University of Bologna

**Dipartimento di Informatica –
Scienza e Ingegneria (DISI)**

Engineering Bologna Campus

Class of

Infrastructures for Cloud Computing and Big Data M

Class Starting…

Basics, Objectives, and initial Models

Antonio Corradi

Academic year 2019/2020

Class Web Site

iol.unibo.it

https://iol.unibo.it/course/view.php?id=47887

Mobile Middleware Research group

https://middleware.unibo.it/courses/iccbd/

Find there

- Teaching contents (lessons, exercises)
- Information & discussion exchange
- Some project topic and area proposals

The available lab

- **LAB2** available non class schedule
- Middleware tools there, also individual practice
  CORBA, OpenStack, Hadoop, SPARK, …

Via Web

- Many papers available
- Some personal deepening hints

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CLASS MAIN GOALS

The course aims at delivering a novel vision of systems (mainly **distributed)** and at building a **deep, informal, practical, and meditated experience** of their **operations**

⚠ **We are immersed into those systems, personally, socially, and as part of organizations**

We are interested in a **system viewpoint**, i.e., **what is behind those systems,** and their **behavior** and **impact, both** from the **user perspective** but **more important** with **the point of view** of the **implementers and designers**

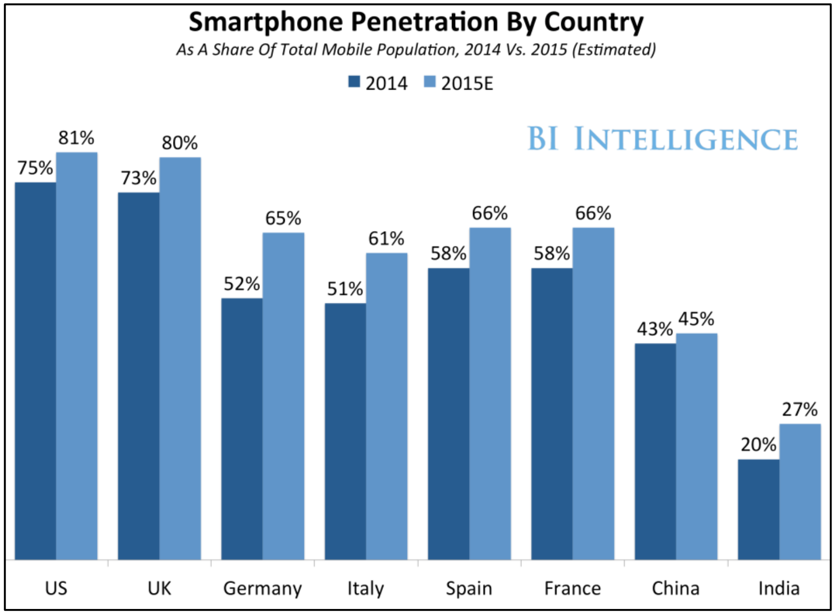
In particular, we focus on the **experience of operations** rather than in **static planning and configuration**

we **aim at the entire life cycle** operations

Course Targets

There are many Distributed Systems you use in your everyday experience

- **Private Personal PC**
- **Private Smartphone**
- **Corporate PC**
- **Corporate Smartphone/Tablet**



In Italy, we have a large number of cellular phones, but not so many smartphones, and also a very deep and large usage of them

Also other (Cloud) remote resources are used

Course Targets

Distributed Systems pervasively available

Within companies / organizations used in workday experience to **support any business aspect** but also at private user level

- **Personal machines and local servers**
- **Internal Electronic Data Processing (EDP) data center**
- **Outsourced resources Cloud**

In general, companies have a *conservative attitude* toward ICT resources, but have also a **consolidated usage of**
not on-premises resources

Course Targets

Large global corporations that provide **Cloud services** **(Amazon, Google, IBM, PAs,…)**

Organization of internal architecture that provides Cloud services with needed Quality of Service

- **Cloud Data Center Organization**
- **Interaction with other Data Centers and Cloud**
- **Intra and inter Cloud**

In general, one **Cloud provider** has several local data centers and keep them as a **central bone**, but has to maintain *external available resources* and *extra-organization agreement* for special dedicated situations

Cloud is a Revolution…

Cloud is a buzzword to be used in advertising and it is sometimes depicted as a revolution

The are many books about Cloud as a revolutionary technology

In general terms, there is **no *solution of continuity*** both under an **organization** and a **technical perspective**

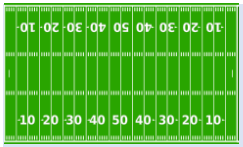
Cloud are Cheaper… and Winning…

Range in size from “edge” facilities to **megascale**

Scale economies

Approximate **costs for a small size center** (1K servers) and a **larger**, 50K server center

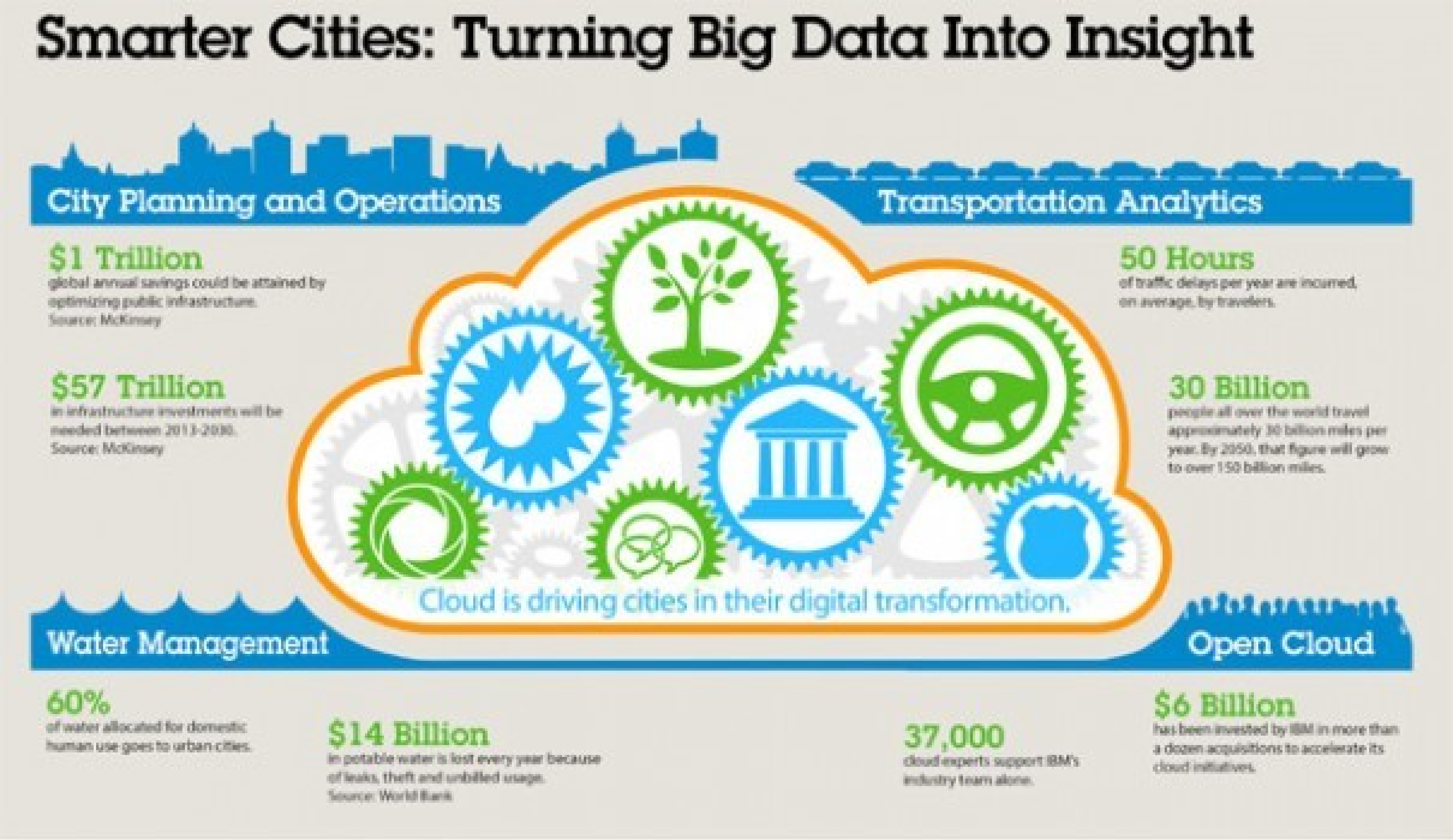
Technology	Cost in small-sized Data Center	Cost in Large Data Center	Cloud Advantage
Network	$95 per Mbps/ month	$13 per Mbps/ month	7.1
Storage	$2.20 per GB/ month	$0.40 per GB/ month	5.7
Administration	~140 servers/ Administrator	>1000 Servers/ Administrator	7.1



Each data center is
11.5 times
the size of a football field

Cloud and Big Data

Smart cities and different services



Smarter Cities: Turning Big Data Into Insight

City Planning and Operations

$1 Trillion
global annual savings could be attained by
optimizing public infrastructure.
Source: McKinsey

$57 Trillion
in infrastructure investments will be
needed between 2013-2030.
Source: McKinsey

Transportation Analytics

50 Hours
of traffic delays per year are incurred,
on average, by travelers.

30 Billion
people all over the world travel
approximately 30 billion miles per
year. By 2050, that figure will grow
to over 150 billion miles.

