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Cloud Computing Paradigms

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The historical 4 utilities

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(1) Water

(2) Electricity

(3) Gas

(4) Phone/Internet

Cloud as public utility

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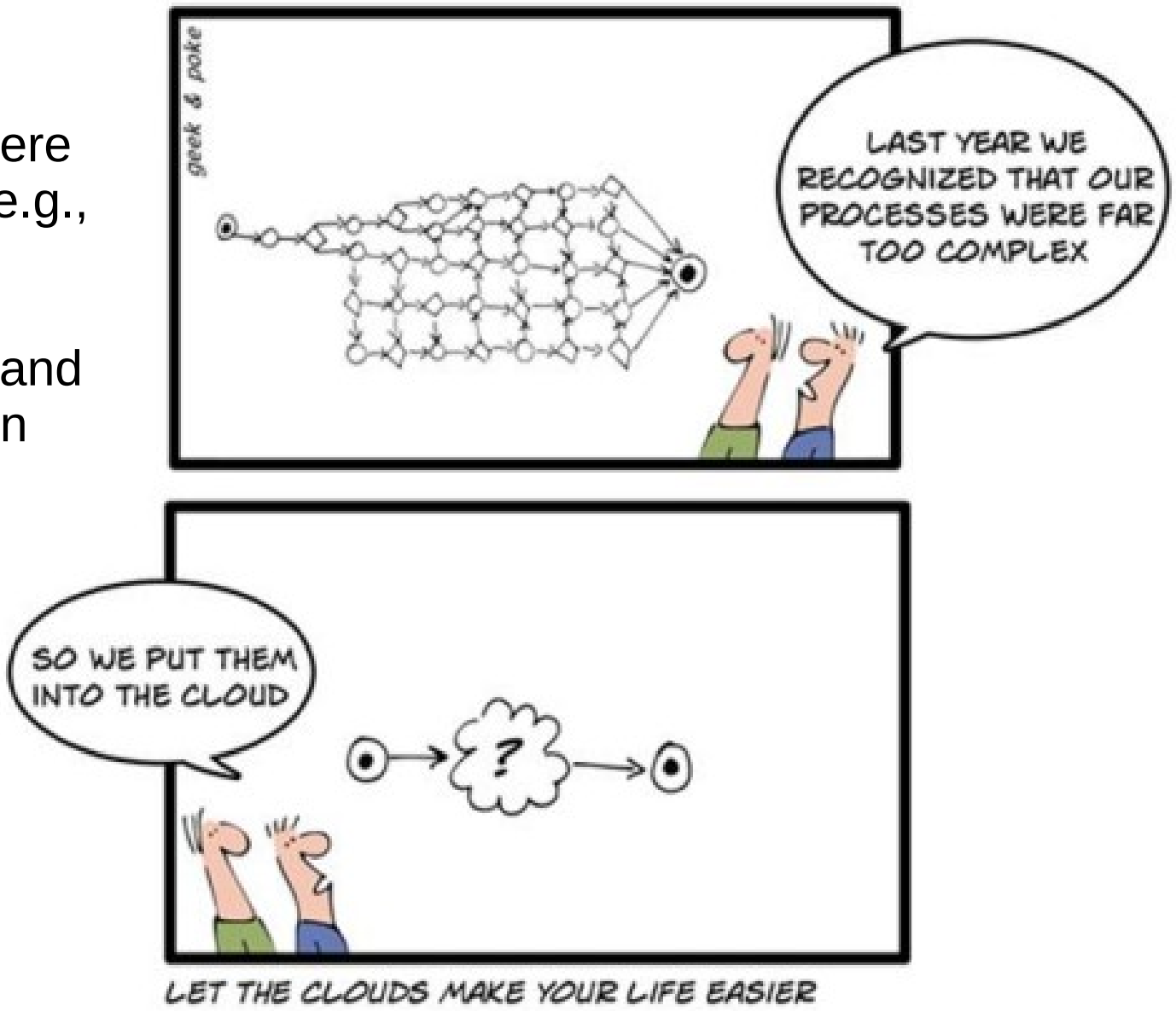
Cloud as…

...evolution of Internet where the company resources (e.g., applications, business processes, collaboration instruments, storage, hw and sw can be accessed as on online service



Vision and evolution

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- [John McCarthy, MIT, 1961]: **“Computing may someday be organized as a public utility”**

- [Jeff Bezos, CEO Amazon, 2006]: **“Let us use our spare resources for making profit by offering them as services to the public”**

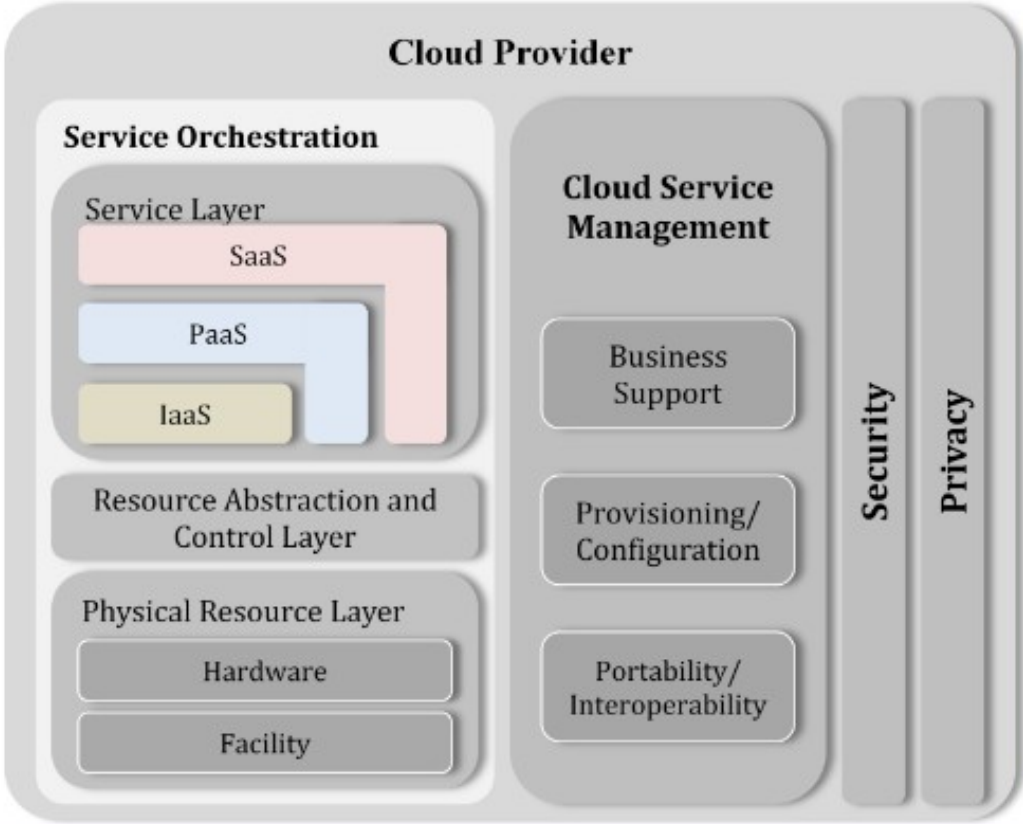
  ➔The CLOUD COMPUTING was born

- [Steve Ballmer, CEO Microsoft, 2016]: **“The cloud is the future, everything else is accessory”**

The NIST definition

National Institute of Standards and Technology's delivers this definition **after 5 years** since cloud was borns (from a *private* initiative – differently from other disruptive innovations as Internet and Web), need for standardization

"Cloud computing is a model for enabling **ubiquitous, convenient, on-demand** network access to a **shared pool of configurable computing resources** (e.g., networks, servers, storage, applications, and services) that can be **rapidly provisioned and released with minimal management effort or service provider interaction**. This Cloud model promotes **availability, elasticity, and security**. [...]."



