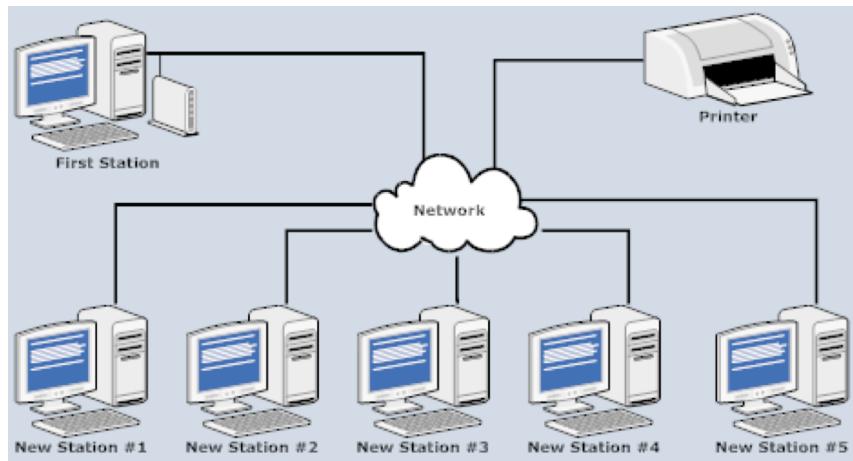
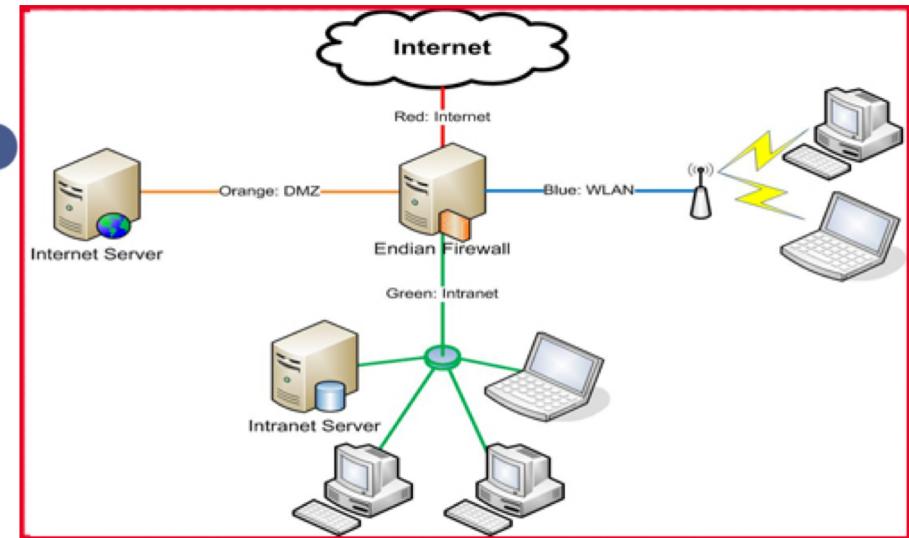
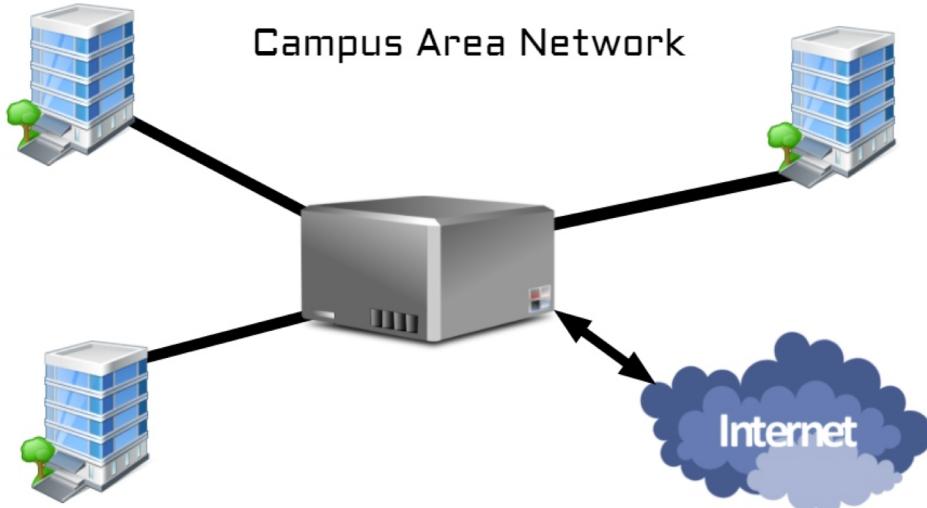


A 3D rendering of the words "Cloud Computing" floating above a white cloud against a white background. The word "Cloud" is in a light blue font, and "Computing" is in a larger, bold blue font. The clouds are rendered with soft shadows and highlights to give them a three-dimensional appearance.



Outline

- Definition and Trend
- Why Cloud Computing
- Architecture
- Characteristics
- Deployment Types
- Services Types



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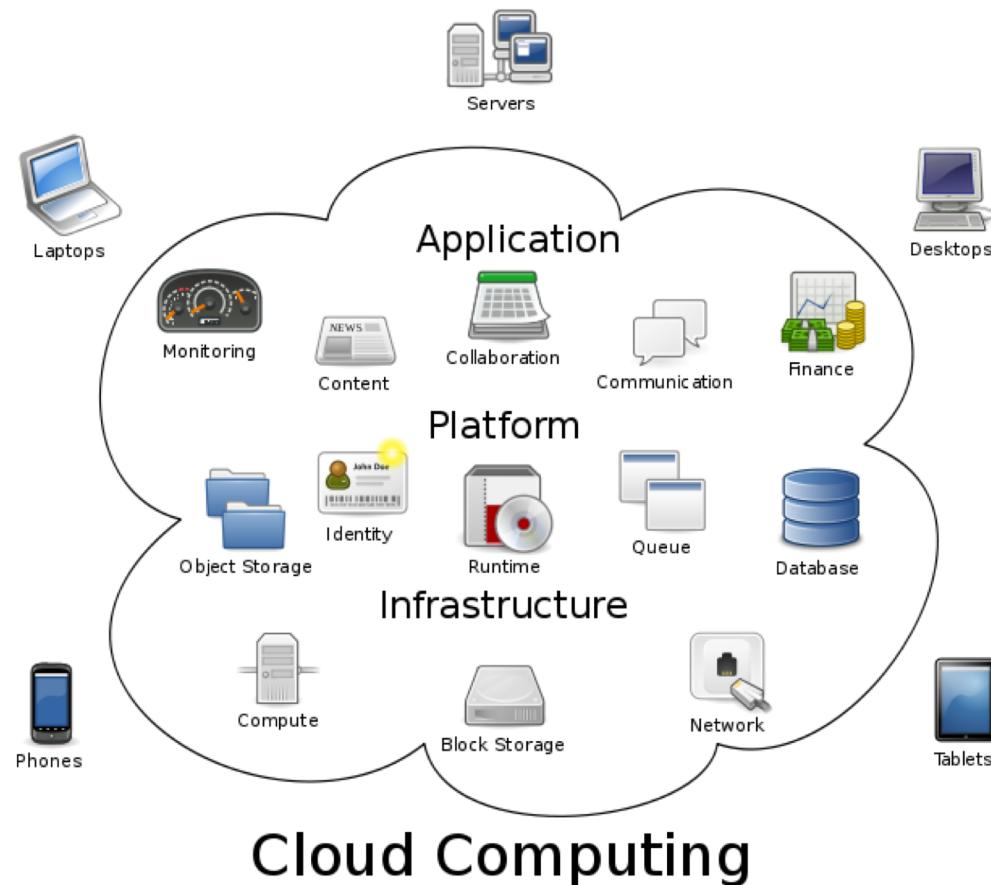
Cloud computing