Cloud is driving cities in their digital transformation.

Water Management

60%
of water allocated for domestic
human use goes to urban cities.

$14 Billion
in potable water is lost every year because
of leaks, theft and unbilled usage.
Source: World Bank

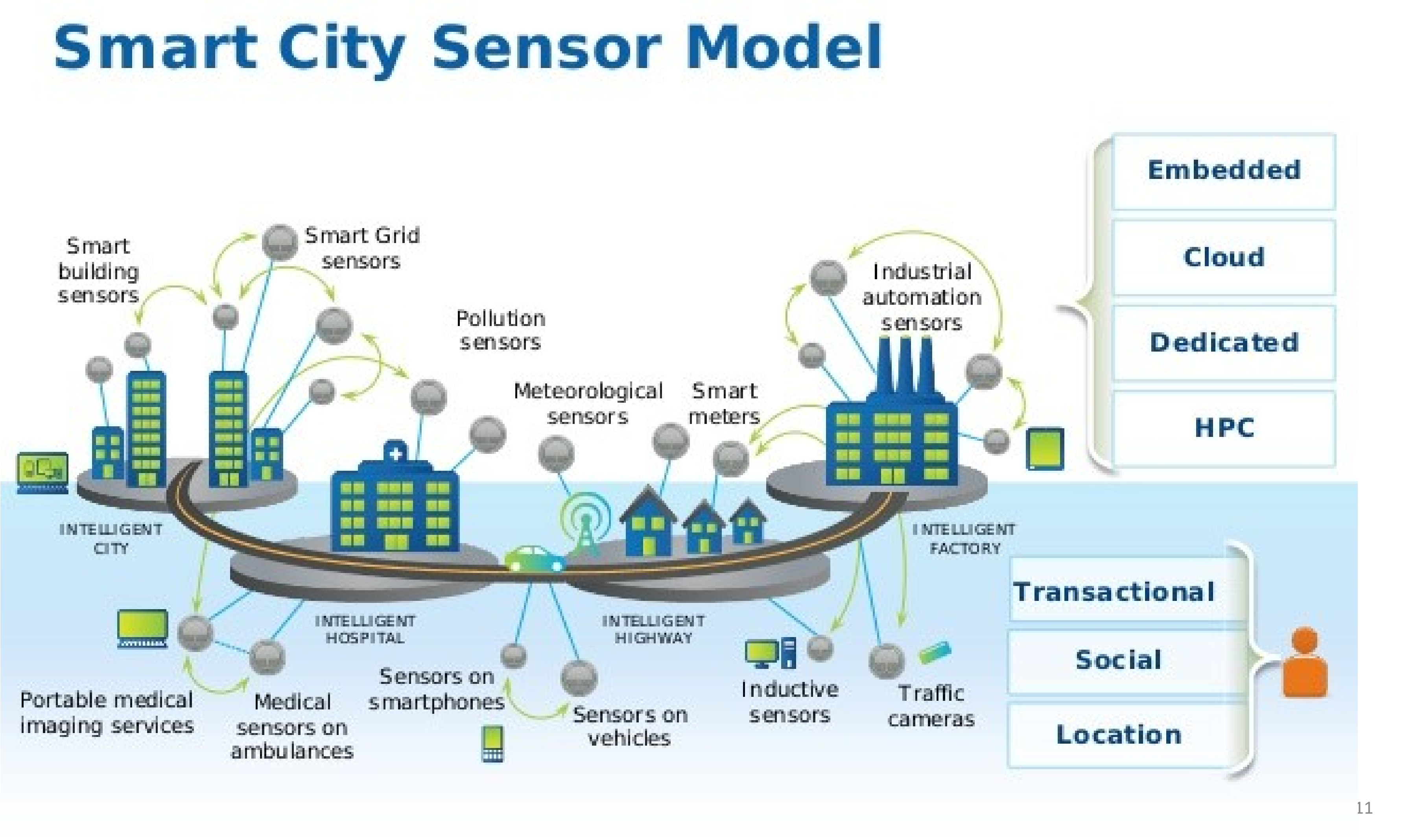
Open Cloud

37,000
cloud experts support IBM's
industry team alone.

$6 Billion
has been invested by IBM in more than
a dozen acquisitions to accelerate its
cloud initiatives.

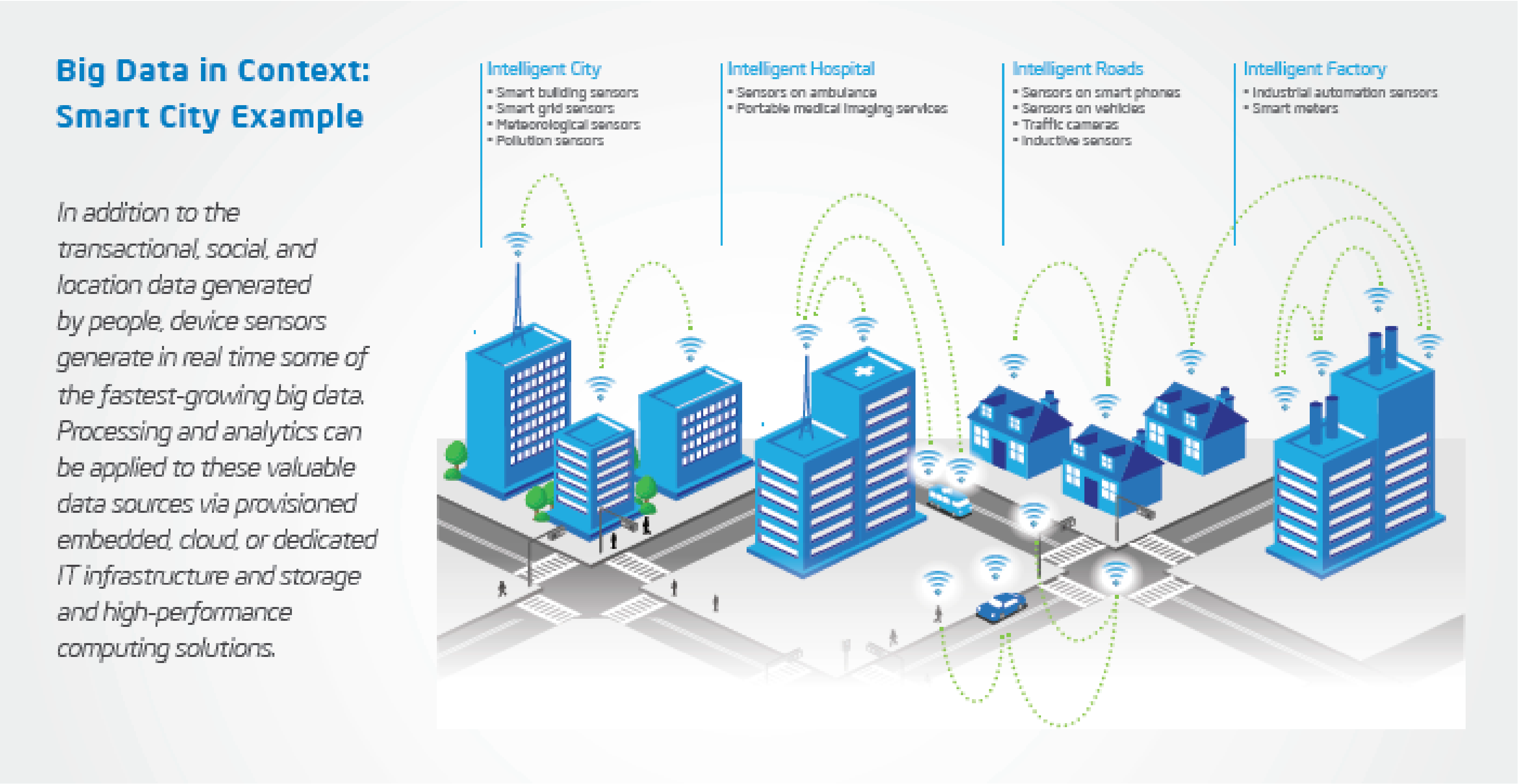
Smart Cities for Sensing

Smart cities and sensing data (**IoT**)



Smart Cities for Big Data

Smart cities produce many data of many different kind



Big Data in Context: Smart City Example

In addition to the transactional, social, and location data generated by people, device sensors generate in real time some of the fastest-growing big data. Processing and analytics can be applied to these valuable data sources via provisioned embedded, cloud, or dedicated IT infrastructure and storage and high-performance computing solutions.