The NIST definition

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5 Key Points emerging from the NIST definition

- **On-demand service**
  - No reservation in advances, resource available when needed, no human intermediary in the loops
- **Broad Network Access**
  - Data centers connected at the network with multiple, redundant, high capacity connections
- **Resource pooling**
  - Not infinite but the perception of the customers is almost that – due to its dynamic behavior
- **Rapid elasticity**
  - Related to the on-demand service: speed to have more resource (order of seconds / minutes) and possibility to release resources
- **Measured Service**
  - Capability to measure all the usage of resources done by the customers and monitoring resources

Cloud Computing definition

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AWS Definition

- "*Cloud Computing is the on-demand delivery of compute power, database, storage, applications and other IT resources via the Internet with pay-as-you-go pricing model*"

Cloud Paradigms

Two main classes of paradigms

Main actors

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3 main actors

- **Provider**: provider of cloud services – owner of the cloud infrastructure
- **Customer (organization)**: organization that makes use of (and pays for) the cloud services offered by the provider, generally offering an added value as for example the development of software services – usually the *service provider*
- **(Final) User**: user that makes use of the services properly configured and made available by the customer

Service paradigms (prevalent)

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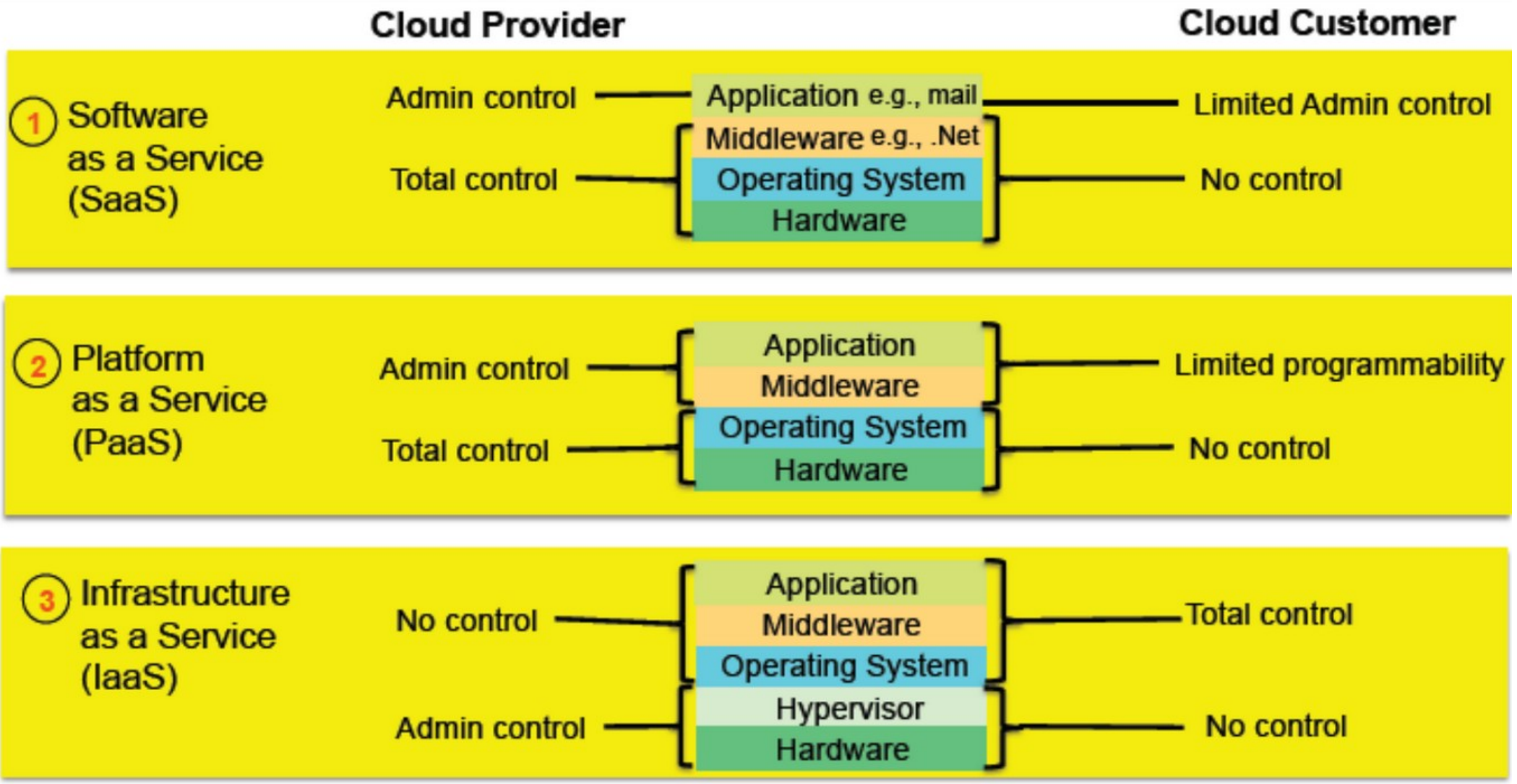
- **Infrastructure as a Service (IaaS)**
- **Platform as a Service (PaaS)**
- **Software as a Service (SaaS)**

