

Service Models for Cloud Computing

Computação na Cloud
Mestrado em Engenharia Informática

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Credits

- These slides are based on the following documents:
- Distributed and Cloud Computing: From Parallel Processing to the Internet of Things, Kai Hwang, Jack Dongarra, Geoffrey C. Fox (Authors), Morgan Kaufmann, 1st edition, 2011, ISBN-13: 978-0123858801, 672 pages.
- These are sometimes called the cloud computing stack, IIT Kanpur, PGP OM, <https://www.coursehero.com/file/pvmr1do/These-are-sometimes-called-the-cloud-computing-stack-because-they-build-on-top/>
- SaaS vs PaaS vs IaaS: What's The Difference and How To Choose, Stephen Watts, Muhammad Raza, June 15, 2019, <https://www.bmc.com/blogs/saas-vs-paas-vs-iaas-whats-the-difference-and-how-to-choose/>
- : NIST Cloud Computing Reference Architecture, Recommendations of the National Institute of Standards and Technology, 2011, <https://nvlpubs.nist.gov/nistpubs/Legacy/SP/nistspecialpublication500-292.pdf>
- What Is Platform-as-a-Service (PaaS)?, Cloudflare, <https://www.cloudflare.com/learning/serverless/glossary/platform-as-a-service-paas/>
- FaaS (Function-as-a-Service), IBM Cloud Education, 30 July 2019, <https://www.ibm.com/cloud/learn/faas#toc-what-is-fa-j2qiBzdQ>
- D. B. Fernandes, L. Soares, J. Gomes, M. Freire, P. Inácio, Security Issues in Cloud Environments: A Survey, International Journal of Information Security (Springer), 13(2), pp. 113–170, April 2014.



Agenda

- Classification of Service Models for Cloud Computing
- Software as a Service (SaaS)
- Platform as a Service (PaaS)
- Infrastructure as a Service (IaaS)
- Comparison of SaaS, PaaS, IaaS
- Functions as a Service (FaaS)
- Anything as a Service (XaaS)



Classification of Service Models for Cloud Computing

- Cloud services can be generally categorized into:
 - **Software as a Service (SaaS),**
 - **Platform as a Service (PaaS),**
 - **Infrastructure as a Service (IaaS).**
- These models are offered based on various Service Levels Agreements (SLAs) between providers and users, which is, in a broad sense, addressed in terms of service availability, performance, and data protection and security.
- The classification into three types of service models is common, but is not unique.

Source: Distributed and Cloud Computing: From Parallel Processing to the Internet of Things, Kai Hwang, Jack Dongarra, Geoffrey C. Fox (Authors), Morgan Kaufmann, 1st edition, 2011.



Classification of Service Models for Cloud Computing

- Cloud computing services may also be classified into four categories:
 - **Software as a Service (SaaS),**
 - **Functions as a Service (FaaS),**
 - **Platform as a Service (PaaS),**
 - **Infrastructure as a Service (IaaS).**
- These are sometimes called the **cloud computing stack**, because they build on top of one another.



Classification of Service Models for Cloud Computing

- IaaS, PaaS, SaaS Service models were proposed more than ten years ago, when hardware level virtualization dominated the landscape of virtualized computing environments.
- With the maturation of virtualization at the operating system level, container technology became attractive and competing with the virtual machines on which IaaS and PaaS service models were based.
- The popularity of containers lead to a new kind of services usually known as Containers as a Service or derived designations, such as Kubernetes as a Service.



Classification of Service Models for Cloud Computing

- On the other hand, a new kind of services are emerging with a fast growing rate around Platform as a Service, which are usually known as Serverless Computing.
- These new services include Functions as a Service and Back-end as a Service.
- Therefore, depending on the context, new service models are being proposed, being currently common to find classifications with four or five service models.
- Serverless Computing is addressed along next chapter.
- Here, we mainly focus on SaaS, PaaS, and IaaS



Classification of Service Models for Cloud Computing

- **Infrastructure as a service (IaaS)** is the most basic category of cloud computing services that allows you rent IT infrastructure (servers or VM's) from a cloud provider on a pay-as-you-go basis.
- **Platform as a service (PaaS)** refers to the supply an on-demand environment for developing, testing, delivering and managing software applications. It is designed to quickly create web or mobile apps, without worrying about setting up or managing the underlying infrastructure of servers, storage, network and databases needed for development.



