



Introduction to Cloud Computing

DAT159 – IoT/Cloud Module

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Practical Information

- 12:15 - 13:00 [Cloud Computing Lecture]
- 13:15 - 13:25 [Demo Node Red Simulation - Room Heating Control Assignment: Peder Aalen]
- 13:30 - 14:00 [Continue with assignment 2 - demo/approve]

Resources (Further Reading)

- NIST Cloud Computing. <https://csrc.nist.gov/projects/cloud-computing>
- Arshdeep Bahga and Vijay Madisetti. Cloud Computing: A Hands-On-Approach. (Chapters 1 & 2) - Handout
- Siow, E., Tiropanis, T., & Hall, W. (2018). Analytics for the Internet of Things: A survey. ACM Computing Surveys (CSUR), 51(4), 74. (Available on Canvas)

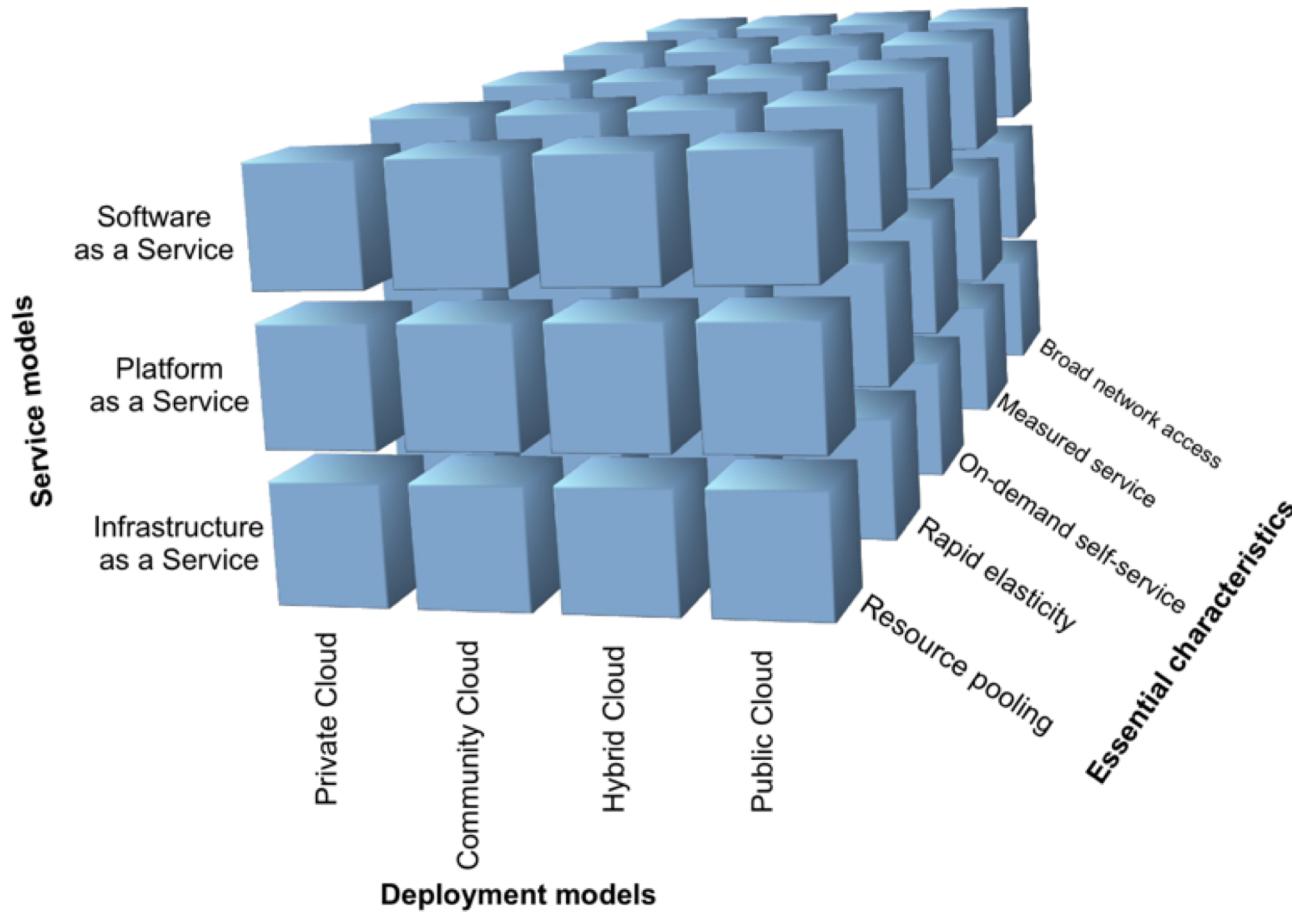
Introduction and Concepts

- Cloud Computing definition
- Characteristics of cloud computing
- Relevant Technologies
- Cloud service models
- Cloud deployment models
- Cloud Storage and Compute Technologies
- IoT Data Analytics



Source: wikipedia

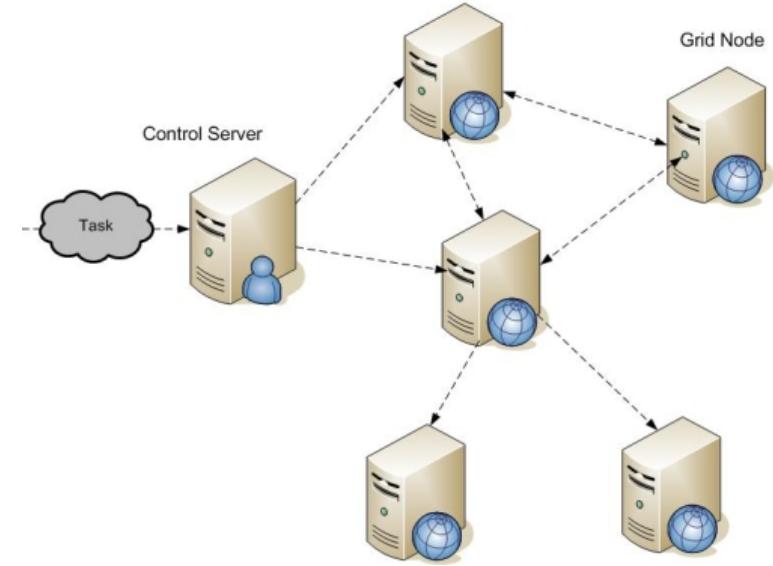
Cloud Computing Overview



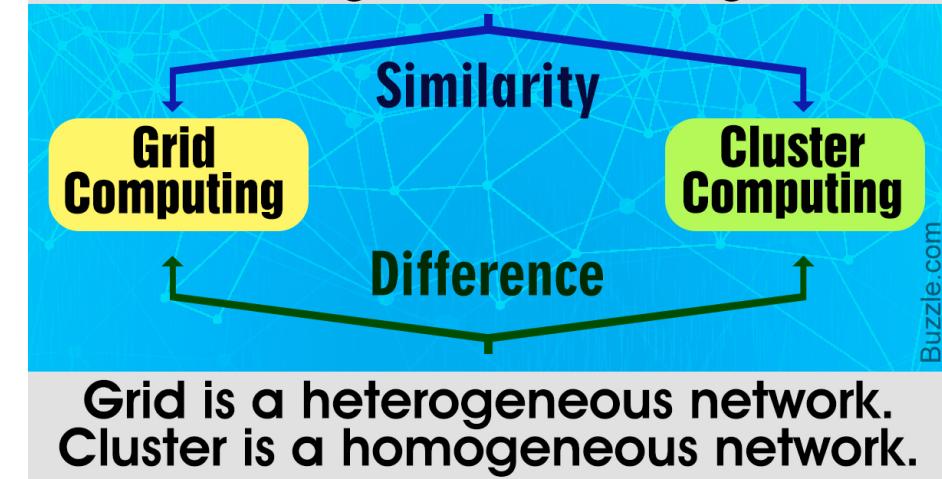
<http://www.katescomment.com/images/CloudCube.png>

Cloud Computing

- Not a new concept
 - Grid Computing
 - parallel and distributed system that enables the sharing, selection, and aggregation of geographically distributed "autonomous" resources dynamically at runtime depending on their availability, capability, performance, cost, and users' quality-of-service requirements.
 - Cluster Computing
 - set of loosely or tightly connected computers that work together so that, in many respects, they can be viewed as a single system (wikipedia).
 - Utility Computing
 - a service provisioning model in which a service provider makes computing resources and infrastructure management available to the customer as needed, and charges them for specific usage rather than a flat rate (wikipedia)
 - = Grid computing + Cluster computing + Utility computing?