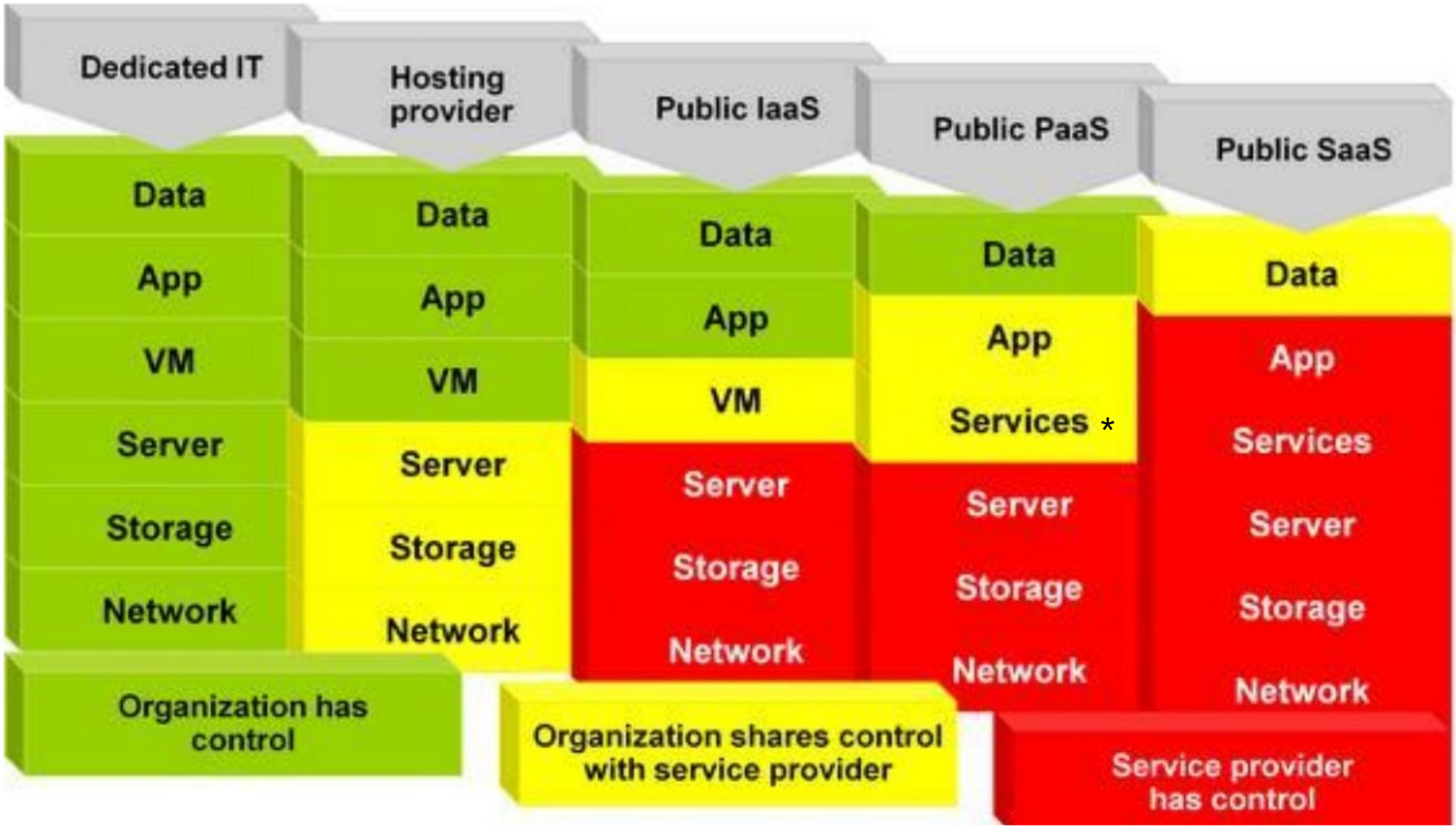
Model "as a Service (aaS)" Building blocks

- Shared (multi-tenant)
  - Pay per use
  - Hourly/monthly bill

Service paradigms

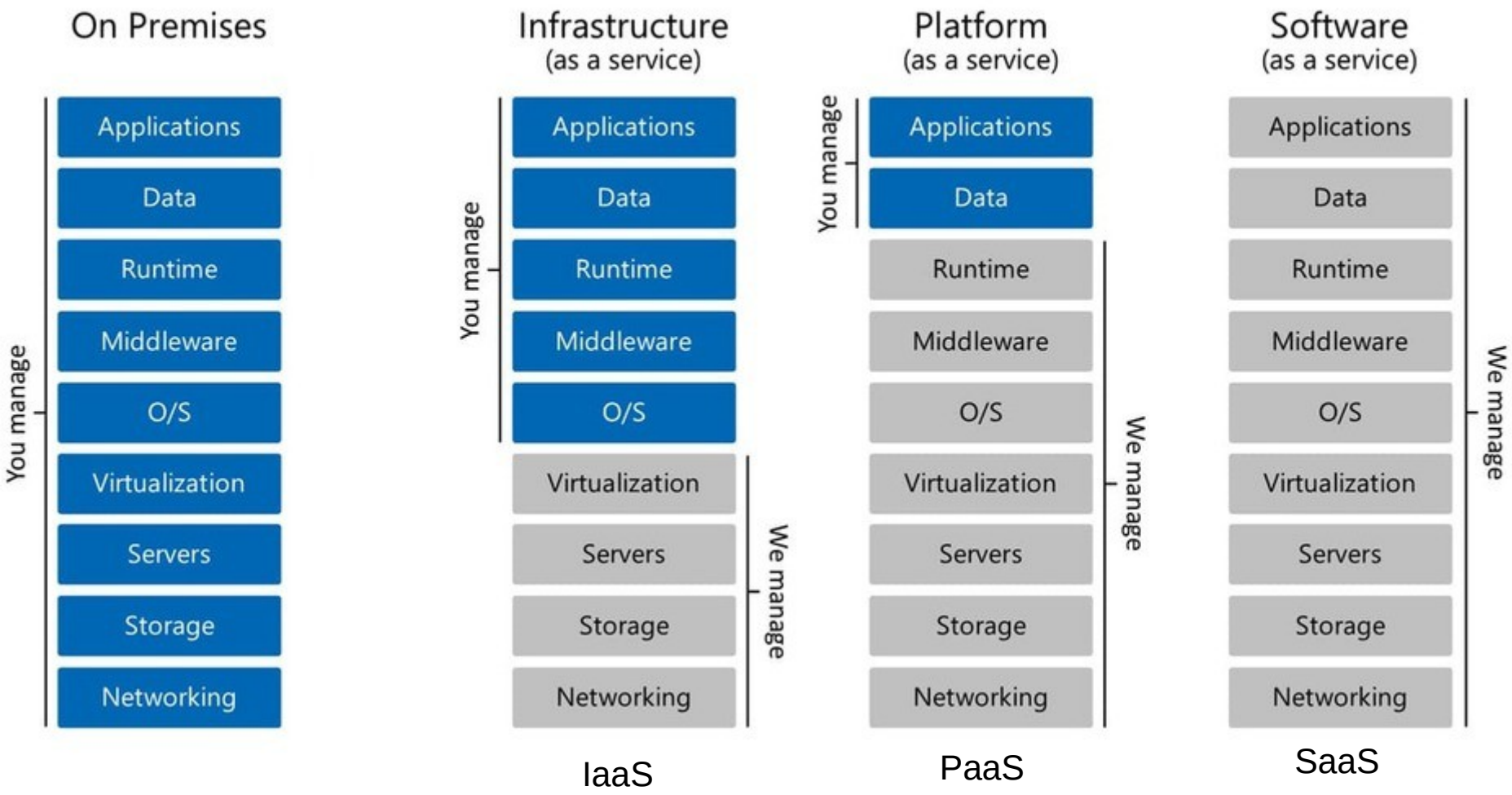


Service paradigms



* Managed Virtual Machines offering to app engine applications some ‘service’ → a bit more flexibility over app platform, CPU and memory options

