

# Cloud Computing Introduction and Foundations Concepts

Evolution towards Cloud Computing

Reference:

- [cam-san] Chapter 2

# Cloud Computing - Definition

- **NIST, the US National Institute of Standards and Technology:** *“Cloud Computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort of service provider interactions”*
- **My Mom:** “The place where my phone saves my emails, contacts, pictures, so I don’t lose them”

# Evolution of technology

- Cloud computing is not an abrupt innovation, instead, **it is the result of a series of developments that have taken place over the past few decades**
- The concept traces back to 1960, when McCarthy (the same who coined the term 'artificial intelligence') wrote: *Évolution de cette Branche de l'IT*  
*Partie de la définition de cloud computing*
  - 'computation may someday be organized as public utility', like water, electricity, gas, etc...
- It took, however, more than 40 years for technology to develop and mature for cloud computing: only the composition of some key technologies has enabled cloud computing
- Several decades of research, especially in the domain of parallel and distributed computing, have paved the way

# The origin – Mainframes

- Commercial usage of computing started around 1970s with mainframes
- Organizations acquired such hardware to automate basic data processing, e.g. payroll management
- Mainframes were large supercomputers installed in a room. They were so high priced that it *was hard for a company to have more than one*
- Multiple users were sharing the mainframe at the same time: the common approach was to implement a time-shared utilization
- Different users were accessing the mainframe from terminals

CREATE A SCHEDULE WITH  
TIME - SLOT

# The origin – Mainframes

- Terminals were dumb terminals, i.e. were only capable of transferring input-output data to/from the mainframe (the server)
- This centralized processing environment was a bottleneck
- Users had always to wait for a long time in queue

↳ Saw in TERMINAL  
DEN ACCESS



# PC Revolution

- At the end of the 70s less expensive computers came into the market
- Those Personal Computers (PCs) provided some processing and storage capabilities to run applications
- The need to maintain expensive mainframes systems soon became less important

↳ Il crollo dei PC causò un  
crollo dei mainframes



Il PC è più affidabile e più veloce

# Network of PCs

- Big organizations installed multiple PCs in different offices
- Each one, however, was functioning independently → *Ogni computer ha il suo PC che non*
- Network communication technologies were introduced to allow communication between PCs for data transfer *comunicazione tra loro*
- LAN: Local Area Network (LAN) and Wide Area Network (WAN) were introduced at that time: *EVOLUZIONE* *NATION-WIDE / INTERNATIONAL-WIDE*  
*computer in the same office or placed at distance could communicate* *1 a distanza comunicano tra loro*
- Over time communication technologies improved, increasing the bandwidth

→ *QUANTITA' DI DATI CHE SI POSSONO SCAMBIARE TRA DI LORO*

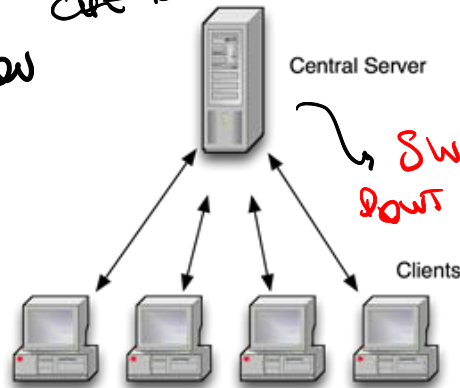
# Distributed applications

two specific tasks  
essentially on the  
PC

- Client/Server computing: we have a server (offering some service/information) and a client

Collection of data points  
are maintained information

• WEB APPLICATION

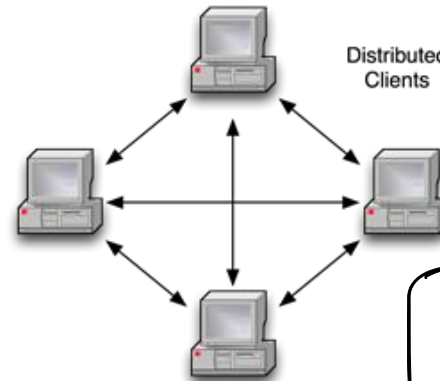


Client / Server

Single point of failure

- Peer to peer computing: each and every computer can play the role of a client as well as a server