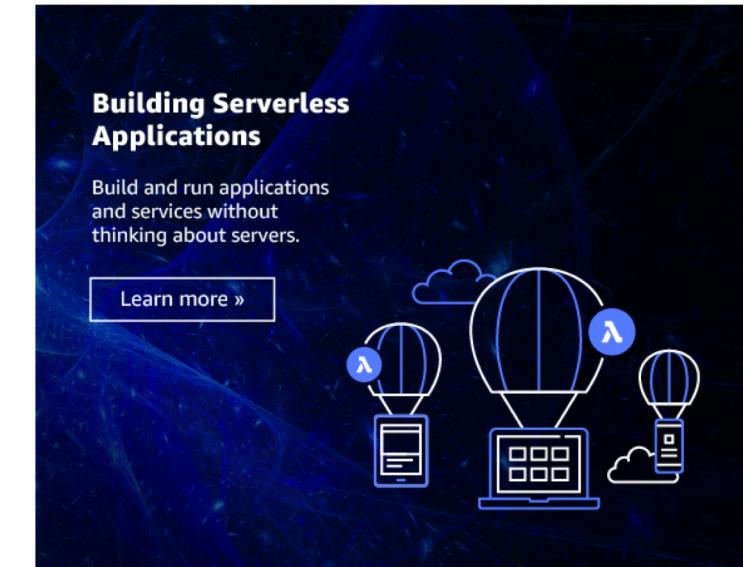
They solve computing problem by connecting computers together.



Cloud Computing - NIST

The U.S. National Institute of Standards and Technology (NIST) definition:

- 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.



Characteristics of Cloud Computing

- 5 – core characteristics (NIST)
 1. On-demand Self Service
 2. Broad Network Access
 3. Resource pooling
 4. Rapid Elasticity
 5. Measured/Metered Services

Characteristics of Cloud Computing

1. On-demand self service:

- Cloud computing resources can be provisioned on-demand by the users, without requiring interactions with the cloud service provider.
- The process of provisioning resources is automated.
- computing capabilities
 - server time, network storage, number of servers etc.

2. Broad network access:

- Cloud computing resources can be accessed over the network using standard access mechanisms that provide platform-independent access through the use of heterogeneous client platforms such as workstations, laptops, tablets and smartphones.

Characteristics of Cloud Computing

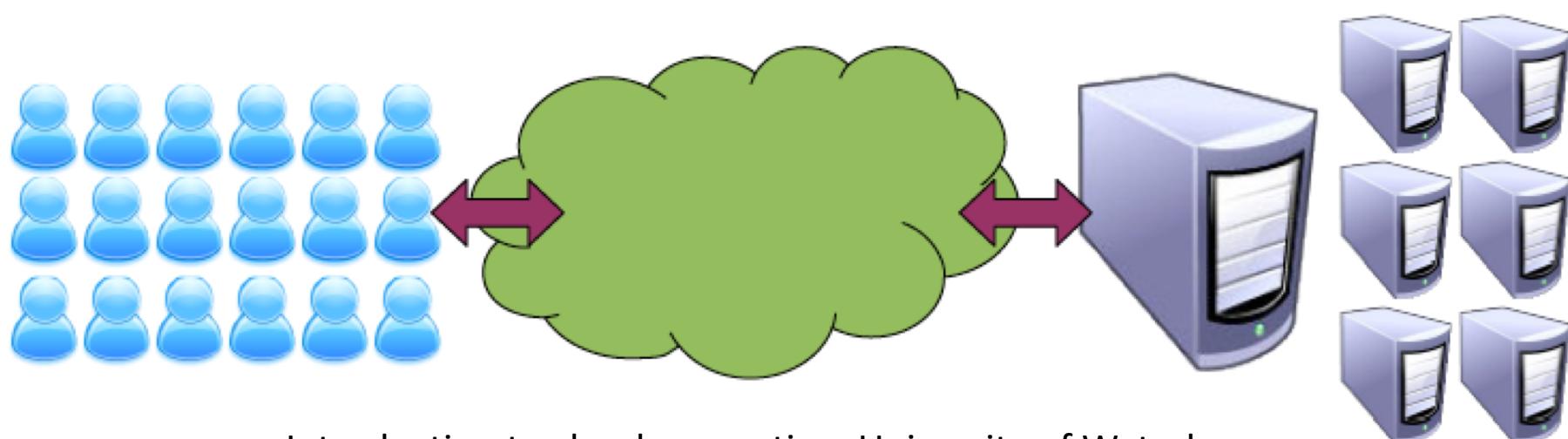
3. Resource pooling: The computing and storage resources provided by cloud service providers are pooled to serve multiple users using multi-tenancy

- computing resources
 - storage, processing, memory, network bandwidth and virtual machines
- location independence
 - no control over the exact location of the resources
- Implications
 - performance, scalability, security?

Characteristics of Cloud Computing

4. Rapid elasticity:

- Cloud computing resources can be provisioned rapidly and elastically.
- Cloud resources can be rapidly scaled up or down based on demand.
 - Horizontal scaling (scaling out): launching and provisioning additional server resources
 - Vertical scaling (scaling up): increasing computing capacity of the server resources while keeping the number of server resources constant



Characteristics of Cloud Computing

5. Measured service: Cloud computing resources are provided to users on a pay-per-use model.

- The usage of the cloud resources is measured and the user is charged based on some specific metrics (metering capability of service/resource abstractions)
 - storage
 - processing
 - bandwidth
 - active user accounts

Characteristics of Cloud Computing

- **Additional characteristics**
- Performance:
 - Cloud computing provides improved performance for applications since the resources available to the applications can be scaled up or down based on the dynamic application workloads.

