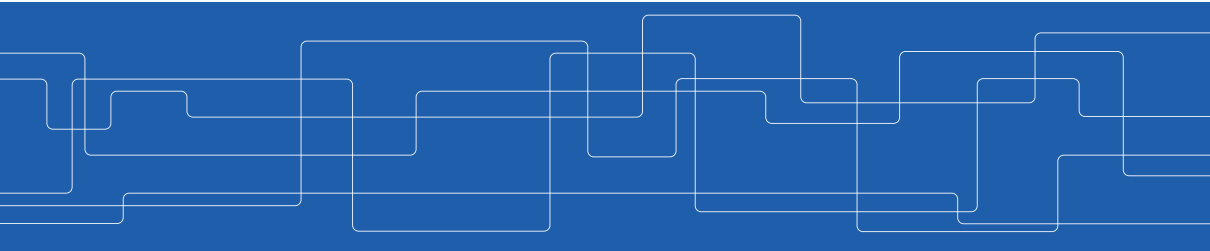
An Introduction to Data Intensive Computing

Amir H. Payberah
payberah@kth.se
2022-08-30



Course Information

Course Objective

- Provide students with a solid foundation for understanding large scale distributed systems used for storing and processing massive data.
- Cover a wide variety of advanced topics in data intensive computing platforms, i.e., the frameworks to store and process big data.

Intended Learning Outcomes (ILOs)

- ILO1: Understand the main concepts of data-intensive computation platforms.

Intended Learning Outcomes (ILOs)

- ILO1: Understand the main concepts of data-intensive computation platforms.
- ILO2: Apply the grabbed knowledge to store and process massive data.

Intended Learning Outcomes (ILOs)

- ILO1: Understand the main concepts of data-intensive computation platforms.
- ILO2: Apply the grabbed knowledge to store and process massive data.
- ILO3: Analyze the technical merits of data-intensive computation platforms.

The Course Assessment

- Task1: the review questions.

The Course Assessment

- Task1: the review questions.
- Task2: the lab assignments.

The Course Assessment

- Task1: the review questions.
- Task2: the lab assignments.
- Task3: the essay and the presentation.

The Course Assessment

- Task1: the review questions.
- Task2: the lab assignments.
- Task3: the essay and the presentation.
- Task4: the project.

The Course Assessment

- Task1: the review questions.
- Task2: the lab assignments.
- Task3: the essay and the presentation.
- Task4: the project.
- Task5: the final exam.

How Each ILO is Assessed?

	Task1	Task2	Task3	Task4	Task5
ILO1	x	x			x
ILO2		x		x	
ILO3			x		

Task1: The Review Questions

- Five set of review questions, one set for each week.
- The review questions are graded P/F.
- They should be done individually.

Task2: The Lab Assignments

- Four lab assignments, each focuses on a specific topic.
- No deadline.

Task3: The Essay and The Presentation

- One module for each group: writing an essay and presenting it to their opponents (another group).

Task3: The Essay and The Presentation

- One module for each group: writing an essay and presenting it to their opponents (another group).
- Grading of this task has the following parts:

Task3: The Essay and The Presentation

- One module for each group: writing an essay and presenting it to their opponents (another group).
- Grading of this task has the following parts:
  - E: Essay (weight 50%)

Task3: The Essay and The Presentation

- One module for each group: writing an essay and presenting it to their opponents (another group).
- Grading of this task has the following parts:
  - E: Essay (weight 50%)
  - P: Presentation (weight 20%)

Task3: The Essay and The Presentation

- One module for each group: writing an essay and presenting it to their opponents (another group).
- Grading of this task has the following parts:
  - E: Essay (weight 50%)
  - P: Presentation (weight 20%)
  - Q: Reviewing essay and asking questions (weight 20%)

Task3: The Essay and The Presentation

- One module for each group: writing an essay and presenting it to their opponents (another group).
- Grading of this task has the following parts:
  - E: Essay (weight 50%)
  - P: Presentation (weight 20%)
  - Q: Reviewing essay and asking questions (weight 20%)
  - A: Answering questions (weight 10%)

Task3: The Essay and The Presentation

- One module for each group: writing an essay and presenting it to their opponents (another group).
- Grading of this task has the following parts:
  - E: Essay (weight 50%)
  - P: Presentation (weight 20%)
  - Q: Reviewing essay and asking questions (weight 20%)
  - A: Answering questions (weight 10%)
- Eeach part is graded A-F.

