Cloud Computing

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Course overview

- Objectives
  - Understand the main cloud computing concepts, architectures and technologies
  - Gain practical experience with modern cloud platforms

Course contents

- Lectures
  - Introduction to cloud computing
  - IaaS
  - PaaS
- Practicals
  - AWS

Today's lecture

- Overview of cloud computing
- Types of clouds
- Virtualisation

Collaboration service demand skyrocketed amid the pandemic

2,900%

Growth of daily participants between December and April 2020

ZOOM

2.5 million

New connected users in 1 week, up 25%

slack

12 million

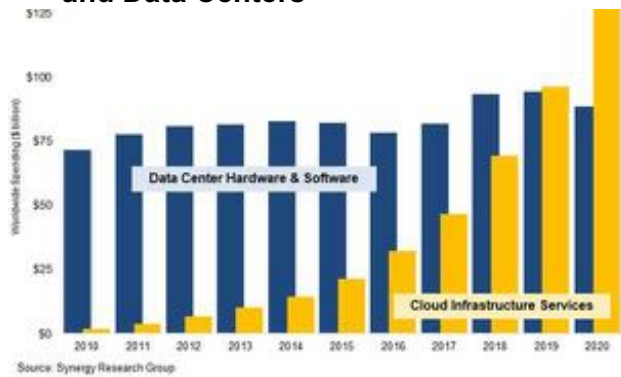New daily active users in 1 week, up 37.5%

Microsoft Teams

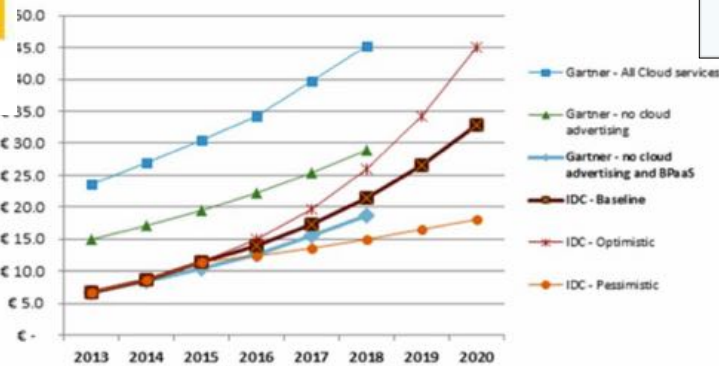**15.8 million**

New subscribers between January and March

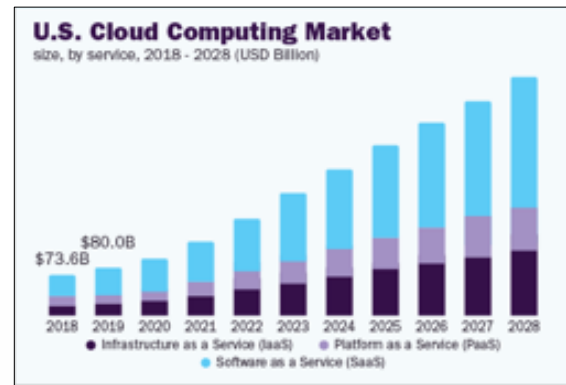NETFLIX

All made possible by the cloud

Worldwide Enterprise Spending on Cloud and Data Centers

Source: Synergy Research Group

http://ec.europa.eu/newsroom/document.cfm?doc_id=41184

https://www.grandviewresearch.com/industry-analysis/cloud-computing-industry

What is the cloud?

An old dream

"If computers of the kind I have advocated become the computers of the future, then computing may someday be organized as a **public utility** just as the telephone system is a public utility...The computer utility could become the basis of a new and important industry"
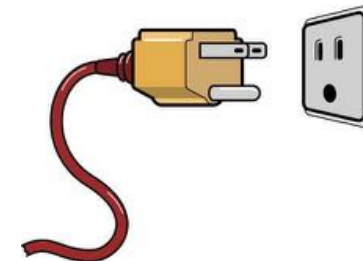

John McCarthy
MIT Centennial (1961)

Power grid analogy

- *Private power generators*

- *Electricity as utility*

What is the cloud?

Delivering computing resources as a service

What is the cloud?

- *"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"*
  - National Institute of Standards and Technology (NIST)

Essential characteristics

- On-demand self-service
- Broad network access
- Resource pooling
- Elasticity
- Metered service

On-demand self-service

- Consumers can easily manage resource capacity as needed automatically
  - No human interaction with cloud provider
  - Based on APIs and user interfaces