Characteristics of Cloud Computing

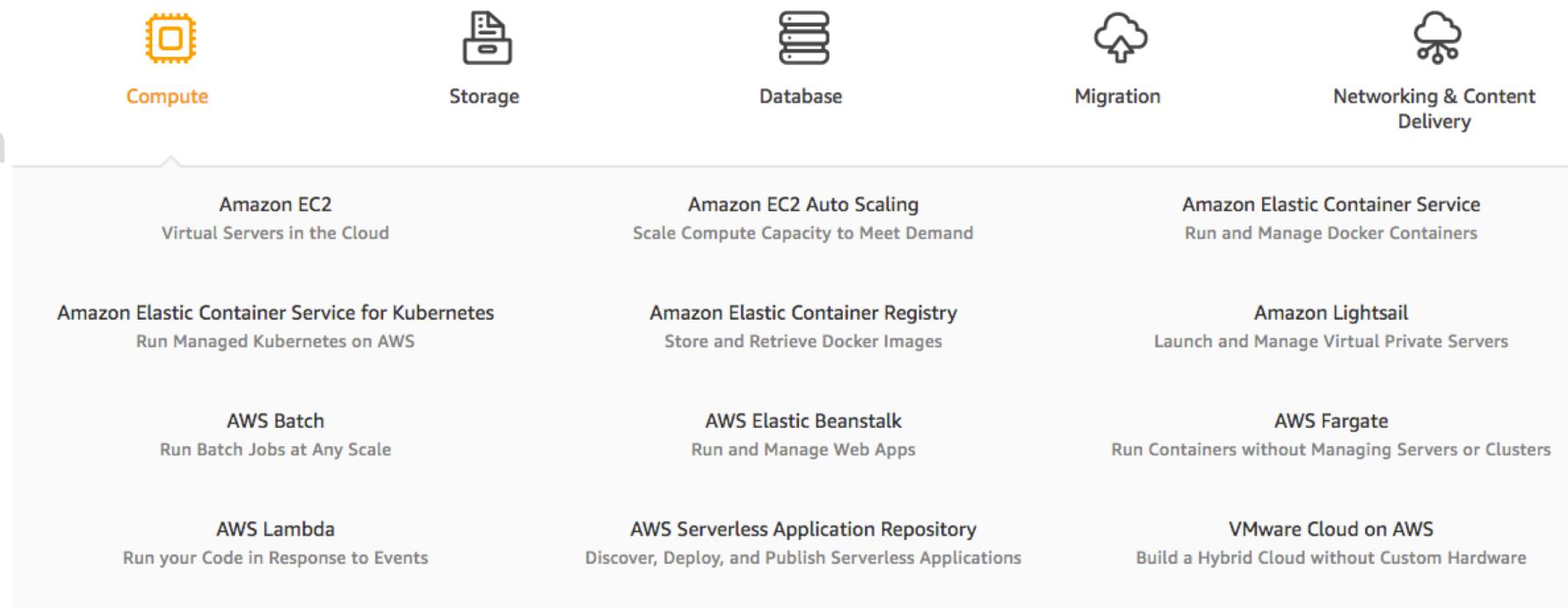
- Reduced costs:
 - Cloud computing provides cost benefits for applications as only as much computing and storage resources as required can be provisioned dynamically, and upfront investment in purchase of computing assets to cover worst case requirements is avoided.
- Outsourced Management:
 - Cloud computing allows the users (individuals, large organizations, small and medium enterprises and governments) to outsource the IT infrastructure requirements to external cloud providers.

Characteristics of Cloud Computing

- Reliability:
 - Applications deployed in cloud computing environments generally have a higher reliability since the underlying IT infrastructure is professionally managed by the cloud service.
 - Load balancing
 - Failover

Example Public Cloud Vendors (Providers)

- Amazon Cloud
- Google Cloud Platform
- Windows Azure
- IBM Cloud



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Deploy infrastructure	Develop apps	Manage data and AI
Linux virtual machines	 .NET	Relational Databases
Windows virtual machines	 PHP	SQL database as a service
Azure Blueprints	 Python	SQL Data Warehouse as a service
	 Node.js	PostgreSQL database as a service
	 Java	MySQL database as a service
	 Go	NoSQL
	App Models	Azure Cosmos DB
	Web Apps	Storage
	Serverless Functions	Blob Storage
	Containers	AI and Cognitive Services
	Microservices with Kubernetes	Machine Learning
	Microservices with Service Fabric	Cognitive Services
Secure and manage resources		
Azure Security Center		
Azure Monitor		
Azure Application Insights		
Azure Cost Management		
Azure Backup		
Azure Site Recovery		

Revelant Technologies

Access

- heterogeneous set of thick & thin clients
 - PCs (enterprise, home), mobile devices, hand-held devices
- high speed broadband access
 - wired & wireless
- data centres
 - large computing capacity
 - distributed

Relevant Technologies

Virtualization

- decoupling from the physical computing resources
- Partitioning the resources of physical system into multiple virtual resources
- Virtualization types (examples):
- Full virtualization - complete decoupling of the guest OS (unmodified) from underlying hardware. Simulation of the underlying hardware
 - VMWare, Oracle VirtualBox
- Para-virtualization – Guest OS is modified to enable communication.
 - Xen

Relevant Technologies

Virtualization types

- memory virtualization
 - decouples volatile random access memory (RAM) resources from individual systems
 - aggregates these resources into a virtualized memory pool available to any computer in the cluster
- storage virtualization
 - abstracting logical storage from physical storage
 - NAS - network attached storage
- data virtualization
 - data as an abstract layer, independent of underlying database systems, structures and storage

Relevant Technologies

Virtualization types

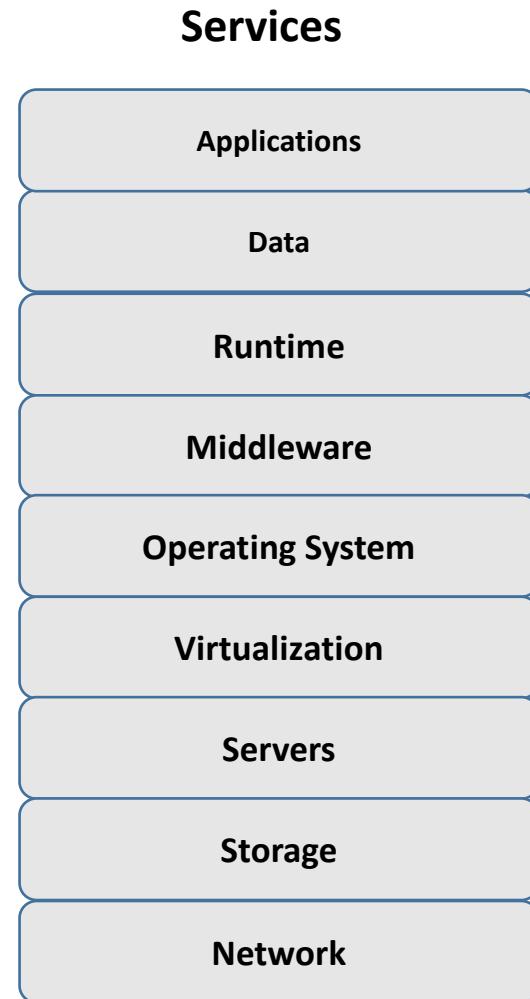
- network virtualization
 - virtualized network addressing space within or across network subnets
 - VPNs

APIs

- required for various operations and applications
 - administration
 - application development
 - resource migration

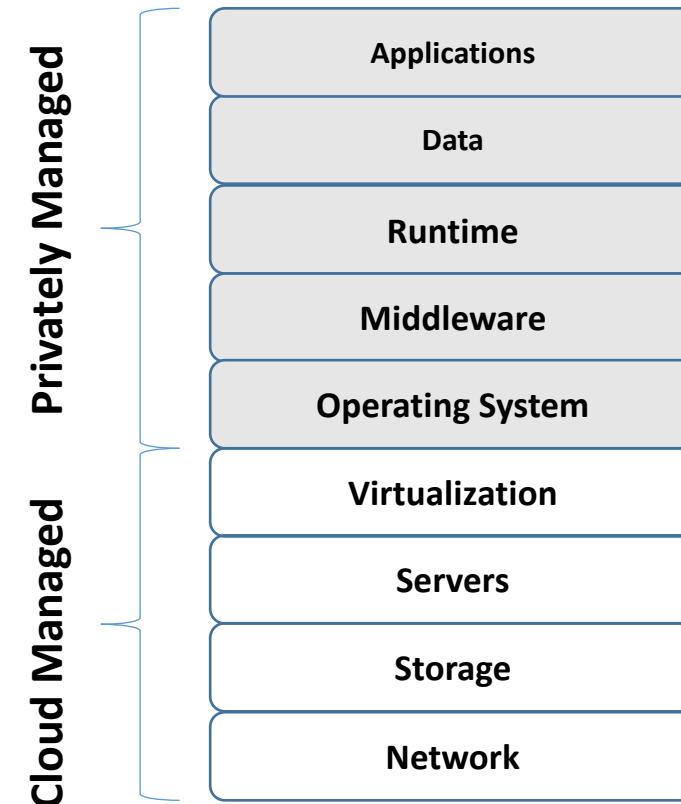
Cloud Service Models

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



Infrastructure as a Service (IaaS)