From Wikipedia, the free encyclopedia

Cloud computing is the delivery of [computing](#) as a service rather than a product, whereby shared resources, software and information are provided to computers and other devices as a utility (like the [electricity grid](#)) over a network (typically the [Internet](#)).

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 - 1.2 Characteristics
 - 1.3 Architecture
- 2 History
- 3 Layers
 - 3.1 Client
 - 3.2 Application
 - 3.3 Platform
 - 3.4 Infrastructure
 - 3.5 Server
- 4 Deployment models
 - 4.1 Public cloud
 - 4.2 Community cloud
 - 4.3 Hybrid cloud



Cloud computing

From Wikipedia, the free encyclopedia

Cloud computing is the use of [computing resources](#) (hardware and software) that are delivered as a service over a [network](#) (typically the [Internet](#)). The name comes from the use of a [cloud-shaped symbol](#) as an abstraction for the complex infrastructure it contains in system diagrams. Cloud computing entrusts remote services with a user's data, software and computation.

There are many types of public cloud computing:^[1]

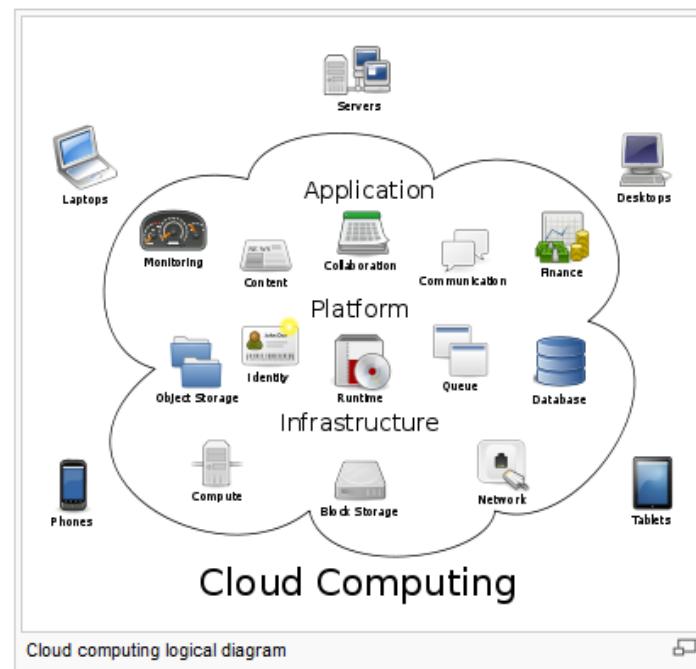
- Infrastructure as a service (IaaS),
- Platform as a service (PaaS),
- Software as a service (SaaS)
- Storage as a service (STaaS)
- Security as a service (SEaaS)
- Data as a service (DaaS)
- Business process as a service (BPaaS)
- Test environment as a service (TEaaS)
- Desktop as a service (DaaS)
- API as a service (APIaaS)

The business model, [IT as a service](#) (ITaaS), is used by in-house, enterprise IT organizations that offer any or all of the above services.

Using software as a service, users also rent application software and databases. The cloud providers manage the infrastructure and platforms on which the applications run.

End users access cloud-based applications through a [web browser](#) or a light-weight desktop or [mobile app](#) while the [business software](#) and user's data are stored on servers at a remote location. Proponents claim that cloud computing allows enterprises to get their applications up and running faster, with improved manageability and less maintenance, and enables IT to more rapidly adjust resources to meet fluctuating and unpredictable business demand.^{[2][3]}

Cloud computing relies on sharing of resources to achieve coherence and [economies of scale](#) similar to a [utility](#) (like the [electricity grid](#)) over a network.^[4] At the foundation of cloud computing is the broader concept of [converged infrastructure](#) and [shared services](#).



Cloud computing logical diagram

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Cloud computing

From Wikipedia, the free encyclopedia



This article may be too technical for most readers to understand. Please help improve this article to make it understandable to non-experts, without removing the technical details. The talk page may contain suggestions.
(January 2013)

Cloud computing is a colloquial expression used to describe a variety of different types of computing concepts that involve a large number of computers connected through a real-time communication network (typically the Internet).^[1] Cloud computing is a jargon term without a commonly accepted non-ambiguous scientific or technical definition. In science, cloud computing is a synonym for distributed computing over a network and means the ability to run a program on many connected computers at the same time. The phrase is also, more commonly used to refer to network based services which appear to be provided by real server hardware, which in fact are served up by virtual hardware, simulated by software running on one or more real machines. Such virtual servers do not physically exist and can therefore be moved around and scaled up (or down) on the fly without affecting the end user - arguably, rather like a cloud.

The popularity of the term can be attributed to its use in marketing to sell hosted services in the sense of application service provisioning that run client server software on a remote location.

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 - \[3.5 Growth and popularity\]\(#\)
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 - \[6.4 Network as a service \\(NaaS\\)\]\(#\)](#)