Service paradigms



You = Customer
We = Cloud Provider

IaaS

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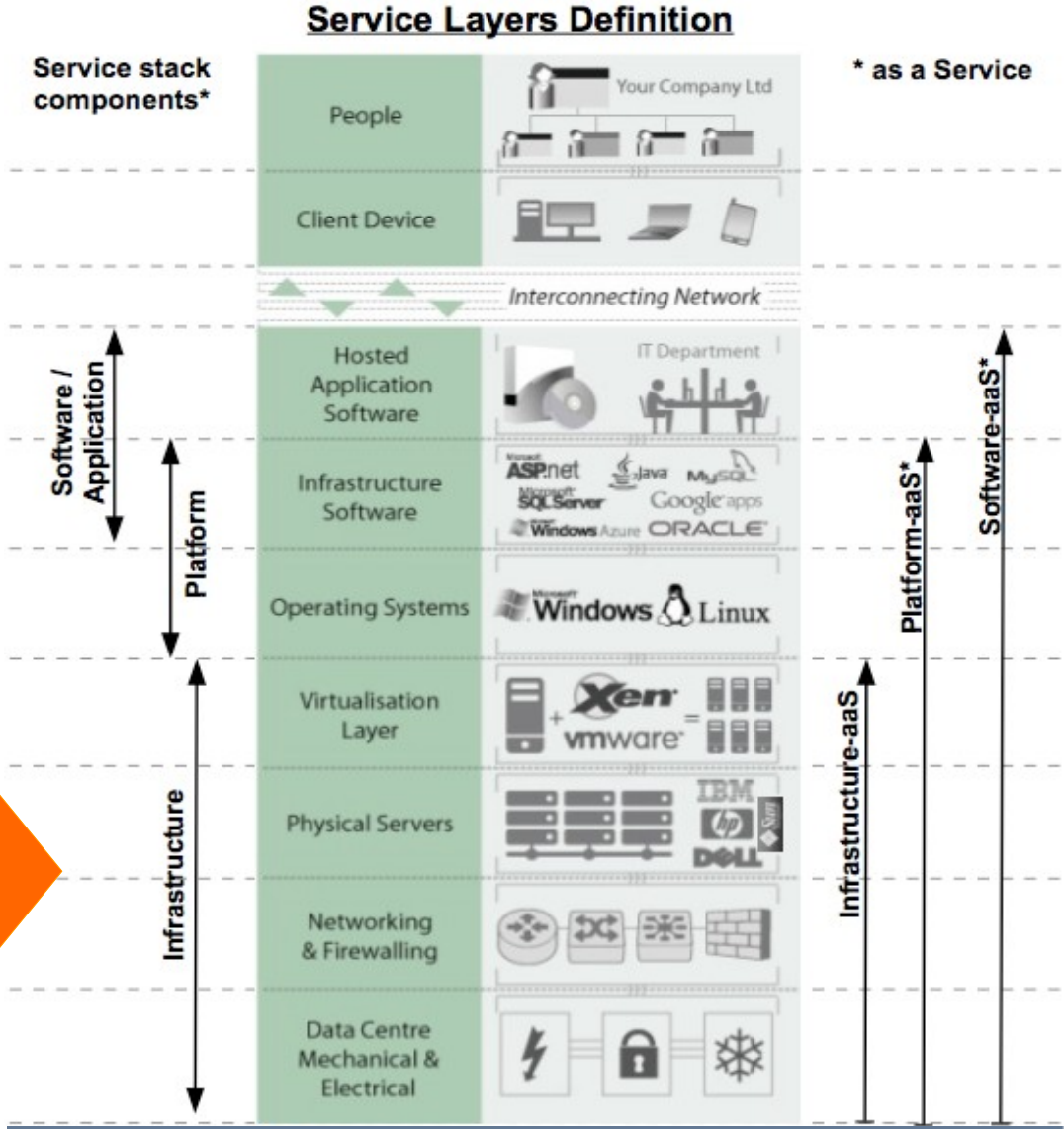
IaaS (Infrastructure as a Service)

The provider provides only the infrastructure

Advanced outosurcing of all ICT resources: it allows to rent **CPU capabilities, storage, network to install over them other resources such as OS, DB and other software**

E.g., Rent of virtual machines (Amazon EC2, IBM Blue Cloud, Microsoft Azure IaaS, ...)



IaaS: main providers

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IaaS Cloud Providers

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Company	2022 Revenue	2022 Market Share (%)	2021 Revenue	2021 Market Share (%)	2021-2022 Growth (%)
Amazon	48,126	40.0	35,380	38.1	36.0
Microsoft	25,858	21.5	19,153	20.6	35.0
Alibaba Group	9,281	7.7	9,060	9.8	2.4
Google	9,072	7.5	6,433	6.9	41.0
Huawei	5,249	4.4	4,190	4.5	25.3
Others	22,746	18.9	18,565	20.0	22.5
Total	**120,333**	**100**	**92,782**	**100**	**29.7**

Source: Gartner (July 2023)

- In 2022, the top five IaaS providers accounted for over 80% of the market
- Google saw the highest growth rate of the top five IaaS vendors, growing 41% in revenue

