



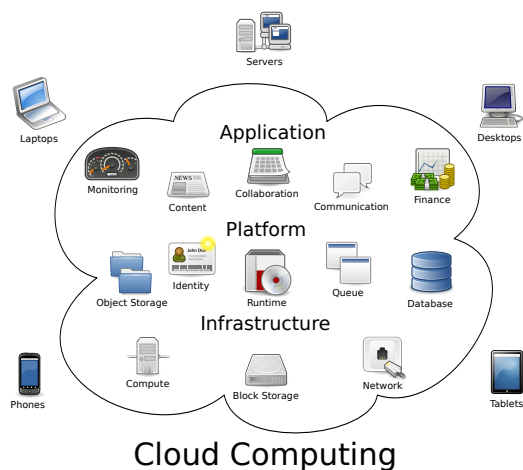
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# Chapter 1

## Cloud computing



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

**Cloud computing** is a computing term or metaphor that evolved in the late 1900s, based on utility and consumption of computer resources. Cloud computing involves deploying groups of remote servers and software networks that allow different kinds of data sources to be uploaded for real time processing to generate computing results without the need to store processed data on the local machine. Clouds can be classified as public, private or hybrid.<sup>[1][2]</sup>

### 1.1 Overview

Cloud computing<sup>[3]</sup> relies on sharing of resources to achieve coherence and economies of scale, similar to a utility (like the electricity grid) over a network.<sup>[2]</sup> 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 re-

sources 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 CAPEX model (buy the dedicated hardware and depreciate it over a period of time) to the OPEX model (use a shared cloud infrastructure and pay as one uses it).

Proponents claim that cloud computing allows companies to avoid upfront infrastructure costs, and focus on projects that differentiate their businesses instead of on infrastructure.<sup>[4]</sup> Proponents also 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.<sup>[4][5][6]</sup> Cloud providers typically use a “pay as you go” model. This can lead to unexpectedly high charges if administrators do not adapt to the cloud pricing model.<sup>[7]</sup>

The present 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 have led to a growth in cloud computing.<sup>[8][9][10]</sup> Companies can scale up as computing needs increase and then scale down again as demands decrease

Cloud vendors are experiencing growth rates of 50% per annum.<sup>[11]</sup>

### 1.2 History of cloud computing

### 1.2.1 Origin of the term

The origin of the term *cloud computing* is unclear. The expression *cloud* is commonly used in science to describe a large agglomeration of objects that visually appear from a distance as a cloud and describes any set of things whose details are not inspected further in a given context.<sup>[12]</sup> Another explanation is that the old programs to draw network schematics surrounded the icons for servers with a circle, and a cluster of servers in a network diagram had several overlapping circles, which resembled a cloud.<sup>[13]</sup>

In analogy to above usage the word *cloud* was used as a metaphor for the Internet and a standardized cloud-like shape was used to denote a network on telephony schematics and later to depict the Internet in *computer network diagrams*. With this simplification, the implication is that the specifics of how the end points of a network are connected are not relevant for the purposes of understanding the diagram. The cloud symbol was used to represent the Internet as early as 1994,<sup>[14][15]</sup> in which servers were then shown connected to, but external to, the cloud.

References to cloud computing in its modern sense appeared early as 1996, with the earliest known mention in a Compaq internal document.<sup>[16]</sup>

The popularization of the term can be traced to 2006 when Amazon.com introduced the Elastic Compute Cloud.<sup>[17]</sup>

### 1.2.2 The 1950s

The underlying concept of cloud computing dates to the 1950s, when large-scale *mainframe computers* were seen as the future of computing, and became available in academia and corporations, accessible via thin clients/terminal computers, often referred to as "dumb terminals", because they were used for communications but had no internal processing capacities. To make more efficient use of costly mainframes, a practice evolved that allowed multiple users to share both the physical access to the computer from multiple terminals as well as the CPU time. This eliminated periods of inactivity on the mainframe and allowed for a greater return on the investment. The practice of sharing CPU time on a mainframe became known in the industry as *time-sharing*.<sup>[18]</sup> During the mid 70s, time-sharing was popularly known as RJE (*Remote Job Entry*); this nomenclature was mostly associated with large vendors such as IBM and DEC. IBM developed the *VM Operating System* to provide time-sharing services.

### 1.2.3 The 1990s

In the 1990s, telecommunications companies, who previously offered primarily dedicated point-to-point data cir-

cuits, began offering *virtual private network* (VPN) services with comparable quality of service, but at a lower cost. By switching traffic as they saw fit to balance server use, they could use overall network bandwidth more effectively. They began to use the cloud symbol to denote the demarcation point between what the provider was responsible for and what users were responsible for. Cloud computing extends this boundary to cover all servers as well as the network infrastructure.<sup>[19]</sup>

As computers became more prevalent, scientists and technologists explored ways to make large-scale computing power available to more users through time-sharing. They experimented with algorithms to optimize the infrastructure, platform, and applications to prioritize CPUs and increase efficiency for end users.<sup>[20]</sup>

Since 2000 cloud computing has come into existence. In early 2008, *OpenNebula*, enhanced in the RESERVOIR European Commission-funded project, became the first open-source software for deploying private and hybrid clouds, and for the federation of clouds.<sup>[21]</sup> In the same year, efforts were focused on providing quality of service guarantees (as required by real-time interactive applications) to cloud-based infrastructures, in the framework of the IRMOS European Commission-funded project, resulting in a real-time cloud environment.<sup>[22]</sup> By mid-2008, Gartner saw an opportunity for cloud computing "to shape the relationship among consumers of IT services, those who use IT services and those who sell them"<sup>[23]</sup> and observed that "organizations are switching from company-owned hardware and software assets to per-use service-based models" so that the "projected shift to computing ... will result in dramatic growth in IT products in some areas and significant reductions in other areas."<sup>[24]</sup>

Microsoft Azure became available in late 2008.

In July 2010, *Rackspace Hosting* and *NASA* jointly launched an open-source cloud-software initiative known as *OpenStack*. The OpenStack project intended to help organizations offer cloud-computing services running on standard hardware. The early code came from NASA's *Nebula platform* as well as from Rackspace's *Cloud Files platform*.<sup>[25]</sup>

On March 1, 2011, IBM announced the *IBM SmartCloud* framework to support *Smarter Planet*.<sup>[26]</sup> Among the various components of the *Smarter Computing* foundation, cloud computing is a critical piece.

On June 7, 2012, Oracle announced the *Oracle Cloud*.<sup>[27]</sup> While aspects of the Oracle Cloud are still in development, this cloud offering is posed to be the first to provide users with access to an integrated set of IT solutions, including the Applications (SaaS), Platform (PaaS), and Infrastructure (IaaS) layers.<sup>[28][29][30]</sup>

### 1.3 Similar concepts

Cloud computing is the result of evolution and adoption of existing technologies and paradigms. The goal of cloud computing is to allow users to take benefit from all of these technologies, without the need for deep knowledge about or expertise with each one of them. The cloud aims to cut costs, and helps the users focus on their core business instead of being impeded by IT obstacles.<sup>[31]</sup>

The main enabling technology for cloud computing is virtualization. Virtualization software separates a physical computing device into one or more “virtual” devices, each of which can be easily used and managed to perform computing tasks. With operating system–level virtualization essentially creating a scalable system of multiple independent computing devices, idle computing resources can be allocated and used more efficiently. Virtualization provides the agility required to speed up IT operations, and reduces cost by increasing infrastructure utilization. Autonomic computing automates the process through which the user can provision resources on-demand. By minimizing user involvement, automation speeds up the process, reduces labor costs and reduces the possibility of human errors.<sup>[31]</sup>

Users routinely face difficult business problems. Cloud computing adopts concepts from **Service-oriented Architecture (SOA)** that can help the user break these problems into **services** that can be integrated to provide a solution. Cloud computing provides all of its resources as services, and makes use of the well-established standards and best practices gained in the domain of SOA to allow global and easy access to cloud services in a standardized way.

Cloud computing also leverages concepts from utility computing to provide **metrics** for the services used. Such metrics are at the core of the public cloud pay-per-use models. In addition, measured services are an essential part of the feedback loop in autonomic computing, allowing services to scale on-demand and to perform automatic failure recovery.