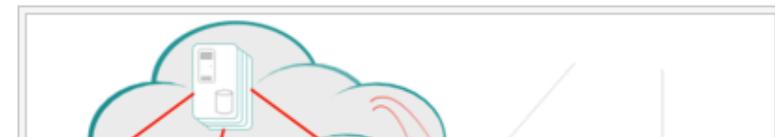
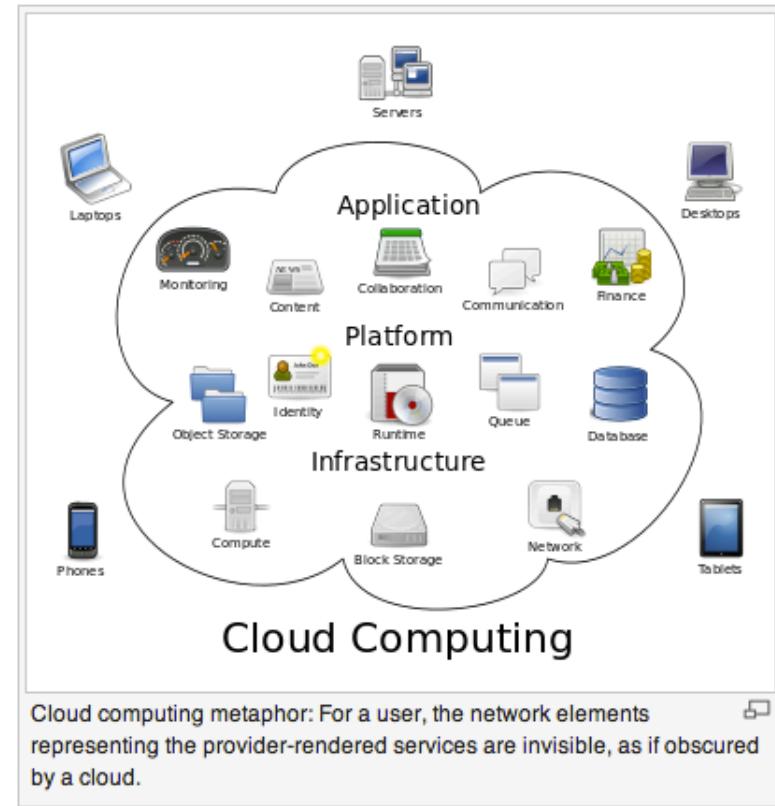
Cloud computing

From Wikipedia, the free encyclopedia

Cloud computing is the delivery of **computing as a service** rather than a **product**, whereby shared resources, software, and information are provided to computers and other devices as a **utility** (like the electricity grid) over a **network** (typically the **Internet**). Clouds can be classified as public, private or hybrid.^[1]

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Cloud computing

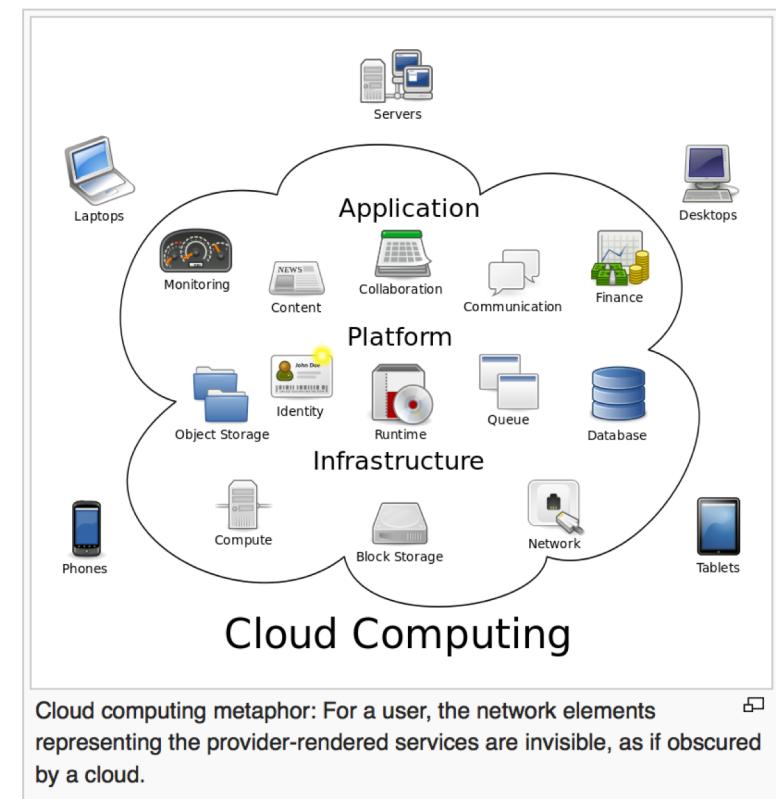
From Wikipedia, the free encyclopedia

Cloud computing is a model for enabling ubiquitous network access to a shared pool of configurable computing resources.^[1]

Cloud computing and storage solutions provide users and enterprises with various capabilities to store and process their data in third-party data centers.^[2] It relies on sharing of resources to achieve coherence and **economies of scale**, similar to a utility (like the **electricity grid**) over a network.^[3] At the foundation of cloud computing is the broader concept of **converged infrastructure** and **shared services**.

Cloud computing, or in simpler shorthand just "the cloud", also focuses on maximizing the effectiveness of the shared resources. Cloud resources are usually not only shared by multiple users but are also dynamically reallocated per demand. This can work for allocating resources to users. For example, a cloud computer facility that serves European users during European business hours with a specific application (e.g., email) may reallocate the same resources to serve North American users during North America's business hours with a different application (e.g., a web server). This approach should maximize the use of computing power thus reducing environmental damage as well since less power, air conditioning, rack space, etc. are required for a variety of functions. With cloud computing, multiple users can access a single server to retrieve and update their data without purchasing licenses for different applications.

The term "moving to cloud" also refers to an organization moving away from a traditional



Cloud computing

From Wikipedia, the free encyclopedia

For the winner of the 2017 Preakness Stakes, see [Cloud Computing \(horse\)](#).

Cloud computing is a computing infrastructure and software model for enabling ubiquitous access to shared pools of configurable resources (e.g., computer networks, servers, storage, applications and services),^{[1][2]} which can be rapidly provisioned with minimal management effort, often over the [Internet](#). Cloud computing allows users, and enterprises, with various computing capabilities to store and process data in either a privately owned cloud, or on a third-party server located in a [data center](#) in order to make data accessing mechanisms more efficient and reliable.^[3] Cloud computing relies on sharing of resources to achieve coherence and [economy of scale](#), similar to a [utility](#).

Advocates note that cloud computing allows companies to avoid, or minimize, up-front infrastructure costs. As well, third party clouds enable organizations to focus on their core businesses instead of expending resources on computer infrastructure and maintenance.^[4] Proponents also claim that cloud computing allows enterprises to get their applications up and running faster, with improved manageability and less maintenance, and enables [information technology](#) (IT) teams to more rapidly adjust resources to meet fluctuating and unpredictable business demand.^{[4][5][6]} Cloud providers typically use a "pay as you go" model. This could lead to unexpectedly high charges if administrators are not familiarized with cloud pricing models.^[7]

In 2009, the availability of high-capacity networks, low-cost computers and storage devices as well as the widespread adoption of [hardware virtualization](#), [service-oriented architecture](#), and [autonomic](#) and utility computing led to a growth in cloud computing.^{[8][9][10]} Companies can scale up as computing needs increase and then scale down again as demands decrease.^[11] In 2013, it was reported that cloud computing had become a highly demanded service or utility due to the advantages of high computing power, cheap cost of services, high performance, scalability, accessibility as well as availability. Some cloud vendors are experiencing growth rates of 50% per year,^[12] but being still in a stage of infancy, it has pitfalls that need to be addressed to make cloud computing services more reliable and user friendly.^{[13][14]}



Cloud computing metaphor: For a user, the network elements representing the provider-rendered services are invisible, as if obscured by a cloud.