PaaS

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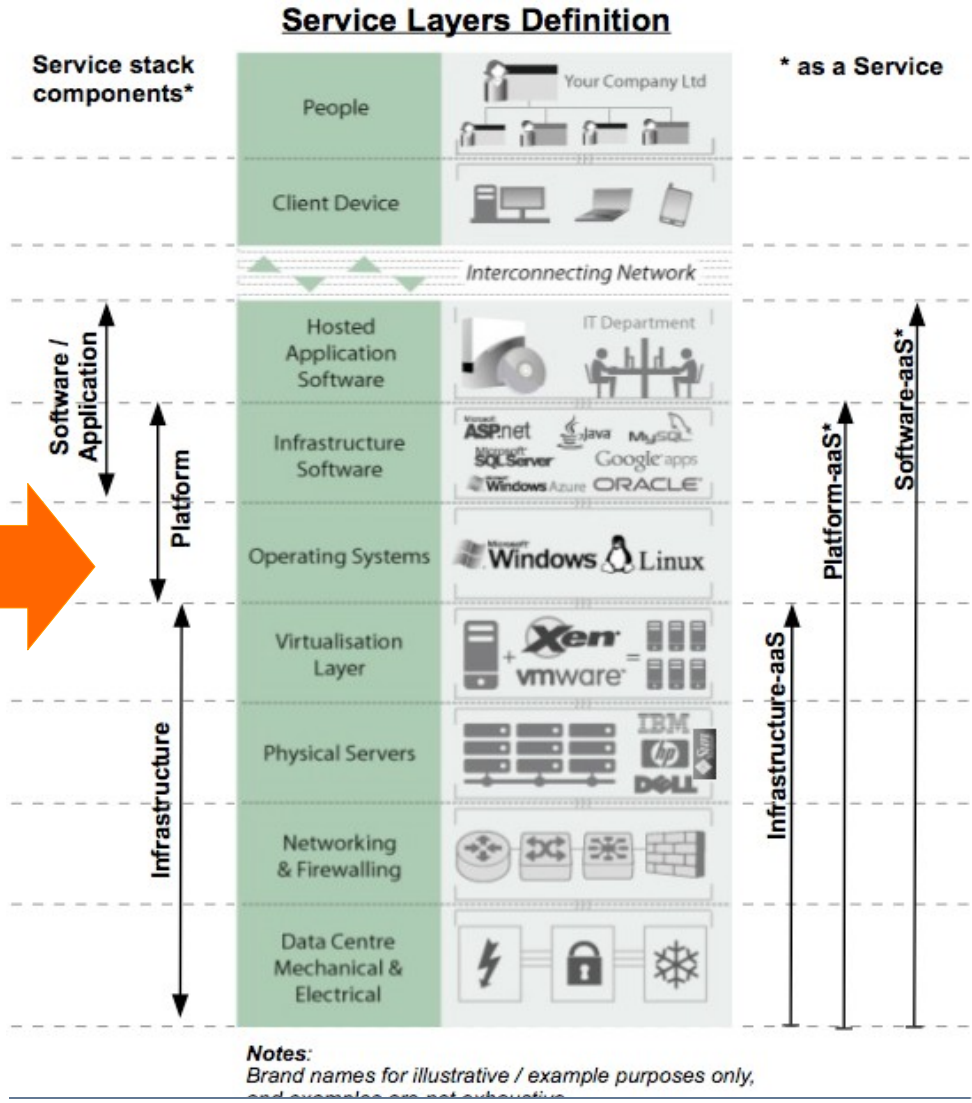
PaaS (Platform as a Service)

The provider provides the use of a platform that allows to develop, test and distribute applications created by using **programming languages, libraries and services (API) supported by the provider**

The customer does not have control on the infrastructure, operating systems, or storage, but has control over the developed applications and on their configurations, and often has support for the monitoring of performance

E.g., Google App Engine



PaaS: main providers

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SaaS

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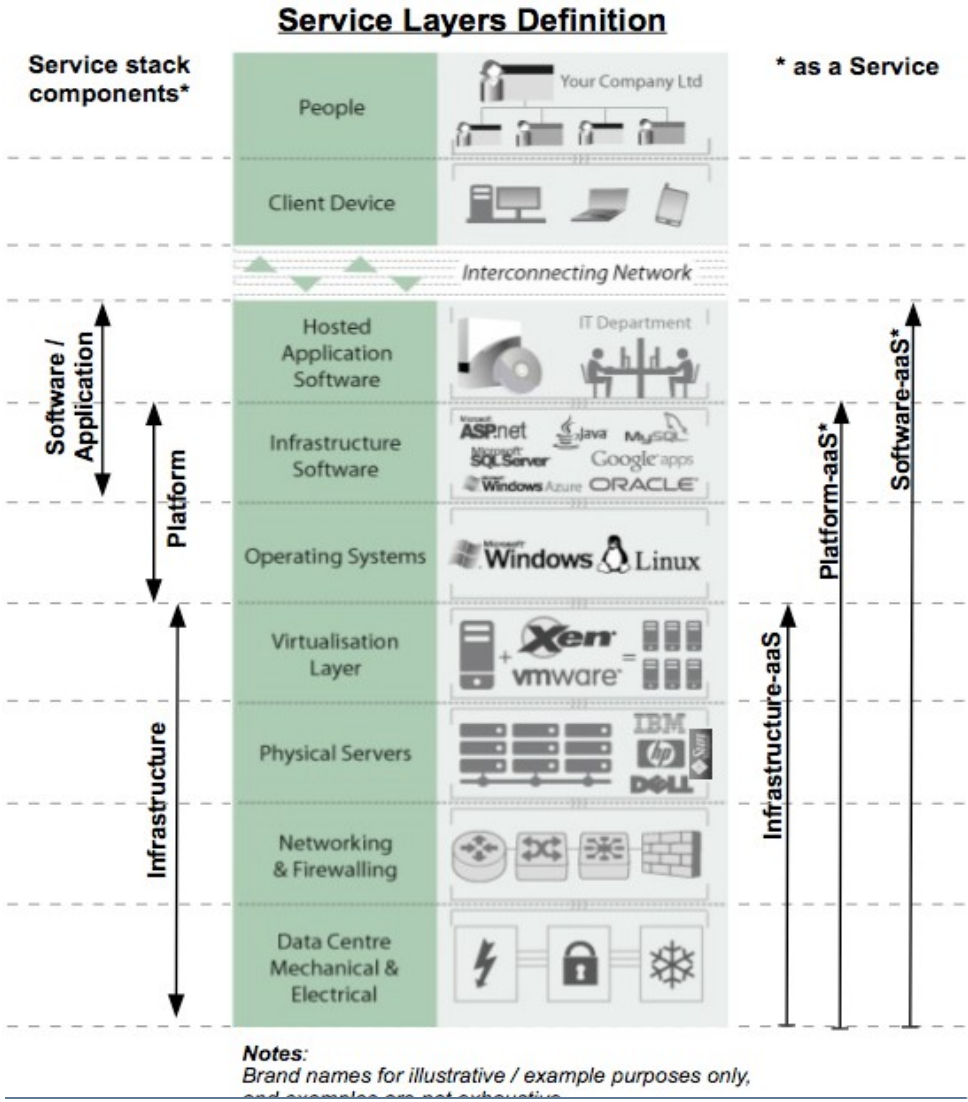
SaaS (Software as a Service)

The provider provides the use of applications on an infrastructure accessible from different devices through a common interface as a **browser Web** or a dedicated client



Examples of SaaS include tools/applications for shared productivity (e.g., email Web-based, calendars, Google docs, Google Drive, Microsoft Office 365) as well as enterprise services (e.g., deliver human resource software, online ERPs, e-commerce systems, customer relationship management tools, and integrated development environments - IDEs)

