URBAN COMPUTING

Image credit: https://www.healtheuropa.eu/cloud-based-services-storing-health-data-in-the-cloud/93053/

NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

AI6128 Urban Computing

Lecture 4

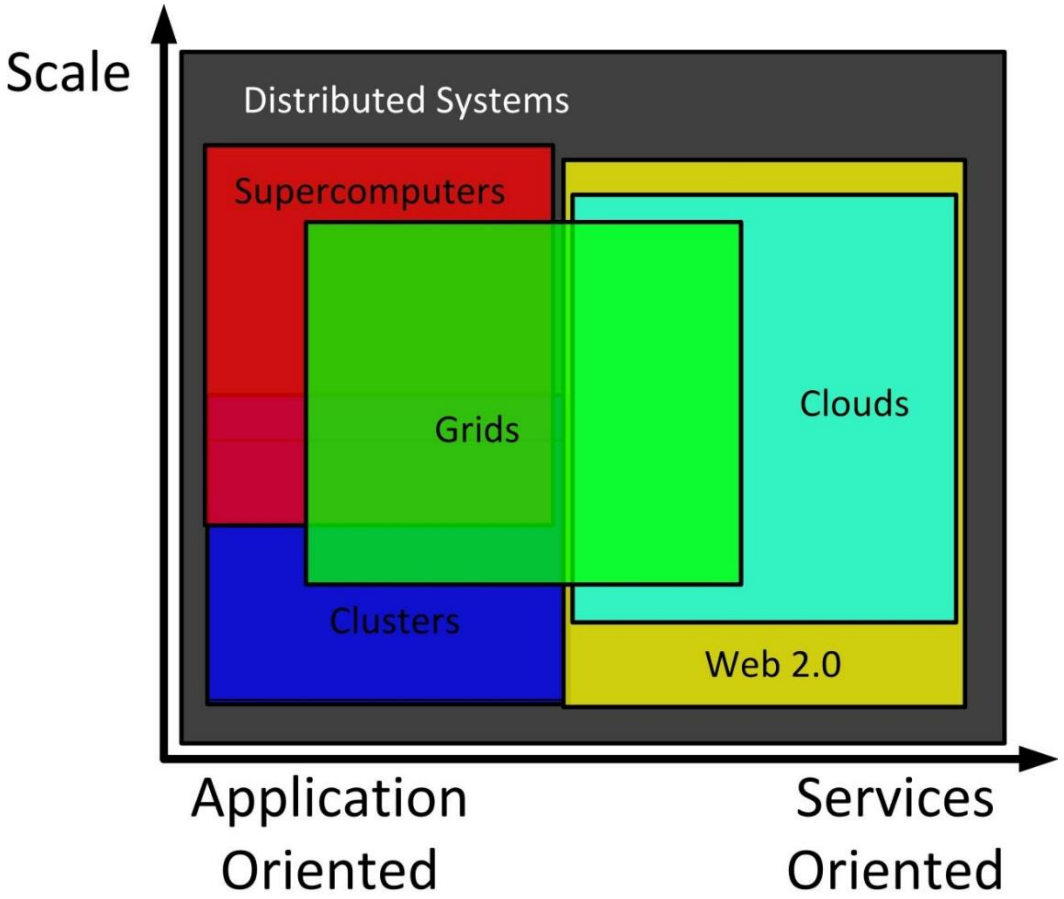
Cloud Computing Support

Content

- Introduction to cloud computing
- Cloud service models
- Microsoft Azure (PaaS)
- Virtualization (IaaS enabler)
- Fog computing
- Artificial intelligence of things (AIoT)

Introduction to Cloud Computing

Backend Computing Schemes



Supercomputing (from 1960s)

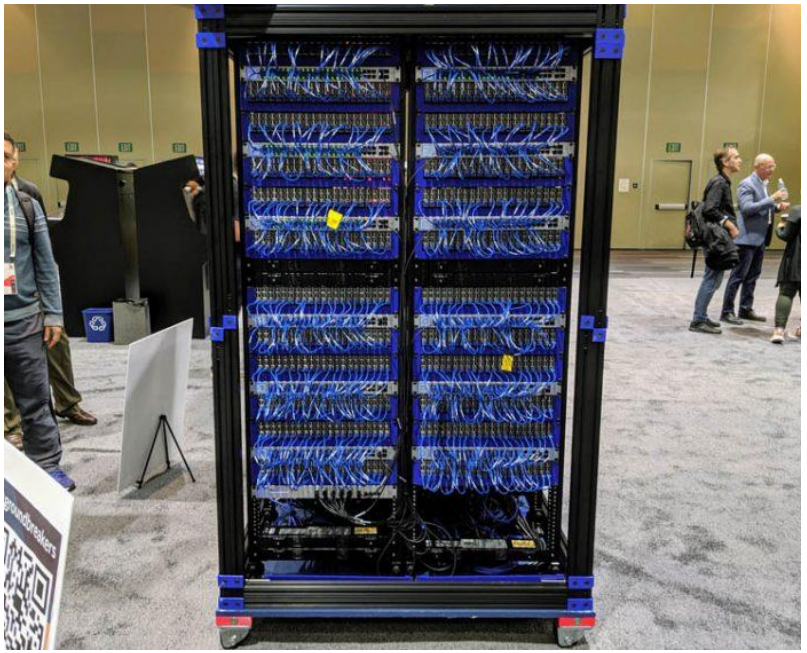
- Computing based on a highly integrated system with a high level of performance and a highly customized OS

IBM Blue Gene/P
164,000 processors
in 2010s

Cluster Computing (from 1960s)

- Computing based on a cluster of co-located servers running general-purpose OS (e.g., Windows, Ubuntu)

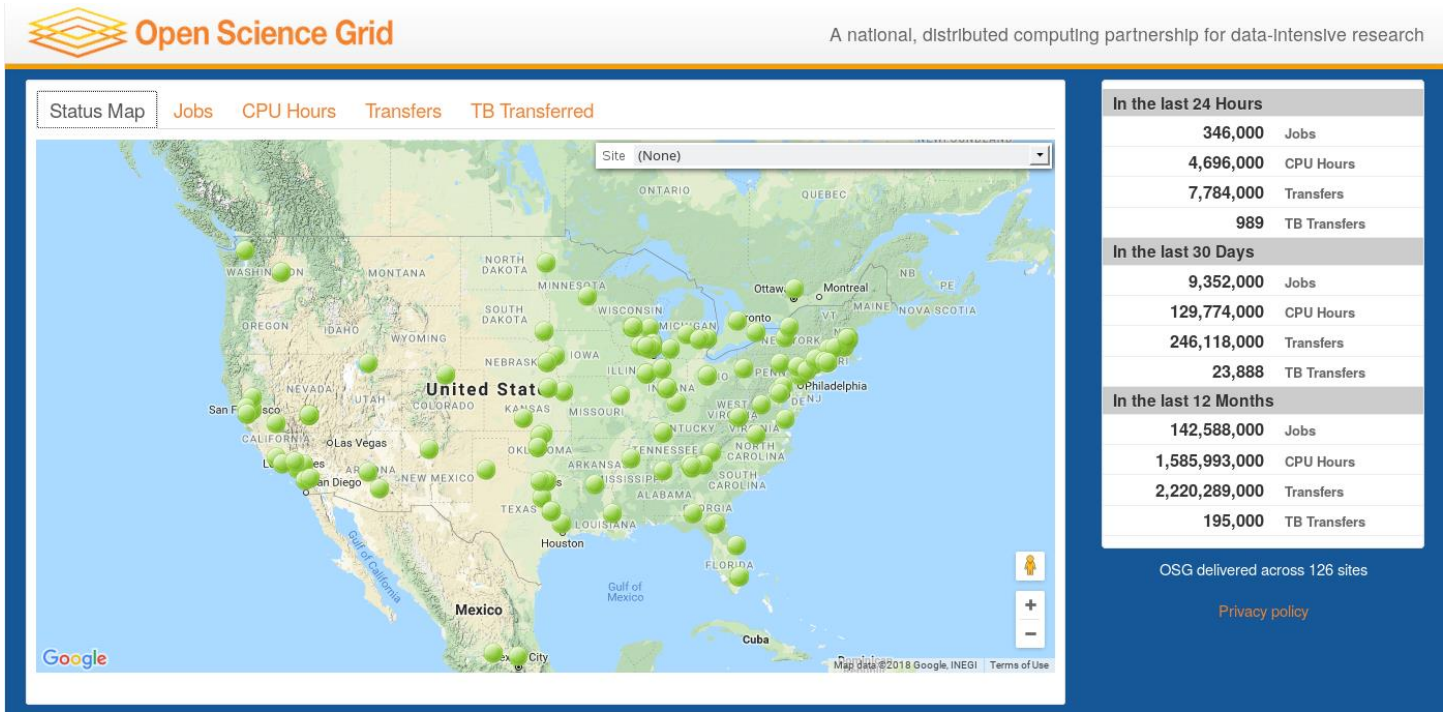
Sun Microsystems Solaris Cluster



Oracle's cluster of 1060 Raspberry Pi nodes (each node $35, 2019)