Information distributed  
TRA 1 client



Peer to Peer

Data - volatility

Interaction was limited to exchange of small data due to network limitations



# Parallel processing

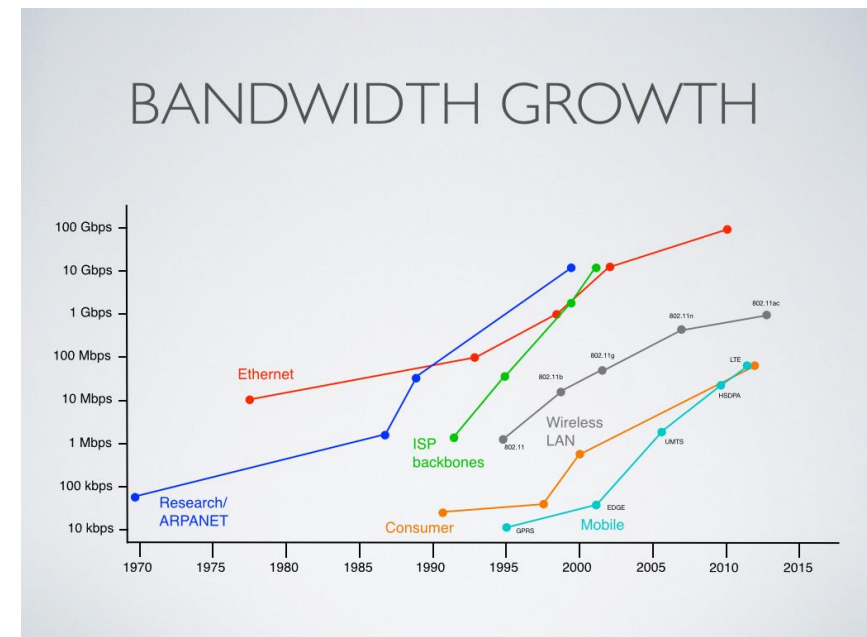
- In early 1980s it was believed that computer performance could only be improved by producing faster and more powerful processors
- **Parallel processing** changed this idea: multiple processors (installed on the same PC or on different PCs) working together to solve a single (big) task that could not be executed on a single one
- The task must be designed to be parallel, i.e. composed by a set of subtasks that could be executed in parallel

Pen ANDALÉ OTRAS, UHETI FISICI DESO SUIWAP  
D.S. PROCESSOR

↓ PROGETTO APPROPRIATE

# Faster Network Communication

- During 1980s advancements in network communication improved significantly data transfer rates (up to 100 Mbps for LANs and up to 64 Kbps in WANs) *Boulton & CA* →
- Such advancements enabled *distributed computing systems: a collection of processors interconnected via communication network to execute a complex task, impossible to be executed on a single PC*

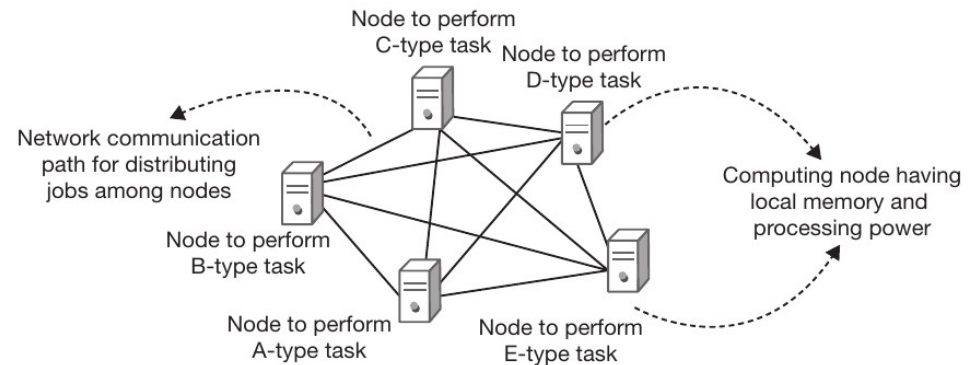


# Distributed computing systems

- Applications are programmed to be executed in a distributed manner as a composition of different tasks
- Each system has its own local memory and processing power
- Nodes communicate to exchange data or results

Complex Task impossible  
DA EXECUTE SU W  
SWAPO PC

SUBSET  
DI TERN



# Cluster computing

BENEFIT: ① RELIABILITY  
② REDUCE OVERHEAD

- The next natural step was the creation of clusters: groups of multiple nodes (computers) all connected to the same LAN to perform the same (or similar) tasks

- Computers are clustered together for a more efficient computing (less communication overhead) and to improve reliability.

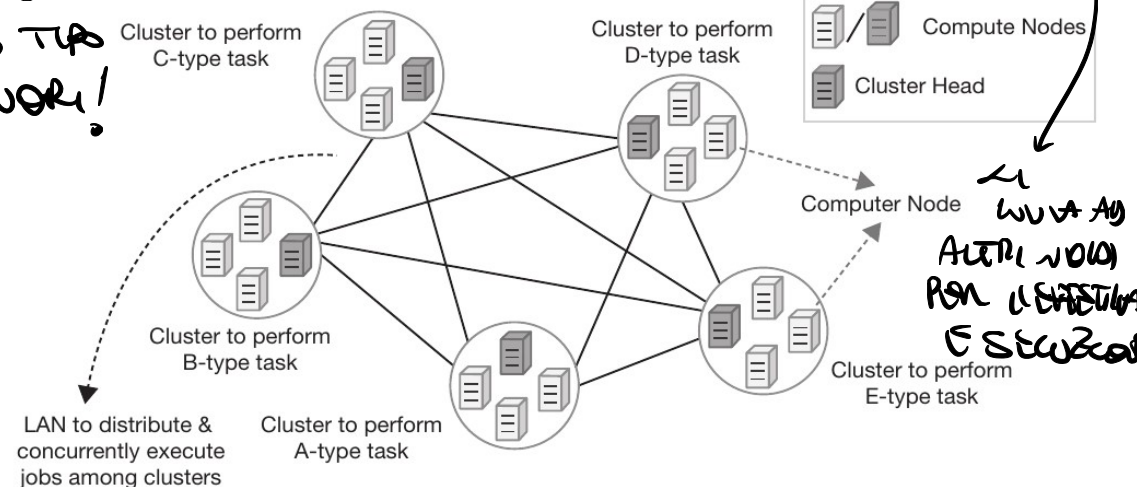
→ RATHER THAN FOR SEPARATE CO

- Pools of homogeneous computing systems were deployed to have more processing power

STRESS TIP  
IN LAURE!