- Vendor provides and provisions computing resources to consumer
 - Virtual computing, storage and network resource can be provisioned on demand
- Consumer is provided with customized virtual machines
- Example:
 - Amazon Elastic Compute Cloud (EC2)
 - Google Compute Engines
 - Azure VMs



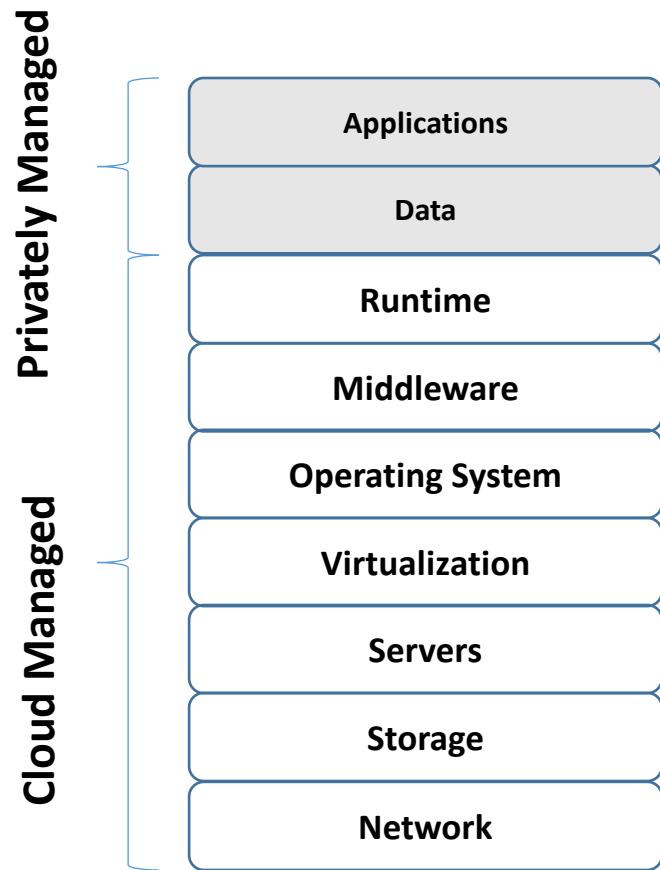
Infrastructure as a Service (IaaS)

Benefits

- Infrastructure scalability
- Integrated management
 - performance, resource consumption/utilization, load
- economical cost
 - hardware, IT support

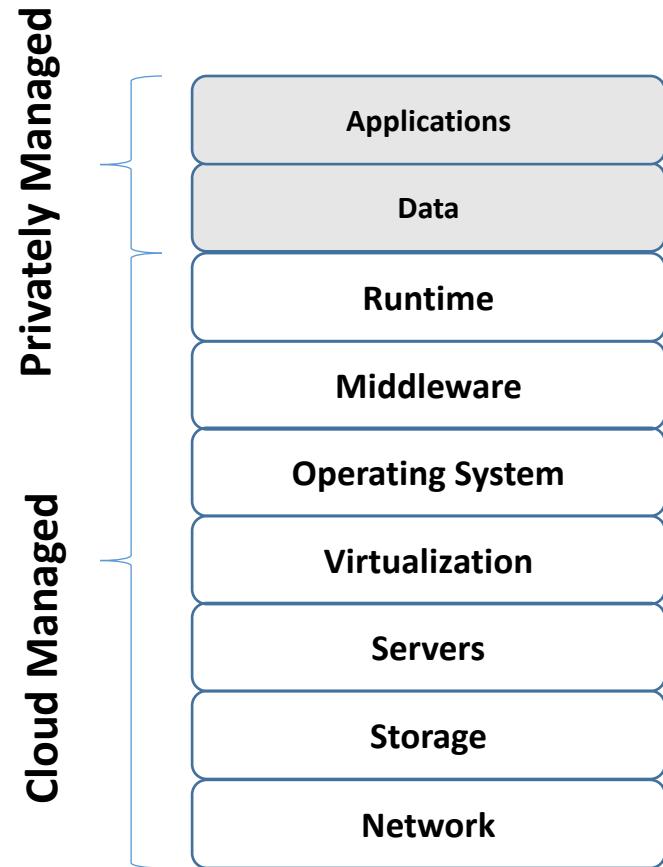
Platform as a Service (PaaS)

- **Development & Deployment:**
 - PaaS provides the users the capability to develop and deploy application in the cloud using the development tools, application programming interfaces (APIs), software libraries and services provided by the cloud service provider.
- **Provider Manages Infrastructure:**
 - The cloud service provider manages the underlying cloud infrastructure including servers, network, operating systems and storage.
- **User Manages Application:**
 - The users, themselves, are responsible for developing, deploying, configuring and managing applications on the cloud infrastructure.



Platform as a Service (PaaS)

- Tools & technology selected by vendor
- Control over data life-cycle
- Benefits
 - rapid development & deployment
 - small startup cost
 - required skills set
 - Money
- Examples:
 - Google App Engine



Platform as a Service (PaaS)

PaaS Disadvantages

- development technology is limited to vendor provided/supported tools and services

Software as a Service (SaaS)

Vendor/provider controlled applications
accessed over the network

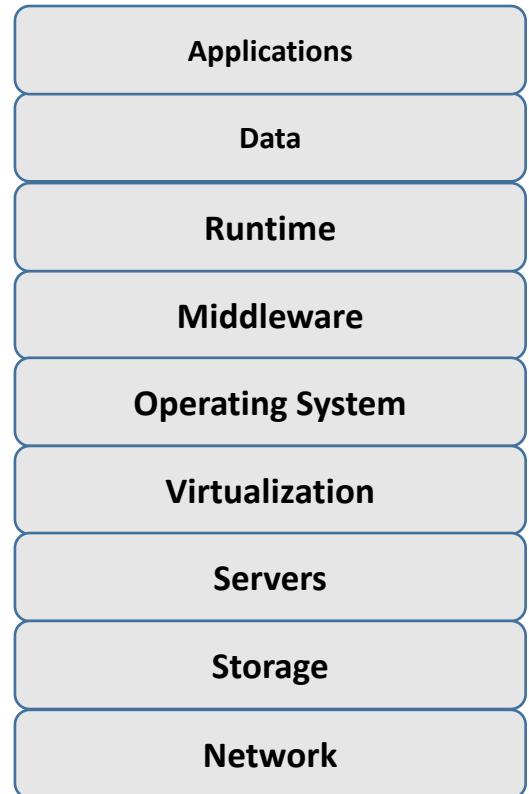
- characteristics
 - network based access
 - multi-tenancy
 - single software release for all
- SaaS Examples
 - Salesforce.com, Google Docs, Office 360



Software as a Service (SaaS)

SaaS Disadvantages

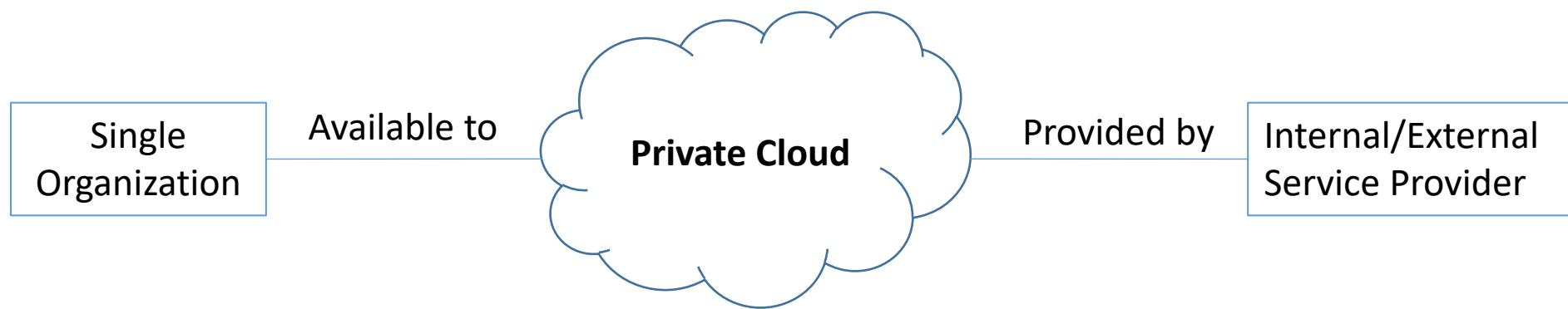
- dependency on
 - network, cloud service provider
- performance
 - limited client bandwidth
- security
 - good: better security than personal computers
 - bad: CSP is in charge of the data
 - ugly: user privacy