Grid Computing

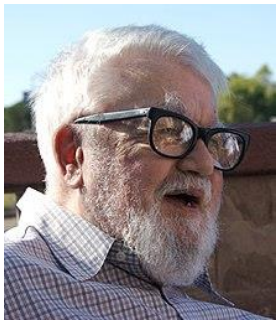
- Interconnected clusters that are geographically distributed



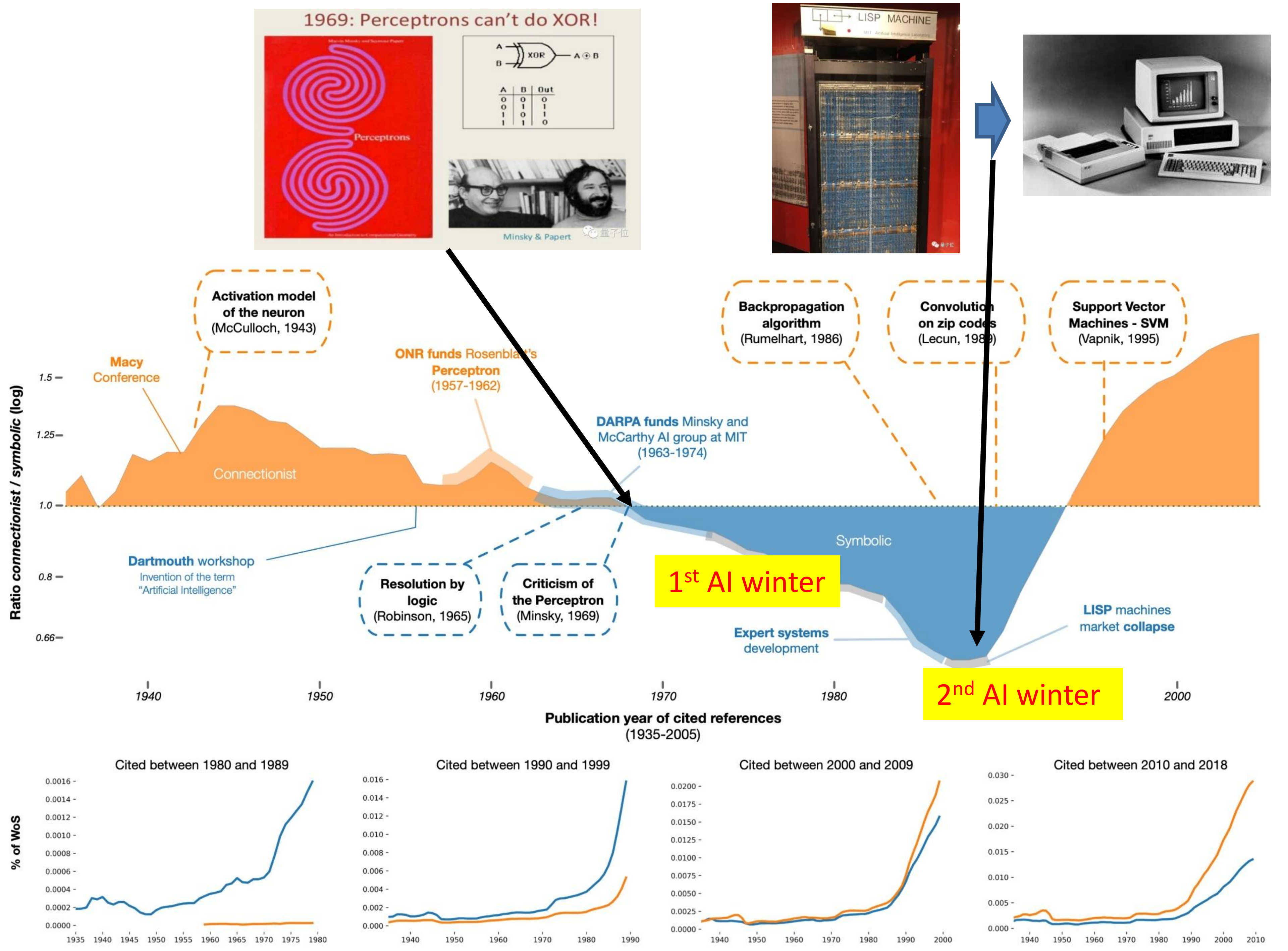
Utility Computing

- Packaging of computing resources (computation, storage, etc) as a metered service similar to a traditional public utility

- Not a new concept
  - "*If computers of the kind I have advocated become the computers of the future, then computing may someday be organized as a public utility just as the telephone system is a public utility... The computer utility could become the basis of a new and important industry.*"
    -- John McCarthy, MIT Centennial in 1961



John McCarthy
1927-2011


1969: Perceptrons can't do XOR!
Perceptrons
XOR
A ⊕ B
A B Out
0 0 0
0 1 1
1 0 1
1 1 0
Minsky & Papert
LISP MACHINE
Activation model of the neuron (McCulloch, 1943)
Macy Conference
ONR funds Rosenblatt's Perceptron (1957-1962)
Backpropagation algorithm (Rumelhart, 1986)
Convolution on zip codes (Lecun, 1989)
Support Vector Machines - SVM (Vapnik, 1995)
DARPA funds Minsky and McCarthy AI group at MIT (1963-1974)
Connectionist
Symbolic
Dartmouth workshop
Invention of the term "Artificial Intelligence"
Resolution by logic (Robinson, 1965)
Criticism of the Perceptron (Minsky, 1969)
1st AI winter
Expert systems development
LISP machines market collapse
2nd AI winter
Ratio connectionist / symbolic (log)
1.5
1.25
1.0
0.8
0.66
1940
1950
1960
1970
1980
2000
Publication year of cited references
(1935-2005)
Cited between 1980 and 1989
Cited between 1990 and 1999
Cited between 2000 and 2009
Cited between 2010 and 2018
% of WoS