Intelligent City
- Smart building sensors
- Smart grid sensors
- Meteorological sensors
- Pollution sensors

Intelligent Hospital
- Sensors on ambulance
- Portable medical imaging services

Intelligent Roads
- Sensors on smart phones
- Sensors on vehicles
- Traffic cameras
- Inductive sensors

Intelligent Factory
- Industrial automation sensors
- Smart meters

BIG DATA EXPECTATIONS

DIGITALIZATION …

Market and big data investments

6.3 billion of USD **2012**
48.3 billion of USD **2018**
expected 45% per year
not only public investments but also private ones

ICT industry market in 2020

5 trillion of USD **2020**
driven by platform for **Mobile broadband**, **Social** business, **Cloud** services, and **Big data** and **analytics**

European effort

Many initiatives also within **Horizon 2020**, also connected with **Open** and **Linked data** (**Bologna Open data**)
NESSI platform proposal on **Big data**

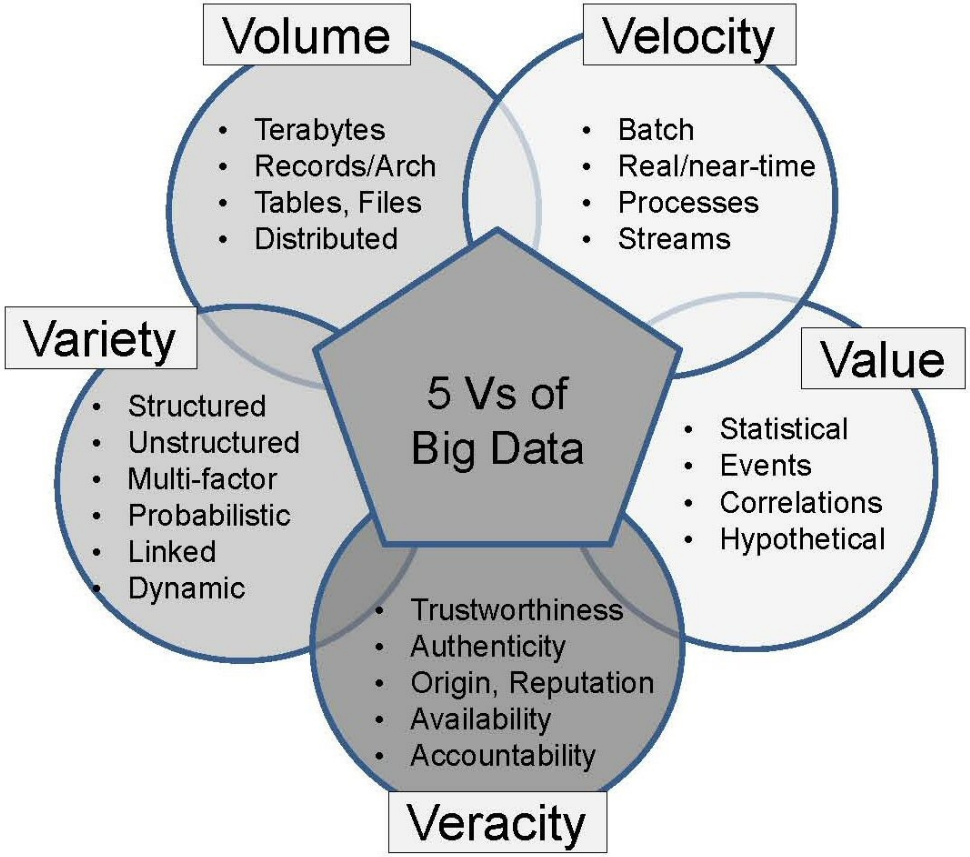
BIG DATA & MORE

Information systems require a **quality-aware vision that can the organize the whole data lifecycle**

5 V's for new data processi
and
novel data treatment

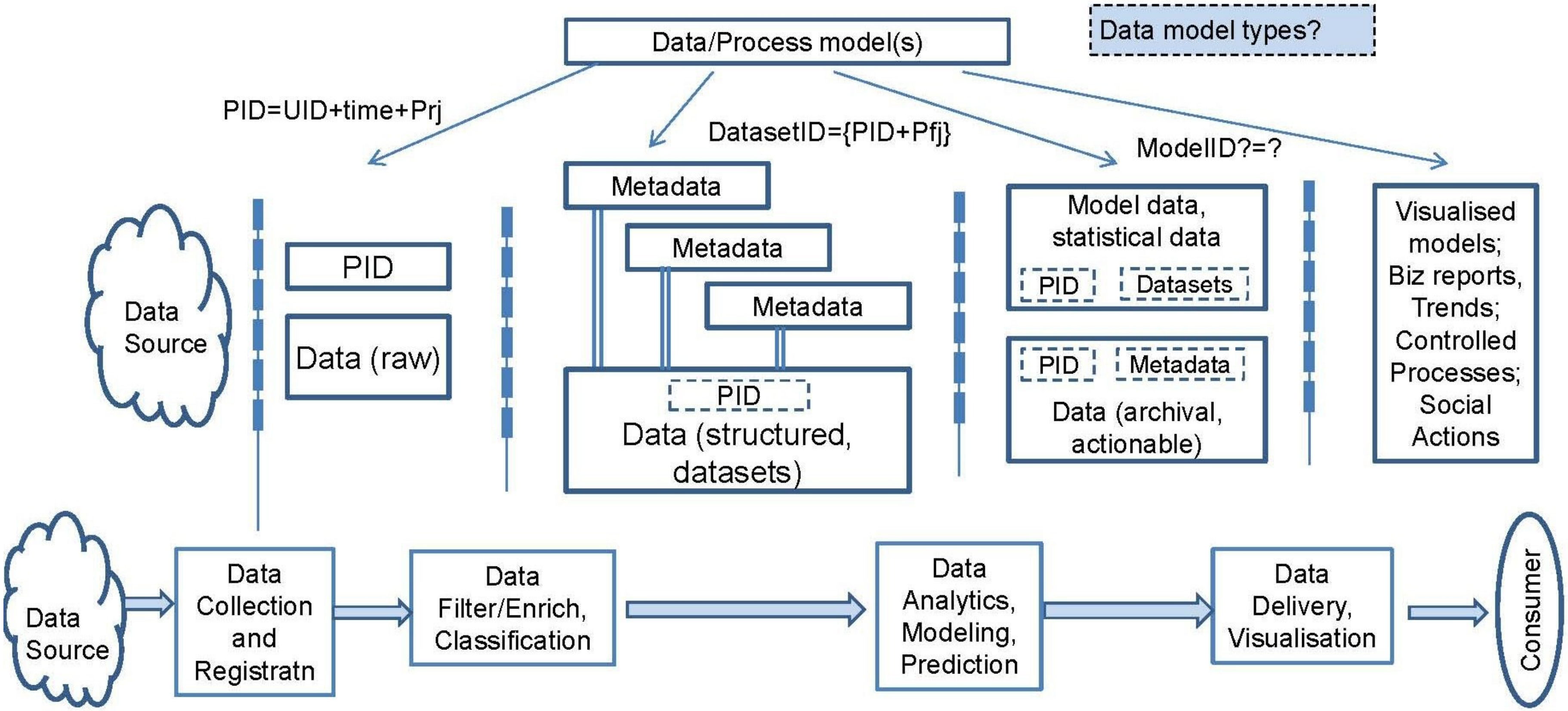
- **Volume of Data**
- **Variety of Data**
- **Velocity**
- **Value**
- **Veracity**