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Cloud computing

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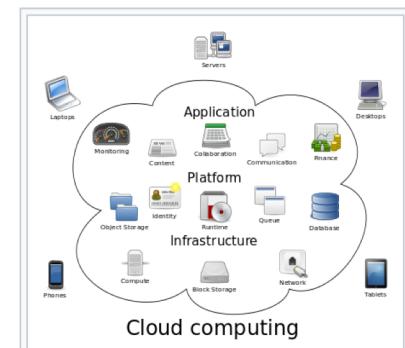
For the winner of the 2017 Preakness Stakes, see [Cloud Computing \(horse\)](#).

Cloud computing is an [information technology](#) (IT) paradigm that enables ubiquitous access to shared pools of configurable [system resources](#) and higher-level services that can be rapidly [provisioned](#) with minimal management effort, often over the [Internet](#). Cloud computing relies on sharing of resources to achieve coherence and [economies of scale](#), similar to a [public utility](#).

Third-party clouds enable organizations to focus on their [core businesses](#) instead of expending resources on computer infrastructure and maintenance.^[1] Advocates note that cloud computing allows companies to avoid or minimize up-front [IT infrastructure](#) costs. Proponents also claim that cloud computing allows enterprises to get their applications up and running faster, with improved manageability and less maintenance, and that it enables IT teams to more rapidly adjust resources to meet fluctuating and unpredictable demand.^{[1][2][3]} Cloud providers typically use a "pay-as-you-go" model, which can lead to unexpected [operating expenses](#) if administrators are not familiarized with cloud-pricing models.^[4]

Since the launch of [Amazon EC2](#) in 2006, the availability of high-capacity networks, low-cost computers and storage devices as well as the widespread adoption of [hardware virtualization](#), [service-oriented architecture](#), and [autonomic](#) and [utility computing](#) has led to growth in cloud computing.^{[5][6][7]}

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Cloud computing metaphor: the group of networked elements providing services need not be individually addressed or managed by users; instead, the entire provider-managed suite of hardware and software can be thought of as an amorphous cloud.

Cloud computing

From Wikipedia, the free encyclopedia

For the winner of the 2017 Preakness Stakes, see [Cloud Computing \(horse\)](#).

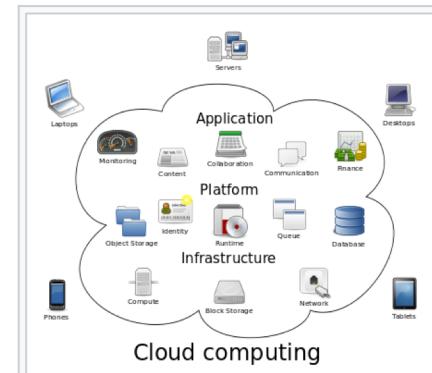
Cloud computing is the on-demand availability of [computer system resources](#), especially [data storage](#) and [computing power](#), without direct active management by the user. The term is generally used to describe data centers available to many users over the [Internet](#). Large clouds, predominant today, often have functions distributed over multiple locations from central servers. If the connection to the user is relatively close, it may be designated an [edge server](#).

Clouds may be limited to a single organization (enterprise clouds^{[1][2]}), or be available to many organizations (public cloud).

Cloud computing relies on sharing of resources to achieve coherence and [economies of scale](#).

Advocates of public and hybrid clouds note that cloud computing allows companies to avoid or minimize up-front [IT infrastructure](#) costs. Proponents also claim that cloud computing allows enterprises to get their applications up and running faster, with improved manageability and less maintenance, and that it enables IT teams to more rapidly adjust resources to meet fluctuating and unpredictable demand.^{[2][3][4]} Cloud providers typically use a "pay-as-you-go" model, which can lead to unexpected [operating expenses](#) if administrators are not familiarized with cloud-pricing models.^[5]

The availability of high-capacity networks, low-cost computers and storage devices as well as the widespread adoption of [hardware virtualization](#), [service-oriented architecture](#) and [autonomic](#) and [utility computing](#) has led to growth in cloud computing.^{[6][7][8]} By 2019, [Linux](#) was the most used type of operating systems used, including in Microsoft's offerings and is thus described as dominant.^[9]



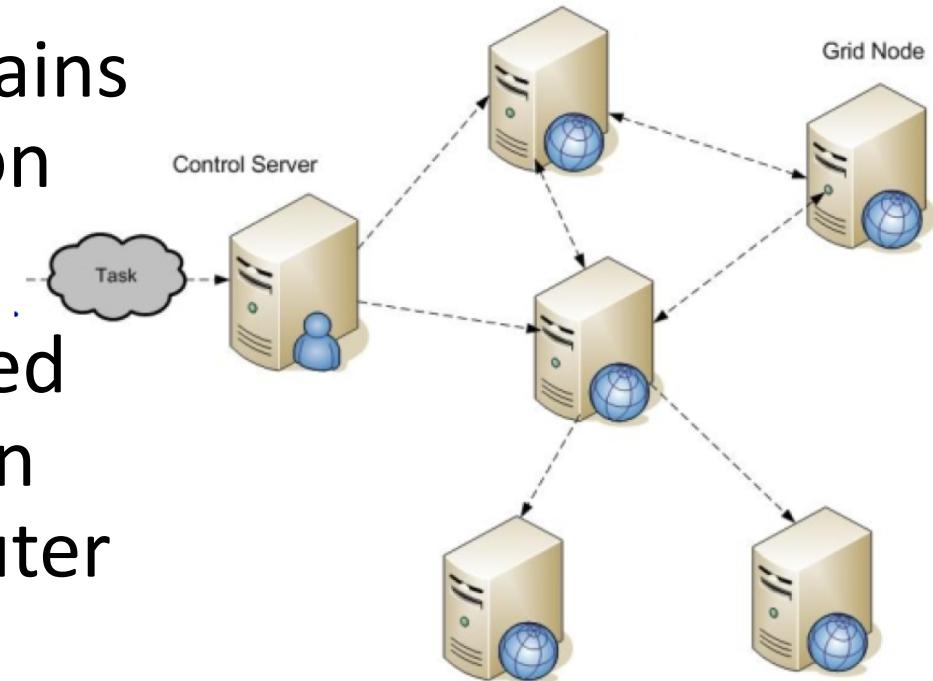
Cloud computing metaphor: the group of networked elements providing services need not be individually addressed or managed by users; instead, the entire provider-managed suite of hardware and software can be thought of as an amorphous cloud.

Related Computing Models

- Grid Computing
- Cluster Computing
- Utility Computing
- ...