Cloud Computing

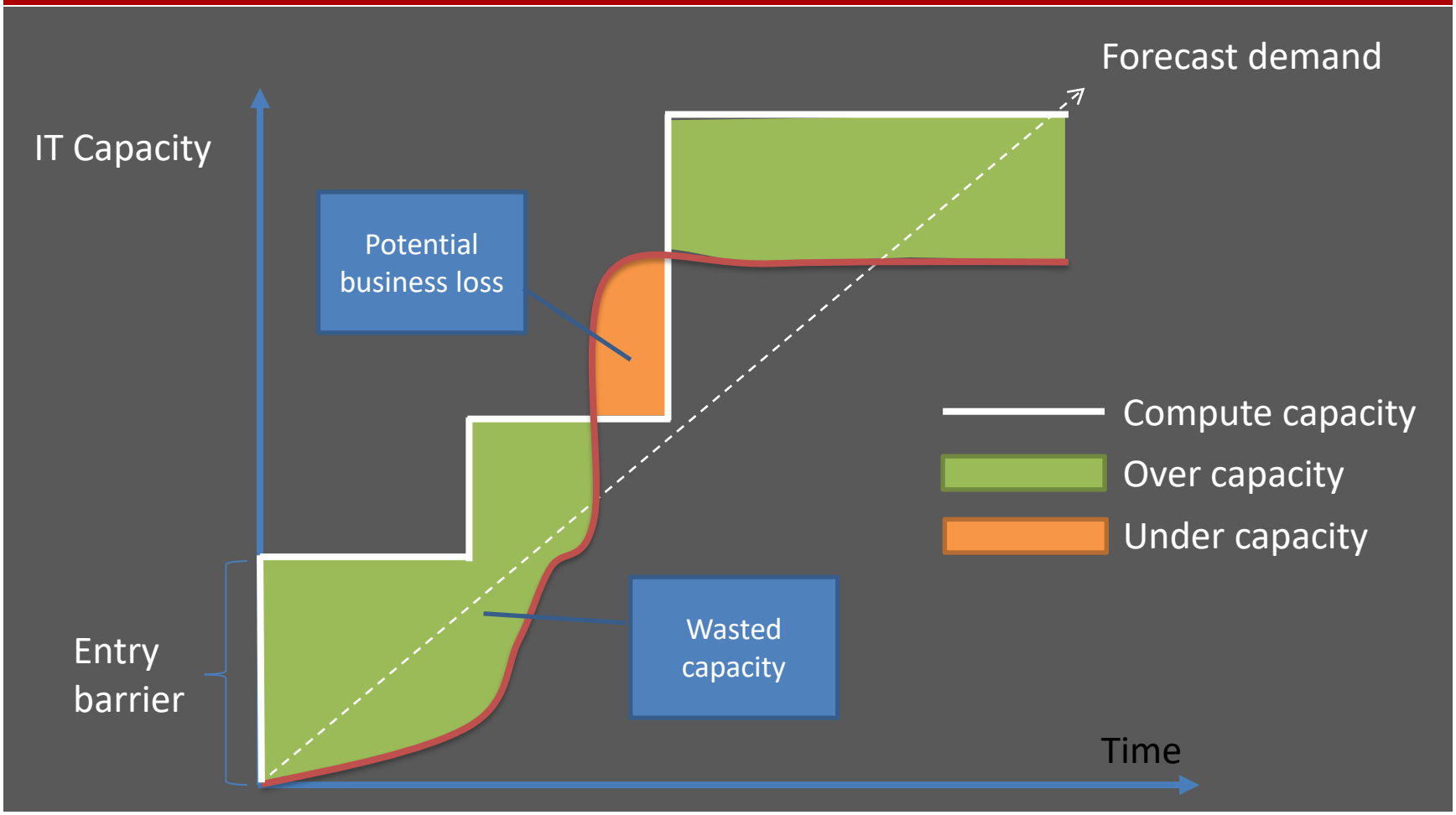
- Is cloud computing
  - grid computing + utility computing ?
  - Difficult to define
    - Means different things to different parties

- Various definitions
  - NIST (National Institute of Standards and Technology)
    Universally accepted definition

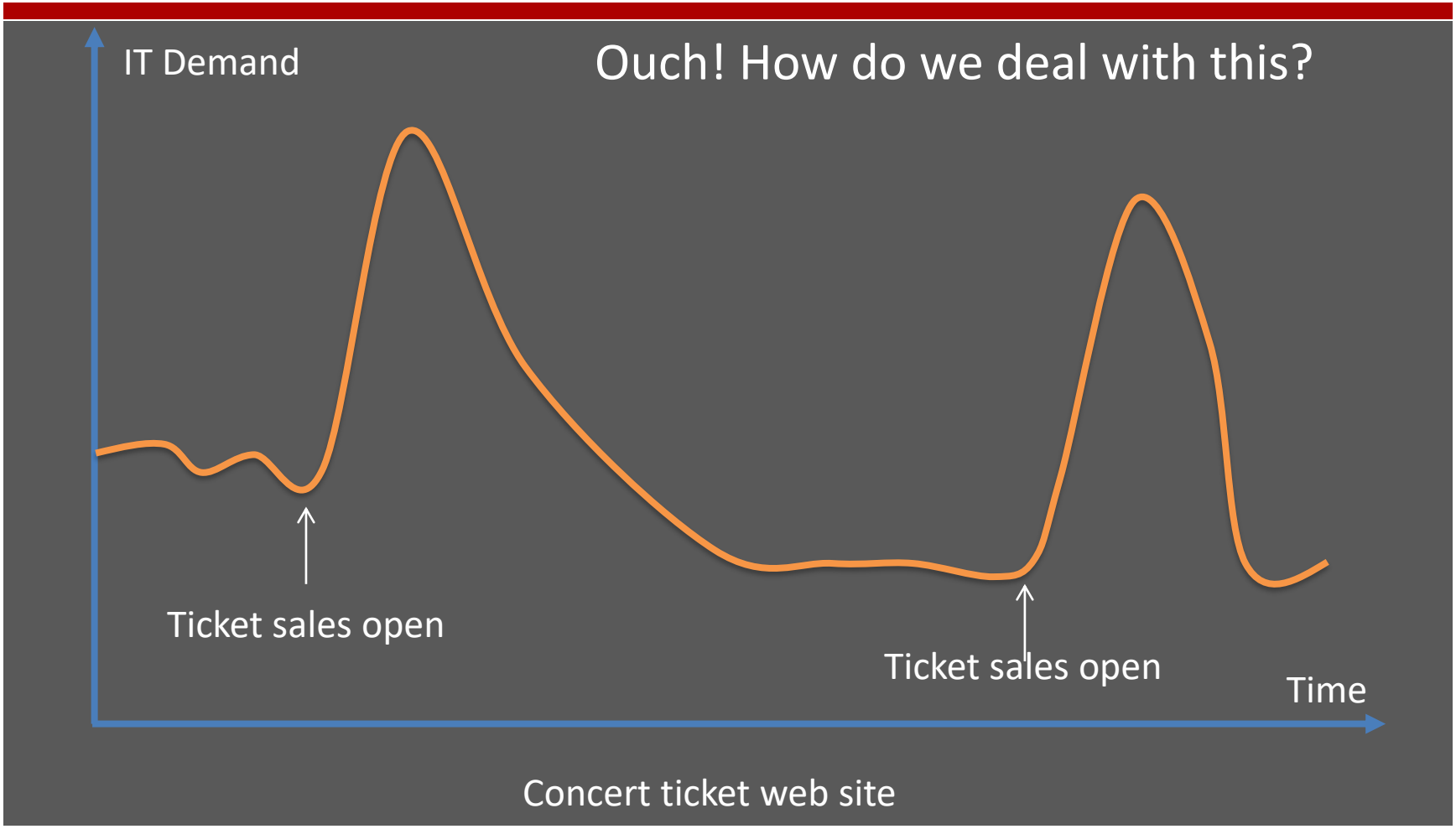
Cloud Computing - NIST

- "Cloud computing is a model for enabling 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."

Managing Demand



Demand Burst



Cloud Computing Solution

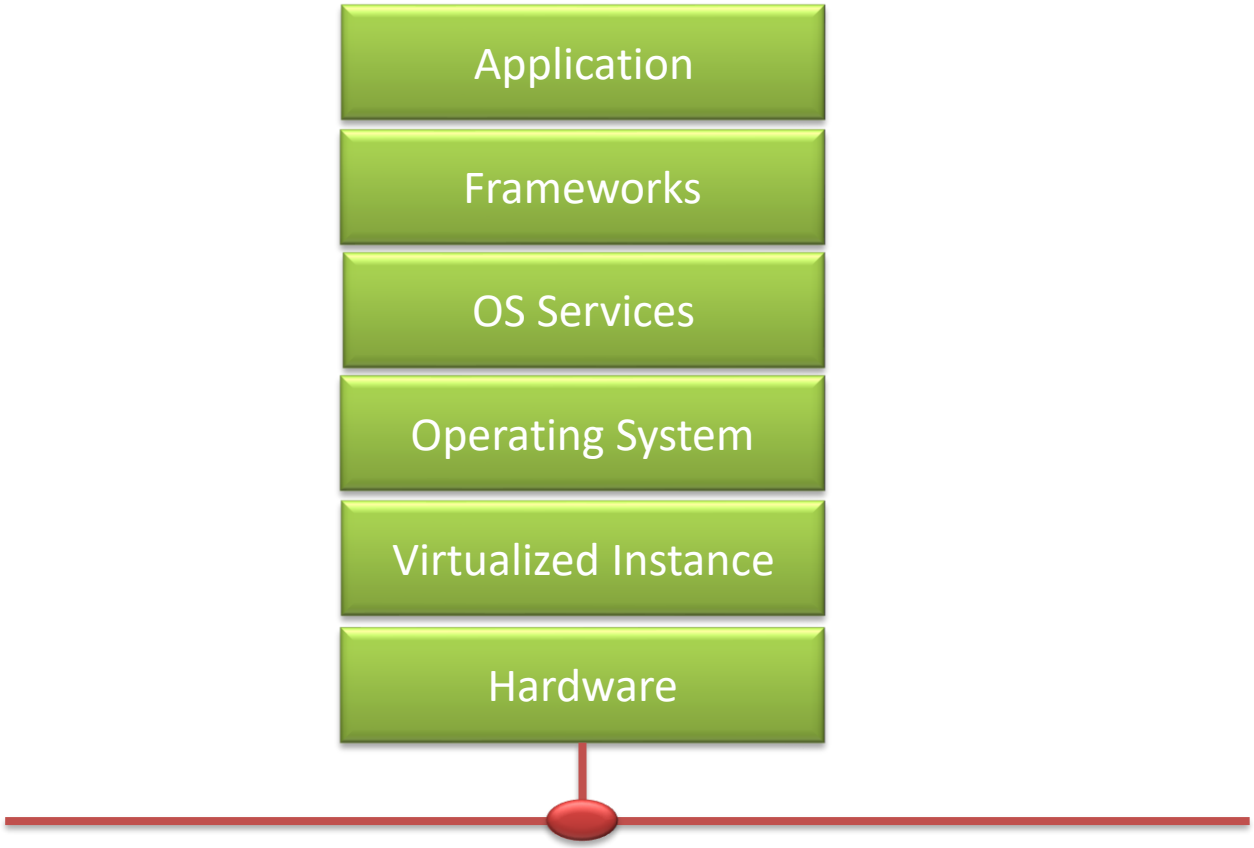
- Shared, multi-tenant environment
- Pools of computing resources
- Resources can be requested as required
- Available via the Internet
  - Private clouds can be available via private WAN
- Pay as you go