6 V's also Data Dynamicity
- **Variability**



Data Transformation Model

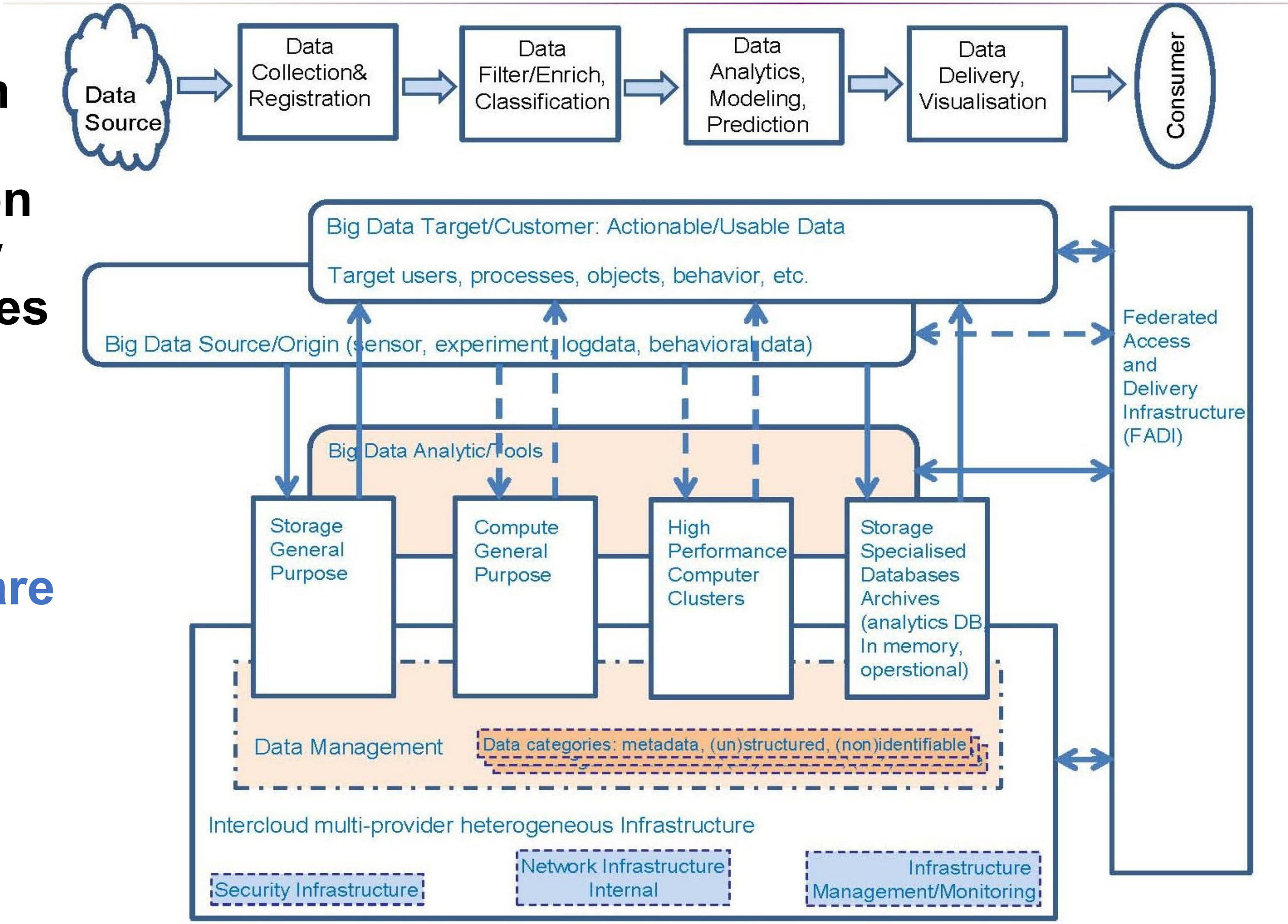
The main workflow is to move data from source to sink via a pipeline easy to map and describe



Data/Process model(s)
Data model types?
PID=UID+time+Prj
DatasetID={PID+Pfj}
ModelID?=?
Data Source
PID
Data (raw)
Metadata
Metadata
Metadata
PID
Data (structured, datasets)
Model data, statistical data
PID
Datasets
PID
Metadata
Data (archival, actionable)
Visualised models; Biz reports, Trends; Controlled Processes; Social Actions
Data Source
Data Collection and Registratn
Data Filter/Enrich, Classification
Data Analytics, Modeling, Prediction
Data Delivery, Visualisation
Consumer

INTEGRATED DATA ARCHITECTURES

Novel Information System organization require **new architectures with novel design principles based on quality-aware services**



Data Source
Data Collection& Registration
Data Filter/Enrich, Classification
Data Analytics, Modeling, Prediction
Data Delivery, Visualisation
Consumer
Big Data Target/Customer: Actionable/Usable Data
Target users, processes, objects, behavior, etc.
Big Data Source/Origin (sensor, experiment, logdata, behavioral data)
Federated Access and Delivery Infrastructure (FADI)
Big Data Analytic/Tools
Storage General Purpose
Compute General Purpose
High Performance Computer Clusters
Storage Specialised Databases Archives (analytics DB, In memory, operstional)
Data Management
Data categories: metadata, (un)structured, (non)identifiable
Intercloud multi-provider heterogeneous Infrastructure
Security Infrastructure
Network Infrastructure Internal
Infrastructure Management/Monitoring

TYPICAL SERVICE ENVIRONMENTS

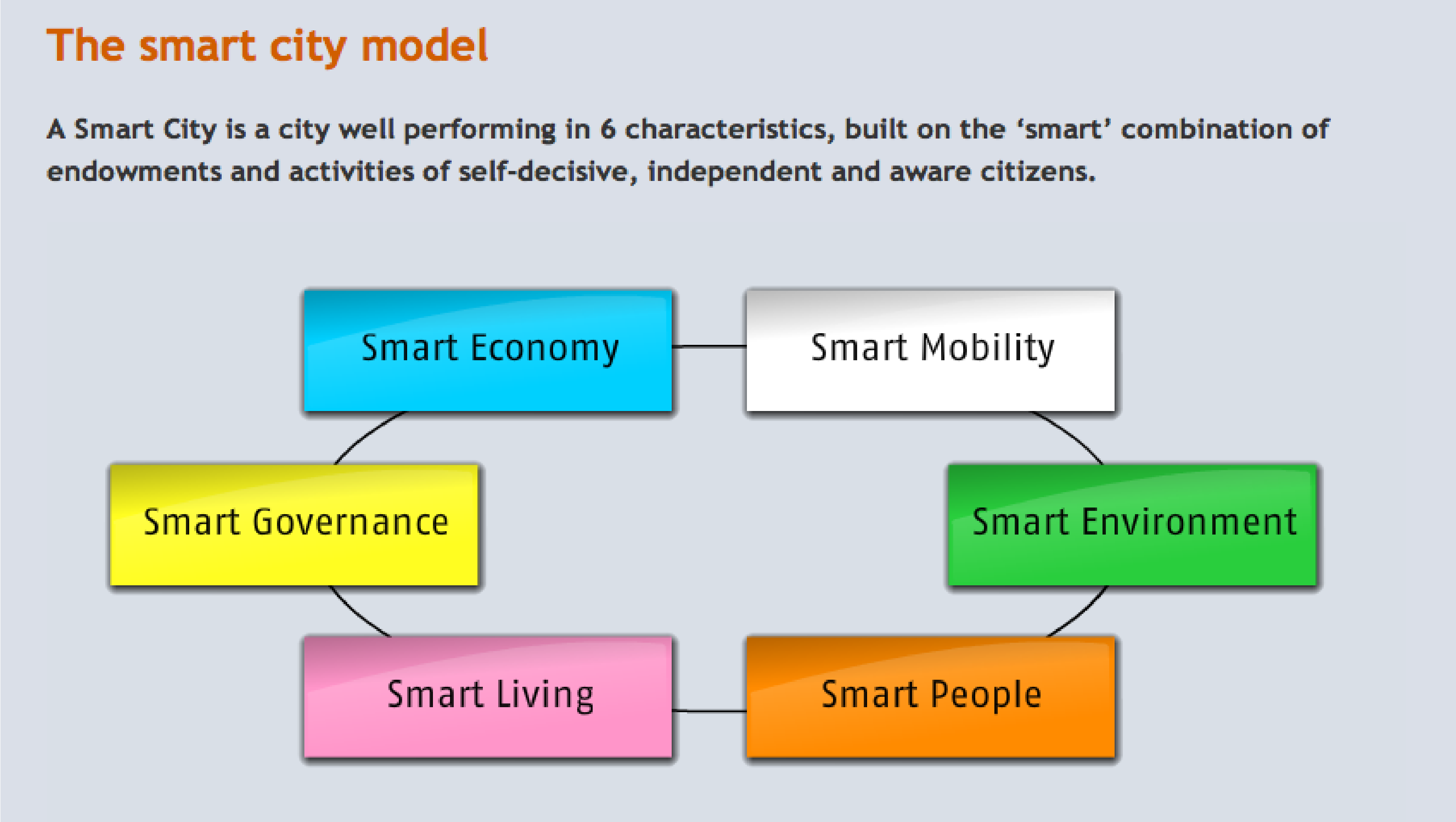
While there are **many application areas that can offer complete scenarios** where you can find all the **topics** and the **solutions** we are interested in this class, we can **focus attention to one specific area**

The **smart city** topic is very **hot** and **pursued** in **several senses**

- It is a goal of public administrations and **EU policy** financing;
- It is an area that can contain many **(open) data and sets**;
- It is an area where **streams of data** can be harvested;
- It is an area where **citizens can move around** and require services also in a localized way;

The smart city contains many **big data** opportunities but also includes, requires, and can manage **many IT resources**

SMART CITY: SMART PERSPECTIVES



The smart city model

A Smart City is a city well performing in 6 characteristics, built on the 'smart' combination of endowments and activities of self-decisive, independent and aware citizens.