Broad network access

- Consumers are physically separated from the computing capabilities

- Those capabilities are available over a network and accessed through standard mechanisms and devices
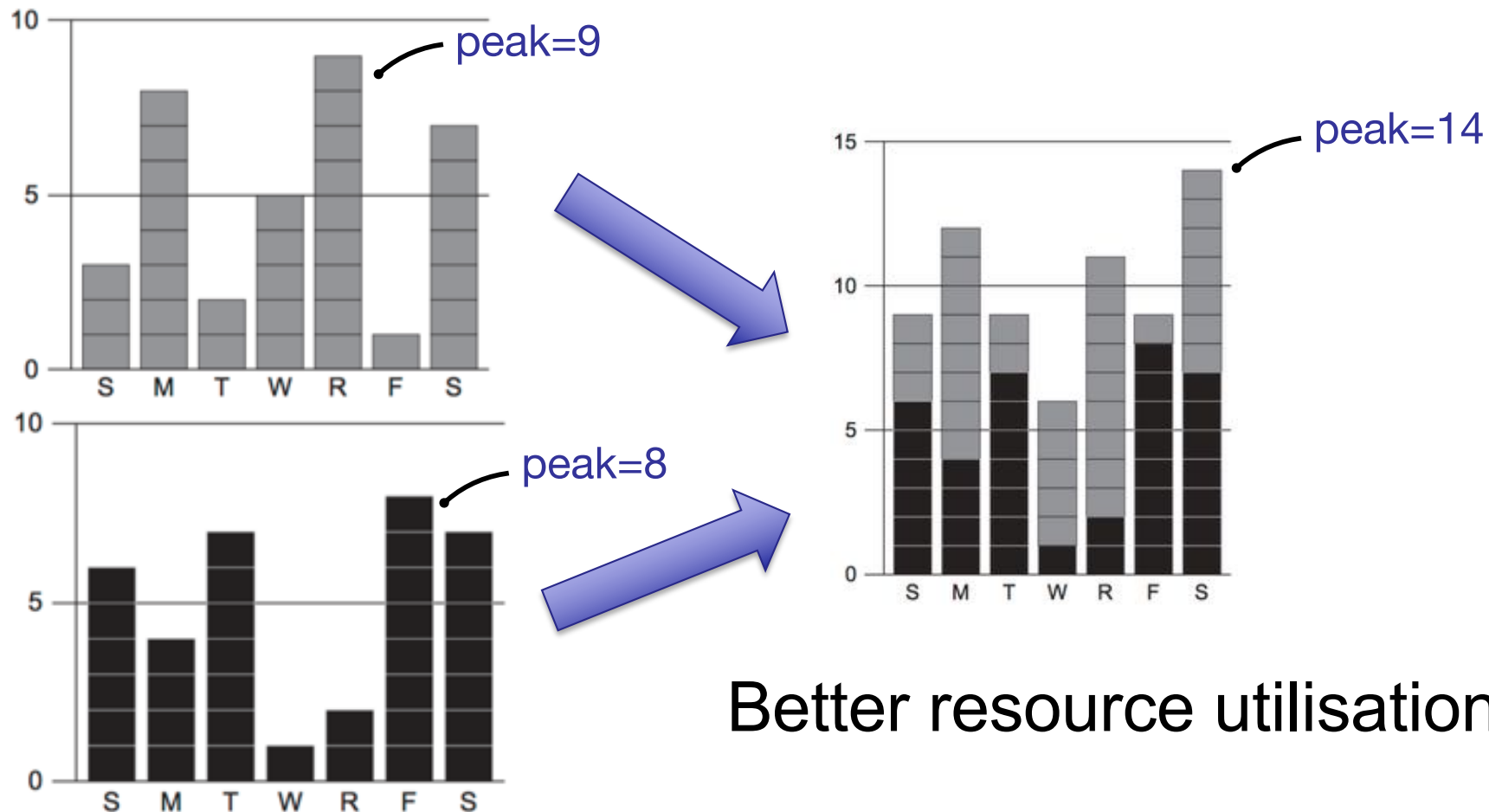
Resource pooling

- Computing resources are put into a common pool and shared among multiple consumers
   - Dynamic resource allocation based on consumer demand