Cloud Service Models

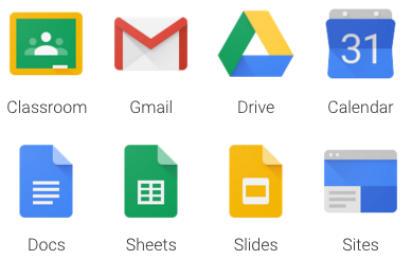
Cloud Service Models

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

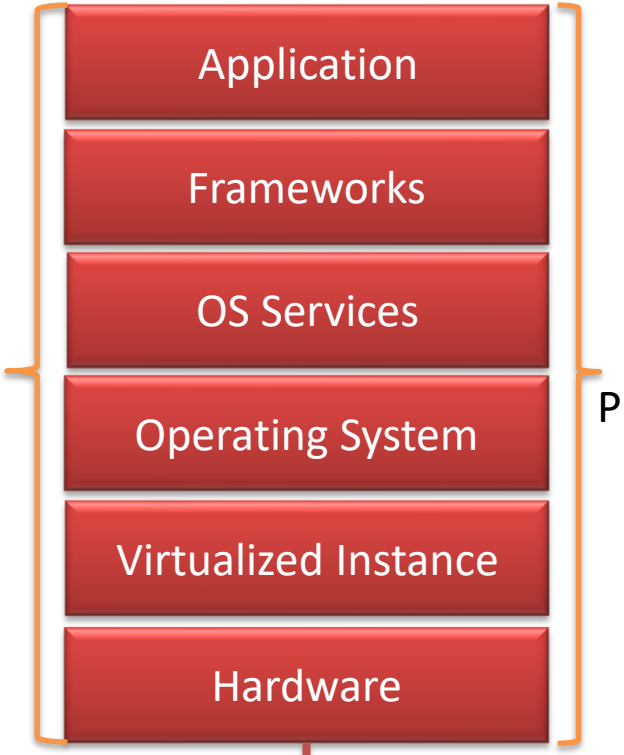
The Stack


Application
Frameworks
OS Services
Operating System
Virtualized Instance
Hardware

Software as a Service (SaaS)



Google Apps



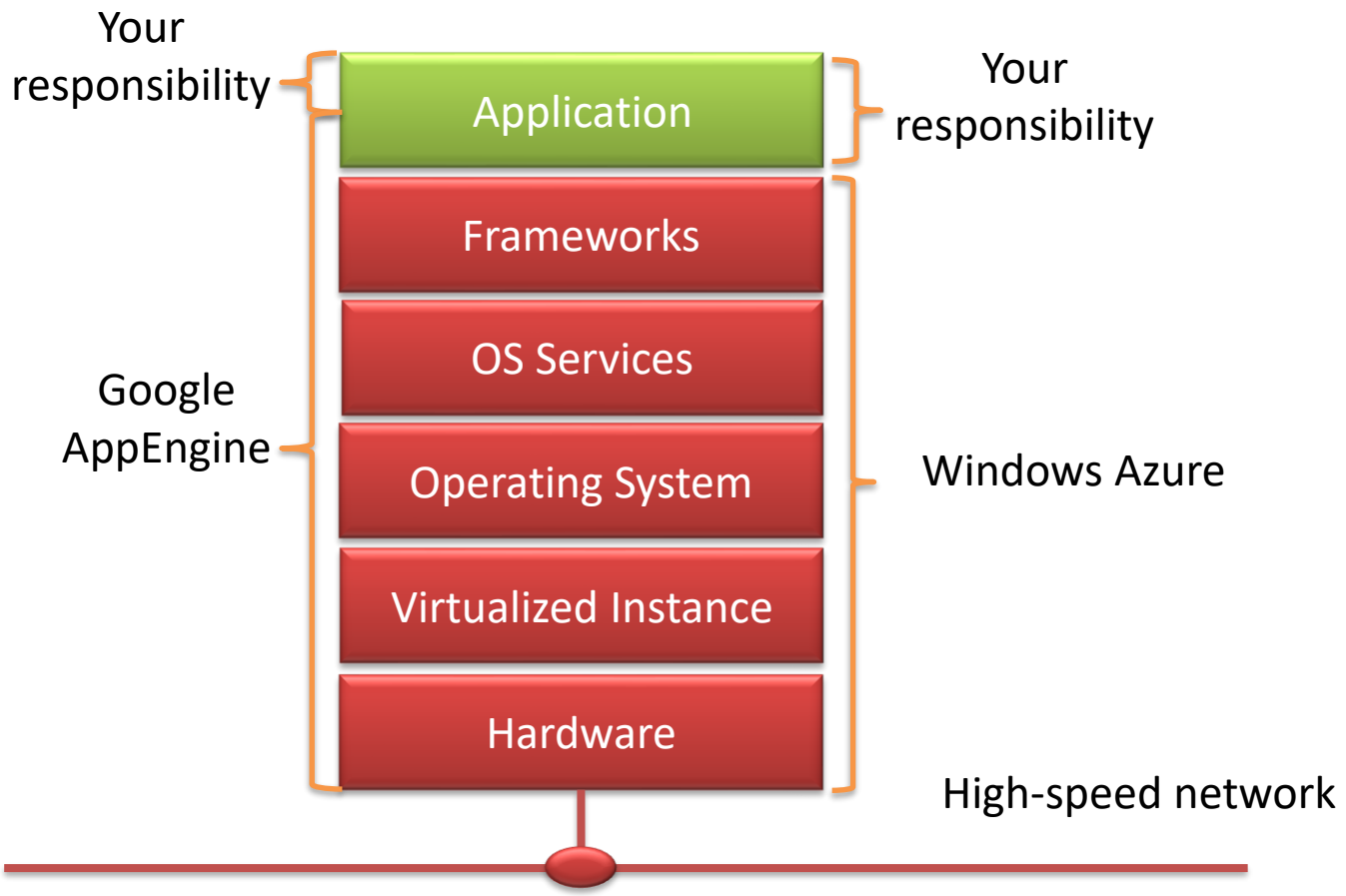
Microsoft Business Productivity Online Services