Task3: The Essay and The Presentation

- One module for each group: writing an essay and presenting it to their opponents (another group).
- Grading of this task has the following parts:
  - E: Essay (weight 50%)
  - P: Presentation (weight 20%)
  - Q: Reviewing essay and asking questions (weight 20%)
  - A: Answering questions (weight 10%)
- Eeach part is graded A-F.
- The final grade is computed as $0.5 \times E + 0.2 \times P + 0.2 \times Q + 0.1 \times A$.

Task4: The Final Project

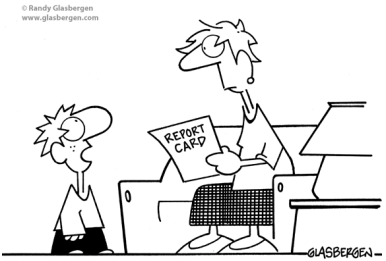
- One final project: source code and oral presentation.
- Proposed by students and confirmed by the teacher.
- They should be done in group.

Task5: The Final Exam

- The final exam covers all the modules presented during the course
- It is graded A-F.

The Final Grade

- To pass the course: you must pass Task 1 and get at least E in Task 3, Task 4, and Task 5.
- The final grade of the course is computed as $0.3 \times Task3 + 0.3 \times Task4 + 0.4 \times Task5$.



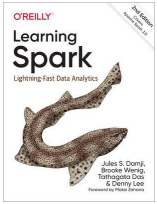
"Why is an A or B better than a C or D?
Aren't all letters equal in the eyes of God?"

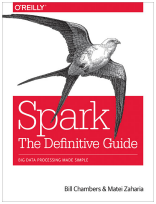
How to Submit the Assignments?

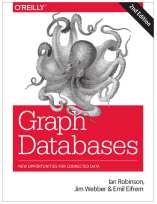
- Through Canvas.
- You will work individually on Task 1 and Task 5.
- You will work in groups of three on Task 3 and Task 4.

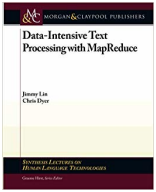
The Course Material

- Mainly based on research papers.
- We also cover the following books.









The Course Web Page

https://id2221kth.github.io

The Questions-Answers Page

https://tinyurl.com/bdenpwc5

The Course Overview

Cloud Computing and Big Data

- The main trends:
  - Computers not getting any faster
  - Internet connections getting faster
  - More people connected to the Internet

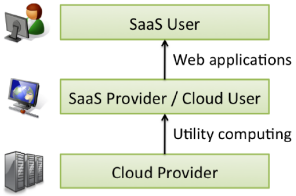
Cloud Computing and Big Data

- The main trends:
  - Computers not getting any faster
  - Internet connections getting faster
  - More people connected to the Internet
- Conclusion: move the computation and storage of big data to the cloud!

Cloud Computing

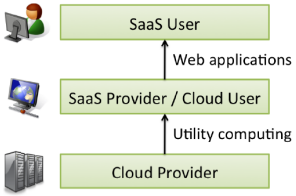
Cloud Computing Definition

- Cloud Computing refers to both:
  1. The applications delivered as services over the Internet
  2. The hardware and systems software in the datacenters that provide those services



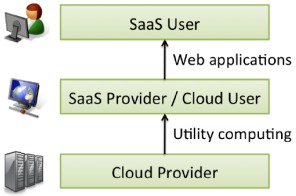
Cloud Computing Definition

- Cloud Computing refers to both:
  1. The applications delivered as services over the Internet
  2. The hardware and systems software in the datacenters that provide those services
- The services: called Software as a Service (SaaS)



Cloud Computing Definition

- Cloud Computing refers to both:
  1. The applications delivered as services over the Internet
  2. The hardware and systems software in the datacenters that provide those services
- The services: called Software as a Service (SaaS)
- The datacenter hardware and software is called cloud



- The NIST definition:
  - Five characteristics
  - Three service models
  - Four deployment models

National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

Cloud Characteristics

Cloud Characteristics

On-demand self-service

Ubiquitous network access

Location transparent resource pooling

Rapid elasticity

Measured service with pay per use

[http://aka.ms/532]

Cloud Characteristics - On-demand Self-Service

- A consumer can independently provision computing capabilities without human interaction with the service provider.