Resource pooling

- Aggregate demand is smoother than individual customer demands

peak=9

peak=8
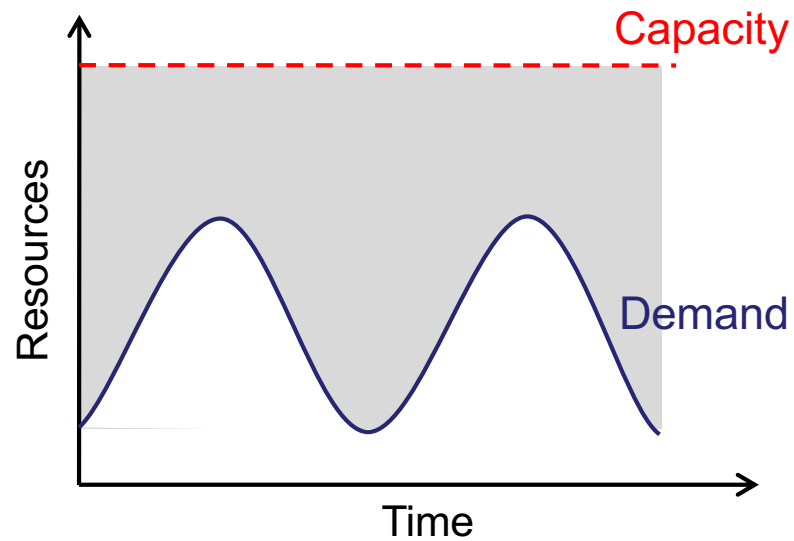
peak=14

Better resource utilisation

Elasticity

- Ability to rapidly add and remove resources in response to demand
  - Enables matching resources to demand
  - Vertical scaling: bigger servers
  - Horizontal scaling: more servers
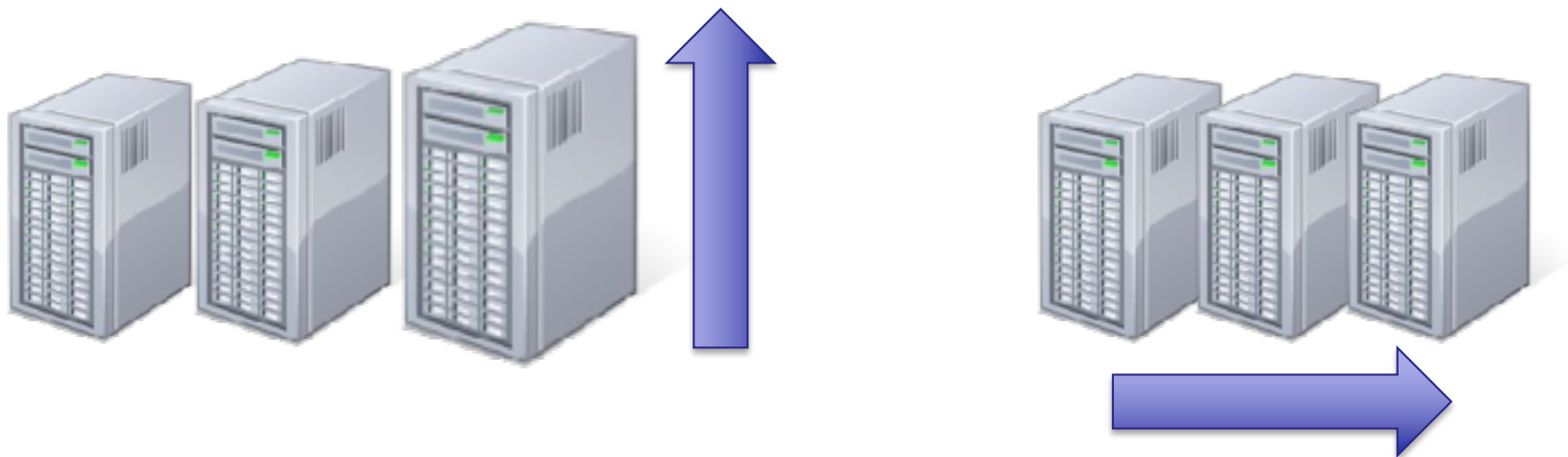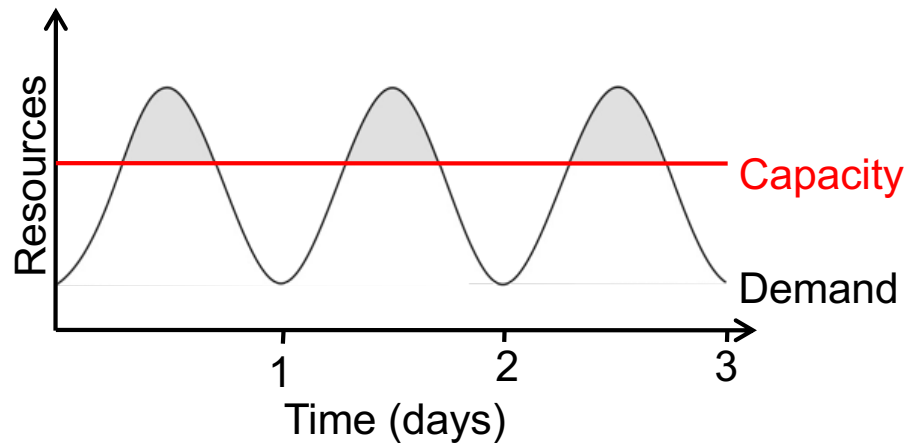
Facing dynamic demand
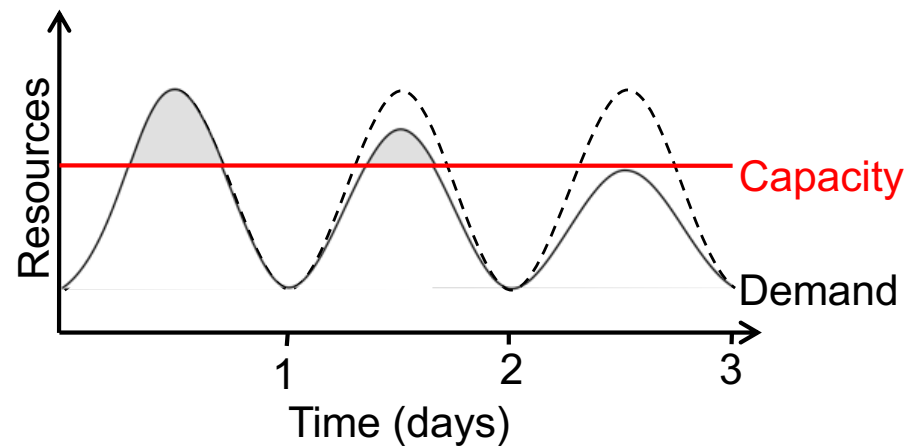
- ## Over-provisioning