High-speed network

Famous SaaS

- Dropbox
- Zoom
- Cisco WebEx
- Google Apps
- Salesforce
- Concur

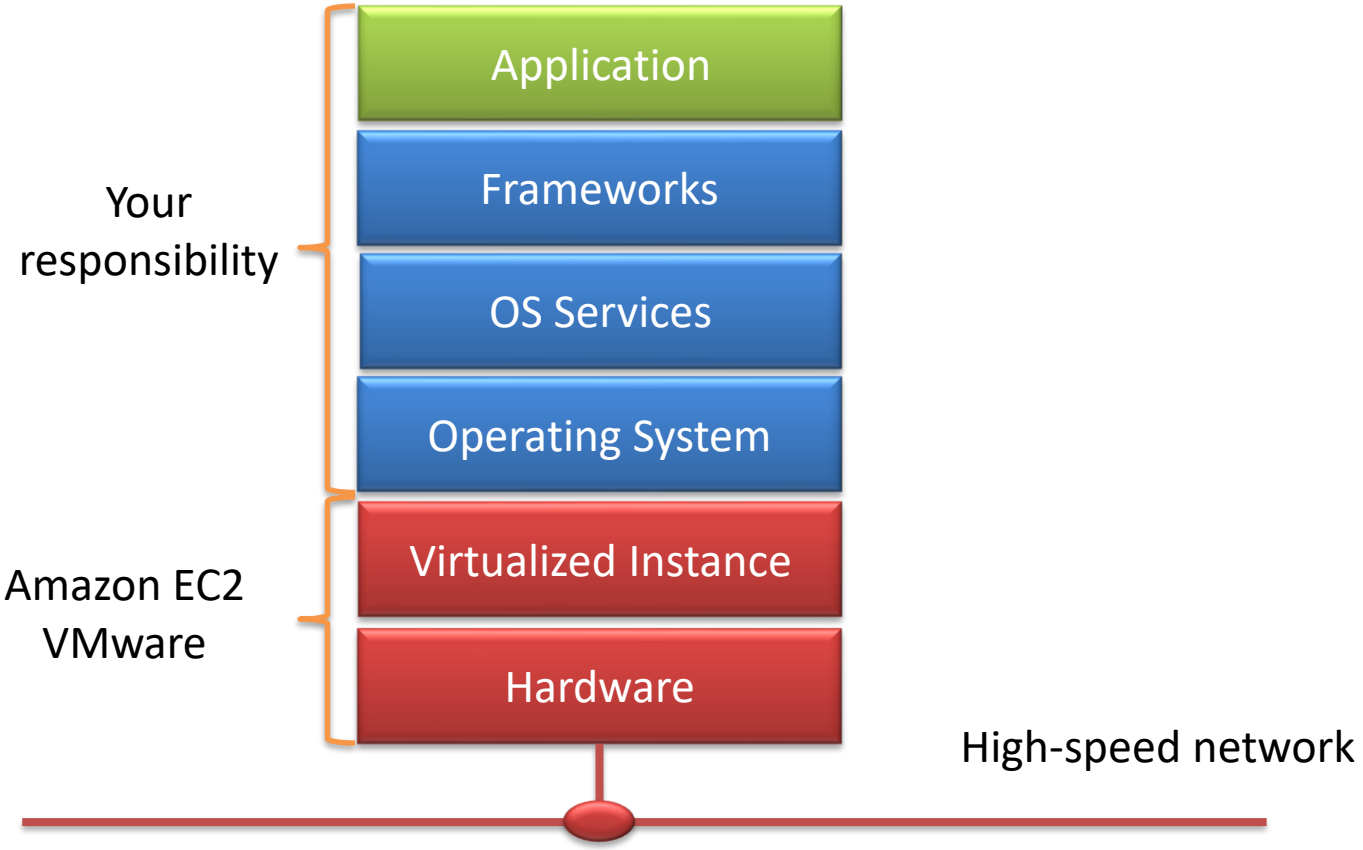
Platform as a Service (PaaS)



Famous PaaS

- Microsoft Azure
- Google App Engine
- Heroku
- Apache Stratos
- OpenSHIFT

Infrastructure as a Service (IaaS)



Famous IaaS

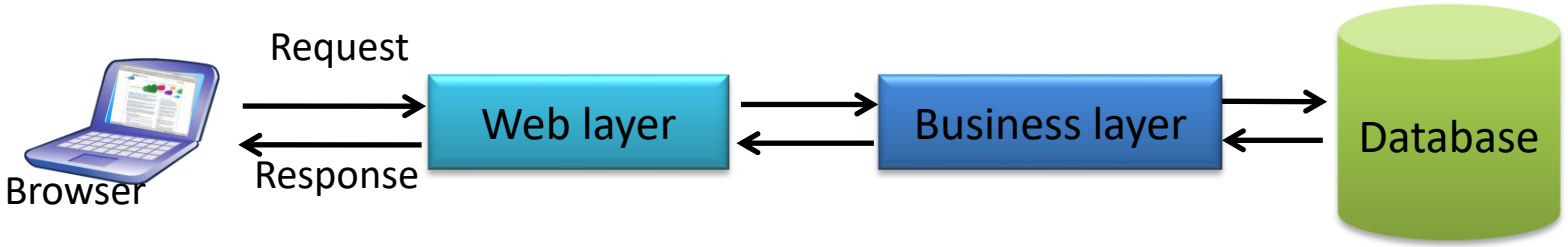
- Microsoft Azure
- Linode
- DigitalOcean
- Rackspace
- Amazon Web Services (AWS)

Geo-Distributed Data Centres

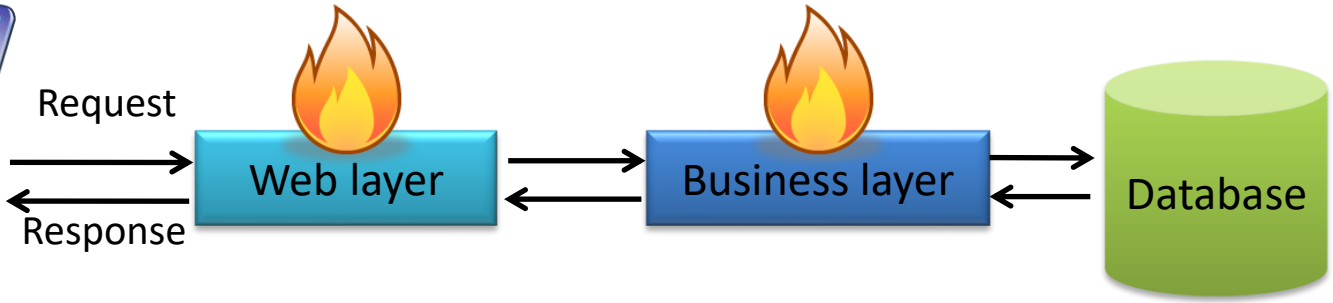
- Larger vendors have proven track records for running services for large numbers of customers
  - Hosted in their own data centres

Microsoft Azure: An example of PaaS

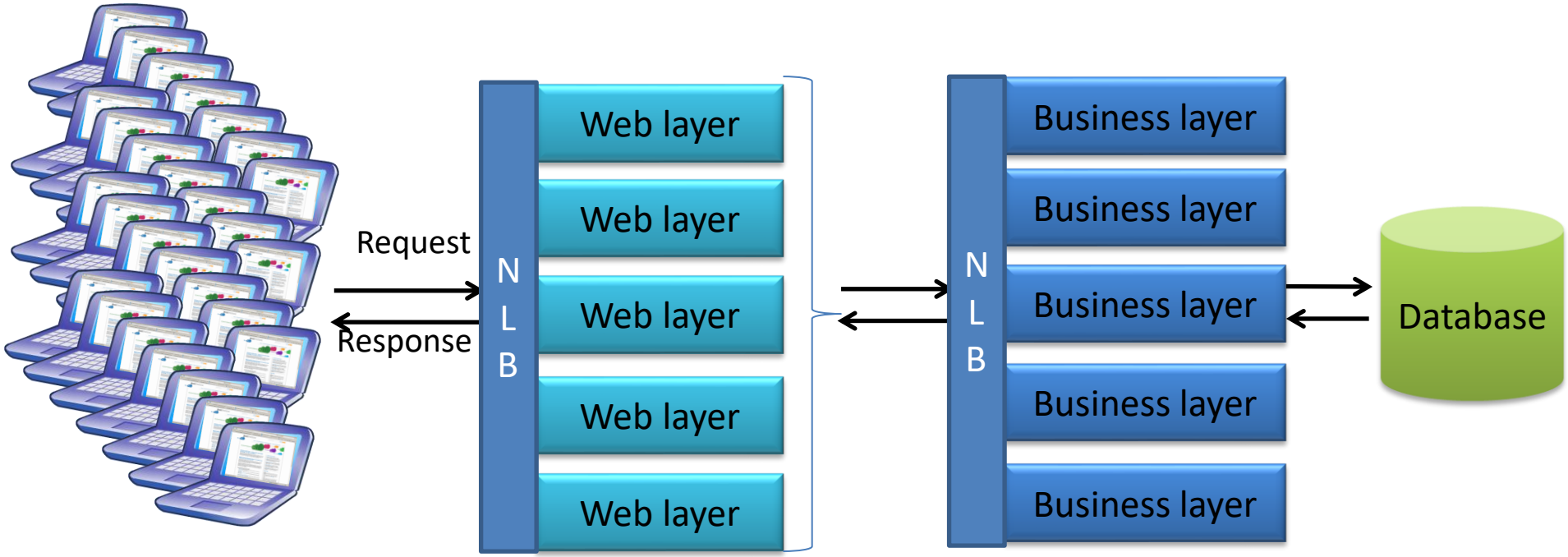
A Typical Application



What do we do when it starts to overheat?