On-demand
self-service

Cloud Characteristics - Ubiquitous Network Access

- Available over the network
- Accessed through mobile phones, laptops, ...

Ubiquitous network access

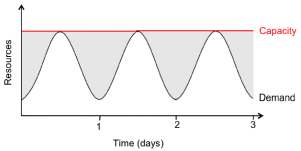
Cloud Characteristics - Resource Pooling

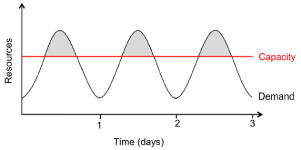
- Provider's computing resources are pooled to serve consumers
- Location transparent

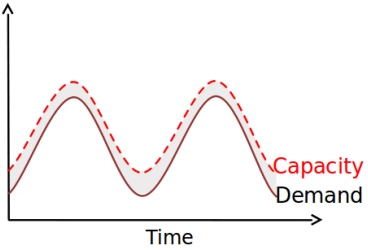
Location transparent resource pooling

Cloud Characteristics - Rapid Elasticity

- Capabilities can be rapidly and elastically provisioned, in some cases automatically.







Cloud Characteristics - Measured Service

- Resource usage can be monitored, controlled, and reported providing transparency for both the provider and consumer.

Measured service with pay per use

Cloud Service Models

Cloud Service Models

SaaS

PaaS

IaaS

[http://aka.ms/532]

- Assume, you just moved to a city and you are looking for a place to live.

- What is your choice?

- What is your choice?
  - Build a new house?
  - Buy an empty house?
  - Live in a hotel?

- Let's build a new house!

- Let's build a new house!
- You can fully control everything you like your new house to have.
- But that is a hard work.

- What if you buy an empty house?

- What if you buy an empty house?
- You can customize some part of your house.
- But never change the original architecture.

- How about living in a hotel?

- How about living in a hotel?
- Living in a hotel will be a good idea if the only thing you care is about enjoying your life.
- There is nothing you can do with the house except living in it.

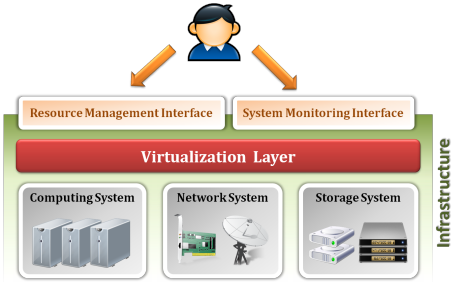
Let's translate it to Cloud Computing

Service Models

- Infrastructure as a Service (IaaS): similar to building a new house.
- Platform as a Service (PaaS): similar to buying an empty house.
- Software as a Service (SaaS): similar to living in a hotel.

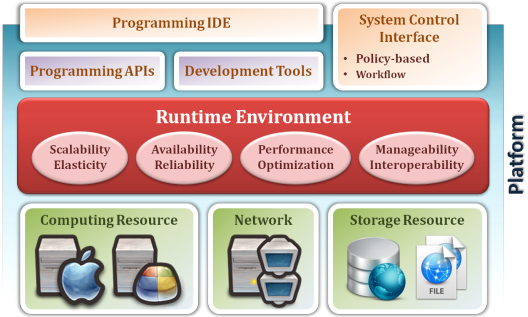
IaaS

- Vendor provides resources, e.g., processing, storage, network, ...
- Consumer is provided customized virtual machines.
- Example: Amazon Web Services (EC2 instances and S3 storage)