Deployment Models

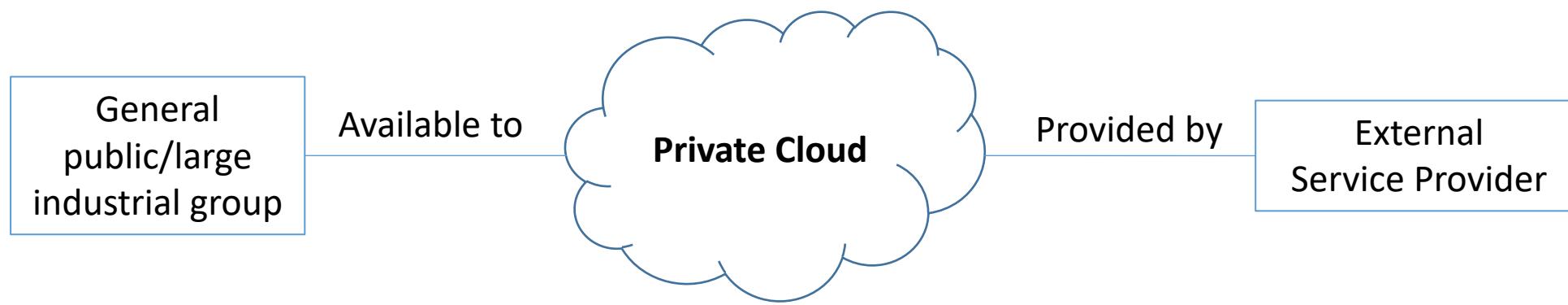
- 4 Deployment Models
 - Private Cloud
 - Public Cloud
 - Hybrid Cloud
 - Community Cloud

Private Cloud



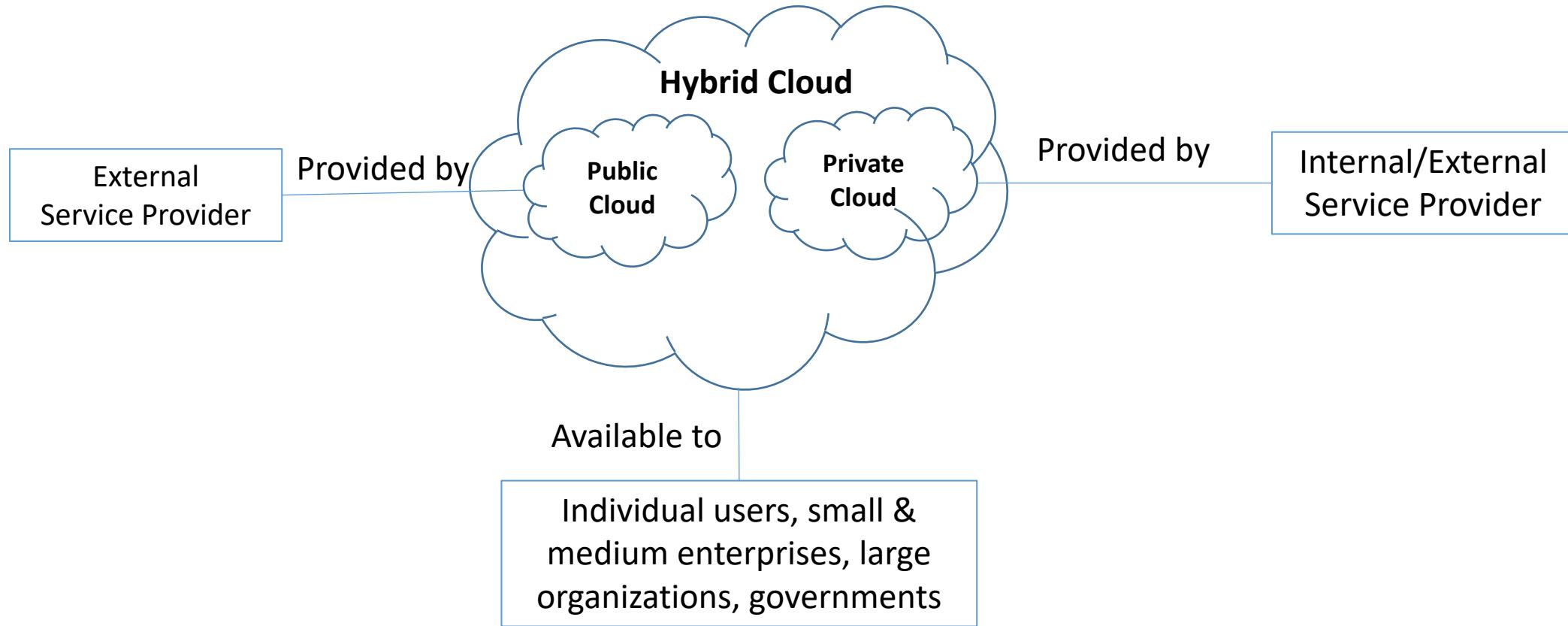
- **infrastructure is operated solely for an organization**
- **managed by the organization or by a third party**

Public Cloud



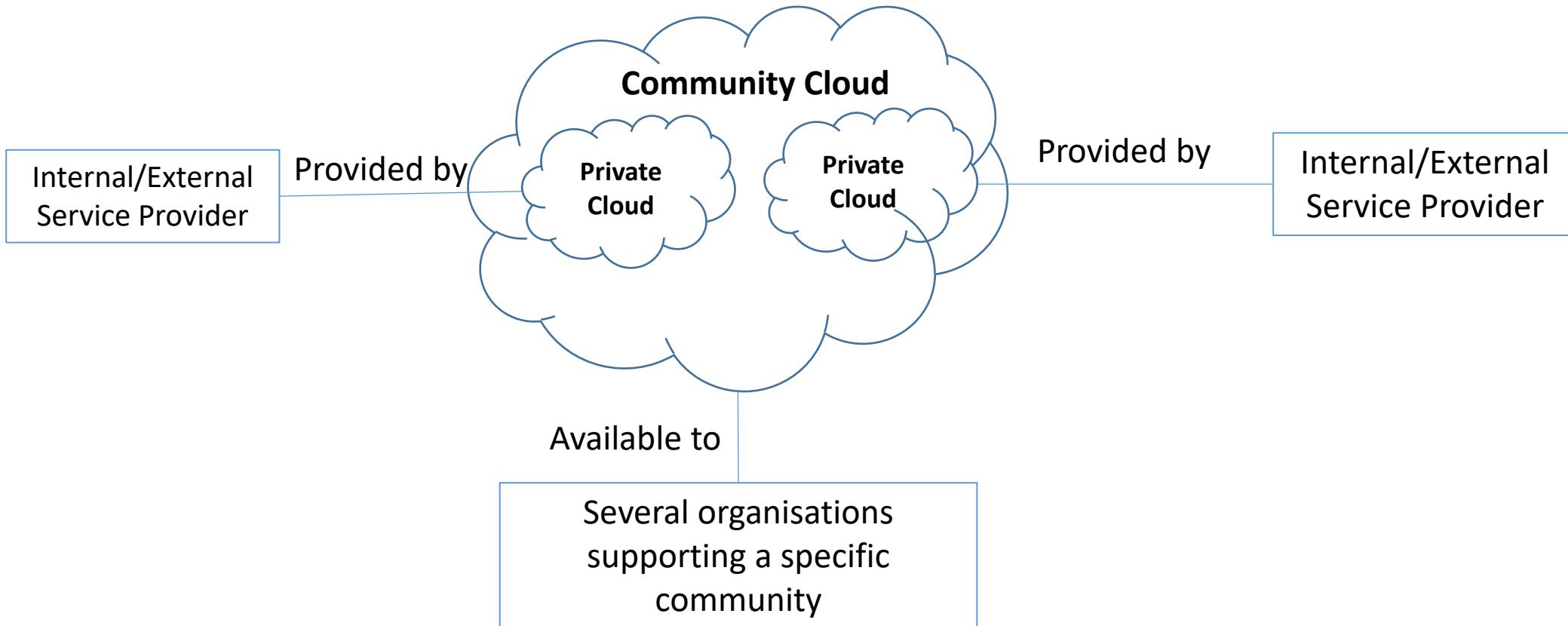
- **infrastructure is made available to the general public**
- **owned by an organization selling cloud services**