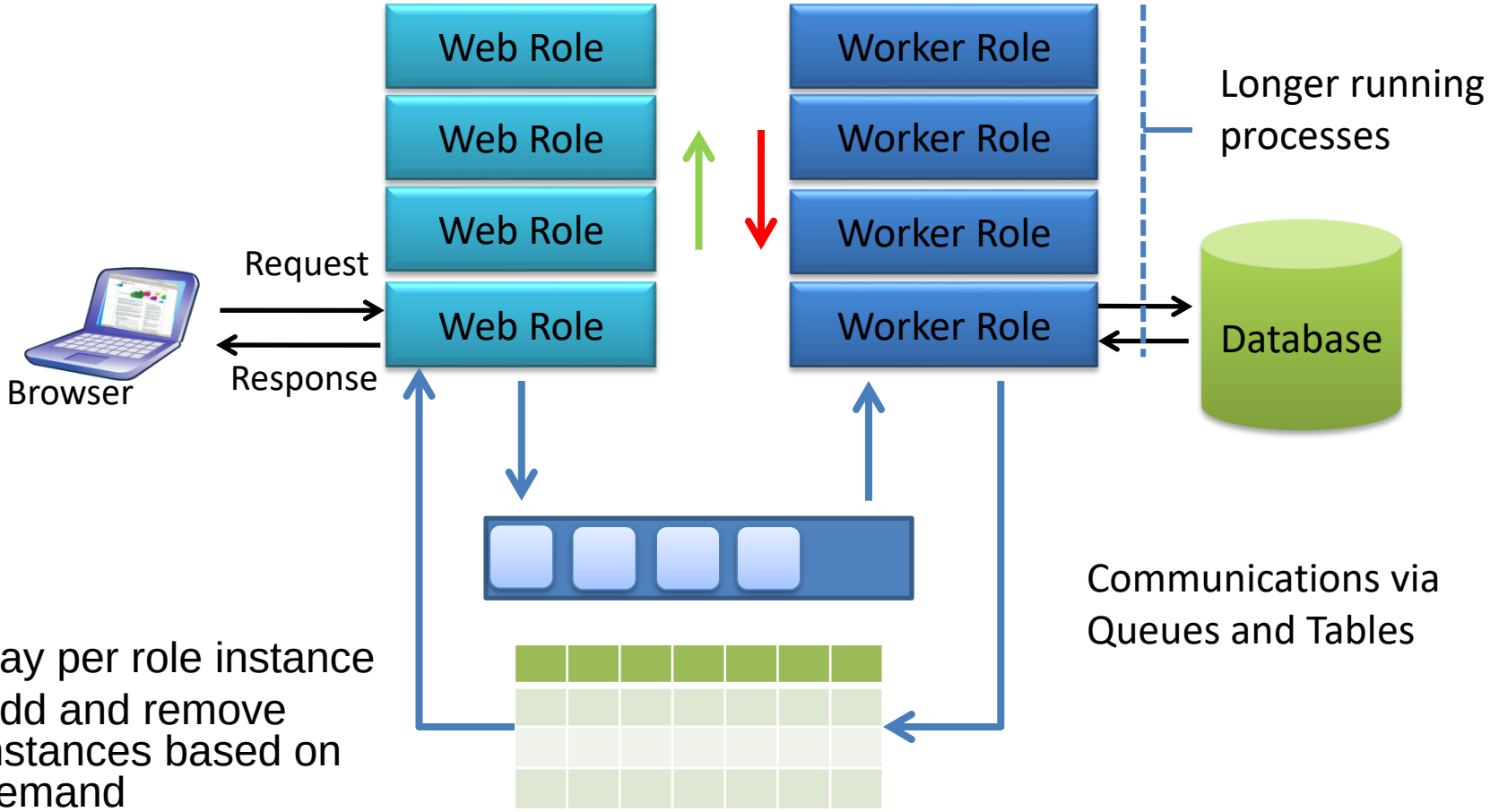


Scale Up



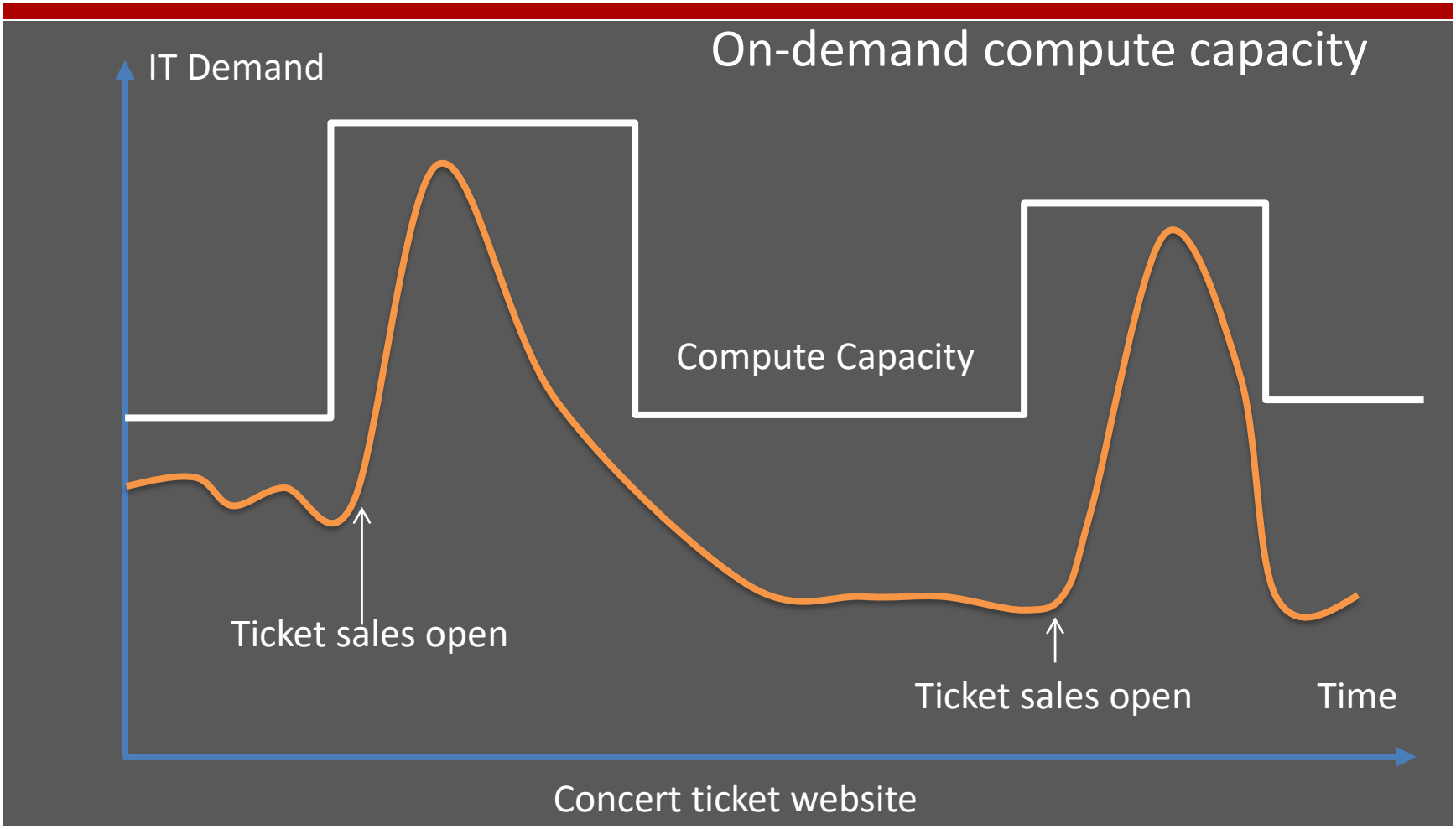
- How much is that going to cost you?
  - Do you need it all the time?
- How long will it take you?
- Do you have the capital expenditure budget?