Resource waste

Facing dynamic demand

- ## Under-provisioning

Lost revenue

Lost users

Facing dynamic demand

- Elastic provisioning
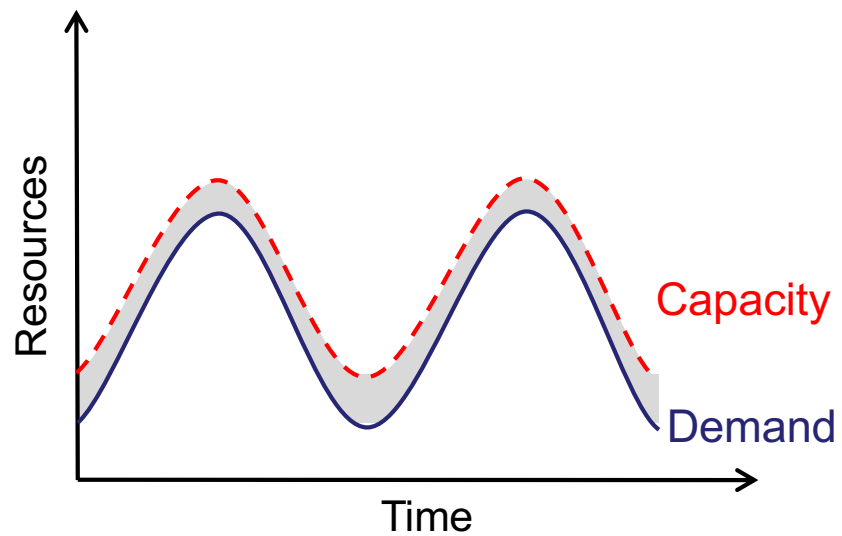
Meeting demand with minimum cost

Metered service

- The resource usage of consumers is continuously measured
  - Forms basis for billing and ensuring fair use

Cloud pricing

- Usage-based pricing (pay-per-use)
  - Most common model
  - E.g., per server hour, per GB transferred
- Subscription Pricing
  - Fixed fee per time period
- Dynamic Pricing
  - E.g., AWS Spot Instances
- Many variations
  - E.g., AWS Reserved Instances