SMART CITY SCENARIO

In a **smart city**, we may consider and appoint **attention** to some **specific behaviors that produce a big data system in interaction with other ones (in the complexity stemming from global interaction)**

- **Group** of **replicated resources** and interacting components
- **Co-creation** of **new contents** such as videos, pictures, etc.
- **Collection** of big data
- **Harvesting** of open data
- **Management** of resources and people information
- **Public services**
- **Specific workflow** for communities

We can also **focus on** some **locality** to work with and test and experience **a smaller-size isolated system**

Requirement for services

In distributed systems, while services must be correctly provided, it **is a compulsory goal** the **Quality of Service (QoS)**, in the sense of **provisioning with some parameters** and **respecting requirements**

The **QoS** has many **different meanings**, because it is a **quality indicator**

It can stress **response time**, **security**, **correctness**, **availability**, **confidence**, **user satisfaction**, …

QoS goals (conflicting?) in the **Old** and the **New World**

- **Old world:** typically, main goals **reliability** and **enforced consistency**
- **New world:** **scalability and availability** matters **most of all**

Focus on **extremely rapid response times:** Amazon estimates that **each millisecond** of delay has a measurable impact on sales!

BEHIND THE WOODS: SUPPORT FOR…

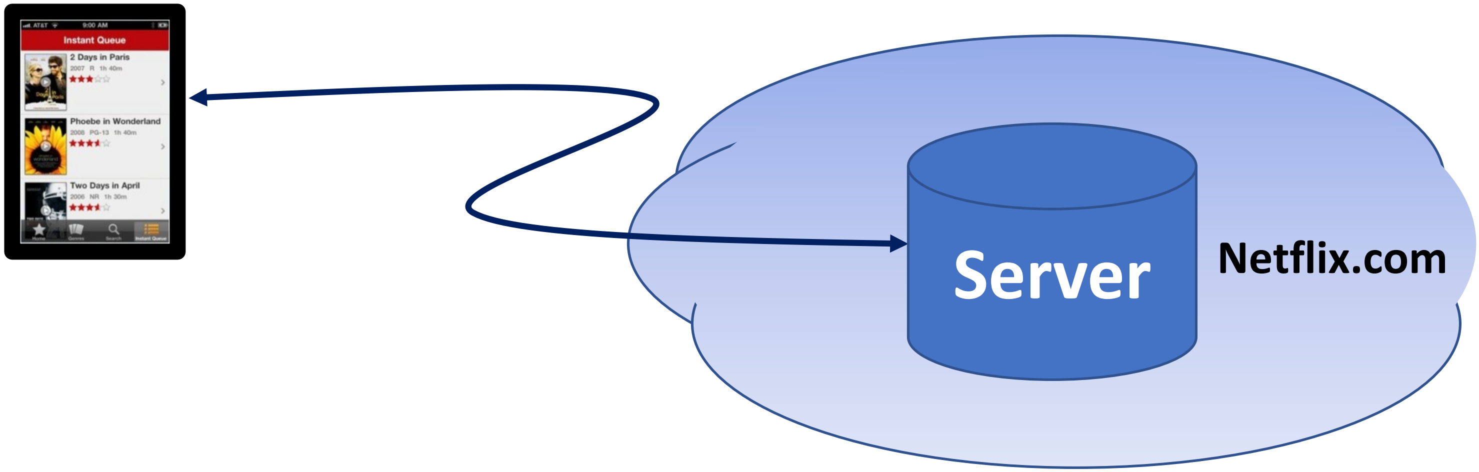
To **provide QoS** distributed systems have to support some coverage of **properties** and **functions**

- **Replication**: usage of multiple copies of resources
- **Grouping**: keeping together different copies and behavior
- **Simplified delivery**: new tools and technologies to fasten development & deployment of complex applications
- **Automated management**: infrastructures taking care of management burden with minimal human intervention
- **Batch data processing:** storage/processing of massive amounts of data, such as for Google Web indexing
- **Streaming data**: dealing with information series coming from a set of grouped info, such as a video, sensors, etc.

An example: Netflix

Personal service to **play movies on demand**

User Perspective



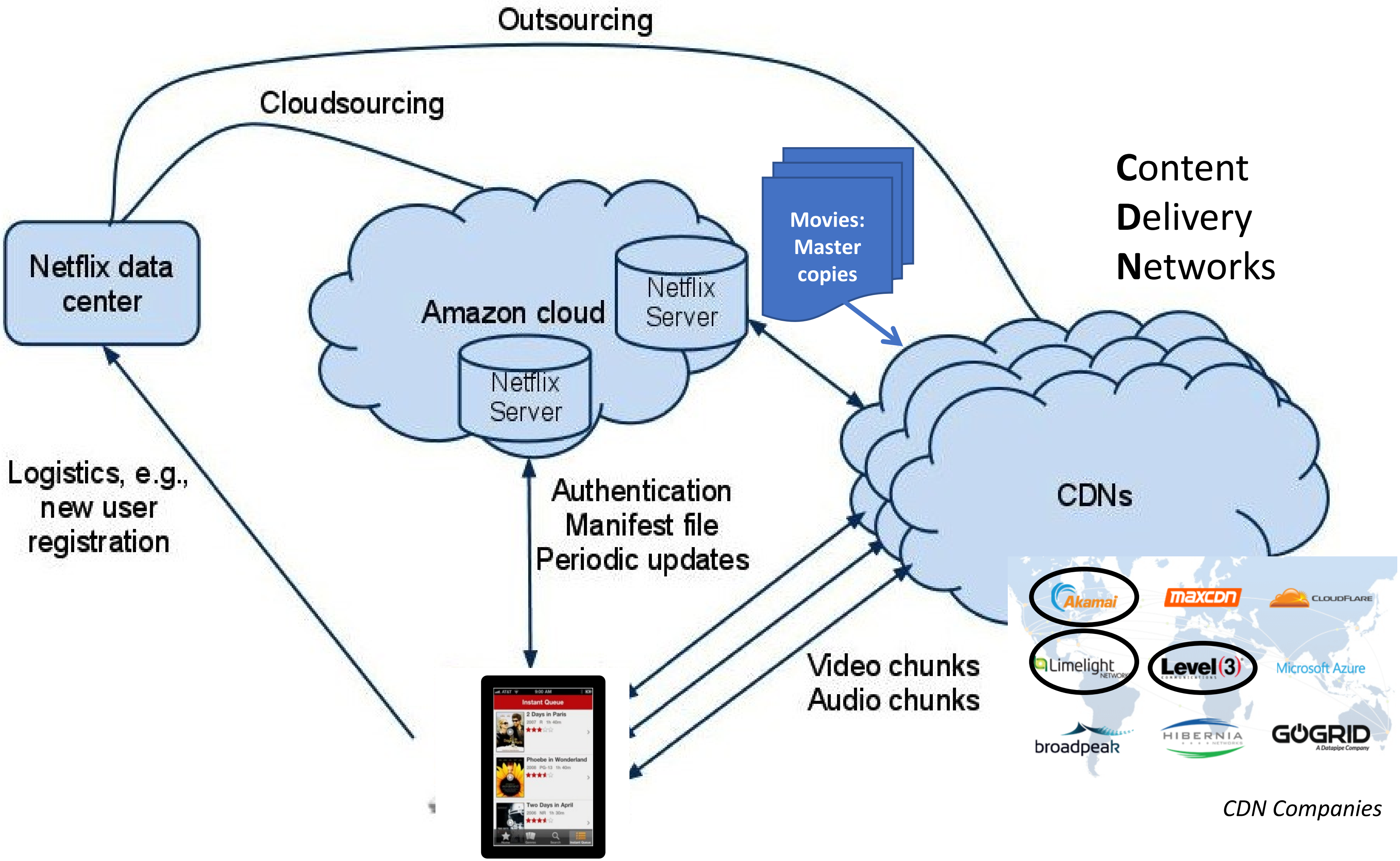
Simple design?