Azure



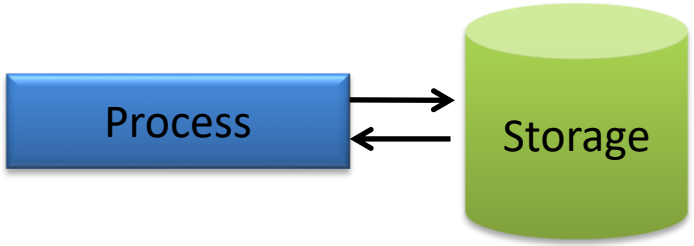
- Pay per role instance
- Add and remove instances based on demand

Demand Burst with Azure



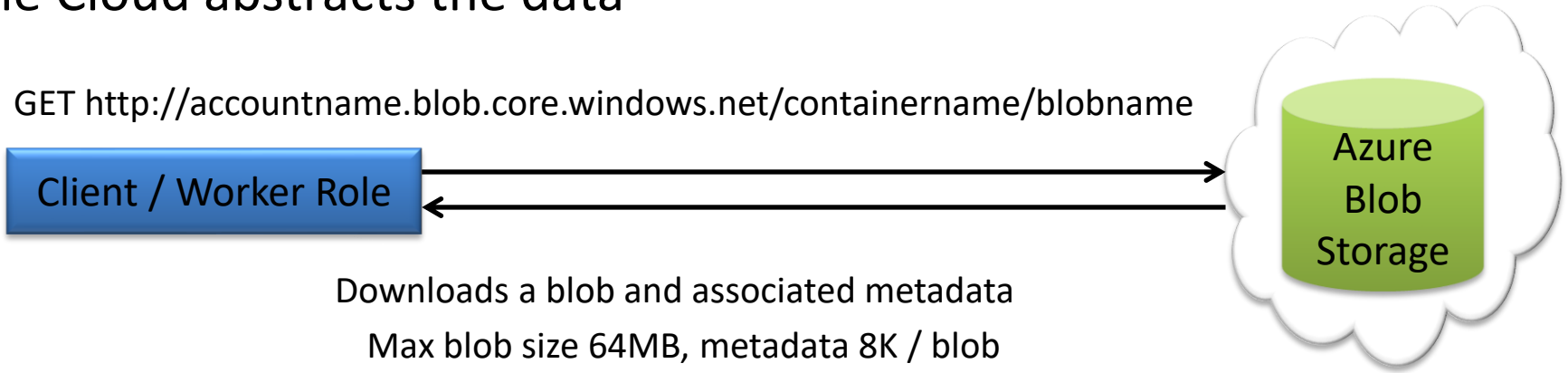
Storage

On-Premise: Tight relationship between process and storage



The Cloud abstracts the data

GET http://accountname.blob.core.windows.net/containername/blobname



Downloads a blob and associated metadata

Max blob size 64MB, metadata 8K / blob

What We Get with PaaS

- An elastic computing platform
- Connect from anywhere, with any device
- Low barrier costs to deploying new applications
  - Rapid provisioning
- Pay as you go
  - Operational costs directly related to profit
- A marketplace through which to sell our services
  - Customers continue to pay as long as they use our services
  - Stop paying, stop providing service
    - No chance of licence abuse

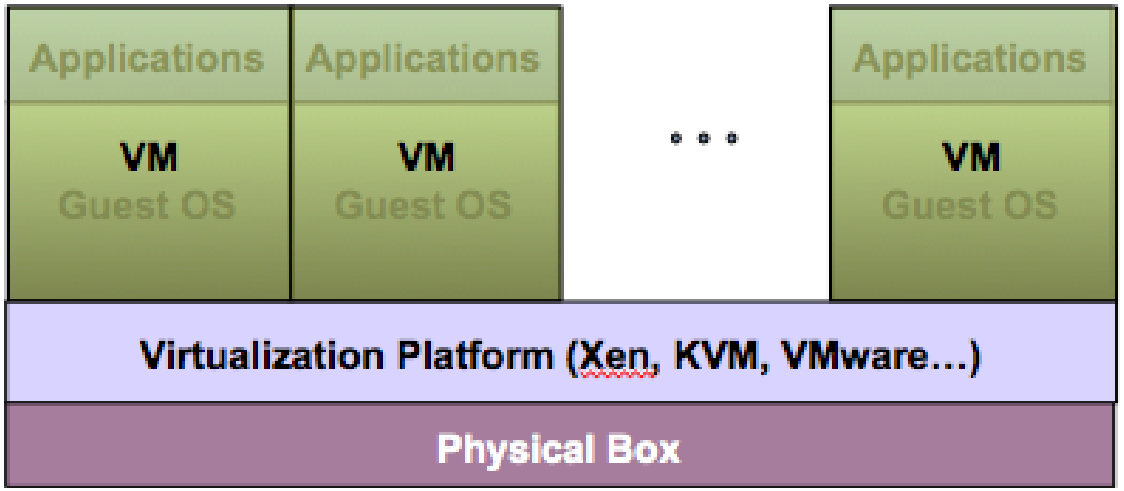
Virtualization: Enabler of IaaS

Virtualization

- Virtualization is the ability to run multiple operating systems on a single physical system and share the underlying hardware resources
- It is the process by which one computer hosts the appearance of many computers.
- Virtualization is used to improve IT throughput and costs by using physical resources as a pool from which virtual resources can be allocated.

Virtualization Architecture

- A Virtual machine (VM) is an isolated runtime environment (guest OS and applications)
- Multiple virtual systems (VMs) can run on a single physical system



Hypervisor

- A hypervisor, a.k.a. a virtual machine manager/monitor (VMM), or virtualization manager, is a program that allows multiple operating systems to share a single hardware host.
- Each guest operating system appears to have the host's processor, memory, and other resources all to itself. However, the hypervisor is actually controlling the host processor and resources, allocating what is needed to each operating system in turn and making sure that the guest operating systems (called virtual machines) cannot disrupt each other.

Benefits of Virtualization

- Sharing of resources helps cost reduction
- Isolation: Virtual machines are isolated from each other as if they are physically separated
- Encapsulation: Virtual machines encapsulate a complete computing environment
- Hardware Independence: Virtual machines run independently of underlying hardware
- Portability: Virtual machines can be migrated between different hosts.

IaaS

Cloud computing takes virtualization one step further:

- You don't need to own the hardware
- Resources are rented as needed from a cloud
- Various providers allow creating virtual servers:
  - Choose the OS and software each instance will have
  - The chosen OS will run on a large server farm
  - Can instantiate more virtual servers or shut down existing ones within minutes
- You get billed only for what you used