Cloud computing is a kind of **grid computing**; it has evolved by addressing the QoS (quality of service) and **reliability** problems. Cloud computing provides the tools and technologies to build data/compute intensive parallel applications with much more affordable prices compared to traditional parallel computing techniques.<sup>[31]</sup>

Cloud computing shares characteristics with:

- **Client–server model** — *Client–server computing* refers broadly to any distributed application that distinguishes between service providers (servers) and service requestors (clients).<sup>[32]</sup>
- **Grid computing** — “A form of distributed and parallel computing, whereby a ‘super and virtual computer’ is composed of a cluster of networked, loosely coupled computers acting in concert to perform very

large tasks.”

- **Mainframe computer** — Powerful computers used mainly by large organizations for critical applications, typically bulk data processing such as: census; industry and consumer statistics; police and secret intelligence services; enterprise resource planning; and financial transaction processing.
- **Utility computing** — The “packaging of computing resources, such as computation and storage, as a metered service similar to a traditional public utility, such as electricity.”<sup>[33][34]</sup>
- **Peer-to-peer** — A distributed architecture without the need for central coordination. Participants are both suppliers and consumers of resources (in contrast to the traditional client–server model).

### 1.4 Characteristics

Cloud computing exhibits the following key characteristics:

- **Agility** improves with users’ ability to re-provision technological infrastructure resources.
- **Cost** reductions claimed by cloud providers. A public-cloud delivery model converts capital expenditure to operational expenditure.<sup>[35]</sup> This purportedly lowers barriers to entry, as infrastructure is typically provided by a third party and does not need to be purchased for one-time or infrequent intensive computing tasks. Pricing on a utility computing basis is fine-grained, with usage-based options and fewer IT skills are required for implementation (in-house).<sup>[36]</sup> The e-FISCAL project’s state-of-the-art repository<sup>[37]</sup> contains several articles looking into cost aspects in more detail, most of them concluding that costs savings depend on the type of activities supported and the type of infrastructure available in-house.
- **Device and location independence**<sup>[38]</sup> enable users to access systems using a web browser regardless of their location or what device they use (e.g., PC, mobile phone). As infrastructure is off-site (typically provided by a third-party) and accessed via the Internet, users can connect from anywhere.<sup>[36]</sup>
- **Maintenance** of cloud computing applications is easier, because they do not need to be installed on each user’s computer and can be accessed from different places.
- **Multitenancy** enables sharing of resources and costs across a large pool of users thus allowing for:

- **centralization** of infrastructure in locations with lower costs (such as real estate, electricity, etc.)
- **peak-load capacity** increases (users need not engineer for highest possible load-levels)
- **utilisation and efficiency** improvements for systems that are often only 10–20% utilised.<sup>[39][40]</sup>
- **Performance** is monitored, and consistent and loosely coupled architectures are constructed using **web services** as the system interface.<sup>[36][41][42]</sup>
- **Productivity** may be increased when multiple users can work on the same data simultaneously, rather than waiting for it to be saved and emailed. Time may be saved as information does not need to be re-entered when fields are matched, nor do users need to install application software upgrades to their computer.<sup>[43]</sup>
- **Reliability** improves with the use of multiple redundant sites, which makes well-designed cloud computing suitable for **business continuity** and **disaster recovery**.<sup>[44]</sup>
- **Scalability and elasticity** via dynamic (“on-demand”) provisioning of resources on a fine-grained, self-service basis in near real-time<sup>[45][46]</sup> (Note, the VM startup time varies by VM type, location, OS and cloud providers<sup>[45]</sup>), without users having to engineer for peak loads.<sup>[47][48][49]</sup>
- **Security** can improve due to centralization of data, increased security-focused resources, etc., but concerns can persist about loss of control over certain sensitive data, and the lack of security for stored kernels. Security is often as good as or better than other traditional systems, in part because providers are able to devote resources to solving security issues that many customers cannot afford to tackle.<sup>[50]</sup> However, the complexity of security is greatly increased when data is distributed over a wider area or over a greater number of devices, as well as in multi-tenant systems shared by unrelated users. In addition, user access to security audit logs may be difficult or impossible. Private cloud installations are in part motivated by users’ desire to retain control over the infrastructure and avoid losing control of information security.

The National Institute of Standards and Technology's definition of cloud computing identifies “five 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.

*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).

*Resource pooling.* The provider’s computing resources are pooled to serve multiple consumers using a multi-tenant model, with different physical and virtual resources dynamically assigned and reassigned according to consumer demand.

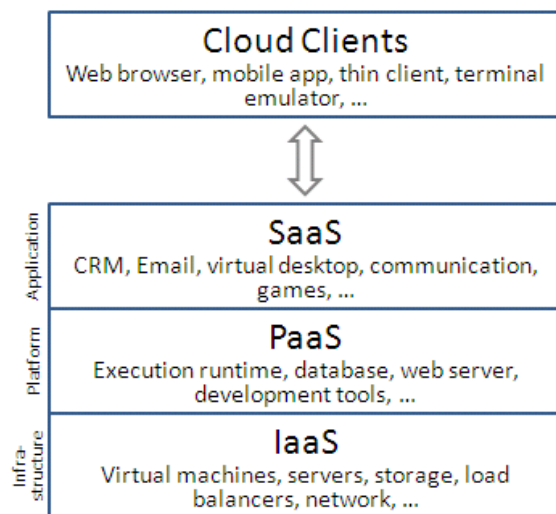
*Rapid elasticity.* Capabilities can be elastically provisioned and released, in some cases automatically, to scale rapidly outward and inward commensurate with demand. To the consumer, the capabilities available for provisioning often appear unlimited and can be appropriated in any quantity at any time.

*Measured service.* Cloud systems automatically control and optimize resource 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.

—National Institute of Standards and Technology<sup>[2]</sup>

## 1.5 Service models

Cloud computing providers offer their services according to several fundamental models:<sup>[2][51]</sup>





### 1.5.1 Infrastructure as a service (IaaS)

See also: [Category:Cloud infrastructure](#)

In the most basic cloud-service model & according to the IETF (Internet Engineering Task Force), providers of IaaS offer computers – physical or (more often) virtual machines – and other resources. (A hypervisor, such as Xen, Oracle VirtualBox, KVM, VMware ESX/ESXi, or Hyper-V runs the virtual machines as guests. Pools of hypervisors within the cloud operational support-system can support large numbers of virtual machines and the ability to scale services up and down according to customers' varying requirements.) IaaS clouds often offer additional resources such as a virtual-machine disk image library, raw block storage, and file or object storage, firewalls, load balancers, IP addresses, virtual local area networks (VLANs), and software bundles.<sup>[52]</sup> IaaS-cloud providers supply these resources on-demand from their large pools installed in data centers. For wide-area connectivity, customers can use either the Internet or carrier clouds (dedicated virtual private networks).

To deploy their applications, cloud users install operating-system images and their application software on the cloud infrastructure. In this model, the cloud user patches and maintains the operating systems and the application software. Cloud providers typically bill IaaS services on a utility computing basis: cost reflects the amount of resources allocated and consumed.<sup>[53][54][55] [56]</sup>

### 1.5.2 Platform as a service (PaaS)

Main article: [Platform as a service](#)  
See also: [Category:Cloud platforms](#)

In the PaaS models, cloud providers deliver a computing platform, typically including operating system, programming language execution environment, database, and web server. Application developers can develop and run their software solutions on a cloud platform without the cost and complexity of buying and managing the underlying hardware and software layers. With some PaaS offers like Microsoft Azure and Google App Engine, the underlying computer and storage resources scale automatically to match application demand so that the cloud user does not have to allocate resources manually. The latter has also been proposed by an architecture aiming to facilitate real-time in cloud environments.<sup>[57]</sup> Even more specific application types can be provided via PaaS, e.g., such as media encoding as provided by services as bitcodin transcoding cloud<sup>[58]</sup> or media.io.<sup>[59]</sup>

### 1.5.3 Software as a service (SaaS)

Main article: [Software as a service](#)

In the business model using software as a service (SaaS), users are provided access to application software and databases. Cloud providers manage the infrastructure and platforms that run the applications. SaaS is sometimes referred to as “on-demand software” and is usually priced on a pay-per-use basis or using a subscription fee.

In the SaaS model, cloud providers install and operate application software in the cloud and cloud users access the software from cloud clients. Cloud users do not manage the cloud infrastructure and platform where the application runs. This eliminates the need to install and run the application on the cloud user's own computers, which simplifies maintenance and support. Cloud applications are different from other applications in their scalability—which can be achieved by cloning tasks onto multiple virtual machines at run-time to meet changing work demand.<sup>[60]</sup> Load balancers distribute the work over the set of virtual machines. This process is transparent to the cloud user, who sees only a single access point. To accommodate a large number of cloud users, cloud applications can be *multitenant*, that is, any machine serves more than one cloud user organization.

