access
  - Data corruption
  - Infrastructure failure, and service unavailability

De-perimeterisation

- Cloud systems can span the boundaries of multiple organizations and cross the security borders
- The complex structure of cloud services can make it difficult to determine who is responsible in case something undesirable happens
- Identity fraud and theft are made possible by the unauthorized access to personal data in circulation and by new forms of dissemination through social networks
  - These could also pose a danger to cloud computing

Privacy issues

- Cloud service providers have already collected petabytes of sensitive personal information stored in data centers around the world
- The acceptance of cloud computing therefore will be determined by privacy issues addressed by these companies and the countries where the data centers are located
- Privacy is affected by cultural differences
  - Some cultures favor privacy, others emphasize community
  - This leads to an ambivalent attitude towards privacy in the Internet which is a global system

Cloud vulnerabilities

- Clouds are affected by malicious attacks and failures of the infrastructure, e.g., power failures
- Such events can affect the Internet domain name servers and prevent access to a cloud or make the service unavailable
  - in 2004 an attack at Akamai caused a domain name outage and a major blackout that affected Google, Yahoo, and other sites
  - in 2009, Google was the target of a denial of service attack which took down Google News and Gmail for several days
  - in 2012 lightning caused a prolonged down time at Amazon

Risks for user companies

- Data confidentiality
- Legislative conformity
- Rejection from clients

Benefits for users

- Ergonomic and productivity
- Accessibility of applications
- Collaboration
- Agility and flexibility
- Quality of service and availability
- Rapid renewing of work stations

User scares

- Data confidentiality
- Dispossession of work station

Cloud activities

- Service management and provisioning including:
  - Virtualization
  - Service provisioning
  - Call center
  - Operations management
  - Systems management
  - Quality of Service management
  - Billing and accounting, asset management
  - Service Level Agreement management
  - Technical support and backups

Cloud activities (cont'd)

- Security management including:
  - ID and authentication
  - Certification and accreditation
  - Intrusion prevention
  - Intrusion detection
  - Virus protection
  - Cryptography
  - Physical security, incident response
  - Access control, audit and trails, and firewalls

Cloud activities (cont'd)

- Customer services such as:
  - Customer assistance and on-line help
  - Subscriptions
  - Business intelligence
  - Reporting
  - Customer preferences
  - Personalization
- Integration services including:
  - Data management
  - Development

Trends

- Autonomic computing
  - Self-healing and self-management services
- Rapid deployment of new services
- Machine Learning on AWS
- Container-as-a-Service: Amazon Elastic Container Service (Amazon ECS)
- End-users self-service
- Multi-clouds

Multi-Clouds

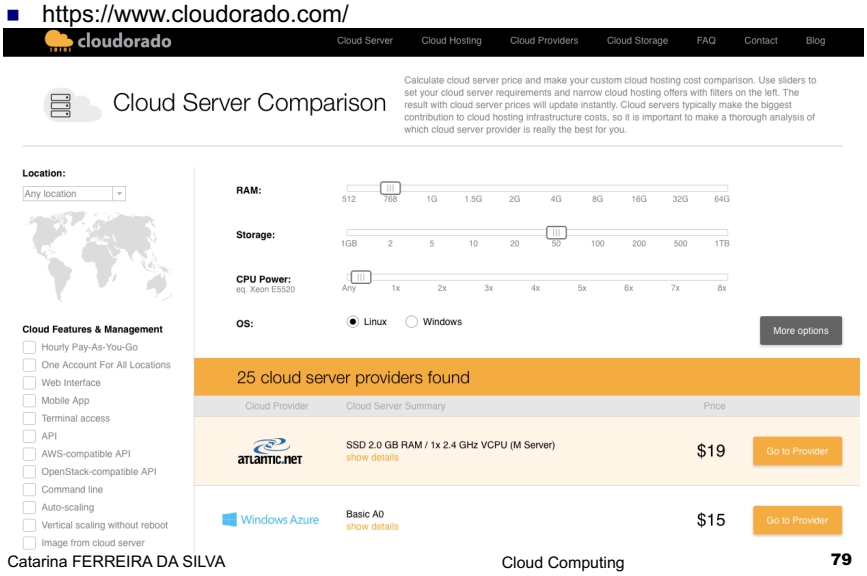
- Standards like (OASIS) TOSCA: Topology and Orchestration Specification for Cloud Applications
  - Open-source language
  - Describe the relationships and dependencies between services and applications
- Describes
  - The Cloud computing services and its components organization
  - The orchestration process
- Provides a common way to manage cloud applications and services
  - Applications and services can be portable across different cloud vendors' platforms