Fog Computing

Edge of Cloud

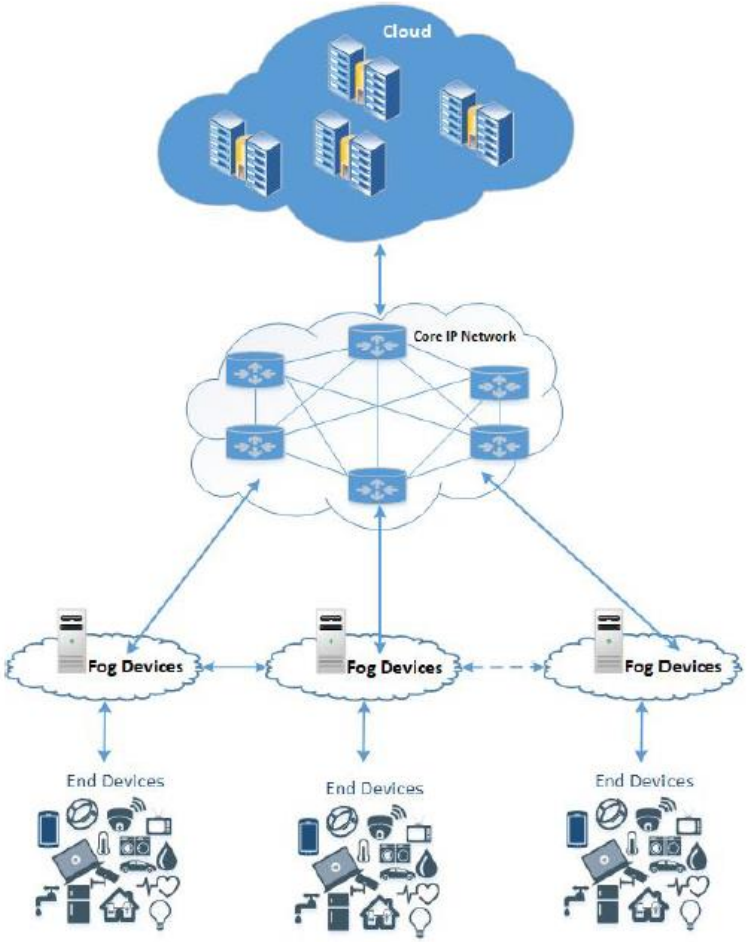
- Why cloud computing isn't sufficient for some applications?
  - Latency (real-time interaction)
    - Video streaming
    - Gaming
    - Augmented reality
  - Geographical distribution
    - Route planning / traffic
    - Massive multiplayer online real-time games

Edge of Cloud (cont'd)

- Mobile deployment
  - Cell phones
  - Vehicles
- Large number of nodes
  - Network of sensor nodes

Fog Computing

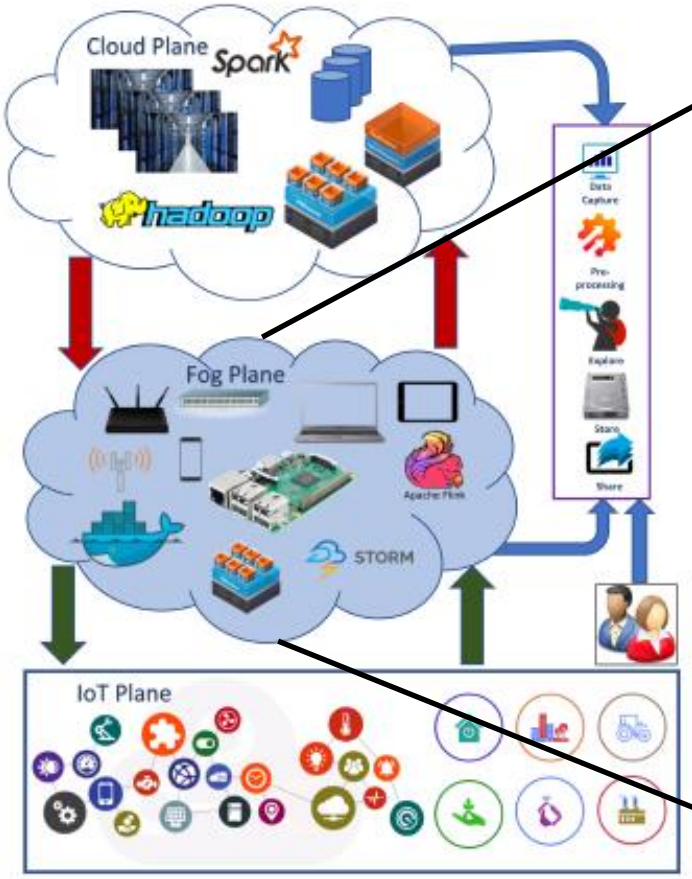
- Fog platform provides low-latency virtualized services and is linked to the Cloud Computing infrastructure
- Edge devices request compute, storage and communication services from the Fog
- The Fog provides local, low-latency response to these requests and forwards relevant data for computationally intensive processing



Fog Computing Characteristics

- Low latency
  - Video delivery, navigation information
- Location awareness
  - Traffic lights, navigation, sensor networks
- Wide-spread geographical distribution
- Mobility
  - Fitness trackers, phones, and vehicles

Layered Architecture



Application
- IoT
- WSN
- CDN
- Autonomous Vehicle
- Traffic Network

Security
- Encryption
- Privacy
- Authentication

Resource Management
- Resource Allocation
- Scheduling
- Energy Savings
- Reliability
- Scalability

Storage
- Data Backup
- Storage Virtualization

Pre and Post-Processing
- Data Analysis
- Data Filtering
- Data Flow
- Data Trimming
- Data Reconstruction

Monitoring
- System Monitoring
- Resource Demand
- Performance Prediction

Fog Device, Server & Gateway
- Device Configuration
- Storage Configuration
- Connectivity
- Computation Requirements

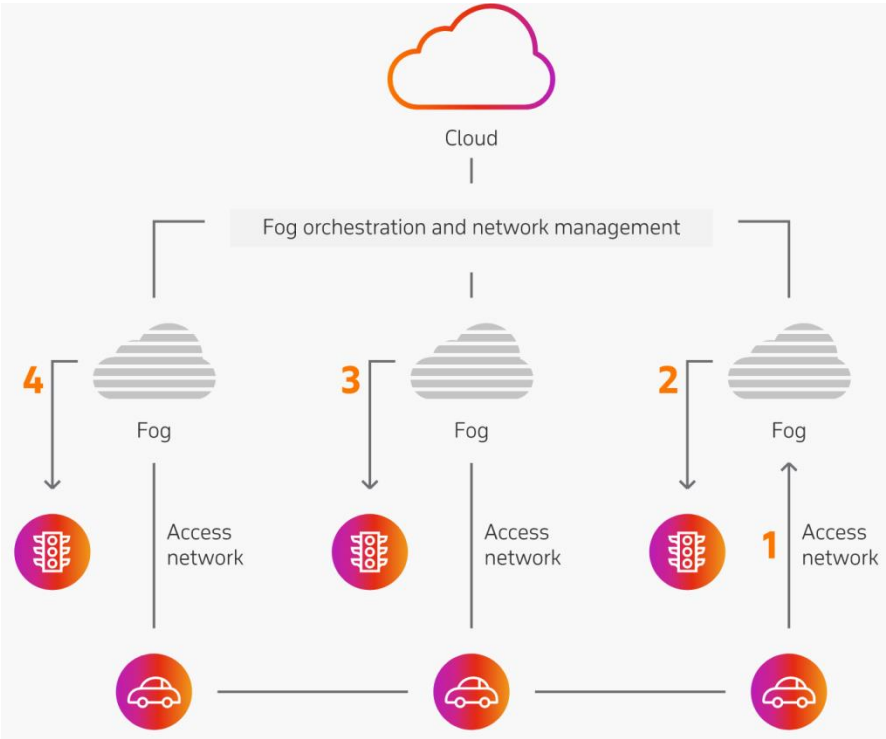
Physical
- Physical Sensors
- Virtual Sensors

A Case Study

- Smart Traffic Light System
- Sensors
  - Measure distance and speed of approaching vehicles
  - Detect presence of pedestrians and cyclists at crossings
- Goals
  - Prevent accidents
  - Maintain a steady flow of traffic
  - Collect relevant data to evaluate and improve the system

A Case Study (cont'd)

- Requirements
  - In situ computing for low latency
  - Middleware orchestration platform
    - Decision making
    - Federated message bus
  - Networking
  - Interplay with cloud



Research Directions

- Programming models
- Computing resource management
- Communications
- Information processing
- Task scheduling
  - Response time reduction
  - Power consumption reduction
  - Offloading and load redistribution
- Economics
  - Pricing, fog computing tokenization

Urban Fog Computing

- Perera, Charith, Yongrui Qin, Julio C. Estrella, Stephan Reiff-Marganiec, and Athanasios V. Vasilakos. "Fog computing for sustainable smart cities: A survey." *ACM Computing Surveys (CSUR)* 50, no. 3 (2017): 1-43.

Standarization

- OpenFog Consortium
  - An association of major tech companies aimed at standarizing and promoting fog computing
  - 840 members currently
- IEEE 1934-2018
  - OpenFog's Reference Architecture for Fog Computing

Learning Objectives

- Understand cloud computing and benefits
- Differentiate cloud service models
  - Tell examples in each model
- Understand relationship between cloud computing and fog computing