The pricing model for SaaS applications is typically a monthly or yearly flat fee per user,<sup>[61]</sup> so price is scalable and adjustable if users are added or removed at any point.<sup>[62]</sup>

Proponents claim SaaS allows a business the potential to reduce IT operational costs by outsourcing hardware and software maintenance and support to the cloud provider. This enables the business to reallocate IT operations costs away from hardware/software spending and personnel expenses, towards meeting other goals. In addition, with applications hosted centrally, updates can be released without the need for users to install new software. One drawback of SaaS is that the users' data are stored on the cloud provider's server. As a result, there could be unauthorized access to the data. For this reason, users are increasingly adopting intelligent third-party key management systems to help secure their data.

## 1.6 Cloud clients

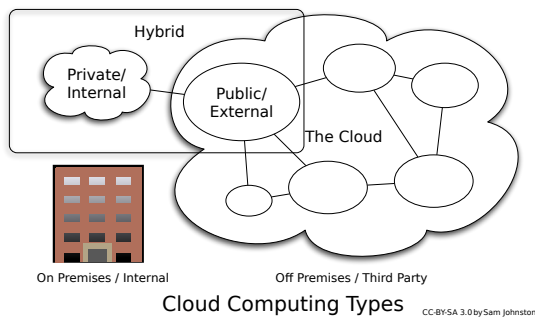
See also: [Category:Cloud clients](#)

Users access cloud computing using networked client devices, such as desktop computers, laptops, tablets and smartphones. Some of these devices – *cloud clients* – rely on cloud computing for all or a majority of their applications so as to be essentially useless without it. Examples are thin clients and the browser-based Chromebook. Many cloud applications do not require specific software



on the client and instead use a web browser to interact with the cloud application. With **Ajax** and **HTML5** these **Web user interfaces** can achieve a similar, or even better, **look and feel** to native applications. Some cloud applications, however, support specific client software dedicated to these applications (e.g., **virtual desktop** clients and most email clients). Some legacy applications (line of business applications that until now have been prevalent in thin client computing) are delivered via a screen-sharing technology.

## 1.7 Deployment models



Cloud computing types

### 1.7.1 Private cloud

Private cloud is cloud infrastructure operated solely for a single organization, whether managed internally or by a third-party, and hosted either internally or externally.<sup>[2]</sup> Undertaking a private cloud project requires a significant level and degree of engagement to virtualize the business environment, and requires the organization to reevaluate decisions about existing resources. When done right, it can improve business, but every step in the project raises security issues that must be addressed to prevent serious vulnerabilities.<sup>[63]</sup> Self-run data centers<sup>[64]</sup> are generally capital intensive. They have a significant physical footprint, requiring allocations of space, hardware, and environmental controls. These assets have to be refreshed periodically, resulting in additional capital expenditures. They have attracted criticism because users “still have to buy, build, and manage them” and thus do not benefit from less hands-on management,<sup>[65]</sup> essentially “[lacking] the economic model that makes cloud computing such an intriguing concept”.<sup>[66][67]</sup>

### 1.7.2 Public cloud

A cloud is called a “public cloud” when the services are rendered over a network that is open for public use. Public cloud services may be free.<sup>[68]</sup> Technically there may be little or no difference between public and private cloud

architecture, however, security consideration may be substantially different for services (applications, storage, and other resources) that are made available by a service provider for a public audience and when communication is effected over a non-trusted network. Saasu is a large public cloud. Generally, public cloud service providers like Amazon AWS, Microsoft and Google own and operate the infrastructure at their **data center** and access is generally via the Internet. AWS and Microsoft also offer direct connect services called “AWS Direct Connect” and “Azure ExpressRoute” respectively, such connections require customers to purchase or lease a private connection to a peering point offered by the cloud provider.<sup>[36]</sup>

### 1.7.3 Hybrid cloud

Hybrid cloud is a composition of two or more clouds (private, community or public) that remain distinct entities but are bound together, offering the benefits of multiple deployment models. Hybrid cloud can also mean the ability to connect collocation, managed and/or dedicated services with cloud resources.<sup>[2]</sup>

Gartner, Inc. defines a hybrid cloud service as a cloud computing service that is composed of some combination of private, public and community cloud services, from different service providers.<sup>[69]</sup> A hybrid cloud service crosses isolation and provider boundaries so that it can't be simply put in one category of private, public, or community cloud service. It allows one to extend either the capacity or the capability of a cloud service, by aggregation, integration or customization with another cloud service.

Varied use cases for hybrid cloud composition exist. For example, an organization may store sensitive client data in house on a private cloud application, but interconnect that application to a business intelligence application provided on a public cloud as a software service.<sup>[70]</sup> This example of hybrid cloud extends the capabilities of the enterprise to deliver a specific business service through the addition of externally available public cloud services. Hybrid cloud adoption depends on a number of factors such as data security and compliance requirements, level of control needed over data, and the applications an organization uses.<sup>[71]</sup>

Another example of hybrid cloud is one where IT organizations use public cloud computing resources to meet temporary capacity needs that can not be met by the private cloud.<sup>[72]</sup> This capability enables hybrid clouds to employ cloud bursting for scaling across clouds.<sup>[2]</sup> Cloud bursting is an application deployment model in which an application runs in a private cloud or data center and “bursts” to a public cloud when the demand for computing capacity increases. A primary advantage of cloud bursting and a hybrid cloud model is that an organization only pays for extra compute resources when they are needed.<sup>[73]</sup> Cloud bursting enables data centers to cre-

ate an in-house IT infrastructure that supports average workloads, and use cloud resources from public or private clouds, during spikes in processing demands.<sup>[74]</sup>

## 1.7.4 Others

### Community cloud

Community cloud shares infrastructure between several organizations from a specific community with common concerns (security, compliance, jurisdiction, etc.), whether managed internally or by a third-party, and either hosted internally or externally. The costs are spread over fewer users than a public cloud (but more than a private cloud), so only some of the cost savings potential of cloud computing are realized.<sup>[2]</sup>

### Distributed cloud

Cloud computing can also be provided by a distributed set of machines that are running at different locations, while still connected to a single network or hub service. Examples of this include distributed computing platforms such as BOINC and Folding@Home. An interesting attempt in such direction is Cloud@Home, aiming at implementing cloud computing provisioning model on top of voluntarily shared resources<sup>[75]</sup>

### Intercloud

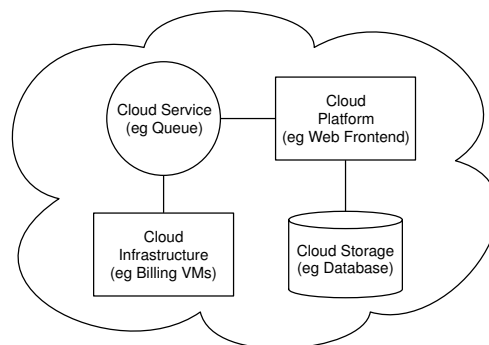
Main article: Intercloud

The Intercloud<sup>[76]</sup> is an interconnected global “cloud of clouds”<sup>[77][78]</sup> and an extension of the Internet “network of networks” on which it is based. The focus is on direct interoperability between public cloud service providers, more so than between providers and consumers (as is the case for hybrid- and multi-cloud).<sup>[79][80][81]</sup>

### Multicloud

Main article: Multicloud

Multicloud is the use of multiple cloud computing services in a single heterogeneous architecture to reduce reliance on single vendors, increase flexibility through choice, mitigate against disasters, etc. It differs from hybrid cloud in that it refers to multiple cloud services, rather than multiple deployment modes (public, private, legacy).<sup>[82][83]</sup>



Cloud computing sample architecture

## 1.8 Architecture

**Cloud architecture**,<sup>[84]</sup> the systems architecture of the software systems involved in the delivery of cloud computing, typically involves multiple *cloud components* communicating with each other over a loose coupling mechanism such as a messaging queue. Elastic provision implies intelligence in the use of tight or loose coupling as applied to mechanisms such as these and others.

### 1.8.1 Cloud engineering

**Cloud engineering** is the application of engineering disciplines to cloud computing. It brings a systematic approach to the high-level concerns of commercialization, standardization, and governance in conceiving, developing, operating and maintaining cloud computing systems. It is a multidisciplinary method encompassing contributions from diverse areas such as systems, software, web, performance, information, security, platform, risk, and quality engineering.