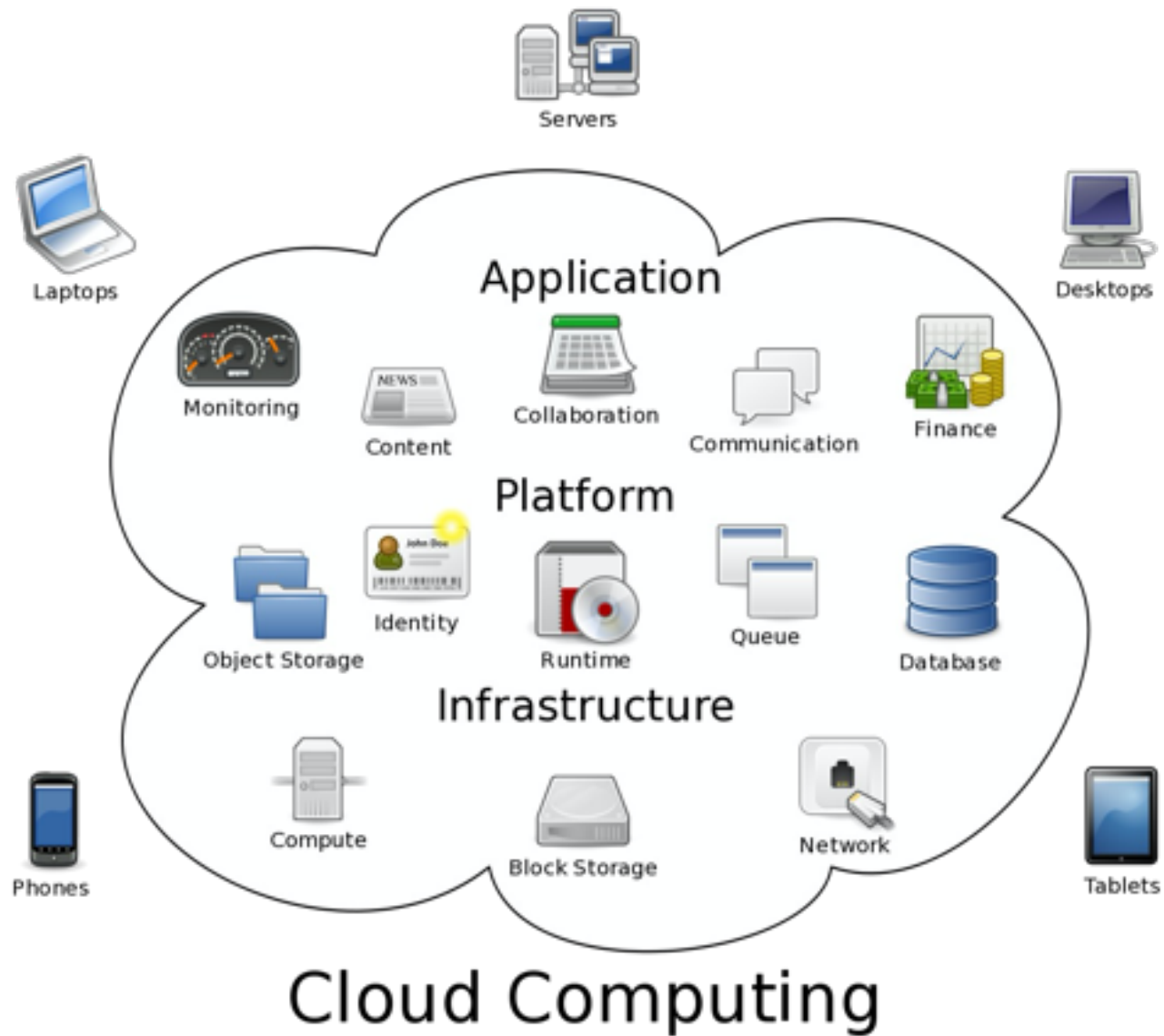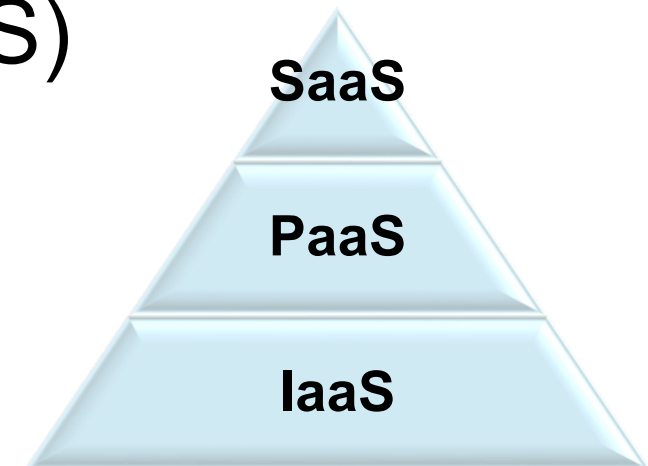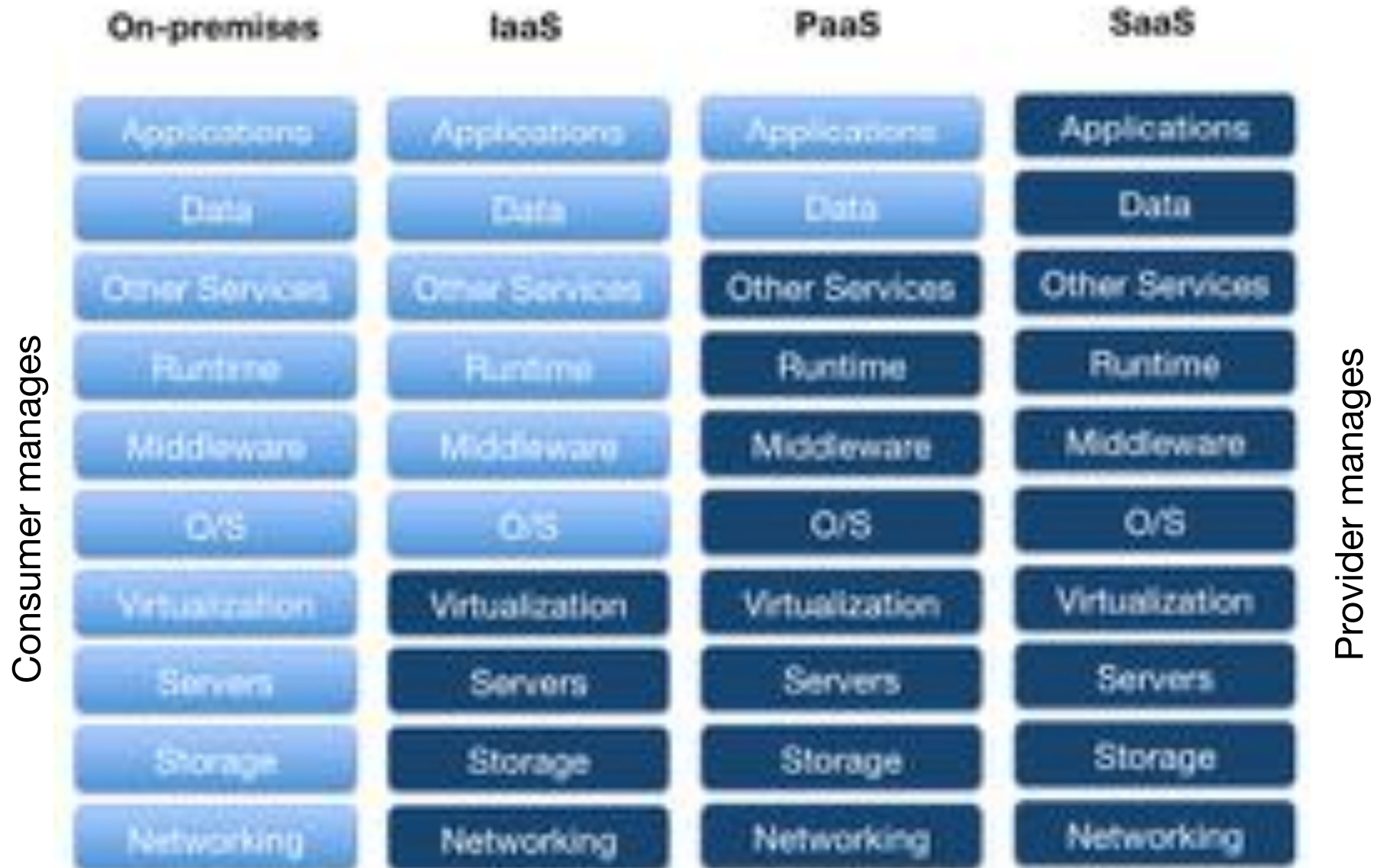# Types of clouds