Grid Computing

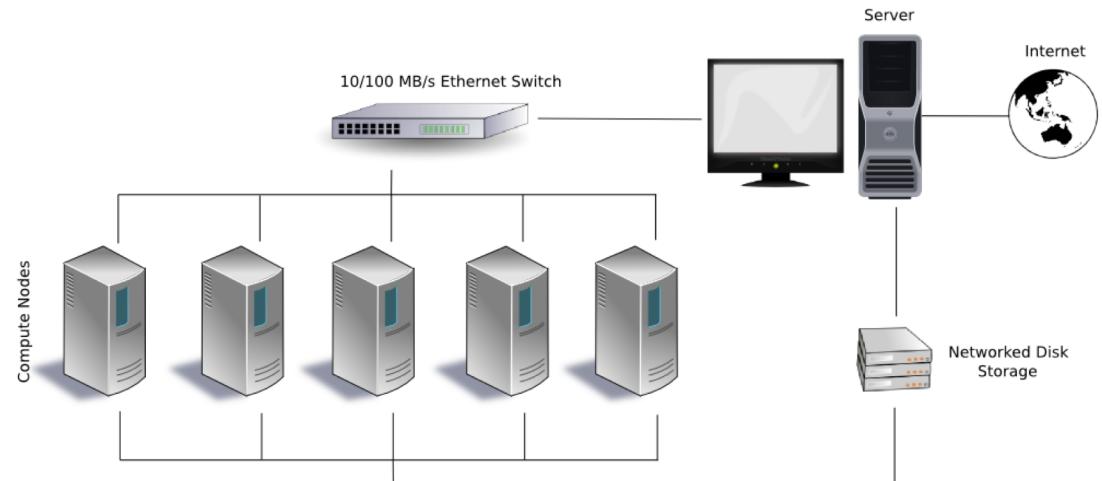
- Def: combination of computer resources from multiple administrative domains applied to a common task*
- Core idea: distributed parallel computation super virtual computer



* wiki

Cluster Computing

- Connected over LAN
- Unlike grid computers, computer clusters have each node set to perform the same task, controlled and scheduled by software.



Utility Computing

- Def: “The packaging of computing resources (computation, storage etc.) as a metered service similar to a traditional public utility” *
- Observation: not a new concept
 - "If computers of the kind I have advocated become the computers of the future, then computing may someday be organized as a public utility just as the telephone system is public utility... The computer utility could become the basis of a new and important industry." - John McCarthy, MIT Centennial in 1961

Cloud Computing

- grid computing + utility computing ??
- means different things to different parties
- Network is a computer
- Various definitions
 - NIST – National Institute of Standards and Technology
 - “universally” accepted definition

Definition of Cloud Computing

- NIST (Sep. 2011): “Cloud computing is 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) that can be rapidly provisioned and released with minimal management effort or service provider interaction.”*

* <http://csrc.nist.gov/groups/SNS/cloud-computing/cloud-def-v15.doc>

Definition of Cloud Computing

- NIST (Sep. 2011): “Cloud computing is 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) that can be **rapidly provisioned** and released with **minimal management** effort or service provider interaction. This cloud model promotes availability and is composed of five essential **characteristics**, three **service models**, and four **deployment models**.”*

* <http://csrc.nist.gov/groups/SNS/cloud-computing/cloud-def-v15.doc>

NIST Essential Characteristics

- On-demand self-service
 - a consumer can *unilaterally* provision computing capabilities *without human interaction* with the service provider
- Computing capabilities
 - server time, network storage, number of servers etc.

NIST Essential Characteristics

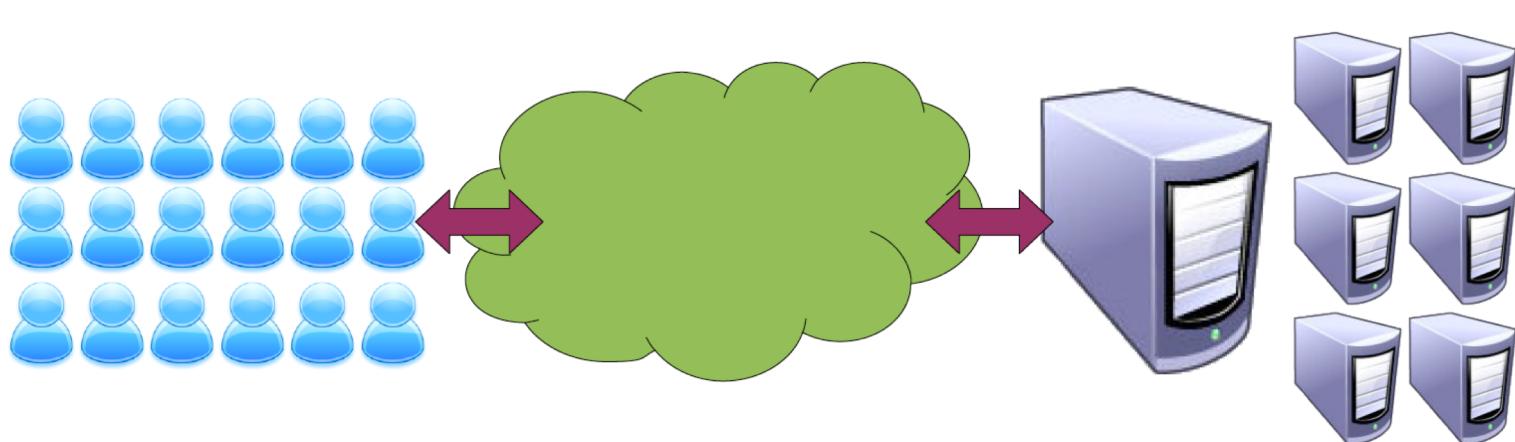
- Broad network access
 - capabilities are
 - available over the network
 - accessed through standard mechanisms
- promote use by
 - heterogeneous thin or thick client platforms

NIST Essential Characteristics

- Multi-tenancy / Resource pooling
 - provider's computing resources are pooled to serve multiple consumers
 - computing resources
 - storage, processing, memory, network bandwidth and virtual machines
 - location independence
 - no control over the exact location of the resources
 - has major implications
 - performance, scalability, security

NIST Essential Characteristics

- Rapid elasticity
 - capabilities can be rapidly and elastically provisioned
 - unlimited virtual resources
 - predicting a ceiling is difficult



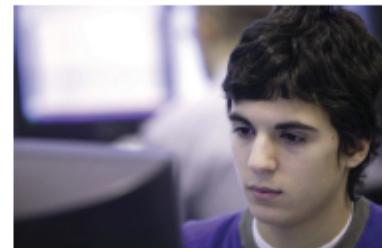
NIST Essential Characteristics

- Measured service
 - metering capability of service/resource abstractions
 - Processing, storage, bandwidth, active user accounts

Relevant Technologies

- Access
 - Servers, (mobile) client devices
 - Network
 - Data centers
- Virtualization
- APIs

Near Future? Current!