## 1.9 Security and privacy

Main article: Cloud computing issues

Cloud computing poses privacy concerns because the service provider can access the data that is on the cloud at any time. It could accidentally or deliberately alter or even delete information.<sup>[85]</sup> Many cloud providers can share information with third parties if necessary for purposes of law and order even without a warrant. That is permitted in their privacy policies which users have to agree to before they start using cloud services.<sup>[86]</sup> Solutions to privacy include policy and legislation as well as end users’ choices for how data is stored.<sup>[85]</sup> Users can encrypt data that is processed or stored within the cloud to prevent unauthorized access.<sup>[85]</sup>

According to the Cloud Security Alliance, the top three

threats in the cloud are “Insecure Interfaces and APIs”, “Data Loss & Leakage”, and “Hardware Failure” which accounted for 29%, 25% and 10% of all cloud security outages respectively - together these form shared technology vulnerabilities. In a cloud provider platform being shared by different users there may be a possibility that information belonging to different customers resides on same data server. Therefore Information leakage may arise by mistake when information for one customer is given to other.<sup>[87]</sup> Additionally, Eugene Schultz, chief technology officer at Emagined Security, said that hackers are spending substantial time and effort looking for ways to penetrate the cloud. “There are some real Achilles’ heels in the cloud infrastructure that are making big holes for the bad guys to get into”. Because data from hundreds or thousands of companies can be stored on large cloud servers, hackers can theoretically gain control of huge stores of information through a single attack — a process he called “hyperjacking”.

There is the problem of legal ownership of the data (If a user stores some data in the cloud, can the cloud provider profit from it?). Many Terms of Service agreements are silent on the question of ownership.<sup>[88]</sup>

Physical control of the computer equipment (private cloud) is more secure than having the equipment off site and under someone else’s control (public cloud). This delivers great incentive to public cloud computing service providers to prioritize building and maintaining strong management of secure services.<sup>[89]</sup> Some small businesses that don't have expertise in IT security could find that it’s more secure for them to use a public cloud.

There is the risk that end users don't understand the issues involved when signing on to a cloud service (persons sometimes don't read the many pages of the terms of service agreement, and just click “Accept” without reading). This is important now that cloud computing is becoming popular and required for some services to work, for example for an intelligent personal assistant (Apple’s Siri or Google Now).

Fundamentally private cloud is seen as more secure with higher levels of control for the owner, however public cloud is seen to be more flexible and requires less time and money investment from the user.<sup>[90]</sup>

## 1.10 The future

According to Gartner’s Hype cycle, cloud computing has reached a maturity that leads it into a productive phase. This means that most of the main issues with cloud computing have been addressed to a degree that clouds have become interesting for full commercial exploitation. This however does not mean that all the problems listed above have actually been solved, only that the according risks can be tolerated to a certain degree.<sup>[91]</sup> Cloud computing is therefore still as much a research topic, as it is a

market offering.<sup>[92]</sup> What is clear through the evolution of Cloud Computing services is that the CTO is a major driving force behind Cloud adoption.<sup>[93]</sup> The major Cloud technology developers continue to invest billions a year in Cloud R&D; for example, in 2011 Microsoft committed 90% of its \$9.6bn R&D budget to Cloud.<sup>[94]</sup>

## 1.11 The cloud revolution is underway

Companies around the world are taking the turn of the cloud. According to estimates of Skyhigh Networks editor (cloud security tools), organizations use an average of 545 cloud hosting services to a total data exabyte. For most of them, the cloud is the future of IT, bringing with it unprecedented flexibility and efficiency. According to figures from Dell Global Technology Adoption Index, the revolution is already well underway with 97% of companies using or planning to use cloud, transforming their technology models and business processes. **Cloud Technology**

## 1.12 See also

- Category:Cloud computing providers
- Category:Cloud platforms
- Cloud computing comparison
- Cloud management
- Cloud research
- Cloud storage
- Edge computing
- Fog computing
- Grid computing
- eScience
- iCloud
- Mobile cloud computing
- Personal cloud
- Robot as a Service
- Service-Oriented Architecture
- Synaptop
- Ubiquitous computing
- Web computing

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## 1.14 External links



## Chapter 2

# Platform as a service

**Platform as a service (PaaS)** is a category of **cloud computing services** that provides a **platform** allowing customers to develop, run and manage **Web applications** without the complexity of building and maintaining the infrastructure typically associated with developing and launching an app.<sup>[1][2][3]</sup> PaaS can be delivered in two ways: as a public cloud service from a provider, where the consumer controls software deployment and configuration settings, and the provider provides the networks, servers, storage and other services to host the consumer's application; or as software installed in private data centers or public infrastructure as a service and managed by internal IT departments.<sup>[4][5]</sup>

### 2.1 Development and uses

Fotango, a London (Old Street) based company owned by Canon Europe launched the world's first public platform as a service known as 'Zimki'. Developed in 2005 with a beta launch in March 2006 and a public launch at EuroOSCON in 2006.<sup>[6]</sup> Zimki was an end to end JavaScript web application development and utility computing platform that removed all the repetitive tasks encountered when creating web applications and web services. All aspects of infrastructure and operations from setting up servers, scaling, configuration, security and backups were done automatically by Zimki, enabling developers to get on with doing what they enjoy: writing code. Zimki introduced the tagline 'Pre-Shaved Yaks'<sup>[7]</sup> to describe the removal of all these repetitive tasks that got in the way of coding.<sup>[8]</sup>

Zimki was a pure play 'pay as you go' platform which enabled developers to build and deploy applications without incurring any start-up costs on a true utility based computing platform. Charging was done on storage used, network traffic and JSOPs (Javascript Operations). It provided a multi-tenant platform where developers created entire applications (front and back end through SSJS) using a single language - Javascript, with all development and application control exposed through APIs and a range of component services from a NoSQL object store to Message Queue services.<sup>[9]</sup> Furthermore all functions within Zimki could be exposed as web services and Zimki

provided billing analysis down to individual functions.

Whilst the Zimki platform was rapidly growing and Fotango was profitable, the parent company decided this area was not core<sup>[10]</sup> and the service was closed in Dec 2007.<sup>[11]</sup> At the time of its closure, Zimki had several thousand developer accounts and had demonstrated the technical viability of Platform as a Service but also provided the first example of the perils of being dependent upon a single provider.<sup>[12]</sup> This risk had been highlighted in July 2007, when the CEO gave a presentation on Zimki at OSCON 2007 which announced that Zimki would no longer be open sourced and discussed the future of what was then called Framework as a Service (later renamed to Platform as A Service) covering the importance of a market of providers based upon an open source reference model<sup>[13]</sup>

In April 2008, Google launched App Engine, with a free trial version limited to 10,000 developers.<sup>[14]</sup> This was said to have "turned the Internet cloud computing space into a fully-fledged industry virtually overnight."<sup>[15]</sup>

The original intent of PaaS was to simplify the code-writing process for developers, with the infrastructure and operations handled by the PaaS provider. Originally, all PaaSes were in the public cloud. Because many companies did not want to have everything in the public cloud, private and hybrid PaaS options (managed by internal IT departments) were created.<sup>[16]</sup>

PaaS provides an environment for developers and companies to create, host and deploy applications, saving developers from the complexities of the infrastructure side (setting up, configuring and managing elements such as servers and databases). PaaS can improve the speed of developing an app, and allow the consumer to focus on the application itself. With PaaS, the consumer manages applications and data, while the provider (in public PaaS) or IT department (in private PaaS) manages runtime, middleware, operating system, virtualization, servers, storage and networking.<sup>[4][17]</sup> Development tools provided by the vendor are customized according to the needs of the user.<sup>[18]</sup> The user can choose to maintain the software, or have the vendor maintain it.<sup>[4]</sup>

PaaS offerings may also include facilities for application design, application development, testing and deployment,

as well as services such as team collaboration, web service integration, and **marshalling**, database integration, security, scalability, storage, persistence, state management, application versioning, application instrumentation, and developer community facilitation. Besides the service engineering aspects, PaaS offerings include mechanisms for service management, such as monitoring, workflow management, discovery and reservation.<sup>[19][20]</sup>

## 2.2 Advantages and disadvantages

The advantages to PaaS are primarily that it allows for higher-level programming with dramatically reduced complexity; the overall development of the application can be more effective, as it has built-in infrastructure; and maintenance and enhancement of the application is easier.<sup>[3]</sup> It can also be useful in situations where multiple developers are working on a single project involving parties who are not located nearby.<sup>[2]</sup>