Classification of Service Models for Cloud Computing

- **Software as a service (SaaS)** is a method for delivering applications over the Internet as per the demand and on a subscription basis. SaaS helps one to host and manage the software application and underlying infrastructure and handle any maintenance (software upgrades and security patching).
- **Functions as a service (FaaS)** adds another layer of abstraction to PaaS, so that developers are completely insulated from everything in the stack below their code. Instead of handling the hassles of virtual servers, containers, and application runtimes, they upload narrowly functional blocks of code, and set them to be triggered by a certain event. FaaS applications consume no IaaS resources until an event occurs, reducing pay-per-use fees.



Software as a Service

- **Software as a Service** (SaaS) refers to browser-initiated application software over thousands of cloud customers.
- The SaaS model provides software applications as a service.
- On the customer side, there is no upfront investment in servers or software licensing.
- On the provider side, costs are kept rather low, compared with conventional hosting of user applications.
- Customer data is stored in the cloud that is either vendor proprietary or publicly hosted to support PaaS and IaaS.

Source: Distributed and Cloud Computing: From Parallel Processing to the Internet of Things, Kai Hwang, Jack Dongarra, Geoffrey C. Fox (Authors), Morgan Kaufmann, 1st edition, 2011.



Software as a Service

- **SaaS Advantages**
- SaaS provides numerous advantages to employees and companies by greatly reducing the time and money spent on tedious tasks such as installing, managing, and upgrading software.
- This frees up plenty of time for technical staff to spend on more pressing matters and issues within the organization.

Source: SaaS vs PaaS vs IaaS: What's The Difference and How To Choose, Stephen Watts, Muhammad Raza, June 15, 2019, <https://www.bmc.com/blogs/saas-vs-paas-vs-iaas-whats-the-difference-and-how-to-choose/>



Software as a Service

- **SaaS Characteristics**
- There are a few ways to help you determine when SaaS is being utilized:
 - Managed from a central location
 - Hosted on a remote server
 - Accessible over the internet
 - Users not responsible for hardware or software updates.

Source: SaaS vs PaaS vs IaaS: What's The Difference and How To Choose, Stephen Watts, Muhammad Raza, June 15, 2019, <https://www.bmc.com/blogs/saas-vs-paas-vs-iaas-whats-the-difference-and-how-to-choose/>



Software as a Service

- **When to Use SaaS**
- SaaS may be the most beneficial option in several situations, including:
 - Startups or small companies that need to launch ecommerce quickly and don't have time for server issues or software
 - Short-term projects that require quick, easy, and affordable collaboration
 - Applications that aren't needed too often, such as tax software
 - Applications that need both web and mobile access.

Source: SaaS vs PaaS vs IaaS: What's The Difference and How To Choose, Stephen Watts, Muhammad Raza, June 15, 2019, <https://www.bmc.com/blogs/saas-vs-paas-vs-iaas-whats-the-difference-and-how-to-choose/>



Software as a Service

- **SaaS Limitations and Concerns**
- **Interoperability.** Integration with existing apps and services can be a major concern if the SaaS app is not designed to follow open standards for integration. In this case, organizations may need to design their own integration systems or reduce dependencies with SaaS services, which may not always be possible.
- **Vendor lock-in.** Vendors may make it easy to join a service and difficult to get out of it. For instance, the data may not be portable—technically or cost-effectively—across SaaS apps from other vendors without incurring significant cost or in-house engineering rework. Not every vendor follows standard APIs, protocols, and tools, yet the features could be necessary for certain business tasks.



Software as a Service

- **SaaS Limitations and Concerns (2)**
- **Lack of integration support.** Many organizations require deep integrations with on-premise apps, data, and services. A SaaS vendor may offer limited support, forcing organizations to invest internal resources in designing and managing integrations. The complexity of integrations can further limit how the SaaS app or other dependent services can be used.
- **Data security.** Large volumes of data may have to be exchanged to the backend data centers of SaaS apps in order to perform the necessary software functionality. Transferring sensitive business information to public-cloud based SaaS service may result in compromised security and compliance in addition to significant cost for migrating large data workloads.