Data Centers

- Gartner : “Cloud computing heralds an evolution of business that is no less influential than e-business”
- IDC : “This is about the IT industry’s new model for the next 20 years”

(2008)

Grid vs. Cluster Computing

- **Characteristics of Grid Computing**
 - Loosely coupled (Decentralization)
 - Diversity and Dynamism
 - Distributed Job Management & scheduling
- **Characteristics of Cluster computing**
 - Tightly coupled systems
 - Single system image
 - Centralized Job management & scheduling system
- **Areas of Grid Computing and it's applications for modeling and computing**
 - 1.Predictive Modeling and Simulations
 - 2.Engineering Design and Automation
 - 3.Energy Resources Exploration
 - 4.Medical, Military and Basic Research
 - 5.Visualization

Grid vs. Cloud Computing

- Ownership
 - Grid is a collection of computers which is owned by multiple parties in multiple locations and connected together so that users can share the combined power of resources.
 - Cloud is a collection of computers usually owned by a single party.
- Resource distribution
 - Grid computing is a decentralized model where the computation could occur over many administrative domains.
 - Cloud computing is a centralized model

Why Cloud? – Economics!

- Economy of scale
 - Eg. milk, power, restaurant, apartment
 - Most of time it is better to rent than buy/build
- Public cloud drivers
 - Simplicity and low up-front cost
 - Infrastructure and administration could run up cost if even moderately successful (with non-negligible up-front cost)
- Similar drivers for private clouds (people cost)
 - Consolidate IT functions (natural step after data center virtualization and server consolidation)

Why Now/Recently? - Availability

- High capacity networks
- Low cost computers and storage
- Virtualization
- Service oriented architecture
- Autonomic and utility computing

Why Now? – Applications!

- Mobile + wireless
 - Mobile applications are naturally cloud-oriented
 - Esp. when they are data- or compute-intensive
- Parallel batch processing & ad hoc compute-intensive tasks
 - Peter Harkins, a Senior Engineer at The Washington Post, used 200 EC2 instances (1,407 server hours) to convert 17,481 pages of Hillary Clinton's travel documents into a form more friendly to use within nine hours after they were released
- Analysis everywhere
 - Big data!
 - Lots of raw data now being collected everywhere
 - Convert to useful information
 - Merge different data sources

Some “*User-Visible*” Characteristics

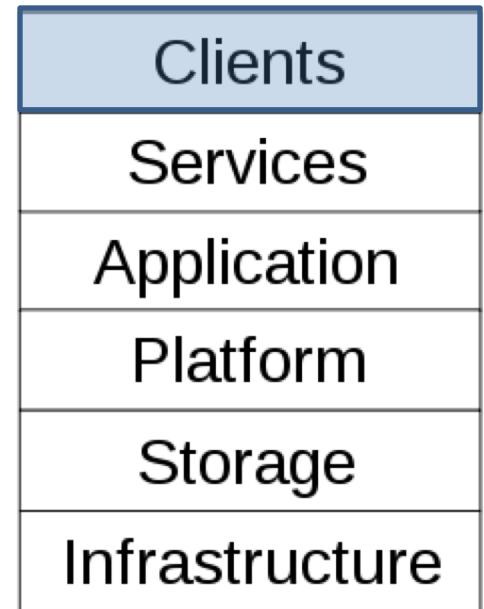
- *On-demand* : Resources when you need them without human interaction with a service provider
- *Self-service*: no email/phone/long waits to IT folks
- *Rapid elastic*: scale resources up and down any time
- *Broad network access*: Accessible over the Internet by heterogeneous client platforms
- User-visible service agreement (SLAs) for performance and availability (sometimes)
- *Pay-as-you-go*: \$ spend proportional to resources used

Some “*Inside-the-cloud*” Properties

- *Scalability*: Usually incrementally
- *Resource pooling*, aka multi-tenancy
- *Migration* of tasks and data
- *Measured/Monitored/Audited* resource usage
- *Failures are the common case* (especially because of scale): design for failure as standard operating procedure (shades of Internet-style thinking)

Architecture

- Client (end user): web browser or an APP
- Service: functions in cloud computing
- Application: cloud user services
- Platform: software infrastructure for applications, e.g., Windows Azure, Google App Engine, VMware
- Storage: disks, tapes, optical, memory, etc.
- Infrastructure: IT hardware and facilities (routers, switches, etc.)