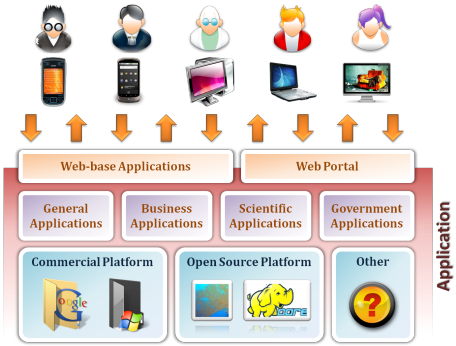
PaaS

- Vendor provides hardware and development environment.
- Example: Google app engine

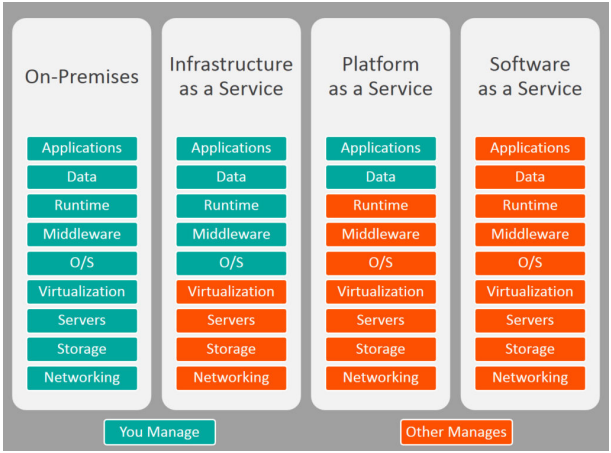


SaaS

- Vendor provides applications accessed over the network.
- Example: Gmail, Github



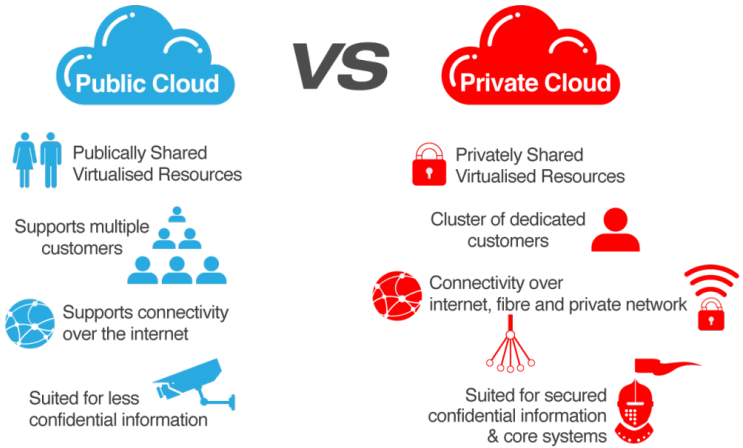
IaaS - PaaS - SaaS



[https://goo.gl/xMko1z]

Deployment Models

Deployment Models



[https://goo.gl/fWmcGK]

Public Cloud Infrastructure Vendors

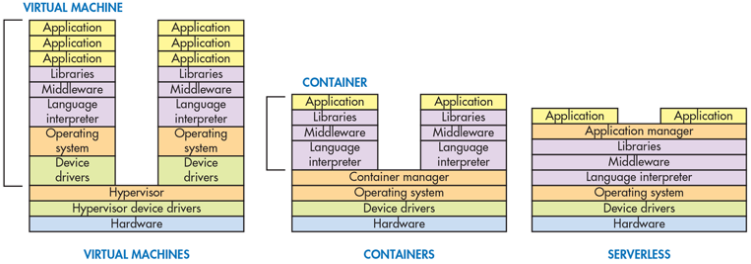
- Amazon Web Services (AWS)
- Microsoft Azure
- Google Cloud Platform
- IBM Bluemix
- ...

Main Services

- Computing
- Storage
- Database
- Big data analytics
- ...