Software as a Service

- **SaaS Limitations and Concerns (3)**
- **Customization.** SaaS apps offer minimal customization capabilities. Since a one-size-fits-all solution does not exist, users may be limited to specific functionality, performance, and integrations as offered by the vendor. In contrast, on-premise solutions that come with several software development kits (SDKs) offer a high degree of customization options.
- **Lack of control.** SaaS solutions involves handing control over to the third-party service provider. These controls are not limited to the software—in terms of the version, updates, or appearance—but also the data and governance. Customers may therefore need to redefine their data security and governance models to fit the features and functionality of the SaaS service.



Software as a Service

- **SaaS Limitations and Concerns (4)**
- **Feature limitations.** Since SaaS apps often come in a standardized form, the choice of features may be a compromising tradeoff against security, cost, performance, or other organizational policies. Furthermore, vendor lock-in, cost, or security concerns may mean it's not viable to switch vendors or services to serve new feature requirements in the future.
- **Performance and downtime.** Since vendor controls and manages the SaaS service, your customers now depend on vendors to maintain the service's security and performance. Planned and unplanned maintenance, cyber-attacks, or network issues may impact the performance of the SaaS app despite adequate service level agreement (SLA) protections in place.

Source: SaaS vs PaaS vs IaaS: What's The Difference and How To Choose, Stephen Watts, Muhammad Raza, June 15, 2019, <https://www.bmc.com/blogs/saas-vs-paas-vs-iaas-whats-the-difference-and-how-to-choose/>



Platform as a Service

- **Platform as a Service (PaaS)**, also known as cloud platform services, provide cloud components to certain software while being used mainly for applications.
- PaaS delivers a framework for developers that they can build upon and use to create customized applications.
- All servers, storage, and networking can be managed by the enterprise or a third-party provider while the developers can maintain management of the applications.

Source: SaaS vs PaaS vs IaaS: What's The Difference and How To Choose, Stephen Watts, Muhammad Raza, June 15, 2019, <https://www.bmc.com/blogs/saas-vs-paas-vs-iaas-whats-the-difference-and-how-to-choose/>



Platform as a Service

- **PaaS Delivery**
- The delivery model of PaaS is similar to SaaS, except instead of delivering the software over the internet, PaaS provides a platform for software creation.
- This platform is delivered via the web, giving developers the freedom to concentrate on building the software without having to worry about operating systems, software updates, storage, or infrastructure.
- PaaS allows businesses to design and create applications that are built into the PaaS with special software components.



Platform as a Service

- **PaaS Advantages**
- No matter the size of the company, using PaaS offers numerous advantages, including:
 - Simple, cost-effective development and deployment of apps
 - Scalable
 - Highly available
 - Developers can customize apps without the headache of maintaining the software
 - Significant reduction in the amount of coding needed
 - Automation of business policy
 - Easy migration to the hybrid model



Platform as a Service

- **PaaS Characteristics**
- PaaS has many characteristics that define it as a cloud service, including:
 - Builds on virtualization technology, so resources can easily be scaled up or down as your business changes
 - Provides a variety of services to assist with the development, testing, and deployment of apps
 - Accessible to numerous users via the same development application
 - Integrates web services and databases

Source: SaaS vs PaaS vs IaaS: What's The Difference and How To Choose, Stephen Watts, Muhammad Raza, June 15, 2019, <https://www.bmc.com/blogs/saas-vs-paas-vs-iaas-whats-the-difference-and-how-to-choose/>



Platform as a Service

- **When to Use PaaS**
- Utilizing PaaS is beneficial, sometimes even necessary, in several situations. For example, PaaS can streamline workflows when multiple developers are working on the same development project. If other vendors must be included, PaaS can provide great speed and flexibility to the entire process.
- PaaS is particularly beneficial if one need to create customized applications.
- This cloud service also can greatly reduce costs and it can simplify some challenges that come up if one is rapidly developing or deploying an app.

Source: SaaS vs PaaS vs IaaS: What's The Difference and How To Choose, Stephen Watts, Muhammad Raza, June 15, 2019, <https://www.bmc.com/blogs/saas-vs-paas-vs-iaas-whats-the-difference-and-how-to-choose/>



Platform as a Service

- **PaaS Limitations and Concerns**
- **Data security.** Organizations can run their own apps and services using PaaS solutions, but the data residing in third-party, vendor-controlled cloud servers poses security risks and concerns. Your security options may be limited as customers may not be able to deploy services with specific hosting policies.
- **Integrations.** The complexity of connecting the data stored within an onsite data center or off-premise cloud is increased, which may affect which apps and services can be adopted with the PaaS offering. Particularly when not every component of a legacy IT system is built for the cloud, integration with existing services and infrastructure may be a challenge.