Trend: SaaS Integration Platforms (SIP)

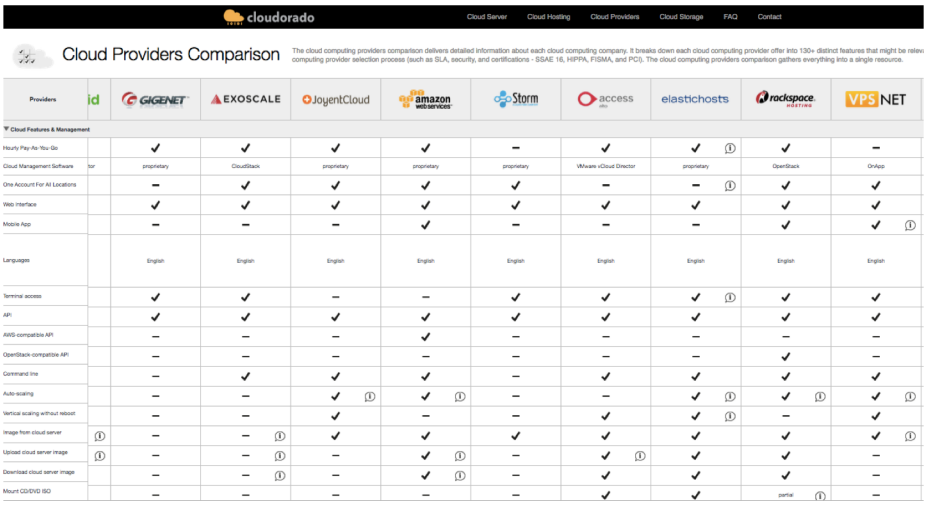
- Results from the widespread fragmentation in the SaaS provider space
- Allow subscribers to access multiple SaaS applications through a common platform
- Referred to as the "third wave" in software adoption
- SIP combine functions for human resource management, payroll accounting, and expense management as an all-in-one solution in promoting collaboration
- Example of SIP providers: Zoho, Sutisoft
- Salesforce, Microsoft, and Oracle are aggressively developing similar SIP

Compare Cloud Computing Providers (1/2)

- https://www.cloudorado.com/



Compare Cloud Computing Providers (2/2)



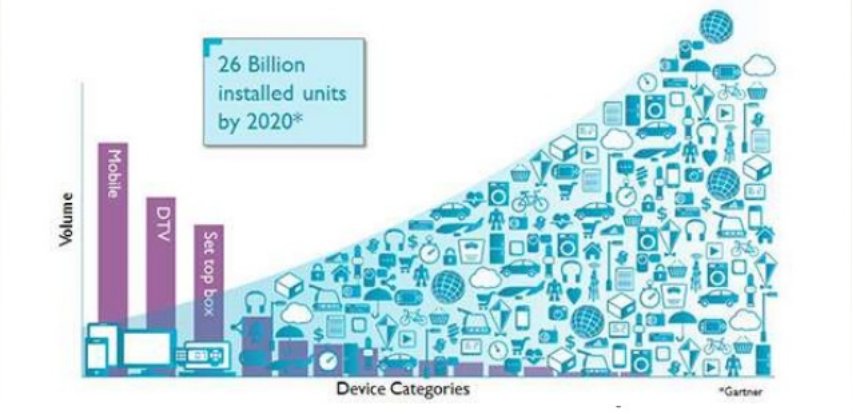
https://www.cloudorado.com/cloud_providers_comparison.jsp