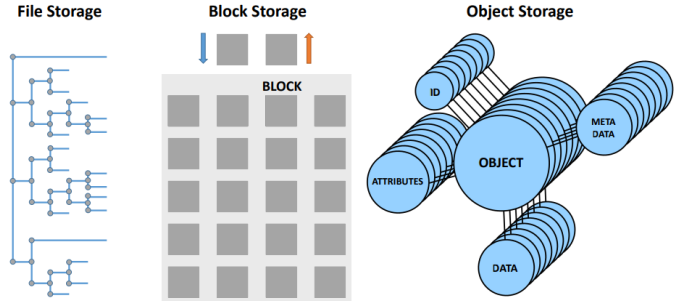
Computing Services

- Virtual machines
- Container services
- Serverless compute



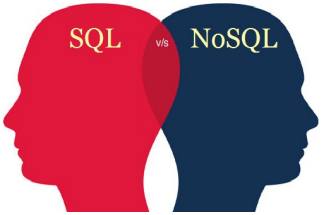
Storage Services

- File storage
- Block storage
- Object storage



Database Services

- Relational Database Management Services (RDBMS)
- NoSQL databases
- In-Memory data services



Big Data Analytics

- Big Data Managed Cluster-as-a-Service
- Data warehouse
- Data streaming
- Data queuing

Big Data

"THAT'S your Ark for the Big Data flood? Noah, you will need a lot more storage space!"

[https://www.kdnuggets.com/2012/12/cartoon-preparing-for-big-data-flood.html]

What is Big Data?

[https://www.sue-anderson.com.au/index.php/2017/08/18/cursing-curious-work]

Big Data

Big data is the data characterized by 4 key attributes: volume, variety, velocity and value.

Big Data

Big data is the data characterized by 4 key attributes: volume, variety, velocity and value.

Buzzwords

ORACLE

Big Data in Simple Words

DevOps Borat
@DEVOPS_BORAT

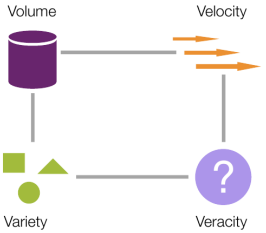
Small Data is when is fit in RAM. Big Data is when is crash because is not fit in RAM.

2/6/13, 8:22 AM



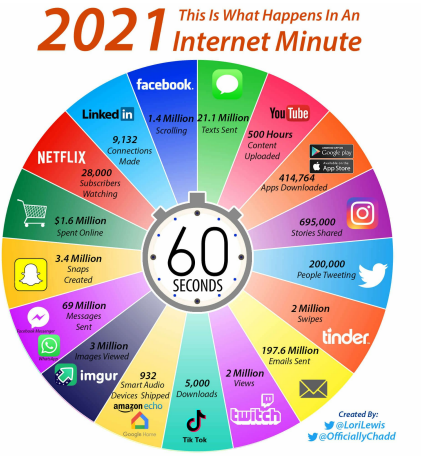

The Four Dimensions of Big Data

- Volume: data size
- Velocity: data generation rate
- Variety: data heterogeneity
- This 4th V is for Vacillation: Veracity/Variability/Value



Big Data Sources

How Much Data?



How To Store and Process Big Data?

Problem

- Traditional platforms fail to show the expected performance.
- Need new systems to store and process large-scale data

Scale Up vs. Scale Out (1/2)

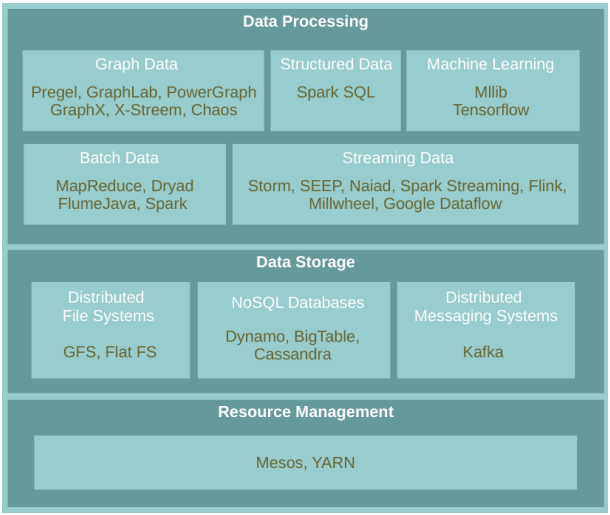
- Scale up or scale vertically: adding resources to a single node in a system.
- Scale out or scale horizontally: adding more nodes to a system.