The primary disadvantage would be the possibility of being locked in to a certain platform. However, most PaaSes are relatively lock-in free.<sup>[15]</sup>

## 2.3 Types

### 2.3.1 Public, private and hybrid

There are several types of PaaS, including public, private and hybrid.<sup>[16]</sup> PaaS was originally intended as an application solution in the public cloud, before expanding to include private and hybrid options.<sup>[16]</sup>

Public PaaS is derived from **software as a service (SaaS)**,<sup>[14]</sup> and is situated in cloud computing between SaaS and **infrastructure as a service (IaaS)**.<sup>[1]</sup> SaaS is software that is hosted in the cloud, so that it doesn't take up hard drive or server space. IaaS provides virtual storage from a provider with adjustable scalability.<sup>[1]</sup> With IaaS, the user still has to manage the server, whereas with PaaS the server management is done by the provider.<sup>[21]</sup>

A private PaaS can typically be downloaded and installed either on a company's on-premises infrastructure, or in a public cloud. Once the software is installed on one or more machines, the private PaaS arranges the application and database components into a single hosting platform.<sup>[22]</sup> Private PaaS vendors include **Apprenda**, which started out on the Microsoft .NET platform before rolling out a Java PaaS; **Red Hat's OpenShift** and **Pivotal Cloud Foundry**.<sup>[23]</sup> Apprenda and Microsoft are considered to be two of the only PaaSes that provide superior .NET support.<sup>[16]</sup>

### 2.3.2 Mobile PaaS

Initiated in 2012, mobile PaaS (mPaaS) provides development capabilities for mobile app designers and developers.<sup>[24]</sup> The **Yankee Group** identified mPaaS as one of its themes for 2014, naming a number of providers including **Kinvey**, **Kumulos** [www.kumulos.com](http://www.kumulos.com) **CloudMine**, **AnyPresence**, **FeedHenry**, **FatFractal** and **Point.io**.<sup>[25][26]</sup>

### 2.3.3 Open PaaS

Open PaaS does not include hosting, but rather it provides open source software allowing a PaaS provider to run applications in an open source environment. For example, **AppScale** allows a user to deploy some applications written for **Google App Engine** to their own servers, providing datastore access from a standard SQL or NoSQL database. Some open platforms let the developer use any programming language, database, operating system or server to deploy their applications.<sup>[27][28]</sup>

### 2.3.4 PaaS for Rapid Development

In 2014, **Forrester Research** defined Enterprise Public Cloud Platforms for Rapid Developers as an emerging trend, naming a number of providers including **OutSystems**, **Mendix**, **Salesforce.com**, and **Acquia**.<sup>[29]</sup>

### 2.3.5 System types

PaaS is found on the following types of systems:

**Add-on development facilities** These facilities customize existing SaaS applications, often requiring PaaS developers and their users to purchase subscriptions to the add-on SaaS application.<sup>[30]</sup>

**Stand alone environments** Stand-alone PaaS environments do not include technical, licensing or financial dependencies on specific SaaS applications or web services, and are intended to provide a generalized development environment.<sup>[30]</sup>

**Application delivery-only environments** Delivery-only PaaS offerings generally focus on hosting services, such as security and on-demand scalability. The service does not include development, debugging and test capabilities, though they may be supplied offline (via an **Eclipse** plugin, for example).<sup>[30]</sup>

## 2.4 Providers

There are various types of PaaS providers. All offer application hosting and a deployment environment, along with various integrated services. Services offer varying levels of scalability and maintenance.<sup>[15]</sup> Developers can write an application and upload it to a PaaS that supports their software language of choice, and the application runs on that PaaS.<sup>[31]</sup>

Public PaaS providers and private PaaS vendors include:

- ActiveState
- Aerobatic
- ApperIQ
- Apprenda
- AppScale
- AWS Elastic Beanstalk
- Cloud Foundry
- CloudControl
- Cloudera
- Distelli
- Corvisa
- Engine Yard
- Google App Engine
- Heroku
- IBM Bluemix
- Jelastic
- Microsoft Azure Web Sites, Azure Cloud Services, Azure Mobile Services
- Mendix
- OpenShift
- Oracle
- OutSystems
- Pivotal Software
- Progress\_Software
  - Previously considered as SaaS, but now as PaaS as well
- QlikView
- Ragic
- Rollbase
- Salesforce.com
- SAP HANA Cloud Platform (HCP)
- WaveMaker

## 2.5 See also

- Network as a service
- Software as a service
- Infrastructure as a service
- Mobile Backend as a service

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## Chapter 3

# Software as a service

**Software as a service (SaaS;** pronounced /sæs/ or /sa:s/<sup>[1]</sup>) is a software licensing and delivery model in which software is licensed on a subscription basis and is centrally hosted.<sup>[2][3]</sup> It is sometimes referred to as “on-demand software”.<sup>[4]</sup> SaaS is typically accessed by users using a thin client via a web browser. SaaS has become a common delivery model for many business applications, including office and messaging software, payroll processing software, DBMS software, management software, CAD software, development software, gamification, virtualization,<sup>[4]</sup> accounting, collaboration, customer relationship management (CRM), management information systems (MIS), enterprise resource planning (ERP), invoicing, human resource management (HRM), content management (CM) and service desk management.<sup>[5]</sup> SaaS has been incorporated into the strategy of all leading enterprise software companies. One of the biggest selling points for these companies is the potential to reduce IT support costs by outsourcing hardware and software maintenance and support to the SaaS provider.

According to a Gartner Group estimate, SaaS sales in 2010 reached \$10 billion, and were projected to increase to \$12.1bn in 2011, up 20.7% from 2010.<sup>[6]</sup> Gartner Group estimates that SaaS revenue will be more than double its 2010 numbers by 2015 and reach a projected \$21.3bn. Customer relationship management (CRM) continues to be the largest market for SaaS. SaaS revenue within the CRM market was forecast to reach \$3.8bn in 2011, up from \$3.2bn in 2010.<sup>[7]</sup>

The term “software as a service” (SaaS) is considered to be part of the nomenclature of cloud computing, along with infrastructure as a service (IaaS), platform as a service (PaaS), desktop as a service (DaaS), backend as a service (BaaS), and information technology management as a service (ITMaaS).<sup>[8]</sup>

### 3.1 History

Centralized hosting of business applications dates back to the 1960s. Starting in that decade, IBM and other mainframe providers conducted a service bureau business, often referred to as time-sharing or utility comput-

ing. Such services included offering computing power and database storage to banks and other large organizations from their worldwide data centers.

The expansion of the Internet during the 1990s brought about a new class of centralized computing, called Application Service Providers (ASP). ASPs provided businesses with the service of hosting and managing specialized business applications, with the goal of reducing costs through central administration and through the solution provider’s specialization in a particular business application. Two of the world’s pioneers and largest ASPs were USI, which was headquartered in the Washington, D.C. area, and Futurelink Corporation, headquartered in Irvine, California.<sup>[9]</sup>

Software as a service essentially extends the idea of the ASP model. The term *Software as a Service (SaaS)*, however, is commonly used in more specific settings:

- Whereas most initial ASPs focused on managing and hosting third-party independent software vendors’ software, as of 2012 SaaS vendors typically develop and manage their own software.
- Whereas many initial ASPs offered more traditional client-server applications, which require installation of software on users’ personal computers, SaaS solutions of today rely predominantly on the Web and only require a web browser to use.
- Whereas the software architecture used by most initial ASPs mandated maintaining a separate instance of the application for each business, as of 2012 SaaS solutions normally utilize a multi-tenant architecture, in which the application serves multiple businesses and users, and partitions its data accordingly.