Source: SaaS vs PaaS vs IaaS: What's The Difference and How To Choose, Stephen Watts, Muhammad Raza, June 15, 2019, <https://www.bmc.com/blogs/saas-vs-paas-vs-iaas-whats-the-difference-and-how-to-choose/>



Platform as a Service

- **PaaS Limitations and Concerns (2)**
- **Vendor lock-in.** Business and technical requirements that drive decisions for a specific PaaS solution may not apply in the future. If the vendor has not provisioned convenient migration policies, switching to alternative PaaS options may not be possible without affecting the business.
- **Customization of legacy systems.** PaaS may not be a plug-and-play solution for existing legacy apps and services. Instead, several customizations and configuration changes may be necessary for legacy systems to work with the PaaS service. The resulting customization can result in a complex IT system that may limit the value of the PaaS investment altogether.



Platform as a Service

- **PaaS Limitations and Concerns (3)**
- **Runtime issues.** In addition to limitations associated with specific apps and services, PaaS solutions may not be optimized for the language and frameworks of your choice. Specific framework versions may not be available or perform optimally with the PaaS service. Customers may not be able to develop custom dependencies with the platform.
- **Operational limitation.** Customized cloud operations with management automation workflows may not apply to PaaS solutions, as the platform tends to limit operational capabilities for end users. Although this is intended to reduce the operational burden on end users, the loss of operational control may affect how PaaS solutions are managed, provisioned, and operated.



Infrastructure as a Service

- **Infrastructure as a Service (IaaS)**, known as cloud infrastructure services, are made of highly scalable and automated compute resources.
- IaaS allows businesses to purchase resources on-demand and as-needed instead of having to buy hardware outright.
- Many limitations associated with SaaS and PaaS models – such as data security, cost overruns, vendor lock-in and customization issues – also apply to the IaaS model.
- Major cloud service providers do not offer pure IaaS services. Providers such as Google and Microsoft offer integrated IaaS and PaaS services.

Source: SaaS vs PaaS vs IaaS: What's The Difference and How To Choose, Stephen Watts, Muhammad Raza, June 15, 2019, <https://www.bmc.com/blogs/saas-vs-paas-vs-iaas-whats-the-difference-and-how-to-choose>



Infrastructure as a Service

- **IaaS Delivery**
- IaaS delivers cloud computing infrastructure, including servers, network, and storage, through virtualization technology. These cloud servers are typically provided to the organization through virtual machines or containers.
- As opposed to SaaS or PaaS, IaaS clients are responsible for managing aspects such as applications, runtime, OSes, middleware, and data. However, providers of the IaaS manage the physical servers, hard drives, networking, virtualization, and storage. Some providers even offer more services beyond the virtualization layer, such as databases or message queuing.



Infrastructure as a Service

- **IaaS Advantages**
- IaaS offers many advantages, including:
 - The most flexible cloud computing model
 - Easy to automate deployment of storage, networking, servers, and processing power
 - Hardware purchases can be based on consumption
 - Clients retain complete control of their infrastructure
 - Resources can be purchased as-needed
 - Highly scalable

Source: SaaS vs PaaS vs IaaS: What's The Difference and How To Choose, Stephen Watts, Muhammad Raza, June 15, 2019, <https://www.bmc.com/blogs/saas-vs-paas-vs-iaas-whats-the-difference-and-how-to-choose>