Hybrid Cloud



- **infrastructure is a composition of two or more clouds deployment models**
- **enables data and application portability because they are bound by standardized or proprietary technology**
- **Take advantage of secured app/data on private cloud + benefits of cost savings on public cloud**

Community Cloud



- **supports a specific community: shared same policy and compliance**
- **infrastructure is shared by several organizations**
- **Access to the same app/data and cost sharing among the larger group**

Cloud Distributed Storage

General Characteristics

- built on distributed file systems
 - GFS - Google File System
 - HDFS – Hadoop Distributed File System
- allows many clients to have access to data and supports operations (create, delete, modify, read, write) on that data
- Each data file may be partitioned into several parts called chunks
- Each chunk may be stored on different remote machines, facilitating the parallel execution of applications
- highly available
 - relaxed consistency
- fault-tolerant
 - replication

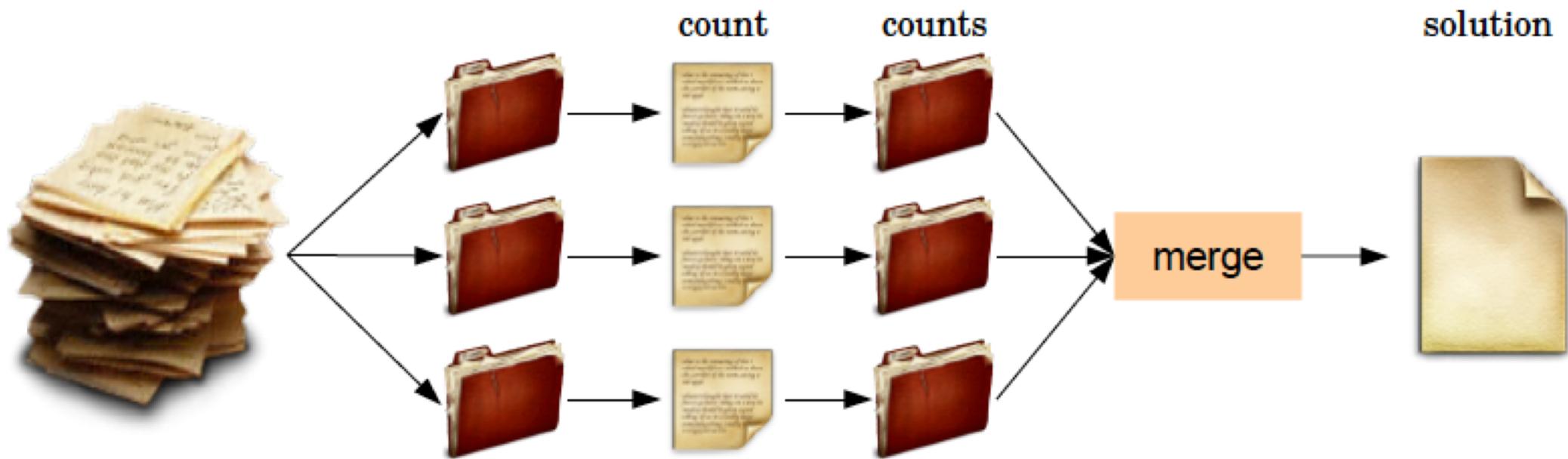
Cloud Distributed Computation

Basic Idea

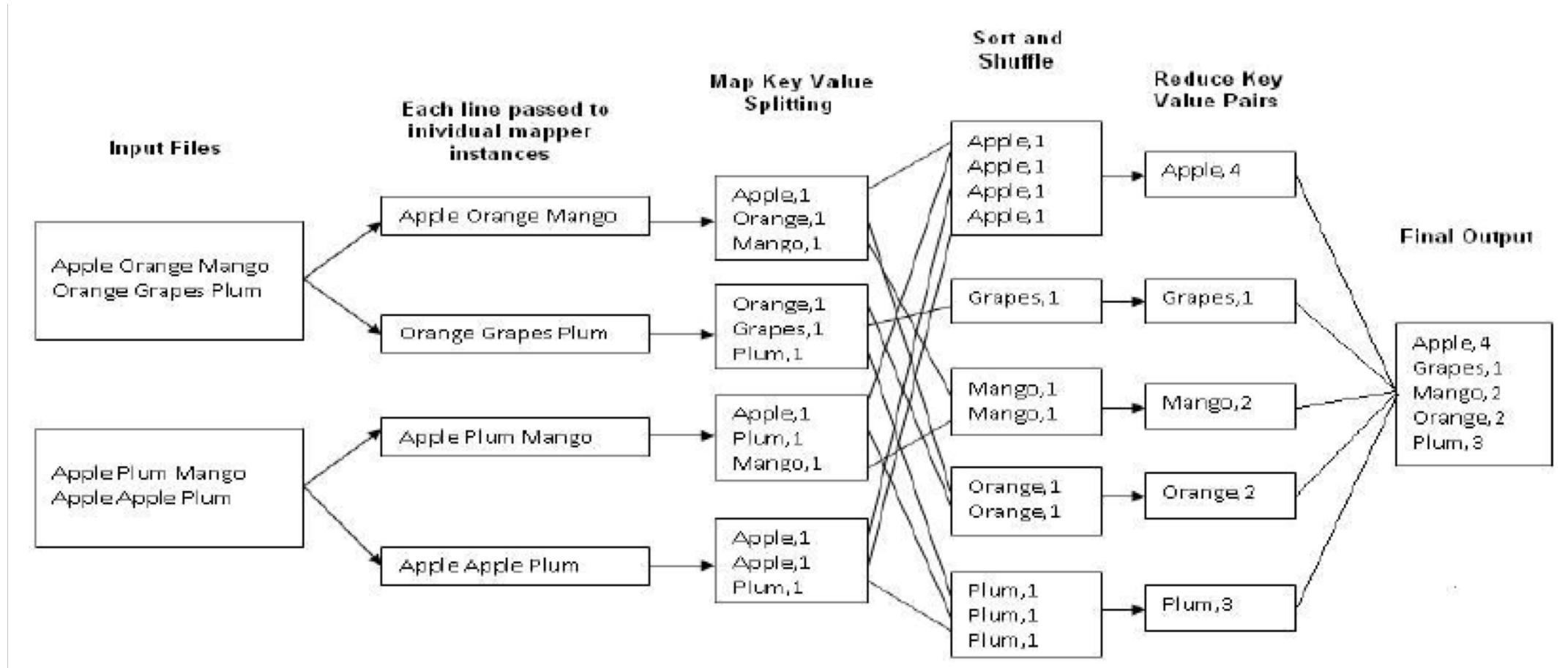
- functional decomposition
 - large problem broken into a set of small problems
 - each small problem
 - can be solved by a functional transformation of input data
 - can be executed in complete isolation
 - parallel computing
- server (task) farm
 - to solve the big problem