Everything as a Service

Service models

- Infrastructure as a Service (IaaS)
  - offers storage and compute resources
- Platform as a Service (PaaS)
  - offers development environments used to create applications
- Software as a Service (SaaS)
  - offers purpose-built business applications

SaaS

PaaS

IaaS

Service models

On-premises	IaaS	PaaS	SaaS
Applications	Applications	Applications	Applications
Data	Data	Data	Data
Other Services	Other Services	Other Services	Other Services
Runtime	Runtime	Runtime	Runtime
Middleware	Middleware	Middleware	Middleware
O/S	O/S	O/S	O/S
Virtualization	Virtualization	Virtualization	Virtualization
Servers	Servers	Servers	Servers
Storage	Storage	Storage	Storage
Networking	Networking	Networking	Networking

Consumer manages

Provider manages

Pizza as a service

Infrastructure as a Service

- The cloud provider delivers raw computing resources (typically virtualised)
  - servers, storage, networking, …

- Consumers use these resources to deploy and run arbitrary software, including operating systems and applications

Platform as a Service

- The cloud provider delivers a complete application development and hosting environment
  - APIs, IDE plug-ins, services, tools, …
- Consumers write, deploy and manage their applications using this environment

Software as a Service

- The cloud provider delivers running applications
- Consumers access the applications using thin clients
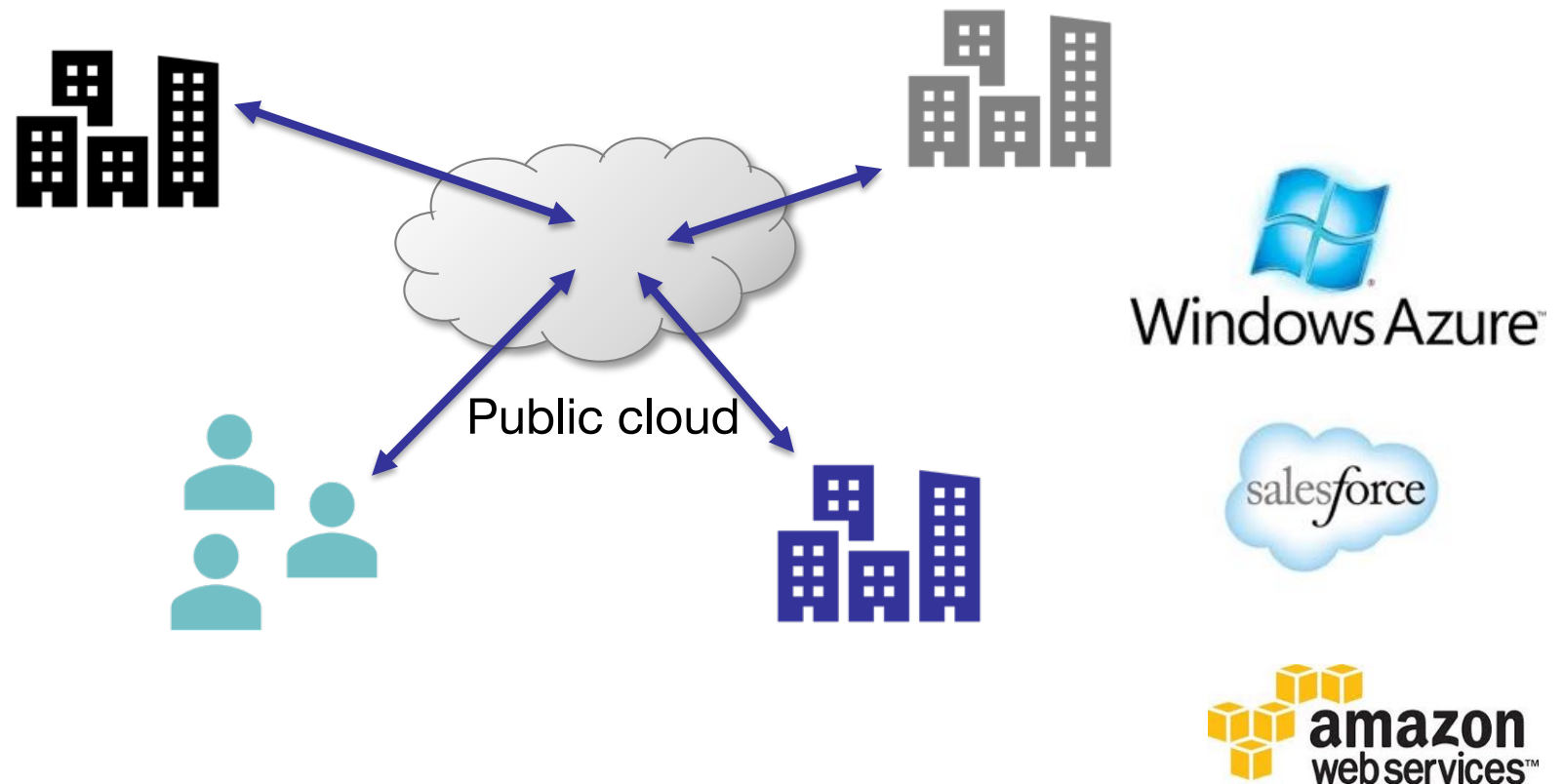- Typically priced using a subscription fee