Infrastructure as a Service

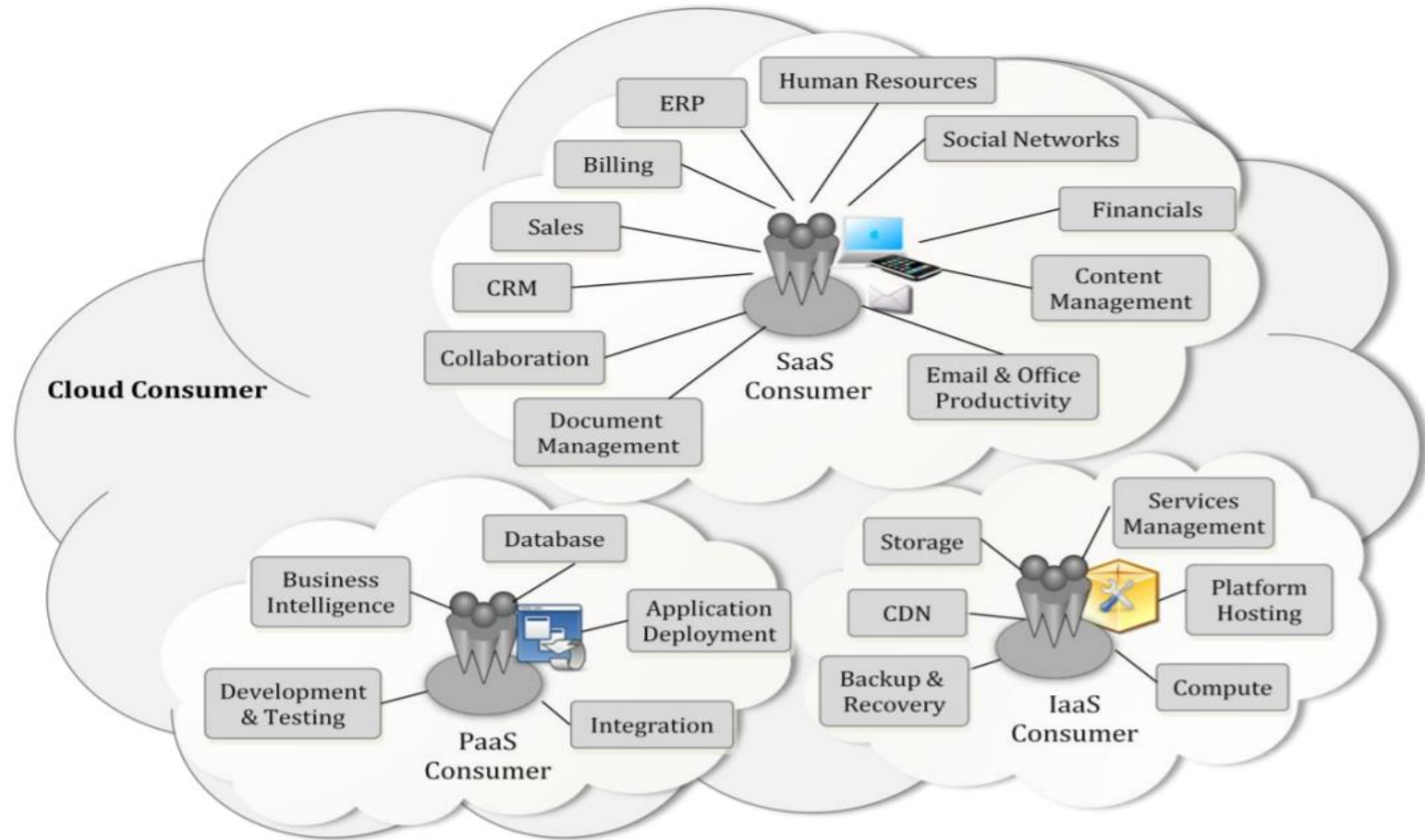
- **IaaS Characteristics**
- Characteristics that define IaaS include:
 - Resources are available as a service
 - Cost varies depending on consumption
 - Services are highly scalable
 - Multiple users on a single piece of hardware
 - Organization retain complete control of the infrastructure
 - Dynamic and flexible

Source: SaaS vs PaaS vs IaaS: What's The Difference and How To Choose, Stephen Watts, Muhammad Raza, June 15, 2019, <https://www.bmc.com/blogs/saas-vs-paas-vs-iaas-whats-the-difference-and-how-to-choose/>