Netflix owns the data center and content distribution infrastructure

BUT, **in reality**….

Netflix owns **neither** a data center **nor** a distribution infrastructure

NETFLIX: THE COMPLEX PICTURE



Outsourcing

Cloudsourcing

Netflix data center

Amazon cloud

Netflix Server

Netflix Server

Movies: Master copies

Content **D**elivery **N**etworks

CDNs

Logistics, e.g., new user registration

Authentication Manifest file Periodic updates

Video chunks Audio chunks

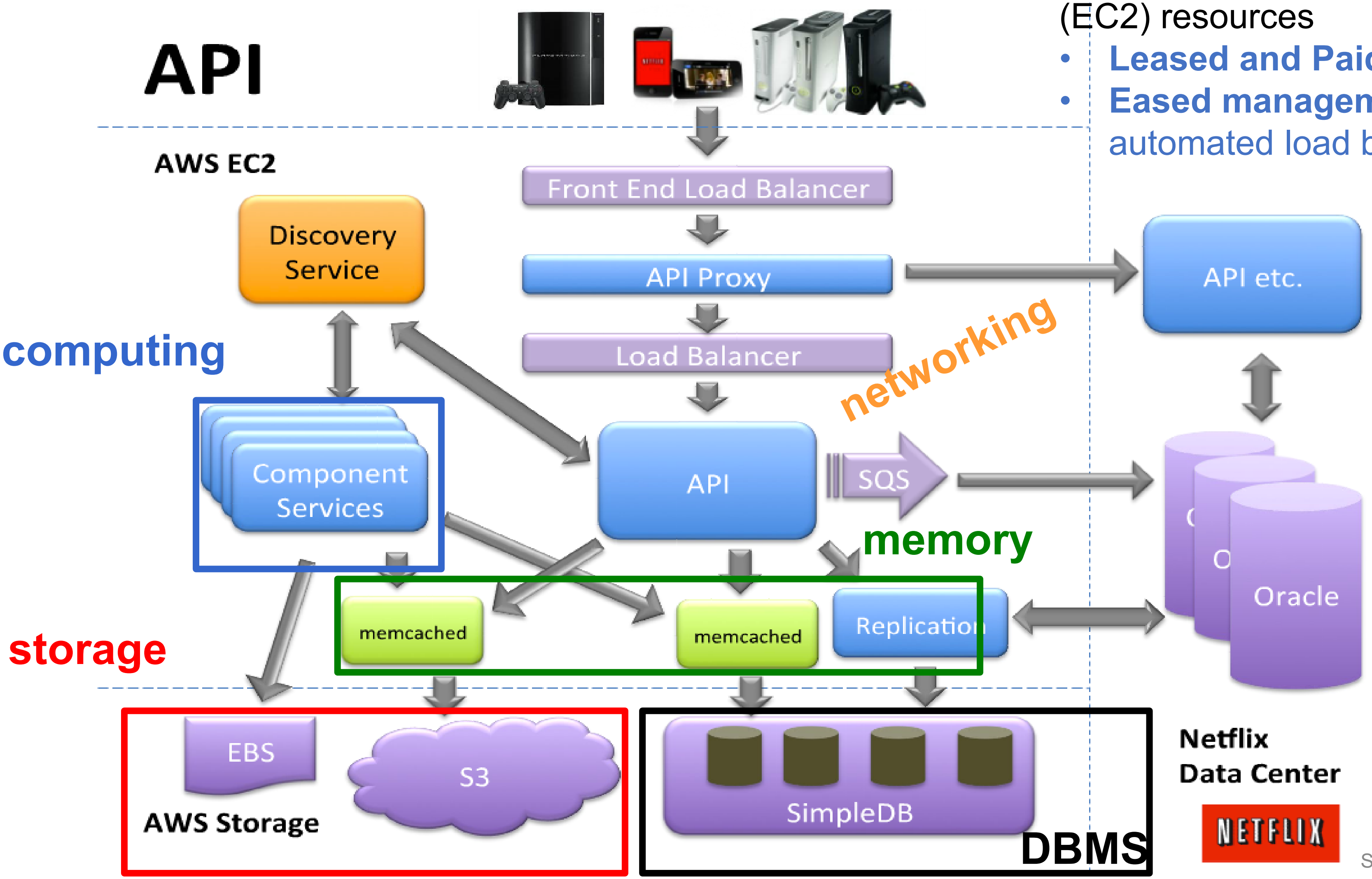
CDN Companies

V.K. Adhikari *et al.*, “Unreeling Netflix: Understanding and Improving Multi-CDN Movie Delivery“, *IEEE INFOCOM*, 2012.

Netflix & AWS EC2 in a Nutshell

Amazon Web Services (WS) **Elastic Cloud Computing** (EC2) resources

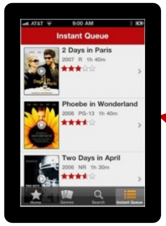
- **Leased and Paid-per-use**
- **Eased management** (e.g., automated load balancing)

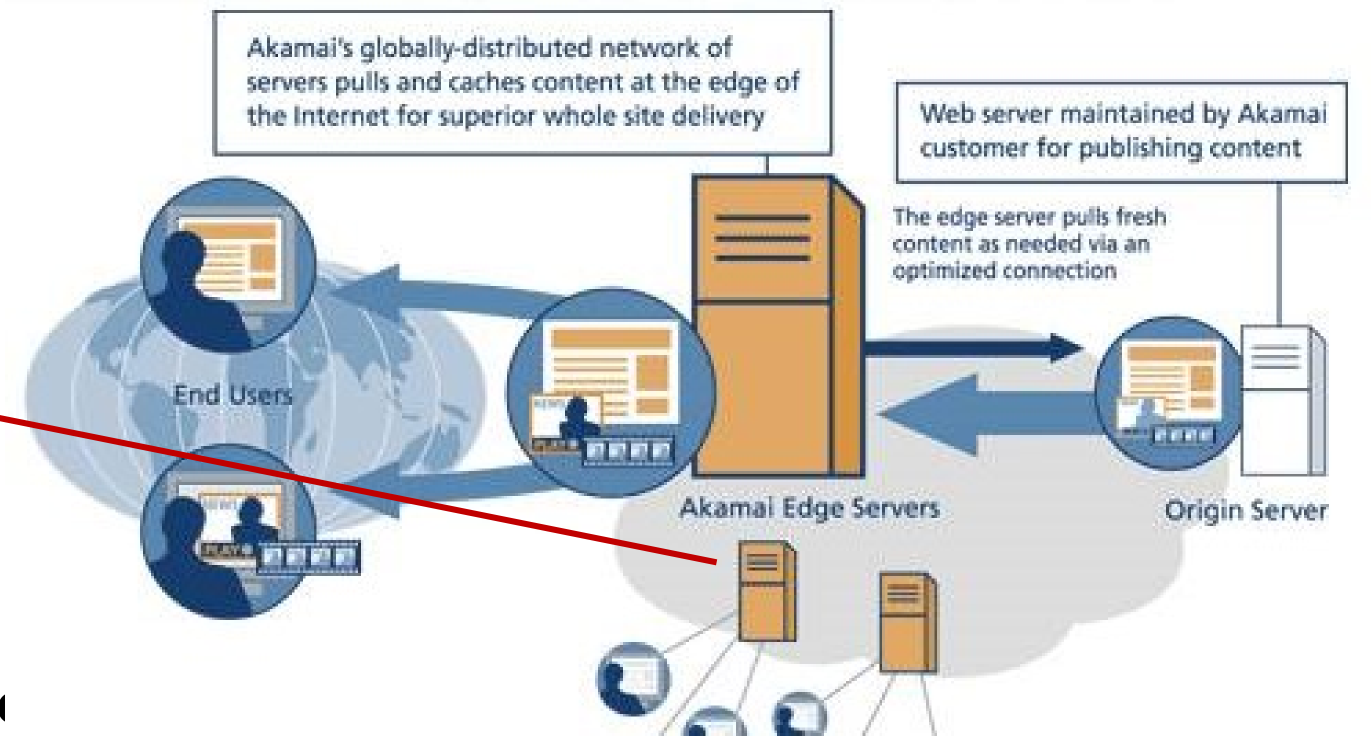


NETFLIX & AKAMAI CDN IN A NUTSHELL

Many resources

- Capillary **worldwide network**
- Externalized **infrastructure management**




Akamai's globally-distributed network of servers pulls and caches content at the edge of the Internet for superior whole site delivery
Web server maintained by Akamai customer for publishing content
The edge server pulls fresh content as needed via an optimized connection
End Users
Akamai Edge Servers
Origin Server