The acronym allegedly first appeared in an article called “Strategic Backgrounder: Software As A Service,” internally published in February 2001 by the Software & Information Industry Association’s (SIIA) eBusiness Division.<sup>[10]</sup>

DbaaS (Database as a Service) has emerged as a sub-variety of SaaS.<sup>[11]</sup>



## 3.2 Distribution

The Cloud (or SaaS) model has no physical need for indirect distribution since it is not distributed physically and is deployed almost instantaneously. The first wave of SaaS companies built their own economic model without including partner remuneration in their pricing structure (except when there were certain existing affiliations). It has not been easy for traditional software publishers to enter into the SaaS model. Firstly, because the SaaS model does not bring them the same income structure, secondly, because continuing to work with a distribution network was decreasing their profit margins and was damaging to the competitiveness of their product pricing. Today a landscape is taking shape with SaaS and managed service players who combine the indirect sales model with their own existing business model, and those who seek to redefine their role within the 3.0 IT economy.<sup>[12]</sup>

## 3.3 Pricing

Unlike traditional software which is conventionally sold as a perpetual license with an up-front cost (and an optional ongoing support fee), SaaS providers generally price applications using a subscription fee, most commonly a monthly fee or an annual fee.<sup>[13]</sup> Consequently, the initial setup cost for SaaS is typically lower than the equivalent enterprise software. SaaS vendors typically price their applications based on some usage parameters, such as the number of users using the application. However, because in a SaaS environment customers' data reside with the SaaS vendor, opportunities also exist to charge per transaction, event, or other unit of value, such as the number of processors required.<sup>[14]</sup>

The relatively low cost for user provisioning (i.e., setting up a new customer) in a multi-tenant environment enables some SaaS vendors to offer applications using the freemium model.<sup>[14]</sup> In this model, a free service is made available with limited functionality or scope, and fees are charged for enhanced functionality or larger scope.<sup>[14]</sup> Some other SaaS applications are completely free to users, with revenue being derived from alternate sources such as advertising.<sup>[15]</sup>

A key driver of SaaS growth is SaaS vendors' ability to provide a price that is competitive with on-premises software. This is consistent with the traditional rationale for outsourcing IT systems, which involves applying economies of scale to application operation, i.e., an outside service provider may be able to offer better, cheaper, more reliable applications.

## 3.4 Architecture

The vast majority of SaaS solutions are based on a multi-tenant architecture. With this model, a single version of the application, with a single configuration (hardware, network, operating system), is used for all customers ("tenants"). To support scalability, the application is installed on multiple machines (called horizontal scaling). In some cases, a second version of the application is set up to offer a select group of customers with access to pre-release versions of the applications (e.g., a beta version) for testing purposes. This is contrasted with traditional software, where multiple physical copies of the software — each potentially of a different version, with a potentially different configuration, and often customized — are installed across various customer sites.

While an exception rather than the norm, some SaaS solutions do not use multi-tenancy, or use other mechanisms—such as virtualization—to cost-effectively manage a large number of customers in place of multi-tenancy.<sup>[16]</sup> Whether multi-tenancy is a necessary component for software-as-a-service is a topic of controversy.<sup>[17]</sup>

## 3.5 Characteristics

While not all software-as-a-service applications share all traits, the characteristics below are common among many SaaS applications:

### 3.5.1 Configuration and customization

SaaS applications similarly support what is traditionally known as application *customization*. In other words, like traditional enterprise software, a single customer can alter the set of configuration options (a.k.a., parameters) that affect its functionality and look-and-feel. Each customer may have its own settings (or: parameter values) for the configuration options. The application can be customized to the degree it was designed for based on a set of predefined configuration options.

For example: to support customers' common need to change an application's look-and-feel so that the application appears to be having the customer's brand (or— if so desired—co-branded), many SaaS applications let customers provide (through a self service interface or by working with application provider staff) a custom logo and sometimes a set of custom colors. The customer cannot, however, change the page layout unless such an option was designed for.



### 3.5.2 Accelerated feature delivery

SaaS applications are often updated more frequently than traditional software,<sup>[18]</sup> in many cases on a weekly or monthly basis. This is enabled by several factors:

- *The application is hosted centrally, so an update is decided and executed by the provider, not by customers.*
- The application only has a single configuration, making development testing faster.
- The application vendor does not have to expend resources updating and maintaining backdated versions of the software, since there is only a single version.<sup>[19]</sup>
- The application vendor has access to all customer data, expediting design and regression testing.
- The solution provider has access to user behavior within the application (usually via web analytics), making it easier to identify areas worthy of improvement.

Accelerated feature delivery is further enabled by agile software development methodologies.<sup>[20]</sup> Such methodologies, which have evolved in the mid-1990s, provide a set of software development tools and practices to support frequent software releases.

### 3.5.3 Open integration protocols

Since SaaS applications cannot access a company's internal systems (databases or internal services), they predominantly offer integration protocols and application programming interfaces (APIs) that operate over a wide area network. Typically, these are protocols based on HTTP, REST, SOAP and JSON.

The ubiquity of SaaS applications and other Internet services and the standardization of their API technology has spawned development of mashups, which are lightweight applications that combine data, presentation and functionality from multiple services, creating a compound service. Mashups further differentiate SaaS applications from on-premises software as the latter cannot be easily integrated outside a company's firewall.

### 3.5.4 Collaborative (and “social”) functionality

Inspired by the success of online social networks and other so-called *web 2.0* functionality, many SaaS applications offer features that let its users collaborate and share information.

For example, many project management applications delivered in the SaaS model offer—in addition to traditional project planning functionality—collaboration features letting users comment on tasks and plans and share documents within and outside an organization. Several other SaaS applications let users vote on and offer new feature ideas.

While some collaboration-related functionality is also integrated into on-premises software, (implicit or explicit) collaboration between users or different customers is only possible with centrally hosted software.

## 3.6 Adoption drivers

Several important changes to the software market and technology landscape have facilitated acceptance and growth of SaaS solutions:

- The growing use of web-based user interfaces by applications, along with the proliferation of associated practices (e.g., web design), continuously decreased the need for traditional client-server applications. Consequently, traditional software vendor's investment in software based on fat clients has become a disadvantage (mandating ongoing support), opening the door for new software vendors offering a user experience perceived as more “modern”.
- The standardization of web page technologies (HTML, JavaScript, CSS), the increasing popularity of web development as a practice, and the introduction and ubiquity of web application frameworks like Ruby on Rails or Laravel (PHP) gradually reduced the cost of developing new SaaS solutions, and enabled new solution providers to come up with competitive solutions, challenging traditional vendors.
- The increasing penetration of broadband Internet access enabled remote centrally hosted applications to offer speed comparable to on-premises software.
- The standardization of the HTTPS protocol as part of the web stack provided universally available lightweight security that is sufficient for most everyday applications.
- The introduction and wide acceptance of lightweight integration protocols such as REST and SOAP enabled affordable integration between SaaS applications (residing in the cloud) with internal applications over wide area networks and with other SaaS applications.

### 3.7 Adoption challenges

Some limitations slow down the acceptance of SaaS and prohibit it from being used in some cases:

- Since data are being stored on the vendor's servers, data security becomes an issue.<sup>[21]</sup>
- **SaaS** applications are hosted in the cloud, far away from the application users. This introduces latency into the environment; so, for example, the SaaS model is not suitable for applications that demand response times in the milliseconds.
- Multi-tenant architectures, which drive cost efficiency for SaaS solution providers, limit customization of applications for large clients, inhibiting such applications from being used in scenarios (applicable mostly to large enterprises) for which such customization is necessary.
- Some business applications require access to or integration with customer's current data. When such data are large in volume or sensitive (e.g., end users' personal information), integrating them with remotely hosted software can be costly or risky, or can conflict with data governance regulations.
- Constitutional search/seizure warrant laws do not protect all forms of SaaS dynamically stored data. The end result is that a link is added to the chain of security where access to the data, and, by extension, misuse of these data, are limited only by the assumed honesty of 3rd parties or government agencies able to access the data on their own recognizance.<sup>[22][23][24][25]</sup>
- Switching SaaS vendors may involve the slow and difficult task of transferring very large data files over the Internet.
- Organizations that adopt SaaS may find they are forced into adopting new versions, which might result in unforeseen training costs or an increase in probability that a user might make an error.
- Relying on an Internet connection means that data are transferred to and from a SaaS firm at Internet speeds, rather than the potentially higher speeds of a firm's internal network.<sup>[26]</sup>

The standard model also has limitations:

- Compatibility with hardware, other software, and operating systems.<sup>[27]</sup>
- Licensing and compliance problems (unauthorized copies of the software program putting the organization at risk of fines or litigation).
- Maintenance, support, and patch revision processes.

- Can the SaaS hosting company guarantee the uptime level agreed in the SLA (Service Level Agreement)?

### 3.8 Emerging trends

As a result of widespread fragmentation in the SaaS provider space,<sup>[28]</sup> there is an emerging trend towards the development of SaaS Integration Platforms (SIP).<sup>[29]</sup> These SIPs allow subscribers to access multiple SaaS applications through a common platform. They also offer new application developers an opportunity to quickly develop and deploy new applications. This trend is being referred to as the "third wave" in software adoption - where SaaS moves beyond standalone applications to become a comprehensive platform. Zoho and SutiSoft are two companies that offer comprehensive SIPs today. Several other industry players, including Salesforce, Microsoft, and Oracle are aggressively developing similar integration platforms. Another trend deals with the rise of software products that combine functions for human resource management, payroll accounting, and expense management as an all-in-one solution in promoting collaboration between an employer and an employee. This supplements the ongoing effort of many businesses to create Employee Self-Service tools for their workforce.