Comparison of SaaS, PaaS, IaaS

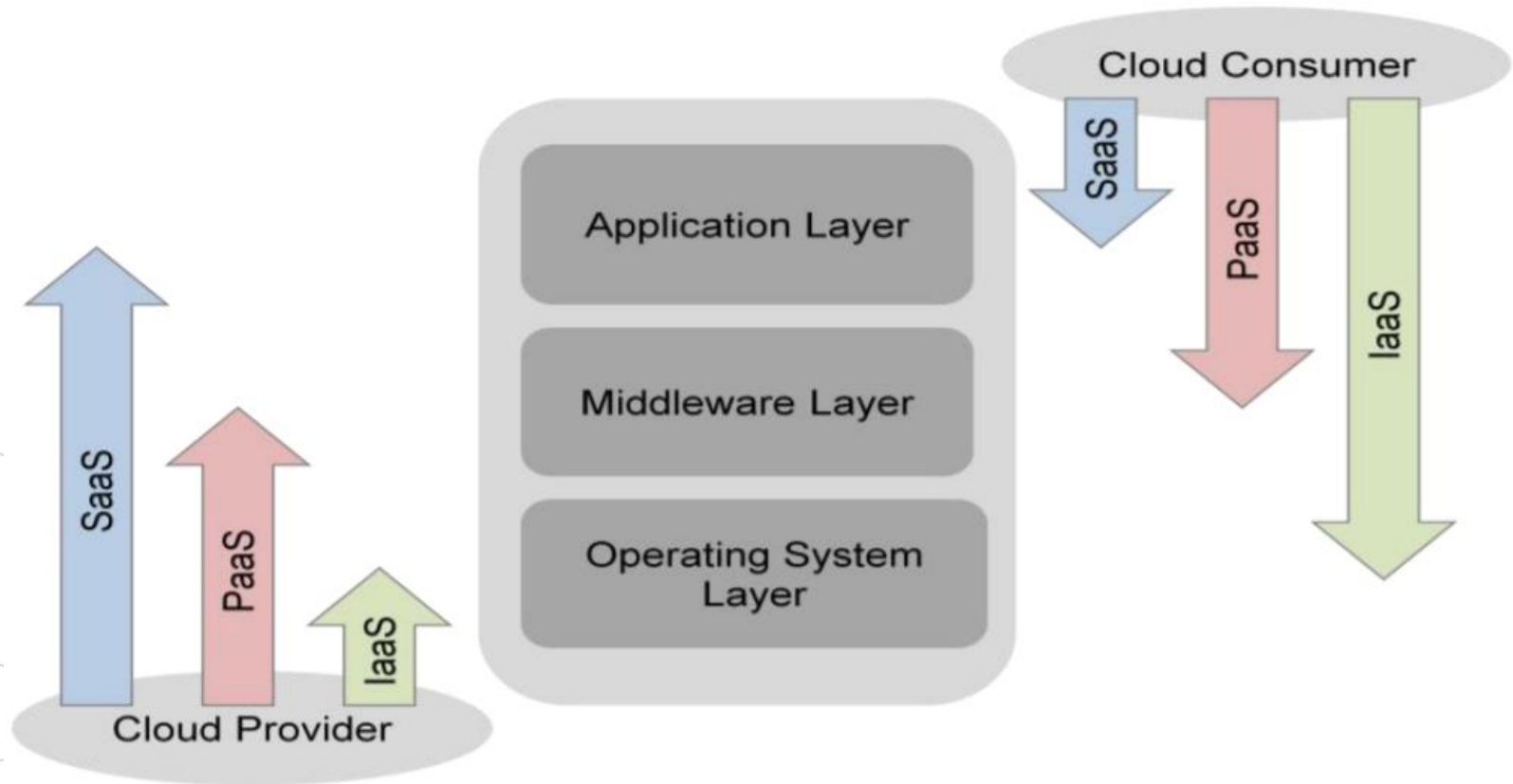
Example services available to a cloud consumer