SaaS: providers

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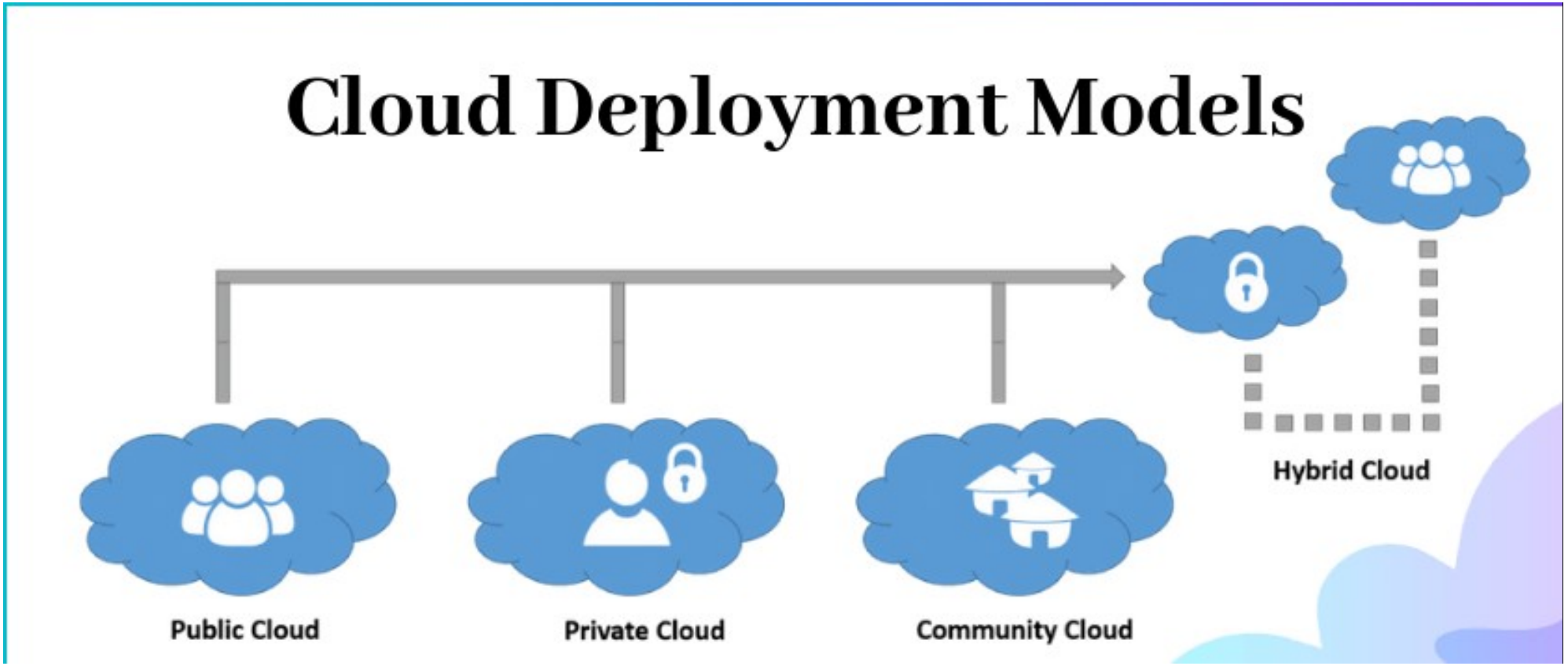
Deployment paradigms



Deployment models

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- **Public cloud.** The cloud infrastructure offers services over the public Internet and is shared by multiple customers. It is owned by an organization (i.e., cloud provider) selling one or more types of cloud services
- **Private cloud.** The cloud infrastructure is operated solely for an organization. It may be managed by the organization itself (private cloud) or by a third party (exclusive cloud) and may exist on premise or off premise
- **Hybrid cloud.** The cloud infrastructure is a composition of two or more clouds (usually private and public), that remain unique entities but are bound together by standardized or proprietary technology that enables data and application portability, used by the same customer: benefits of multiple deployment models
- **Community cloud.** The cloud infrastructure is shared by several organizations and supports a specific community that has shared concerns and/or objectives (e.g., business mission, security requirements, policy, and compliance considerations). It may be managed by the organizations or by a third party and may exist on premise or off premise

Community clouds

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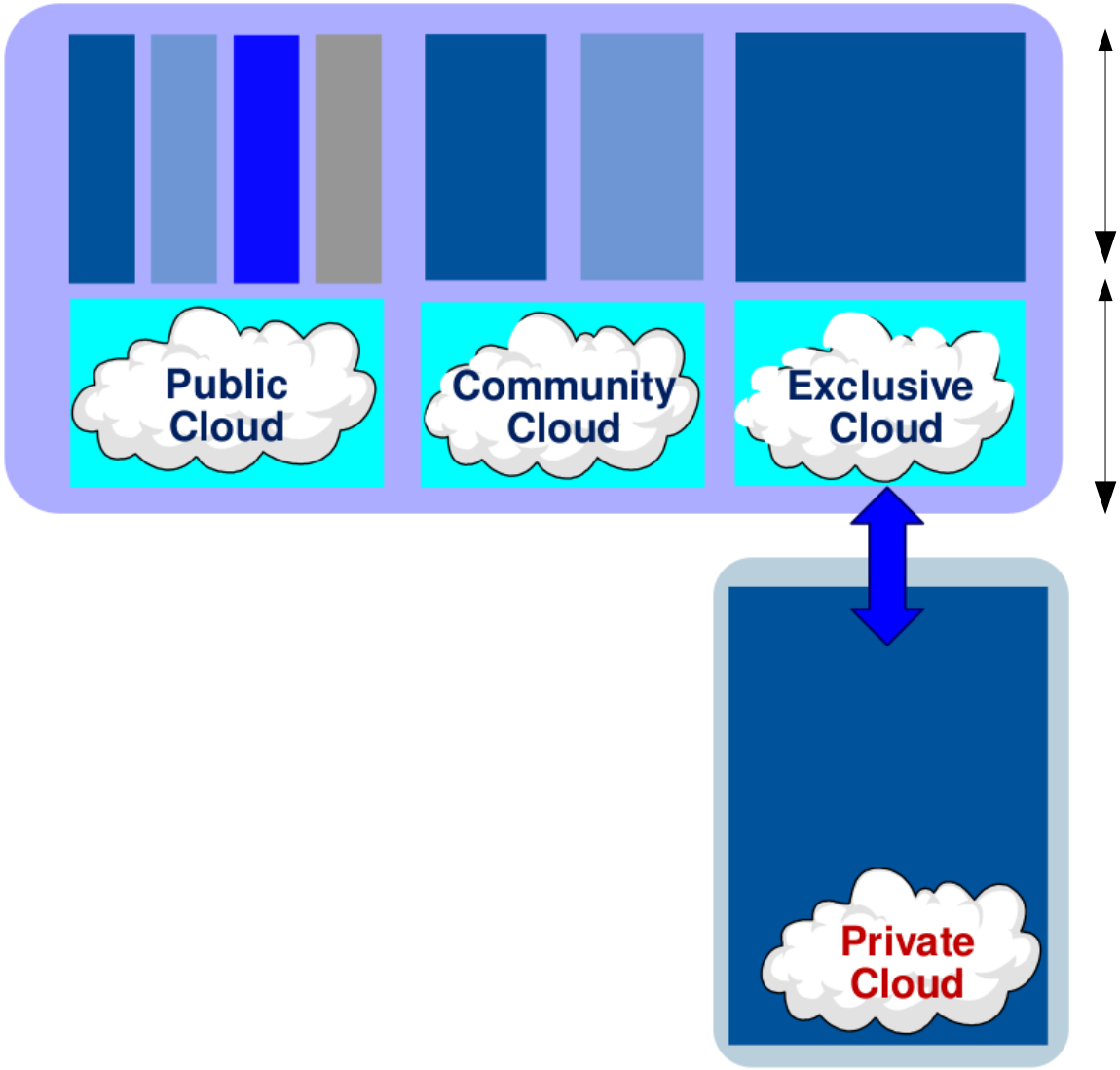
Some examples