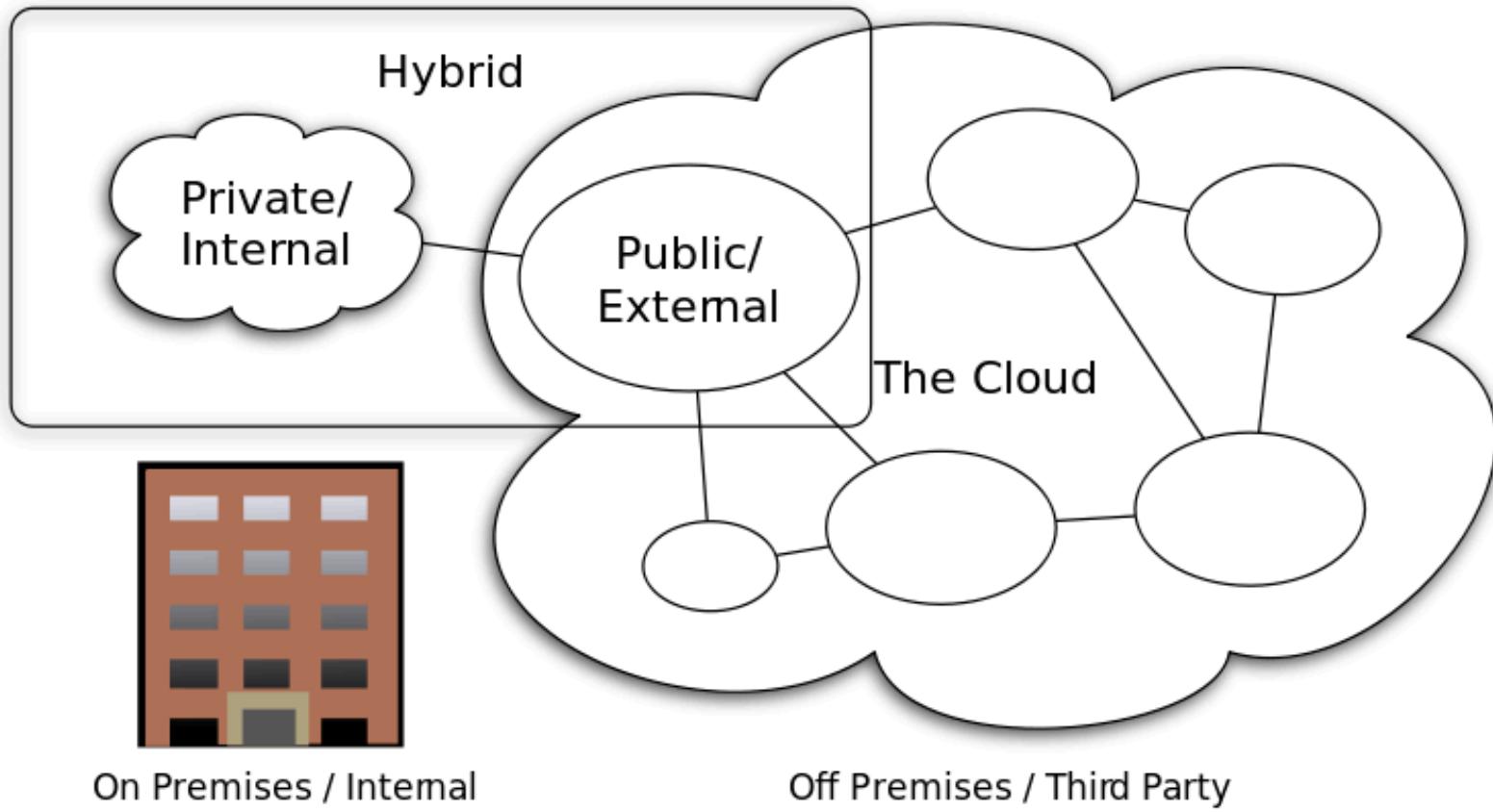


Consumption/Deployment Types

- Public clouds
 - Open for general public
 - May be owned, managed, and operated by a business, academic, or government organization, or their combinations
 - Exists on the premises of a cloud provider
 - Cause for initial hype
- Private clouds
 - For exclusive use of a single organization
 - May be owned, managed, and operated by the organization, a third party or their combinations
 - Exists on or off the organization's premises
 - Main driver ? (once the hype subsides)

Consumption/Deployment Types-2

- Community clouds
 - For exclusive use by a community
 - Eg. Federal government's cloud initiative for various government services
 - May be owned, managed, and operated by the organization, a third party or their combinations
 - Exists on or off the organization's premises
- Hybrid clouds
 - A combination of above distinct cloud infrastructures
 - But bound together by standardized or proprietary technology for portability
 - Cloud bursting (surge protection)
 - (Translate fixed costs into fixed + variable costs)



Cloud Computing Types

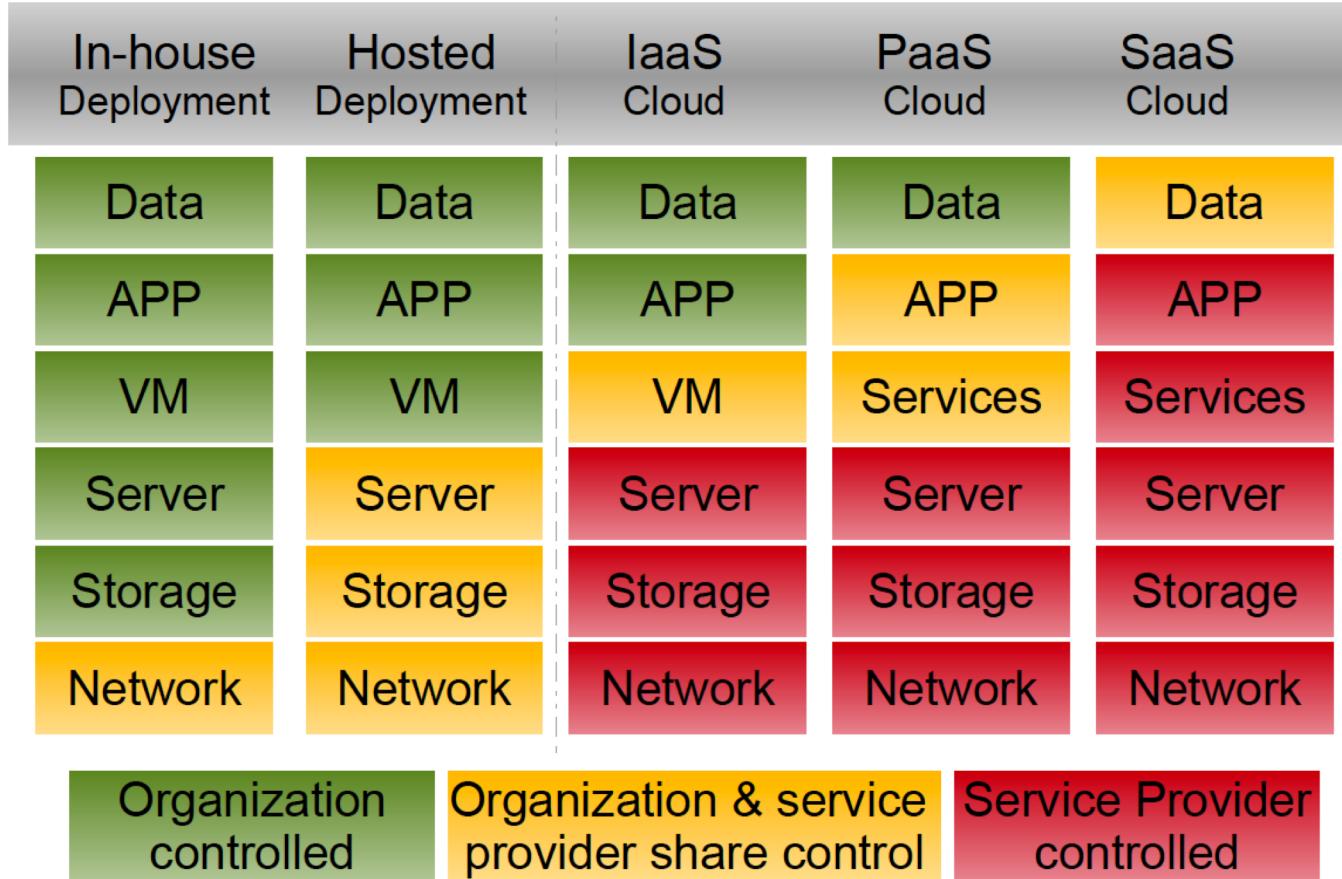
CC-BY-SA 3.0 by Sam Johnston

Services (“X-as-a-Service”)

- Infrastructure (IaaS)
 - Compute servers, storage, network (basic stuff)
- Platform (PaaS)
 - App development frameworks
- Software (SaaS)
 - Productivity apps, personal finance, ...



Services vs. Control



Visualizing the Boundaries of Control in the Cloud. Dec 2009.