Deployment models

- Public cloud
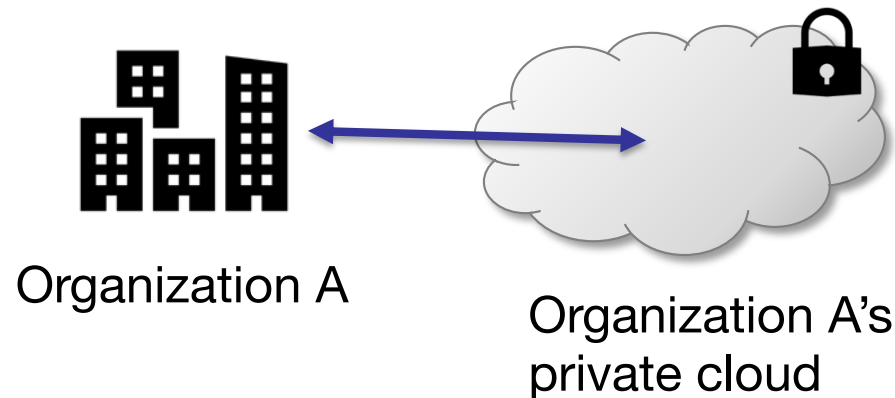- Private cloud
- Hybrid cloud

Public cloud

- Open to use to the general public; owned by an organisation selling cloud services

Public cloud

Private cloud

- Available for exclusive use by a single organisation; it may be managed by the organisation or a third party and may exist on premise or off premise

Organization A

Organization A's
private cloud

Hybrid cloud

- A combination of two or more clouds enabling data and application portability

e.g., "*cloud bursting*" for handling demand spikes

Organization A

Organization A's private cloud

Public cloud

AWS Outposts

Azure Stack
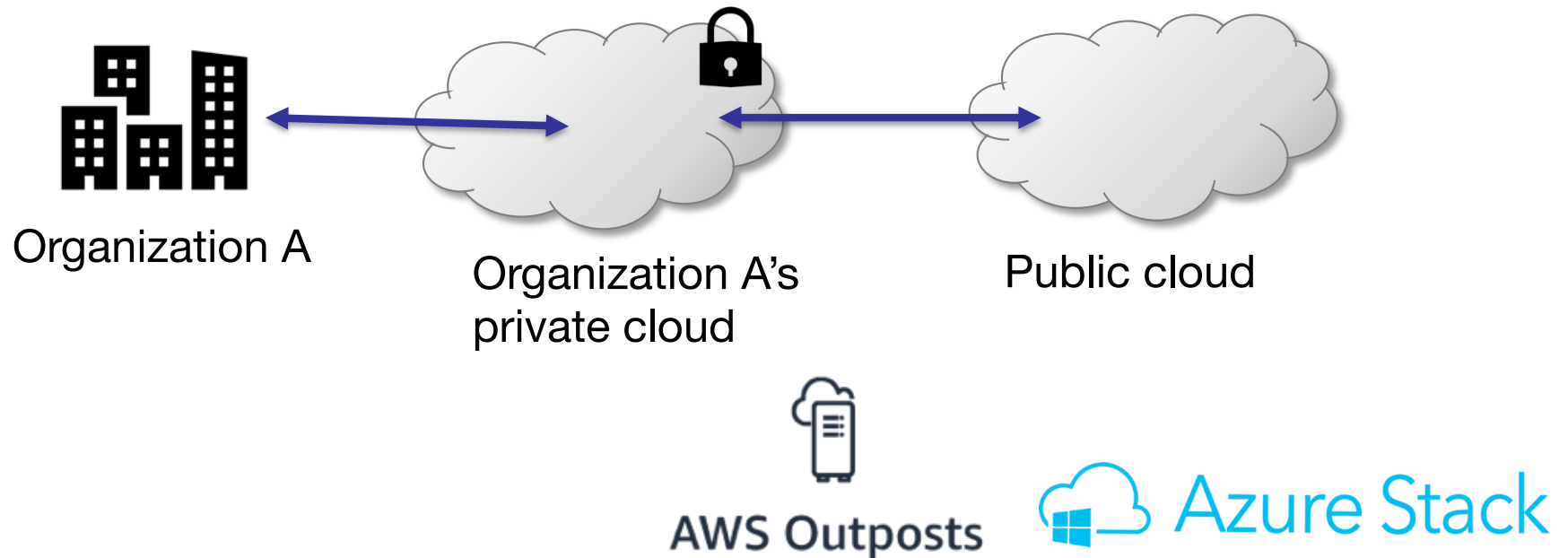
Cloud benefits

- Economic benefits
  - Lower cost of using resources because of elasticity and usage-based pricing
    - Even if clouds are more expensive on a unit-cost basis, the cloud can be cheaper overall
  - Lower cost of provisioning resources because of pooling
  - Change from capital to operational expenses

Cloud benefits

- Agility benefits
  - Reduced time to market
  - No need for months of planning, purchasing, provisioning, and configuring.