How to grant **Q**

- **Replicating** content and servers
- **Low latency** through identification of **nearby Edge Servers**

Industry 4.0

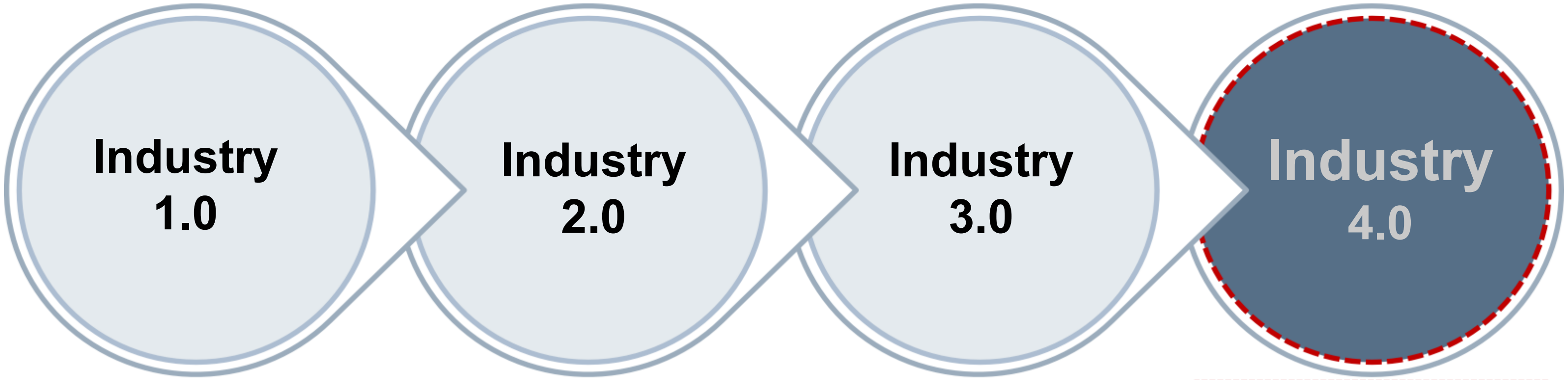
Industry 4.0 was a spreading trend toward an evolution of traditional **industrial processes** and **it became** a reality

Industry 4.0 (**I4.0**) has multiple meanings

- connects / merges **production with ICT**
- merges **customer data with machine data**
- goes **M2M**: Machines communicate with Machines
- components and machines autonomously manage **production in a flexible, efficient, and resource-saving manner**

Industry 4.0

Industry 4.0 is in the trends of the **industrial revolutions**



Industry 1.0

Industry 2.0

Industry 3.0

Industry 4.0

1760s to 1900

Use of steam and mechanically-driven production facilities

1900 to 1970s

Electric power-driven mass production based on division of labor

1970s to date

Extensive use of controls, IT, and electronics for an **automated and high productivity** environment

Future & Smart:

based on **integration** of **virtual** and **physical production systems**

DEFINITION OF INDUSTRY 4.0

INDUSTRIE 4.0 represents the **coming fourth industrial revolution** on the way to an **Internet of Things, Data** and **Services**

Established in Europe (Germany)

“The **information-intensive** transformation of manufacturing in a **connected environment** of data, people, processes, services, systems and production assets with the generation, leverage and utilization of actionable information as a way and means to realize the **smart factory and new manufacturing ecosystems**”

Source: Frost & Sullivan

DEFINITION OF INDUSTRY 4.0

Smart industry or “INDUSTRIE 4.0” refers to the **technological evolution from embedded systems to cyber-physical systems**…

Decentralized intelligence helps create
intelligent object networking and
independent process management,
with the **interaction of the real and virtual worlds**
representing a crucial new aspect of the manufacturing and
production process

Source: Frost & Sullivan

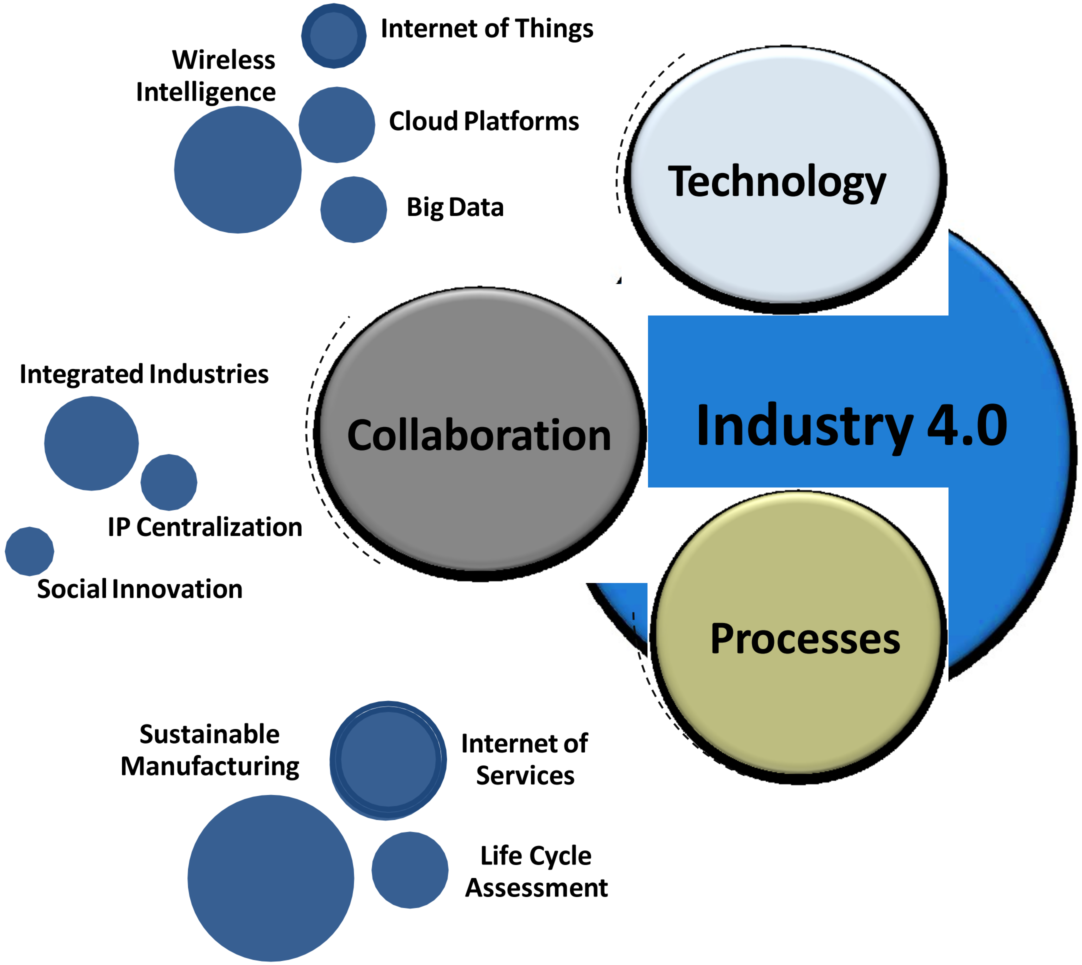
Industry 4.0 Environment

Industry 4.0 is in the sense of
product innovation in manufacturing

as an effort

in three areas

- **Technology**
- **Collaboration**
- **Processes**



Source: Frost & Sullivan

INTERESTING TARGET SYSTEMS

There are many **interesting applications in interesting systems**

We are **interested in connected and distributed systems**

in-the-small

A **set of locations closely interconnected with several application running** but **limited in distance** and **high-bandwidth connections** and **limited communication times**

Local installations

in-the-large

A **very large set of interconnected locations with a non-countable number of interacting applications depending on each other's**

In general, global world-wide systems

COURSE CORE

The complexity of applications in-the-large asks for ready-to-use off-the-shelf solutions

The answer toward a better usage is "Middleware"

We can give **a first definition**

Middleware is a **set of tools and components** already available for the best **system performance** mainly under the **user required perspective**