Comparison of SaaS, PaaS, IaaS

Scope of controls between provider and consumer





Comparison of SaaS, PaaS, IaaS

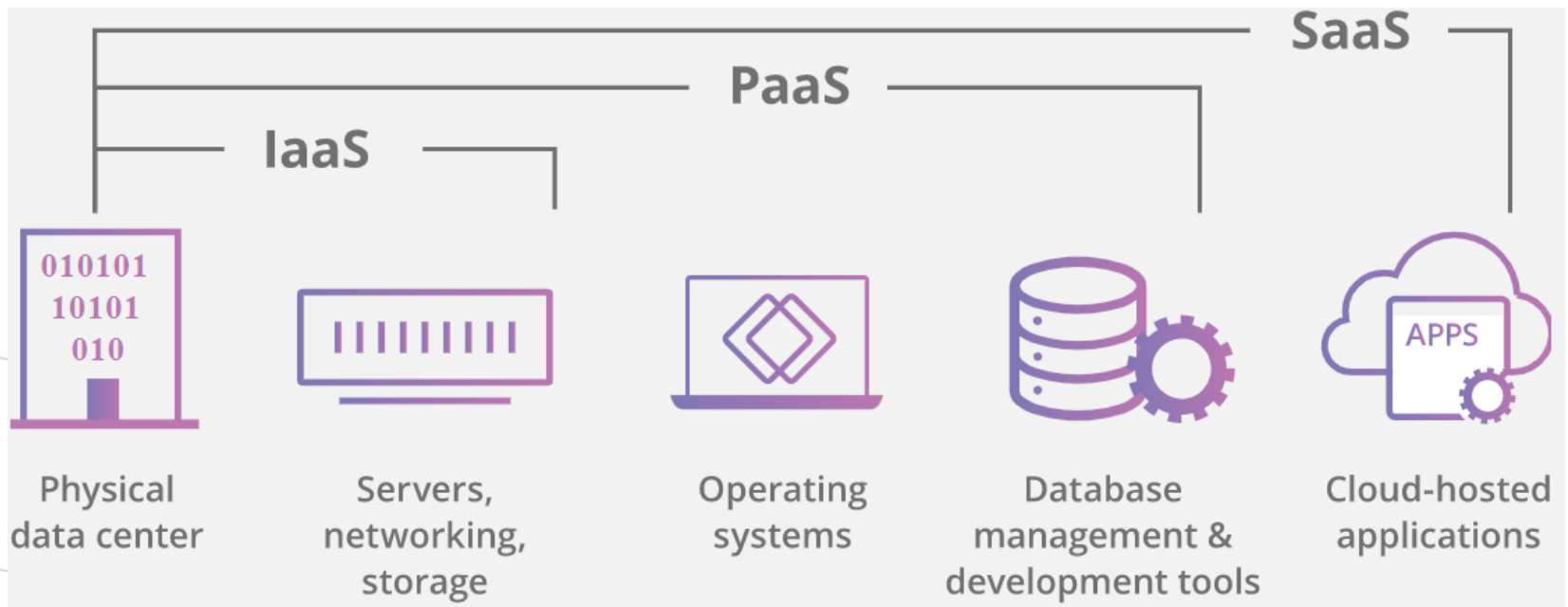
- **Common Examples of SaaS, PaaS, & IaaS**
- **SaaS:** Google GSuite (Apps), Microsoft SharePoint, Office 365, Dropbox, Salesforce, Cisco WebEx, SAP Concur, GoToMeeting.
- **PaaS:** AWS Elastic Beanstalk, Windows Azure (Compute), Heroku, Google App Engine, Apache Stratos, OpenShift.
- **IaaS:** DigitalOcean, Linode, Rackspace, Amazon Web Services (AWS), Cisco Metapod, Google Compute Engine (GCE).

Source: SaaS vs PaaS vs IaaS: What's The Difference and How To Choose, S. Watts, M. Raza, June 15,