### 3.9 Data escrow

*Software as a service data escrow* is the process of keeping a copy of critical software-as-a-service application data with an independent third party. Similar to source code escrow, where critical software source code is stored with an independent third party, SaaS data escrow is the same logic applied to the data within a SaaS application. It allows companies to protect and insure all the data that resides within SaaS applications, protecting against data loss.<sup>[30]</sup>

There are many and varied reasons for considering SaaS data escrow including concerns about vendor [bankruptcy]<sup>[31]</sup> unplanned service outages and potential data loss or corruption. Many businesses are also keen to ensure that they are complying with their own data governance standards or want improved reporting and business analytics against their SaaS data. A research conducted by Clearpace Software Ltd. into the growth of SaaS showed that 85 percent of the participants wanted to take a copy of their SaaS data. A third of these participants wanted a copy on a daily basis.<sup>[32]</sup>

### 3.10 Criticism

One notable criticism of SaaS comes from Richard Stallman of the Free Software Foundation referring to it as

Service as a Software Substitute (SaaS).<sup>[33]</sup> He considers the use of SaaS to be a violation of the principles of free software.<sup>[34]</sup> According to Stallman,

With SaaS, the users do not have a copy of the executable file: it is on the server, where the users can't see or touch it. Thus it is impossible for them to ascertain what it really does, and impossible to change it. SaaS inherently gives the server operator the power to change the software in use, or the users' data being operated on.

This criticism does not apply to all SaaS products. In 2010, *Forbes* contributor Dan Woods noted that Drupal Gardens, a free web hosting platform based on the open source Drupal content management system, is a “new open source model for SaaS”. He added, “Open source provides the escape hatch. In Drupal Gardens, users will be able to press a button and get a source code version of the Drupal code that runs their site along with the data from the database. Then, you can take that code, put it up at one of the hosting companies, and you can do anything that you would like to do.”<sup>[35]</sup>

Andrew Hoppin, a former Chief Information Officer for the New York State Senate, refers to this combination of SaaS and open source software as OpenSaaS and points to WordPress as another successful example of an Open-SaaS software delivery model that gives customers “the best of both worlds, and more options. The fact that it is open source means that they can start building their websites by self-hosting WordPress and customizing their website to their heart's content. Concurrently, the fact that WordPress is SaaS means that they don't have to manage the website at all -- they can simply pay WordPress.com to host it.”<sup>[36]</sup>

### 3.11 See also

- Servicizing
- Cloud-based integration
- Application service provider

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B., John Reaves, Scwlong, Wynand.winterbach, Nabeez, Mike hayes, Tped, Frap, StefanB sv, Jacob Poon, OSborn, Uozef, Billytkid, Gvnyar, LuchoX, Abrahami, Speedplane, Valenciano, Preetesh.rao, Dreadstar, Drphilharmonic, DMacks, Shswanson, Vina-iwbot-enwiki, Bejnar, Vasily Faronov, Spiritia, KenCavallon, Acrooney, ArglebargleIV, AbdullahHaydar, Harryboyles, Gandalf44, JzG, Kuru, Oskilian, Tomhubbard, Gobonobo, Darktemplar, Robofish, JoshuaZ, Kashmiri, Minna Sora no Shita, IronGargoyle, Ckatz, Kompere, Beetstra, Mr Stephen, Ehheh, Larrymcp, Optakeover, Wagggers, TastyPoutine, Dr.K., Kvng, Belfry, Keahapana, Hu12, Meitar, Quaeler, SpoNman, Jonasalmeida, IvanLanin, UncleDouggy, Rnb, Mjboniface, Majora4, Courcelles, Dlohcierekim, Chris55, Patrickwooldridge, FatalError, JForget, VoxLuna, Ourhistory153, Randhirreddy, Earthlyreason, Eric, JohnCD, Bill.albing, Kmrmgill, NaBUru38, Flood6, Sanspeur, WeisheitSuchen, Alexamies, Myasuda, Metatinara, Jehfes, Rotiro, Yaris678, Cydebot, Mblumber, MC10, UncleBubba, Anthonyhcole, GREvolution824, Dancter, Clovis Sangrail, Christian75, Ameliorate!, Kozuch, Neustradamus, Casliber, Malleus Fatuorum, Thijs!bot, Epbr123, Kubanczyk, Dschrader, Wikid77, Vicweast, Shoabinz, Ugarit, Vondruska, Vertium, John254, James086, Edchi, EdJohnston, Nick Number, Bob.gourley@comcast.net, Heroeswithmetaphors, Tree Hugger, Dawnseeker2000, Escarbot, Porqin, MrMarmite, Seaphoto, Shirt58, Marokwitz, Smartse, Dinferno, Silver seren, MrKG, Lbecque, DaudSharif, Tangurena, Dougher, Berek, MER-C, Dsp13, Jldupont-enwiki, MB1972, Mwarren us, Rms77, Ispabierto, Greensburger, East718, Ny156uk, Spojrzzenie, Magioladitis, Swikid, Bongwarrior, Lmbhull, JamesBWatson, Mathematrucker, GaryGo, Steven Walling, Cic, ForthOK, Jeffsnx, Hamiltonstone, Be-nice:-), Pleft, Kibbled bits, Cpl Syx, Balaarjunan, SBunce, JaGa, Kgfleischmann, Philg88, Piko-las, Zevnik, Curtbeckmann, Pisapatis, Dezrtluer, CliffC, Iamthenewno2, Casieg, CitizenB, Parveson, Jack007, Xiler, Bus stop, Vermtt, Miguelcaldas, Alankc, Mariolina, Linuxbabu-enwiki, JonathanReinhart, Tgeairn, J.delanoy, PCock, Trusilver, Anandcv, Vpfaiz, Uncle Dick, Maurice Carbonaro, Jesant13, Ginsengbomb, Mathglot, Jarrad Lewis, Tsmitty31, Betswiki, Tonyshan, Staceyeschneider, NewEng-landYankee, Quantling, BostonRed, Biglovinb, Olegwiki, Bshende, KylieTastic, Raspalchima, HenryLarsen, Paulmmn, Songjin, Bonadea, Pegordon, Swolfsg, Idioma-bot, Laurenced, Martin.ashcroft, Imtiyazali4all, Bobwhitten, Obdurodon, Huygens 25, Vranak, 28bytes, VolkovBot, Jeff G., Dogbertwp, Edeskonline, Bkengland, Priyo123, FatUglyJo, Nylo, Philip Trueman, A.Ward, TXiKiBoT, Itangalo, Vip-inhari, Technopat, Guillaume2303, Anonymous Dissident, Danielchalef, Markus95, Markfetherolf, GcSwRhc, Monkey Bounce, Piperh, Rich Janis, Felipebm, Martin451, Broadbot, Willit63, Amog, Figureskatingfan, Everything counts, SpecMode, Johnpltsui, Andy Ding-ley, Finngall, Haseo9999, Lamro, Garima.rai30, The Seventh Taylor, Falcon8765, VanishedUserABC, Nelliejellynoona, SapeNov, Lit-tleBenW, Jimmi Hugh, Logan, OsamaK, Biscuitin, SieBot, Skyrail, Moonriddengirl, EwokiWiki, Doctorfree, Sakaal, Dawn Bard, Timothy Cooper, Navywings, Yintan, SuzanneIAM, Kpalsson, Jerryobject, Fishtron, Keilana, Chmyr, Heyitscory, Bentogoa, Happsaylor, Flyer22, Jojalozzo, Nopetro, Snideology, Yerp, Reservoirhill, OsamaBinLogin, Dominik92, Xe7al, North wiki, Techman224, Vykk, Rosiestep, Fuddle, StaticGull, Classivertsen, Bijoyr, WikiLaurent, Superbeecat, Laser813, Shinerunner, Denisarona, Motyka, Dlhrohrer2003, Mar-tariux, Simonmartin74, Ellassint, ClueBot, GorillaWarfare, Wasami007, The Thing That Should Not Be, Cdhkmmaes, Nnemo, Czarkoff, Axorc, Jasapir, Drmies, VQuakr, Mild Bill Hiccup, Myokobuall, Allenmwnc, Enc1234, LizardJr8, Bob bobato, Darren uk, Esthon-enwiki, Auntof6, 718 Bot, Pointillist, Jonathan.robie, Loadbang, Stuart.clayton.22, Ktr101, Excirial, Pumpmeup, Alexbot, Jusdafax, Sajeer50, Hfoxwell, Eeekster, Nasonmedia, Muhandes, SunnySideOfStreet, Technobadger, 842U, Cmartell, M.O.X, Razorflame, Jinlye, Schreiber-Bike, Five-toed-sloth, Craig.Coward, Jakemoilanen, Vdmeraj, PCHS-NJROTC, Johnuniq, Vigilium, DumZiBoT, Jack Bauer00, Steveozone, Darkicebot, Beltman R., Lorddunvegan, XLinkBot, AgnosticPreachersKid, Roxy the dog, Njkool, Stickee, Sponsion, Feinoha, Chanakal, Bpgriner, C. A. Russell, Avoided, Fergus Cloughley, Imllorente, Skarebo, WikHead, Galzigler, Mifter, PcCoffee, Jbeans, Eleven even, Jht4060, NonNobisSolum, Richard.McGuire88, Sandipk singh, RealWorldExperience, Y2l2, Edepa, B Fizz, Dbrisinda, Deineka, Bazj, Addbot, American Eagle, TimFreeman701, Ramu50, Mortense, Realtimer77, Sean R Fox, Mabdul, IXavier, VijayKrishnaPV, Fcal-culators, Mkdonqui, Amore proprio, Tanhabot, Barmijo, TutterMouse, Fieldday-sunday, Scientus, Shakeelrashed, CanadianLinuxUser, Ethoslight, Kristiewells, Cst17, Mohamed Magdy, MrOllie, Download, Robert.Harker, Hatfields, Glane23, Mhodapp, Glass Sword, JimDel-Rossi, Favonian, Optatus, Stbrodie1, Terrillja, Numbo3-bot, Superkillball, Cybercool10, HandThatFeeds, Ashleymcneff, Tide rolls, שׁ ןׁ ןׁ ןׁ, Krano, NeD80, Hunyadym, Luckas Blade, Teles, Cloudcoder, Jarble, Mlavannis, Shri ram r, HerculeBot, Enaiburg, Gamber34, Legobot, Avlnet, Jerichochang97, Luckas-bot, BaldPark, ZX81, Yobot, Evagarfer-enwiki, Themfromspace, Dfxdeimos, Legobot II, Librsh, Ja-malystic, Bruce404, Asieo, Indigokk, Reshadipoor, Washburnmav, Identity20, Adam Hauner, Imeson, Javaeu, Thesurfpuh, Achimew, Lerichard, Knoxi171, ByM4k5, Tiburondude, Aburreson, Jean.julius, Sweerek, Peter Flass, Sql er2, WikiScrubber, Sivanesh, IANYL, Deicool, AnomieBOT, Momoricks, Dmichaud, Pgj1997, 1exec1, Cronos4d, ThaddeusB, Jim1138, IHSscj, JackieBot, Iamdavinci, Cloud-Computing, Yaraman, Mblake, AdityaTandon, Csigabi, Felixchu, MaterialsScientist, RobertEves92, JamesLWilliams2010, The High Fin Sperm Whale, Citation bot, Jkelleyy, OllieFury, Shan.rajad23, ArthurBot, Quebec99, YoungManBlues, NW's Public Sock, PavelSolin, LemonairePaides, Mwmaxy, Xqbot, L200817s, Alexlange, Lairdp, Avneralgom, Capricorn42, Rakesh india, Surajpandey10, Pontifical-ibus, Nfr-Maat, Nasnema, Poliverach, Gkorland, Ohspite, Ramnathkc, Wlouth, Tatatemc, Chadastrophic, Dbake, NFD9001, Emrekeneci, Anna Frodesiak, Explorer09, BrianWren, Peterduffell, Macholl, Anamika.search, EricTheRed20, Michael.owen4, MarkCPhinn, Noctur-