<http://kscottmorrison.com/2009/12/01/visualizing-the-boundaries-of-control-in-the-cloud/>

IaaS

- Natural next-step evolution from data center hosting
- Basic storage, compute, and network facilities
- Provide choice of virtual machines to install on bare device, and run
- Internally, mapping to bare device is hidden from user (and presumably multiplexed)
- Amazon EC2, VMWare vCloud, Rackspace, Azure, GoGrid, Verio, Joyent, etc.

IaaS Evolution

- Over time, adding more useful systems software
 - Storage (“EBS”), database (RDS, SimpleDB, SQLAzure, ...), elastic MapReduce, etc.

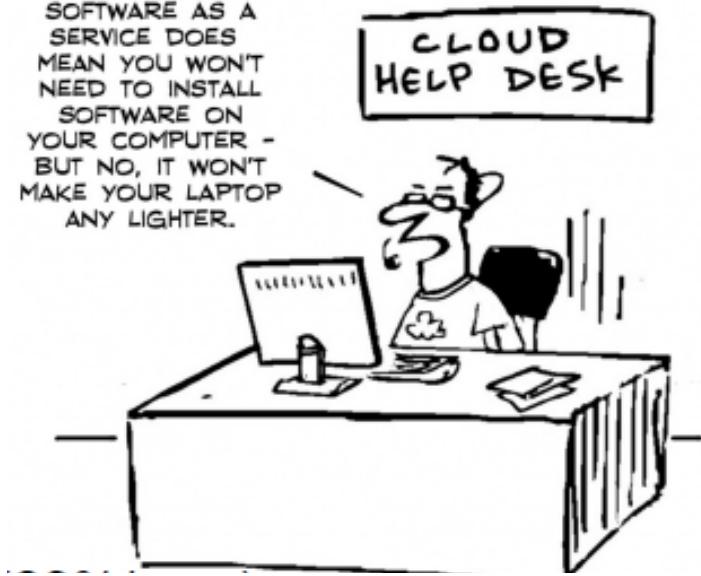
PaaS

- Provide an entire app dev framework
- Google AppEngine is one example
 - Run your web apps on google's infrastructure
 - Run your business apps on google's infrastructure
 - And presumably soon, write and manage your business apps google's infrastructure
- Other examples: Windows Azure, Vmware Foundry, Heroku, Salesforce.com, etc.

SaaS

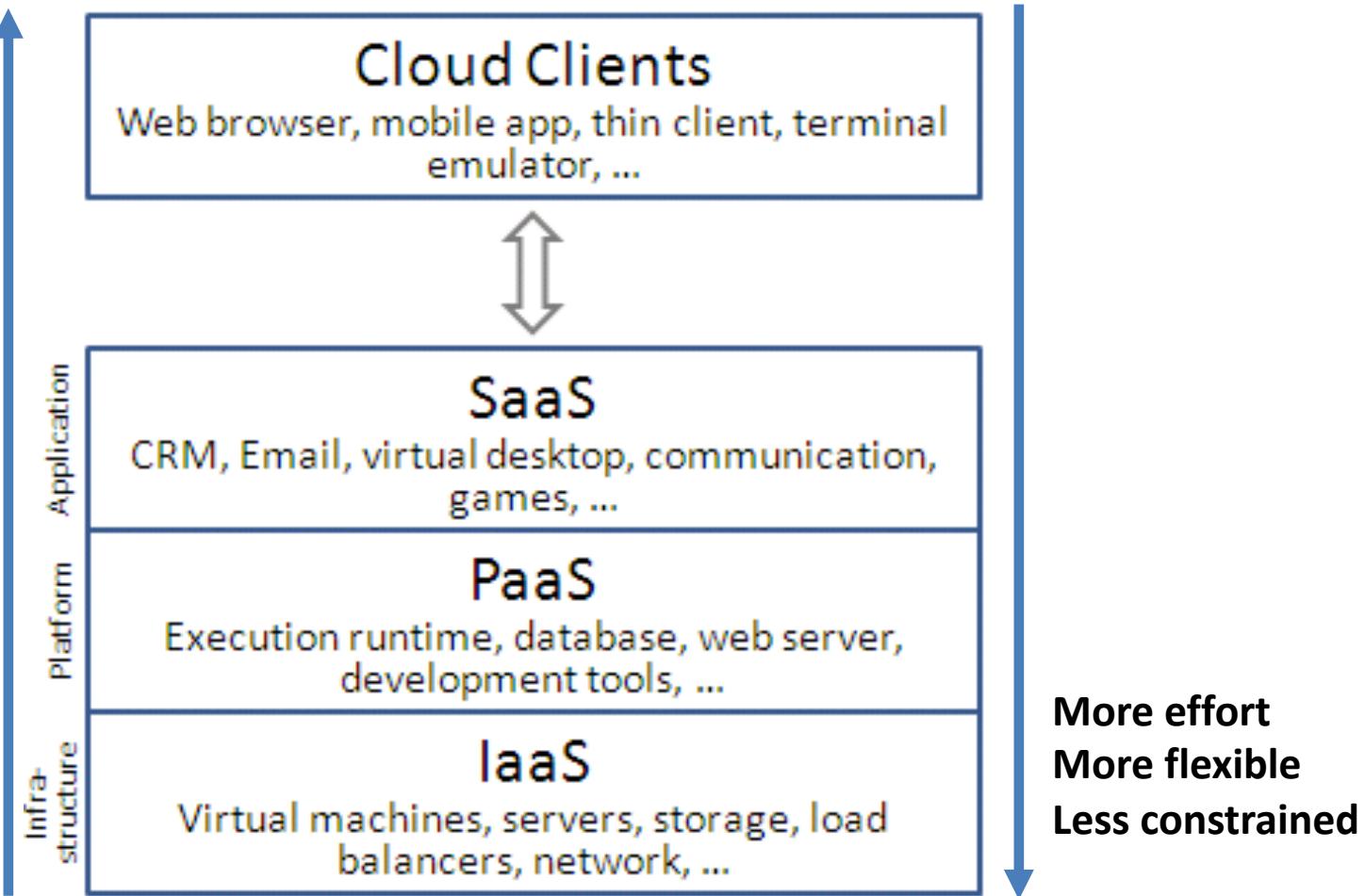
- On-demand software
- Become a common delivery model for most business applications
 - Accounting, collaboration, customer relationship management, enterprise resource planning, human resource management,
- Examples: Gmail/Hotmail, Google Docs, TurboTax, Office 365, Microsoft Office Web Companions, etc.

YES MADAM,
SOFTWARE AS A
SERVICE DOES
MEAN YOU WON'T
NEED TO INSTALL
SOFTWARE ON
YOUR COMPUTER -
BUT NO, IT WON'T
MAKE YOUR LAPTOP
ANY LIGHTER.



XaaS

Less effort
Less flexible
More constrained



More effort
More flexible
Less constrained