Comparison of SaaS, PaaS, IaaS

Overview of SaaS, PaaS and IaaS

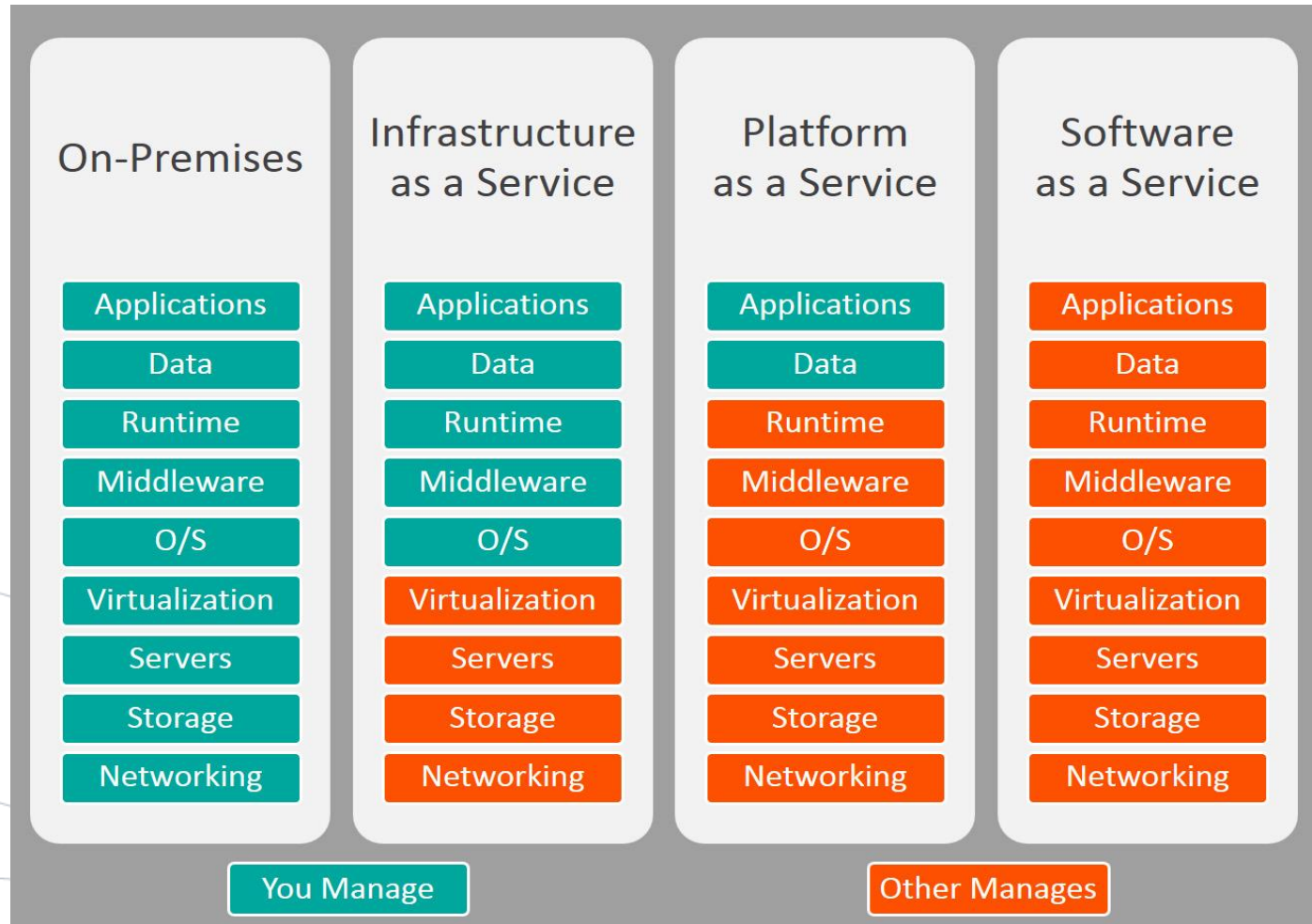


Source: What Is Platform-as-a-Service (PaaS)?, Cloudflare,

33 <https://www.cloudflare.com/learning/serverless/glossary/platform-as-a-service-paas/>



Comparison of SaaS, PaaS, IaaS



Source: SaaS vs PaaS vs IaaS: What's The Difference and How To Choose, S. Watts, M. Raza, June 15, 2019, <https://www.bmc.com/blogs/saas-vs-paas-vs-iaas-whats-the-difference-and-how-to-choose/>



Functions as a Service

- **Functions as a Service (FaaS)** is a cloud computing execution model in which the cloud provider dynamically manages the allocation of machine resources.
- Pricing is based on the actual amount of resources consumed by an application, rather than on pre-purchased resources.
- FaaS is also wrongly known as Serverless computing, but FaaS is indeed a subset of Serverless Computing.
- Serverless computing still requires servers, hence it's a misnomer.
- The name "serverless computing" is used because the server management and capacity planning decisions are completely hidden from the developer.



Functions as a Service

- FaaS allows a code developer to execute code in response to events without the complex infrastructure typically associated with building and launching applications.
- Hosting a software application on the Internet typically requires provisioning and managing a virtual or physical server and managing an operating system and web server hosting processes.
- With FaaS, the physical hardware, virtual machine operating system, and web server software management are all handled automatically by your cloud service provider.
- This allows the code developer to focus solely on individual functions in your application code.

Source: FaaS (Function-as-a-Service), IBM Cloud Education, 30 July 2019,
<https://www.ibm.com/cloud/learn/faas#toc-what-is-fa-j2qiBzdQ>



Anything as a Service (XaaS)

- **Anything as a Service (XaaS)** refers to the fact that cloud systems are able to support and offer anything, or everything, in the form of services, ranging from large resources to personal, specific, and granular requirements.
- Examples include Data as a Service (DaaS), Routing as a Service (RaaS), Desktop as a Service (DaaS), and Security as a Service (SecaaS).
- XaaS is a concept, not a service model for cloud computing.