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Beanilkumar, Mediran, EliyahuStern, Beer2beer, EuroCarGT, Prodirus, Fb2ts, SimonBramfitt, Xxyt65r, Mheikkurinen, Nithdaleman, Jags707, EagerToddler39, Davidogm, Padmaja cool, Zingophalitis, Zeeyanwiki, Mcsantacaterina, Shierro, Weternuni, Webclient101, Raushan Shahi, Sjames1, Mogism, Gotocloud, Derekvicente, Nozomimous, Anderson, Cerabot~enwiki, Chishtigharana, Lone boatman, Fabrice Florin (WMF), PonnagalMalar, Naturelover007, TwoToHello, Thewebartists013, TechyOne, Aloak1, Vikas gupta70, Arnavrox, Frosty, SFK2, MartinMichlmayr, Sk8trboi199, Os connect, Jamesj2345, Shubhi choudhary, Joe1689, Sriharsh1234, Viralsah0704, Millycylan, Lorenrb, Kevin12xd, Choor monster, Drjoseph7, BurritoBazooka, OSRules, Waynej6, Avacam, Khan.sharique1994, Amitgupta2792, Zimzaman, Faizan, Chiefspartan, Epicgenius, Shivalikisam, FallingGravity, Ruinjames, Ramanarawal, Acaliguiran, Vanamonde93, S.sameeramas, JaredRClemence, I am One of Many, John-readyspace, Whitecanvas, Jlamus, Manishrai tester, FunkyMonk101, Carrot Lord, Jp4gs, Melonkelon, Mangai Vellingiri, Lena322, Craig developer, Danieljohnc, Alf32, Solomon35, Rkocher, 5c0tt-noe, Thinkcd, Lsteinb, Tentinator, Marinac93, Aaronito, Evano1van, Kapils1255, Olynickjeff, Marcio10Luiz, EvergreenFir, Cookingwithrye, Jopgro, Fsandlinux, Backendgaming, Frmarz, 5andrew1, Nextlevelwb, Maura Driscoll, Flat Out, Halkemp, Couth, Dreamfigure, Murus, Saqibazmat, Jugaste, Babitaarora, Bloonstdfan360, Comp.arch, Kewi69, Metadox, Jbruch, Podger.the, Henhuawang, Katepressed, Tbilisi2013, Asarada, Zricari, AcidBlob, Rodie151, Fatdan786, Max1685, Mariatim, Ginsuloft, ArmitageAmy, Didi.hristova, IMMS, Insomniac14, Corey Rose, Acalycine, JackmcBarn, Dudewhereismybike, PracticalScrum, TDBA, Bob Staggert, Rkanojia, Pcpded, Jora8488, Deepak1300, Harshac89, Goofette, WikiJuggernaut, Gracecheung08, Cloud guru28, Lucy1982, CloudBurster, PierreCoyne, Sweet-sadamali, LookToLuke, Justuj, Mareep, Wlwells67833, JaconaFrere, Theworm4321, JenniferAndy, Skr15081997, Rax sa, Ssgmu55, Nclemen2, 7Sidz, Sofia Lucifairy, Abhinavgupta007, Sfroberts, Musabhai2, Mgt88drctr, Ajabak, Edwardsmith285, Nyashinski, MthwAndrn, Shanhuayang, Nassaraf, Amenychtas, Uk1211, Deepika Sreerama, Monkbot, Cjwin, Allanamiller, Sylvesta101, Lucyloo10, Kalpesh radadiya, Dansullivanpdx, Honyczek, Bingoarunprasath, BethNaught, Security.successfactors, Jblews, Mboxell, Mannanseo, MorePix, ThatWriterBloke, Ipsrsolutions, JoelAaronSeely, Biblioworm, Science.Warrior, Daniel.moldovan, Schwarrttz, Gk9999, Northbridge Secure, Twoosh, Cloudwizard, Thandi moyo, Wrightandru, Ferozahmed0382, Mkchendil, Tonysmith2014, Manjaribalub, Ramvalleru, Daniela C DeMaria, Brandon Connor, Andy7809, Chicodoodoo, MONISHA GEORGE, MVMeena, KH-1, Garywfchan, Sahit1109, Tweeks-va, Ss.jarvisboyle, Cubexsweatherly, Nicky mathew, Stephenzhang.cs, Srinivas.dgm, Spiderjerky, Dtechinspiration, Amagi82, Lalith269, Headinthecloud, Shantan 1995, Edavinmccoy, Zellabox, Mj3ngr, Abcdudtc, Enkakad, Nei Wg 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