- Security benefits
  - Running secure data centres is *not* the core competence of typical enterprises

Cloud challenges

- Data confidentiality
  - Where is my data?
  - Who can have access ?
- Performance and availability
  - How long do I wait?
  - Is the data transfer speed high enough?
  - What if there is an outage in the cloud?
- Vendor lock-in
  - Can I move from one cloud to another?

Enabling technology: Virtualisation

Virtualisation

- Technology that allows multiple virtual machines to run on a single physical machine

Virtualisation features

- *Isolation*: each virtual machine (VM) is isolated from the host physical machine and the other VMs
    - E.g., a VM may crash or be compromised without affecting other VMs
- *Encapsulation*: the complete state of a VM can be manipulated as a unit
    - E.g., VMs can be migrated across physical machines, suspended, or resumed
    - E.g., one can dynamically modify the resources allocated to a VM

Virtualisation types

- ● Hosted virtualisation
  - ▪ VirtualBox, VMware Workstation, …
- ● Bare-metal (native) virtualisation
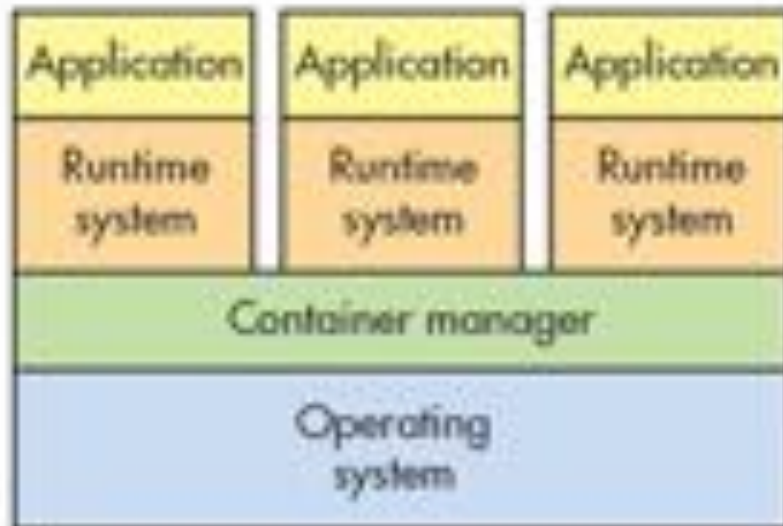 - ▪ Xen, KVM, vSphere, Microsoft Hyper-V, …

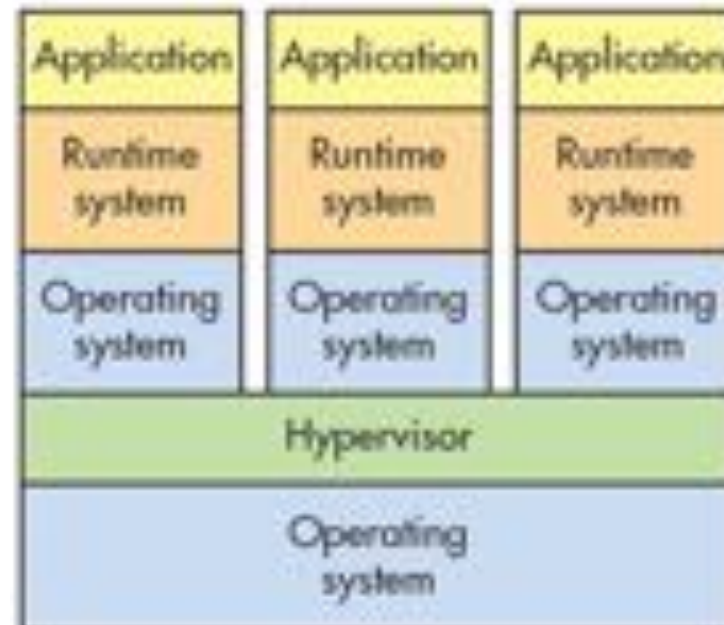Hosted Architecture

Bare-Metal Architecture

Virtualisation types

- ## OS-level virtualisation (container-based virtualisation)
  - ### Docker, LXC, …

Containers

VMs

vs.

Virtualisation benefits

- Faster application development, testing, and deployment

- Cost reduction through server consolidation

- Enhanced availability
  - E.g., migration to accommodate planned maintenance; restoring from snapshots

Virtualisation challenges

- Performance degradation
  - Compared to running directly on physical machine
- Performance isolation
  - Interference between VMs/containers
- Security risks
  - Complexity and potential vulnerabilities introduced by virtualisation layer

Summary

- Cloud computing is about offering resources as a service; its main features include elasticity, metered service and on-demand self-service

- Cloud offerings can be categorised as IaaS, PaaS, or SaaS as well as public, private, or hybrid

- Virtualisation is a critical enabling technology for the cloud

References

- *The Cloud at Your Service*, Jothy Rosenberg and Arthur Mateos, Manning Publications Co., 2010
- *A view of cloud computing*, Michael Armbrust, et al., Commun. ACM 53, 4, 2010
- *Cloudonomics: The Business Value of Cloud Computing*, Joe Weinman, Wiley, 2012
- *Google App Engine,* https://developers.google.com/appengine