A middleware can make **available ready-to-use applications** if a user needs a new functions with no user intervention

A middleware can also **simplify the development of new applications** if the functions are not already available

A middleware can also follow **life cycle to adapt the system** to new requirements and trends

MIDDLEWARE

From the very **complex and differentiated user scenarios,** it is difficult to define **one middleware,** but **many different ones are available and suitable**

We speak of different middlewares for different usage

Different meaning for usage & for adoption and suitable for different environments

1. **Personal usage** (for one **private user**)
2. **Company usage** (for **internal organization**)
3. **Global data center usage** (for large data center provider & cloud provider usage to provide services externally)

Private Users

A first case is one

middleware to support the needs and requirements of a single user that typically

- **Has several private machines** (traditional PC and also several smartphones)
- **Works on private data and applications** (typically configured and loaded but also *apps*)
- **Has to access to remote resources** (either company-based or globally-available on Cloud) also non private

Private Users

Examples of needed support services/functions:

- **Usage of personal Apps and communication tools**, such as **email, Whatsapp, Telegram**, …
- **Transparent synchronization of tools across devices**, such as in **Skype (for chat), Dropbox (file system)**, and many other services
- **Transparent reliability through data replication**, such as personal storage for backups in Amazon S3
- **Access through any kind of UI and remote visual desktop**

Organization Internal Support

A second case is one

middleware to support the needs and requirements of either **a private or public organization with specific goals to provide services to internal users**

- **Has several user machines and applications** (traditional PC, mobile & small group resources, …)
- **Works on company server in local data center** (typically servers and their resources)
- **Has to access to remote resources** (either on other companies or on global Cloud)

Organization Internal Support

Examples of needed support services/functions:

- **Transparent services**: replication/group synch, load balancing, naming, accountability,
- **Non-Transparent Project management** and **support tools**: service monitoring, decision systems, …
  mainly company-based and -negotiated
- **Management** of **service delivery & used resources** (computing, storage, network, …):
  if it is a technology company, both via CLI and visual UI

Cloud Providers

A third case is one

middleware to support the needs and requirements of a (general-purpose) data center typically available in Cloud

- **Has several IT resources** (large quantities of servers in groups, large data servers and storage, more special purpose IT resources, …)
- **Offers services to several client organizations** (typically bare services, and more articulated ones)
- **Has to honor accepted contracts** (not only locally, but also coordinating with provider in need)

CLOUD PROVIDERS

The main goal is to have one

middleware to provide services to an external customership with very differentiated QoS

- only locally, but also coordinating with provider in need)

Examples of needed support services/functions:

- **Management & monitoring of physical infrastructure & of support functions** to enable sharing of resources
- **Advanced physical resource management to grant**: agreed quality levels, isolation (security & performance)
- **Customer Relationships Management** (**CRM**), all services to interact with customers needs, …

The Class Issues

The course aims at **elaborating on the knowledge of distributed systems for the whole life cycle operation**, for the aspects related the execution

- Operations in the **entire life cycle**
- **System management**
- Quality of service (**QoS**)
- Variations during the **life cycle**
- **Recovery and tuning**

Less interest paid to

- Design phases
- Coding
- Preparation and static analysis

CLASS INTERESTS

Topics oriented toward the execution environment

- All the aspects are selected in the sense of their contribution toward a **better execution**
- General topics are conjugated with the idea of their **presence and support for the execution part of the life cycle**, always the **dominant in time**

Individual starting experience

- Capacity of **reading technical papers**
- Skill to **support going depth into a topic**
- **Writing & Presentation** on technical topics
- **Design** a small project and solution sketch

DISTRIBUTED SYSTEMS AND APPLICATIONS

Middlewares to support Distributed Systems

Where a suitable infrastructure (a middleware) handles and manages all system resources

Some interesting Middleware lines

- **Object** middleware **(CORBA,** COM, .NET**, …)**
- **Message exchange** middleware **(MOM)**
- **Overlay Networks, File systems, NoSQL support**
- **Cloud** systems & **middleware (OpenStack, CloudFoundry)**
- **Data processing** & **streaming** middleware **(Hadoop, SPARK)**

Middleware as an **environment** to **support services**

Some tools are common to all different kinds of middleware

Cloud as an Evolution

A **necessary and unavoidable step ahead**

Cloud Architectures and solutions

Possibility of **off-the-shelf solutions organized** around and with **Web-accessible resources** in **remote data centers**

- **ready-to-use Systems**
- **easy Systems**
- **pay-per-use Systems**
- **transparent** (or non) **Systems**
- flexible, **extensible & elastic Systems**
- **reliable Systems**
- **secure Systems**

Pre-Requisites

Skills on **operations in different environments**
(previous lab presence is recommended)

Skills on **most significant models for distributed systems**
concurrency, processing, storage, …

Lateral Skills

Capacity of **implementing** and **controlling** real projects
Capacity of **exploring in an independent way**
Skills in **project engineering**
Skills in **English** …

GOALS

Design of a service/application architecture

Execution and performance of the project

Analysis Capacities

- Understanding of **Principles** and **support environments** for general-purpose services and special-purpose ones
- Understanding of **Projects** and **Solutions** at different levels: conceptual, architectural, at protocol level, algorithmic one, by using different technologies & components

Synthesis Capacities (see site)

- Speech based on some read **paper**, chosen & elaborated
- Design of a ***chosen case study***
- Presentation of a **written report** as a 'to-be-published' article

Class Results

The **final grading** stems from **an oral exam**

to ascertain the **knowledge** and **orientation** about the entire discipline, ranging on all topics, starting with the basics, going through the practical portions of middleware, and also with a possible follow-up on a chosen topic

You can also choose the project activities (for 4 credits), recommended for the Distributed System Computer Engineering path

Assignment of a project on a specific **subject assigned** and **done individually**

PROJECT ACTIVITIES

Projects can deal with any topics of the class

- **Data Monitoring Aggregation for deployments OpenStack multi-region**
- **Monitoring and Scalability of CloudFoundry for PaaS**
- **Linked data and Semantic Data support for Storm real-time processing**
- **Storage Levels and Inputs in Apache Spark**
- **Load balancing in S4**
- **Enhancing networking in Openstack**
- **Multi-Cloud PaaS Services**
- **Infrastructures to support Blockchain**
- **…**

GRADING - WORKFLOW

The final score is via the oral exam (almaesami is the site for the enrollment**)**

First step is the enrollment on the list and find the dates

Scheduled days in almaesami and oral exams for the class on dates:

- First exam (Friday, 12th June 2020)
- Second exam (Friday, 3rd July 2020)
- Third exam (Friday, 18th July 2020)

Grading - Workflow

First step (for the project activity) is the enrollment on the list and find the dates, give in the project, then the enrollment

Scheduled days in almaesami and oral exams for the class on dates:

- Giving in the two-part project (report & implemented project)
- First exam (Friday, 12th June 2020)
- Second exam (Friday, 3rd July 2020)
- Third exam (Friday, 18th July 2020)
- And more oral exams…

Hands-On Seminars

Planning of hands-on experience about some novel directions in relevant technologies not within class hours

Seminars to introduce company technology perspective
Companies can give a picture of what is their experience and which technical roles are significant for and with them

Importance of
Possibility of studying abroad / work experience
Serious language skills (apart from technical)

Some Materials and Items

Class Slides available:

- on the web site of the class
- at the copy center of the School

Some basic books

G. Coulouris, J. Dollimore, T. Kindberg, "***Distributed Systems: Concepts and Design***", Addison-Wesley, (fifth edition) 2012.

A.S. Tanenbaum, M.v.Steen "***Distributed Systems: Principles and Paradigms***", Prentice-Hall, second edition 2006.

B. Forouzan, F. Mosharraf: “***Computer Networks, a top down approach***”, McGrow-Hill, 2011.

M.L. Liu, "***Distributed Computing***", Addison-Wesley, 2003.

SOME (CLASSIC) REFERENCE BOOK

D.L. Galli, "***Distributed Operating Systems: Concepts and Practice***", Prentice-Hall, 2000.

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Please refer to articles on different topics in journals published by two professional organization:

- **ACM** (**Association for Computing Machinery**) e
- **IEEE** (**Institute of Electrical and Electronic Engineering**)

Groups **www.computer.org** **www.comsoc.org**

General magazine:

- *IEEE* ***Computer****, ACM* ***Communications***
- IEEE **Internet Computing** e IEEE **Communications** **(**also **Distributed Systems OnLine** http://dsonline.computer.org**)**

Depth into journals very specific and helpful

- ACM **Computing Surveys** (ACM CS), ACM Transactions on...
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