Scale Up vs. Scale Out (2/2)

- Scale up: more expensive than scaling out.
- Scale out: more challenging for fault tolerance and software development.

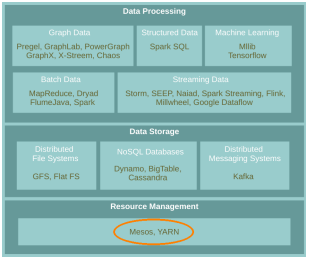

APACHE
HBASE
mahout
hadoop
GraphX
kafka
Storm
Dato
Spark
HIVE
S4 distributed stream computing platform
cassandra
Google Cloud Platform

Big Data Stack



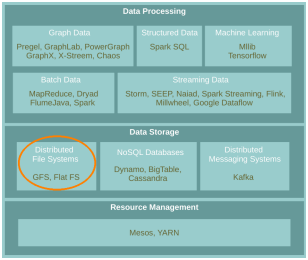
Resource Management

- Manage resources of a cluster
- Share them among the platforms
- Mesos, YARN, Borg, ...



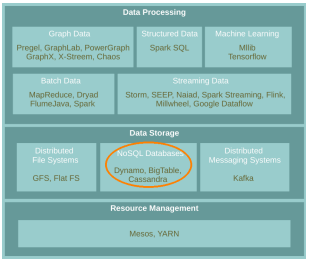
Data Storage - Distributed File Systems

- Store and retrieve files on/from distributed disks
- GFS, HDFS, FlatFS, ...



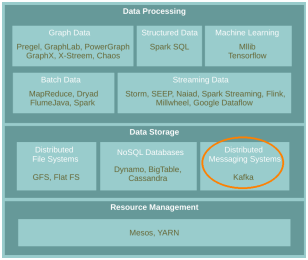
Data Storage - NoSQL Databases

- BASE instead of ACID
- BigTable, Dynamo, Cassandra, ...



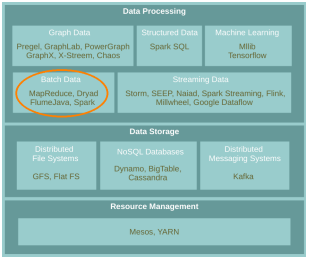
Data Storage - Messaging Systems

- Store streaming data
- Kafka, Flume, ActiveMQ, ...



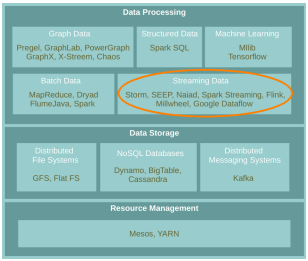
Data Processing - Batch Data

- Process data-at-rest
- Data-parallel processing model
- MapReduce, FlumeJava, Spark, ...



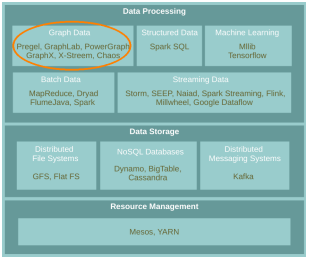
Data Processing - Streaming Data

- Process data-in-motion
- Storm, Flink, Spark Streaming, ...



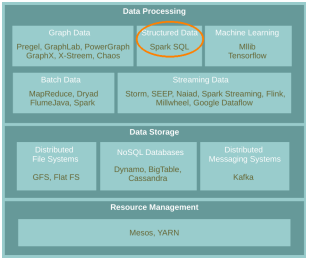
Data Processing - Linked Data (Graph)

- Graph-parallel processing model
- Vertex-centric and Edge-centric programming model
- Pregel, GraphLab, GraphX, ...



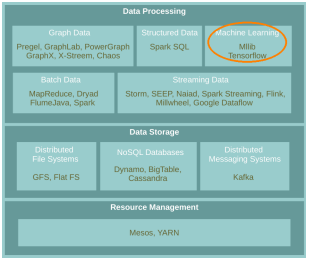
Data Processing - Structured Data

- Take advantage of schemas in data to process
- Hive, Spark SQL, ...