Further reading

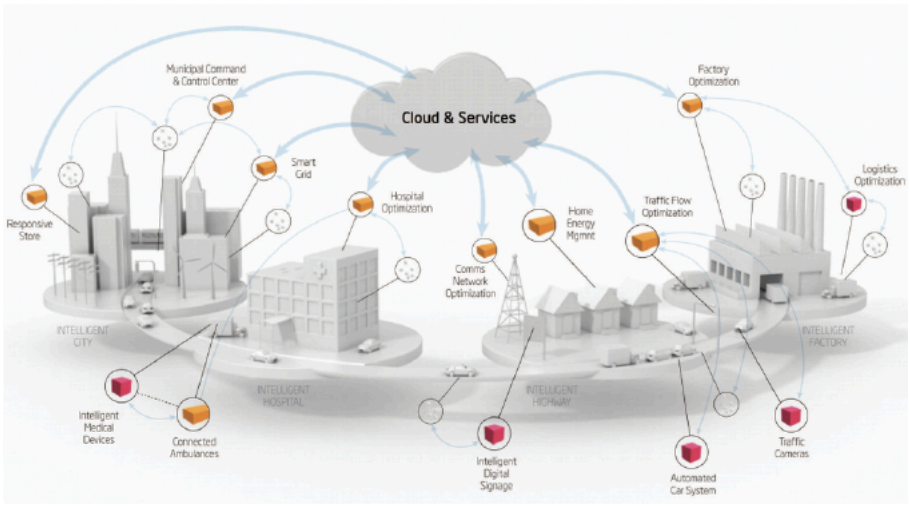
- Mandatory
  - http://en.wikipedia.org/wiki/Cloud_computing
  - Cloud Computing Tutorial, Simple easy learning, *tutorialspoint.com*
  - The NIST Definition of Cloud Computing
  - NIST Cloud Computing Standards Roadmap, 2013
- Recommended
  - *Cloud Computing Bible*, Barrie Sosinsky, Wiley Publishing, Inc. 2011
  - NIST Cloud Computing Reference Architecture
  - NIST Cloud Computing Standards Roadmap
  - A View of Cloud Computing, ACM, vol. 53, nº 4, 2010
  - Cloud Computing, ACM, vol. 51, nº 7, 2008
  - https://www.backblaze.com/blog/vm-vs-containers/

IoT devices and data

1. "The Internet of Things installed base will grow to **26 billion** units by **2020**," says Gartner.

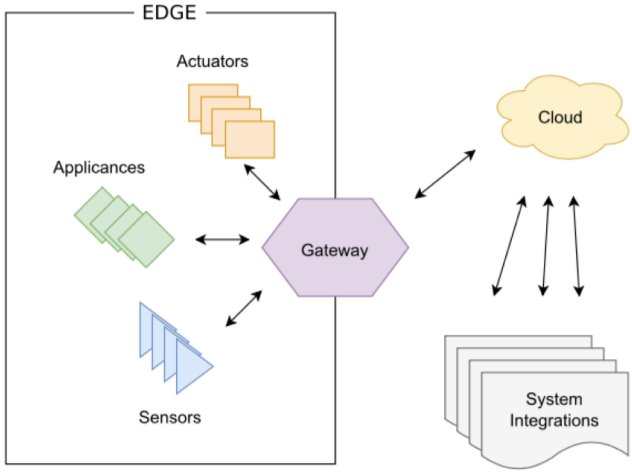


Cloud and Internet of Things/Objects



http://siliconangle.com

Cloud-based based components for IoT



IoT-based smart homes: A review of system architecture, software, communications, privacy and security, Mocrii et al. (2018), Internet of Things, https://doi.org/10.1016/j.iot.2018.08.009

Stage master + doctorat

- ISITEC International, Lyon (me contacter)
- La spécification, le développement, et la mise en service de solution d'objets connectés pour l'optimisation des processus logistiques
- *Différents composants :*
  - Une partie électronique : développement de carte et programmes embarqués
  - Une partie mécanique : conception sous Solidworks
  - Une partie développement de programme informatique : base de données, interface opérateur, réseaux, gestion de périphériques en temps réel