- Public Administrations
- Health care systems
- Small-Medium Enterprises
  - Vertical
  - Provider-Clients
- …

Observation

- 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

Deployment models

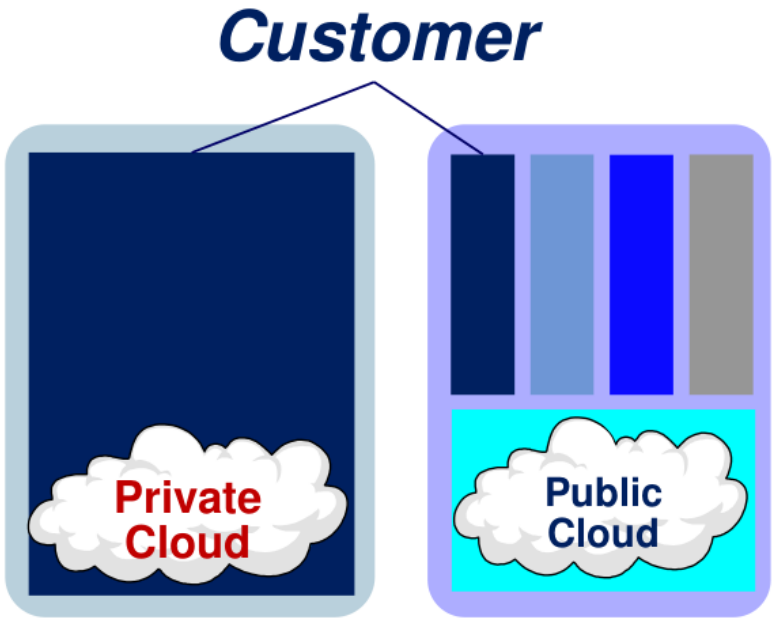


Customers

Providers

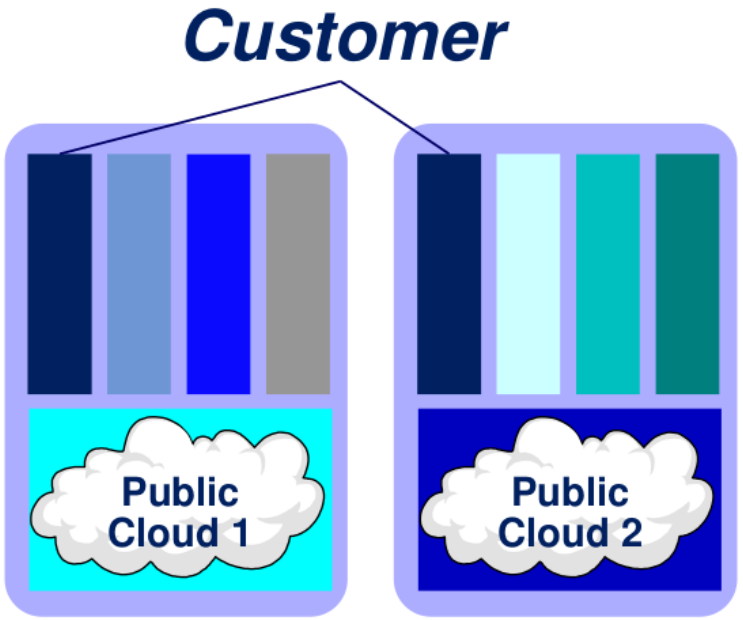
Customers
=
Providers

Hybrid solutions

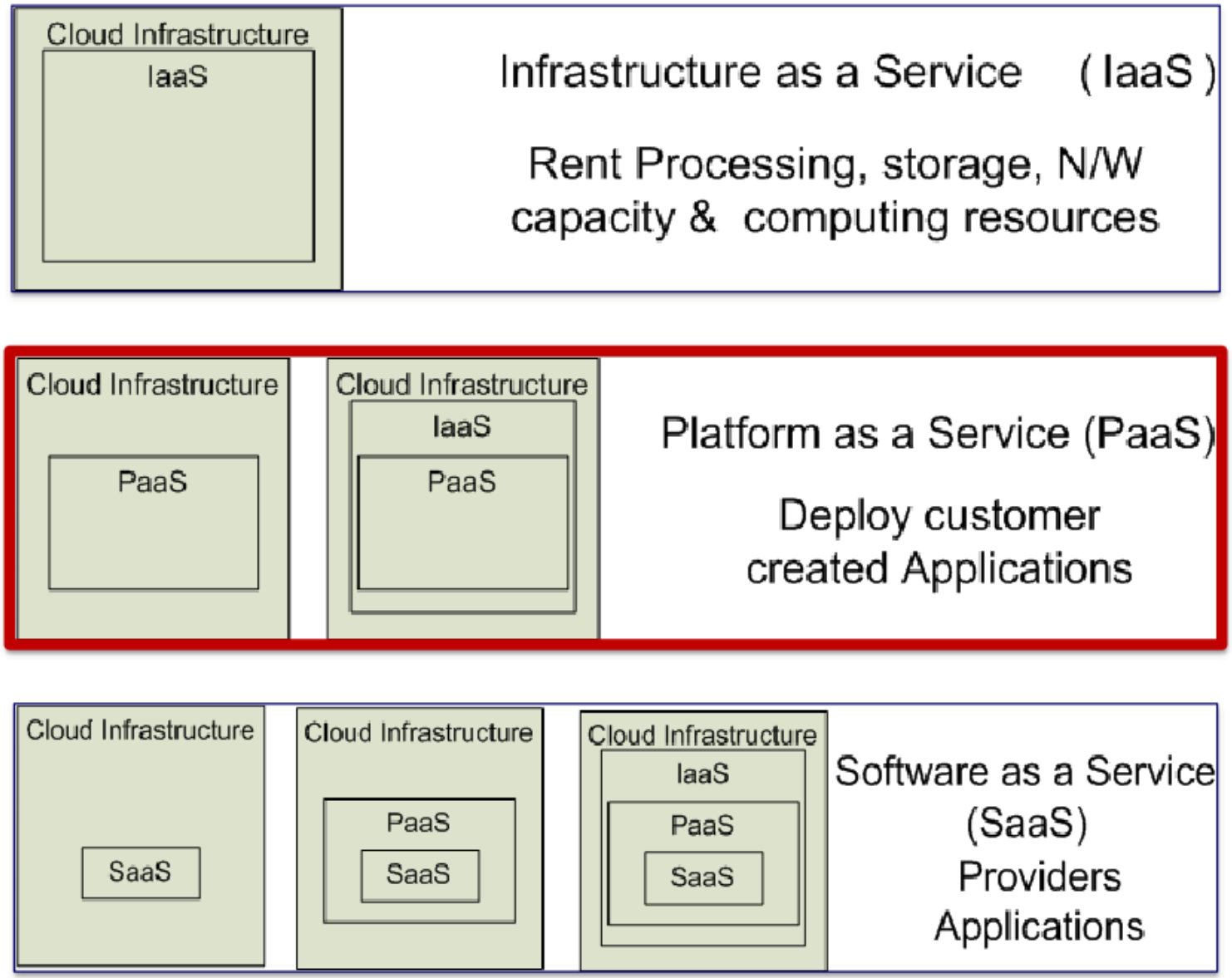


More common definition

Gartner* definition
(*research and consulting company)



Service models: a summary



Cloud Providers

Cloud providers

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Only a handful of major IT players can really build a similar massive infrastructure

Worldwide telco operators are accessing the cloud market

Recently, other big companies

The big players [Gartner, 2013 and 2014]

The distance augments [Gartner, 2016]

The top players [Gartner, 2023]

Disappearing boundaries

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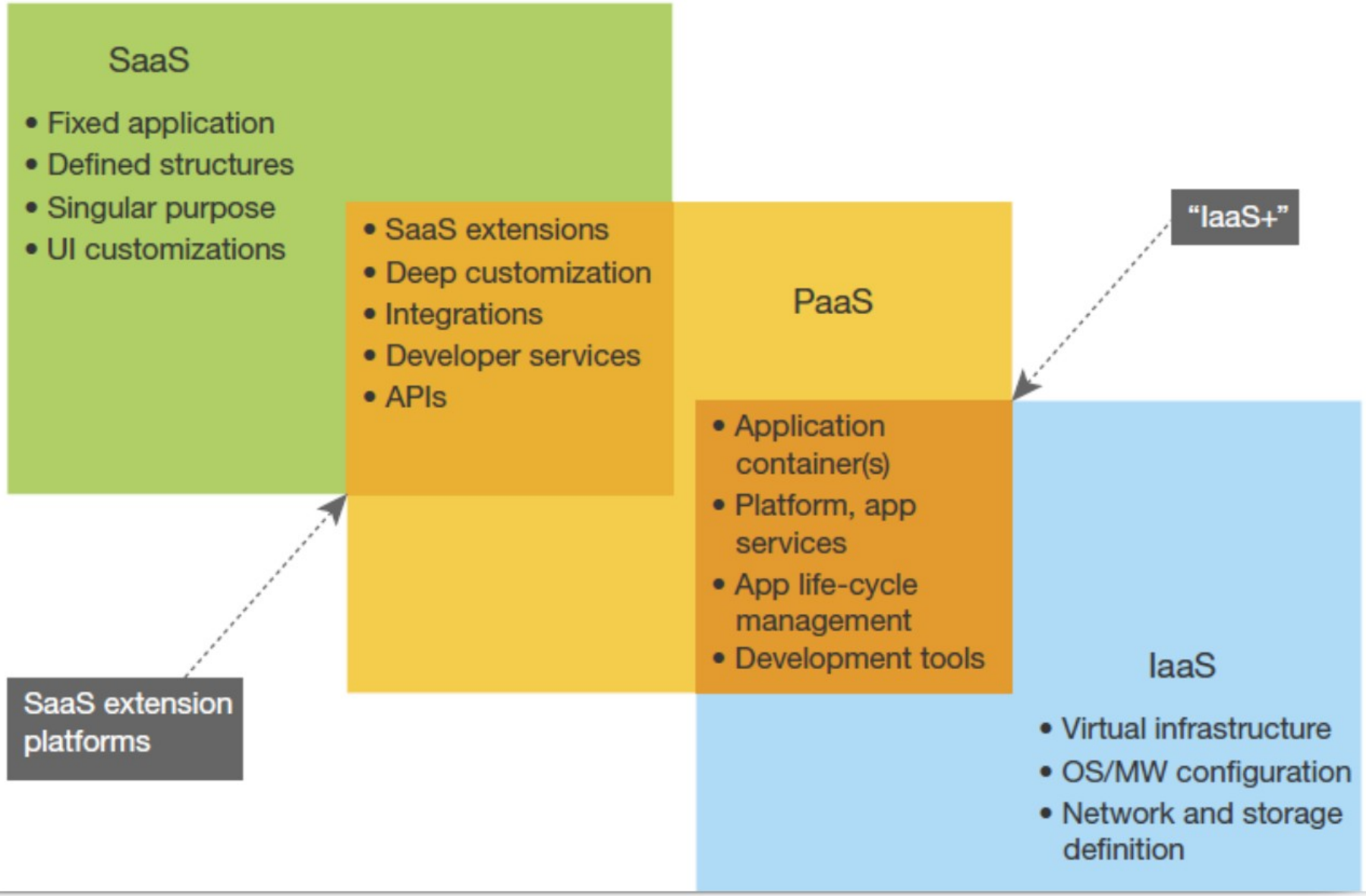

IaaS+

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IaaS+

- Historical IaaS vendors (e.g., Amazon, Rackspace) are building services that deliver the abstraction and hosted middleware benefits that were often associated with PaaS

- **Examples of IaaS+**
  - AWS CloudFormation (create templates to describe AWS resources and dependencies)
  - Amazon Cognito (user management and permissions)

Paas+IaaS

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PaaS+IaaS

- Traditional PaaS vendors are reaching down to the virtual infrastructure
- Some PaaS providers now offer both highly abstracted interface for developers and the ability to configure underlying middleware, database, and some IaaS resource

- **Examples**
  - Heroku, one of Salesforce's cloud platforms, runs on AWS, and the vendor encourages developers to mix Heroku and AWS services

SaaS+PaaS

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SaaS+PaaS

- SaaS vendors are pushing into platforms with extensibility features

- **Examples**
  - Salesforce’s Force.com platform is the leading example of a product that began life as a set of application tools and is now a public cloud platform used for many applications
  - Intuit, Netsuite, Workday, Box and other SaaS vendors are beginning to follow, even if with less complete offerings