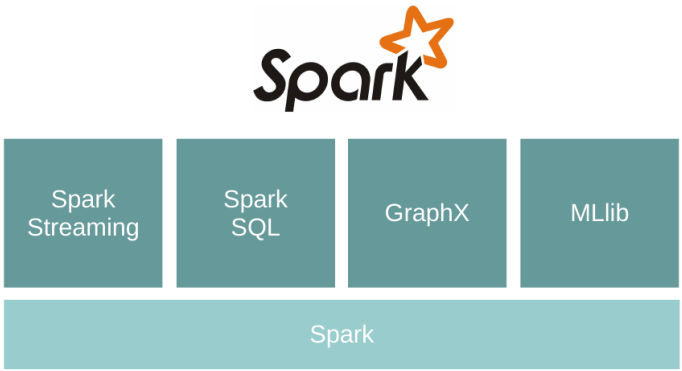


Data Processing - Machine Learning

- Data analysis, e.g., supervised and unsupervised learning
- Mahout, TensorFlow, MLlib, ...

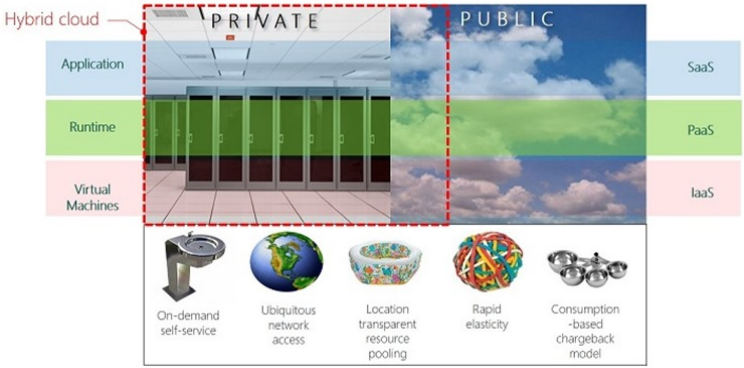


Spark Processing Engine



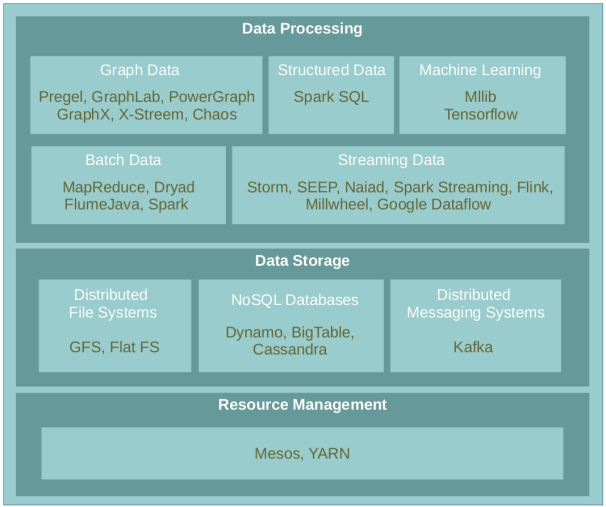
Summary

Summary



[http://aka.ms/532]

Summary


Data Processing
Graph Data
Pregel, GraphLab, PowerGraph
GraphX, X-Streem, Chaos
Structured Data
Spark SQL
Machine Learning
Mllib
Tensorflow
Batch Data
MapReduce, Dryad
FlumeJava, Spark
Streaming Data
Storm, SEEP, Naiad, Spark Streaming, Flink,
Millwheel, Google Dataflow
Data Storage
Distributed
File Systems
GFS, Flat FS
NoSQL Databases
Dynamo, BigTable,
Cassandra
Distributed
Messaging Systems
Kafka
Resource Management
Mesos, YARN

References

- D. Sikeridis et al., A Comparative Taxonomy and Survey of Public Cloud Infrastructure Vendors, arXiv preprint arXiv:1710.01476, 2017.
- A. Fox et al., Above the clouds: A berkeley view of cloud computing, UCB/EECS 28.13 (2009): 2009.
- P. Mell et al., The NIST definition of cloud computing, 2011.

Questions?