Cloud Distributed Computation

Word count problem performed on distributed clusters

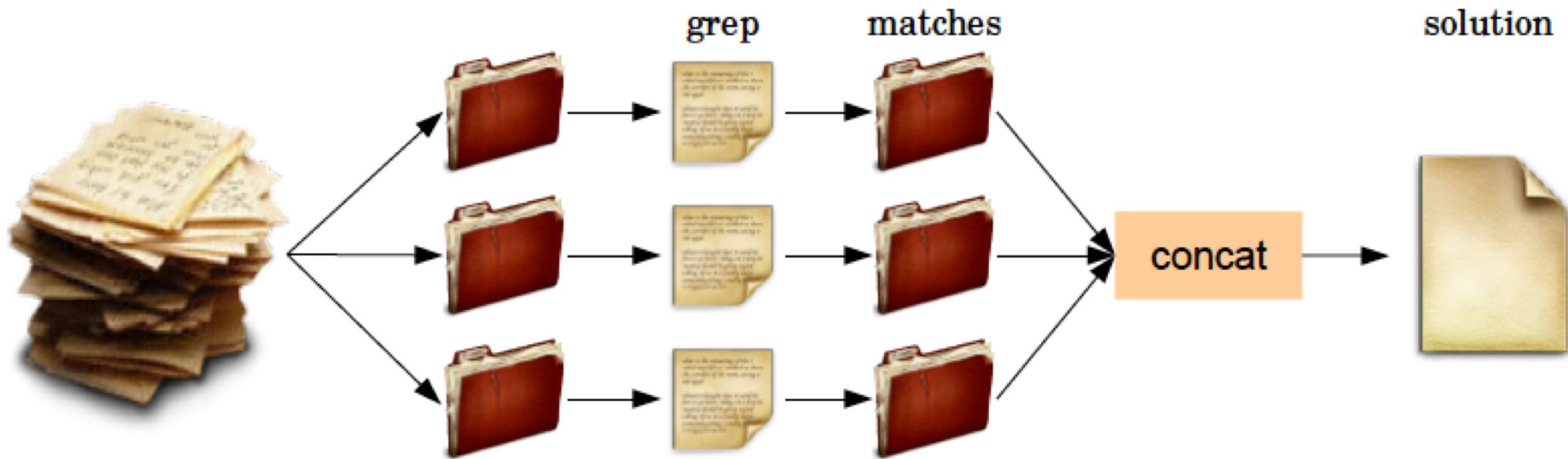


Cloud Distributed Computation

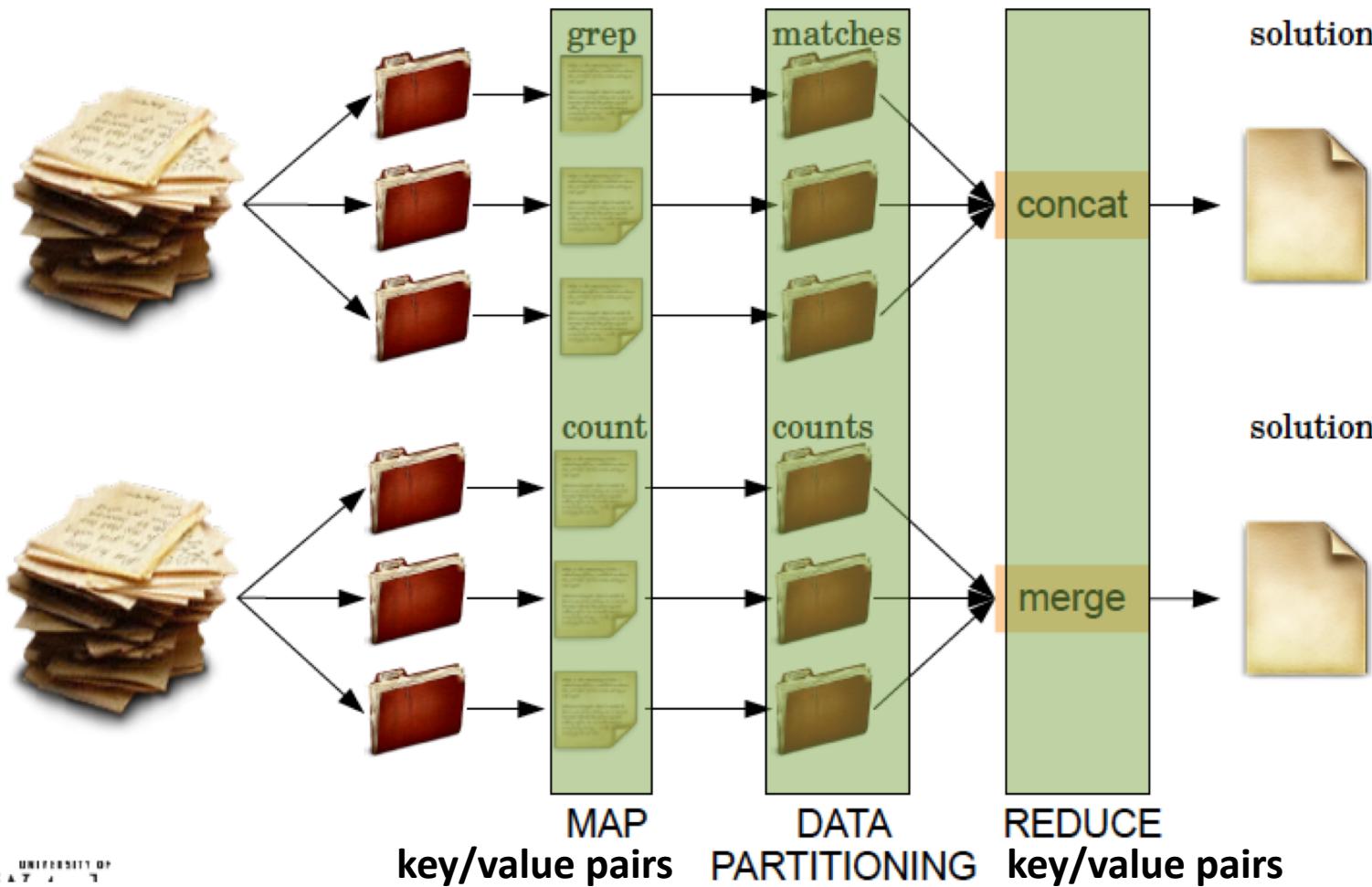


Cloud Distributed Computation

Word search problem performed on distributed clusters



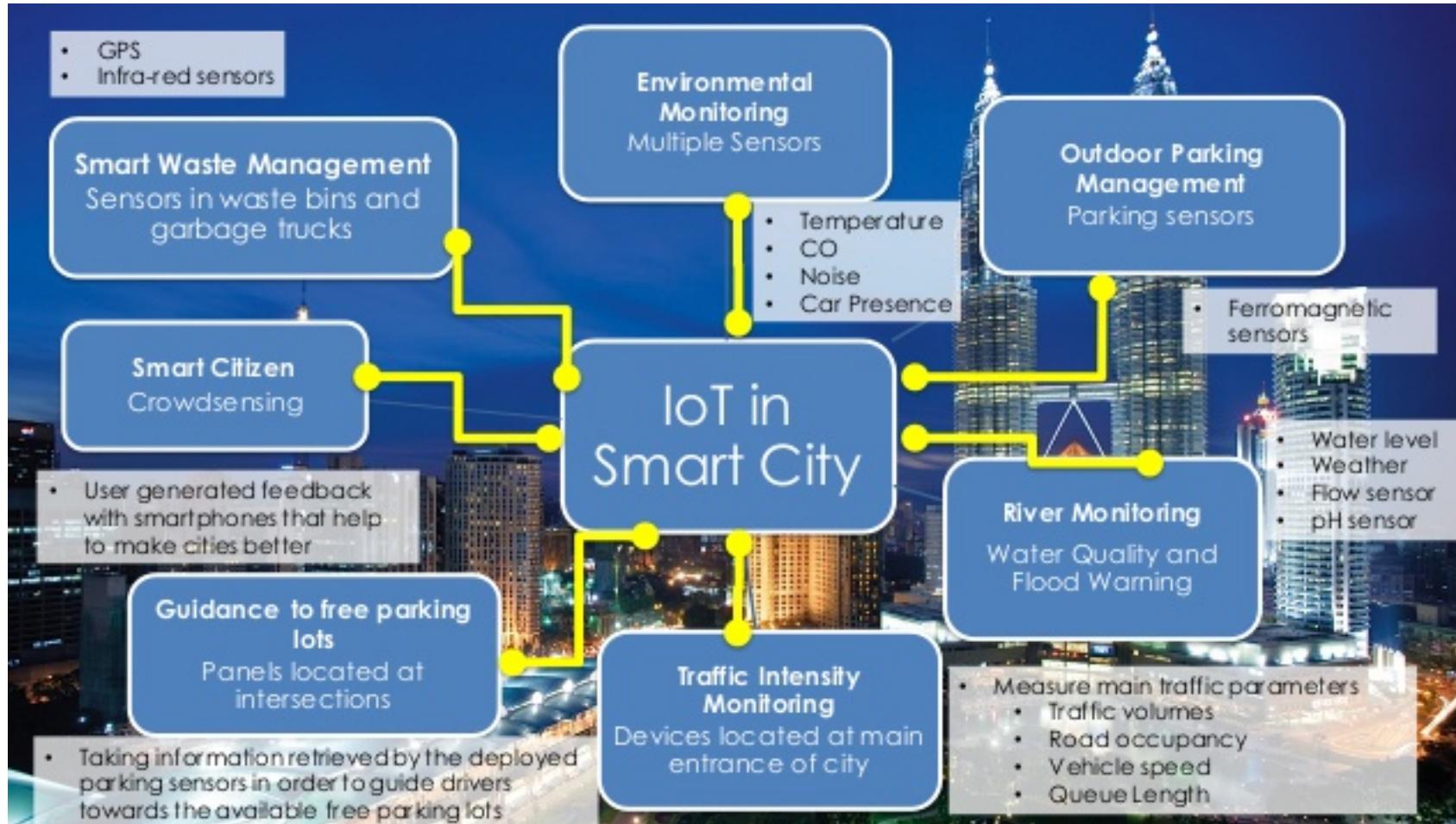
Cloud Distributed Computation - Map Reduce



MapReduce is the heart of Apache Hadoop. It is a programming paradigm that enables massive scalability across hundreds or thousands of servers in a Hadoop cluster.

Data Analytics for IoT

- IoT value lies in the use to which the vast amount of data generated is put

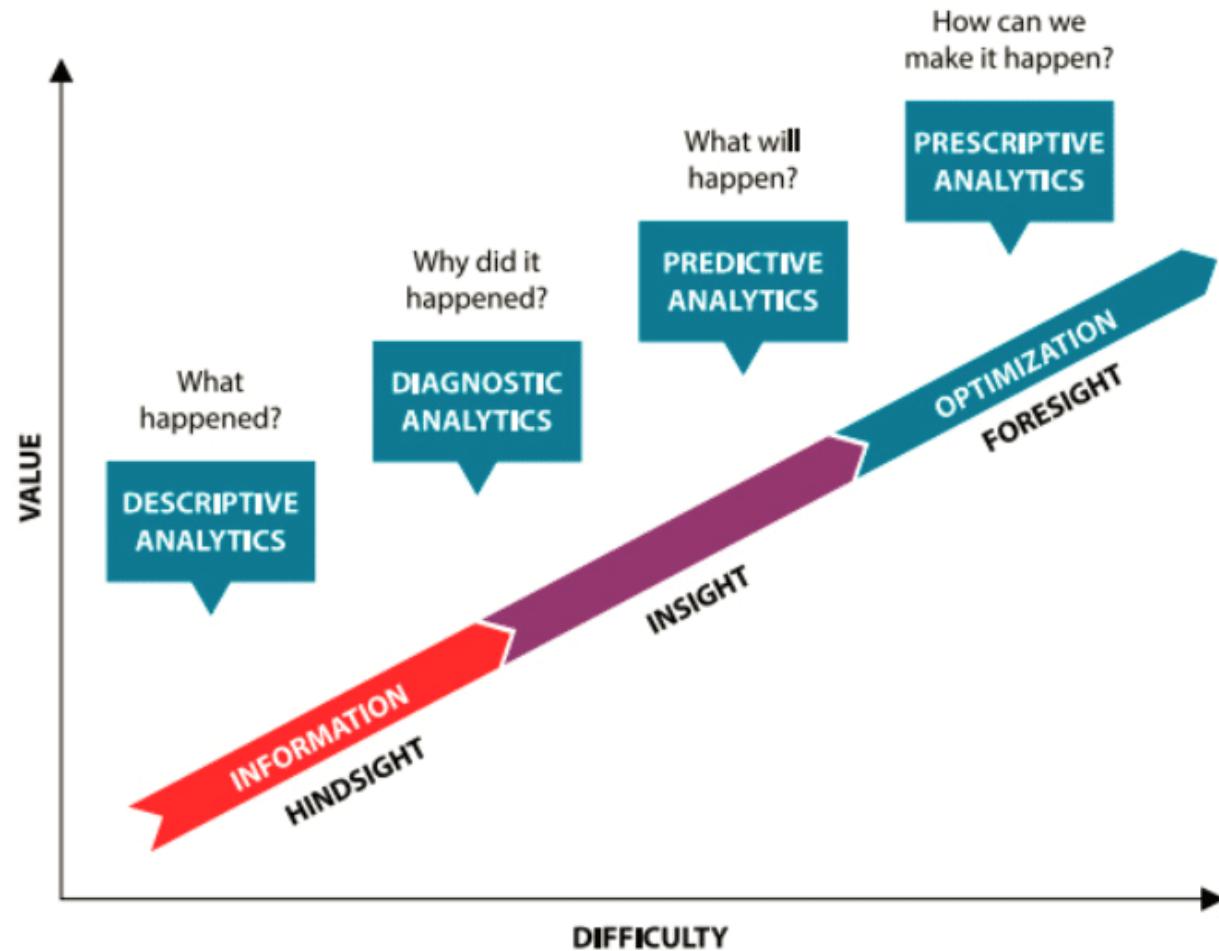


Data Analytics for IoT

- Analytics is the science or method of using analysis to examine something complex (Oxford Dictionary - <http://www.oed.com/view/Entry/273413>)
- When applied to data, analytics is the process of deriving (the analysis step) knowledge and insights from data (something complex)
- Finding hidden knowledge from data
- Analytics is the discovery, interpretation, and communication of meaningful patterns in data and applying those patterns towards effective decision making (wikipedia)

Types of Analytics

- Descriptive
- Diagnostic
- Predictive
- Prescriptive



Methods of Analytics

- Visual Analytics:
 - Interactive visualizations of data
 - Pie Charts
 - Scatter Diagrams
- Data Mining
- Content and Text Analytics
- Video Analytics
- Trend Analytics
- Business Analytics



Practice Questions

- Mention and discuss the different types of service models in cloud computing and give one example of each
- Discuss 5 core characteristics of cloud computing
- Mention and discuss the types of deployment models in cloud computing
- What type of storage is used in cloud computing? Explain
- Explain the MapReduce programming model
- Discuss 3 examples of data analytics operations on IoT data