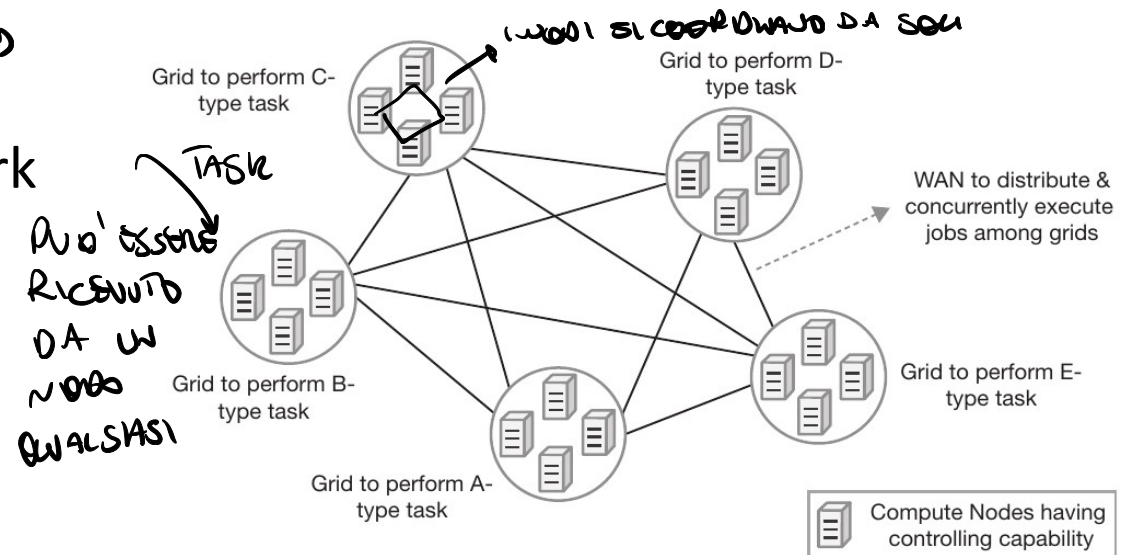
- Among the computers of a cluster, one node was selected as cluster head to control the cluster and distribute the tasks

1. CLUSTER HEAD IS CHOSEN  
THE RECEIVES TASK



# Grid Computing

- The cluster head represented a single point of failure
- To mitigate this risk in early 90s a new architecture was introduced, **grid computing**: a pool of resources in which the control functionalities were implemented in a decentralized manner (not in the cluster head) *to remove the cluster head*
- Computing nodes could be deployed in the same network or could be deployed in different areas (even under different administrative domains)



# Not enough

- Grid computing provided many advantages: *a scalable architecture that could provide high performance computing for complex tasks*
- It had many drawbacks:
  - Real-time scaling was not possible: more computing power/storage -> more nodes -> change in the architecture *DIFFICILE ADATTARE L'ARCHITETTURA A CRESCENTE DOMANDA DI TASK*
  - The system was not fault tolerant: the failure of a node results in the failure of a task *IL FALLITO DI UN SINGOLO NODO CHE STAVA ESECUENDO UN TASK RISULTA NEL FALLIMENTO DEL TASK*
  - Heterogeneous hardware required code adaptation *ADATTARE IL CODICE A SECONDO DEL NODO CHE LO ESEGUE*
- Starting from the late 90s a new set of technologies matured, paving the way for cloud computing

# Hardware Virtualization

- The heterogeneous natures of computing systems architectures posed a challenge to application (software) portability
- The execution of software on different architecture without changes required to decouple software systems from the underlying physical resources of computers
- This would allow to deal with hardware diversity but also to achieve real time scalability
- For this reason, virtualization techniques were defined: a layer of software over the hardware system that could simulate the whole physical system environment



We will see that  
extensively, don't worry!

# Web Based Technologies

- As computing technologies were evolving rapidly, users and business were becoming more dependent on computer systems
- In addition to enabling grid computing to empower the development of large computing systems, faster networks allowed users from different geographical locations to collaborate in almost real time
- The World Wide Web arose as the killer application to spread information and enable collaboration
- Web 2.0 appeared after 2002 as an evolution of Web 1.0, in which user generated content was central



# Service Oriented Architecture

- As the number of IT systems and their size increased, a new model for software development was required
- Service Oriented Architecture (SOA) is a development method in which applications are developed by leveraging software components (software services) interacting each other
- Each service is an independent entity that communicate with the others via messages
- Systems implemented using SOA remain flexible to changes



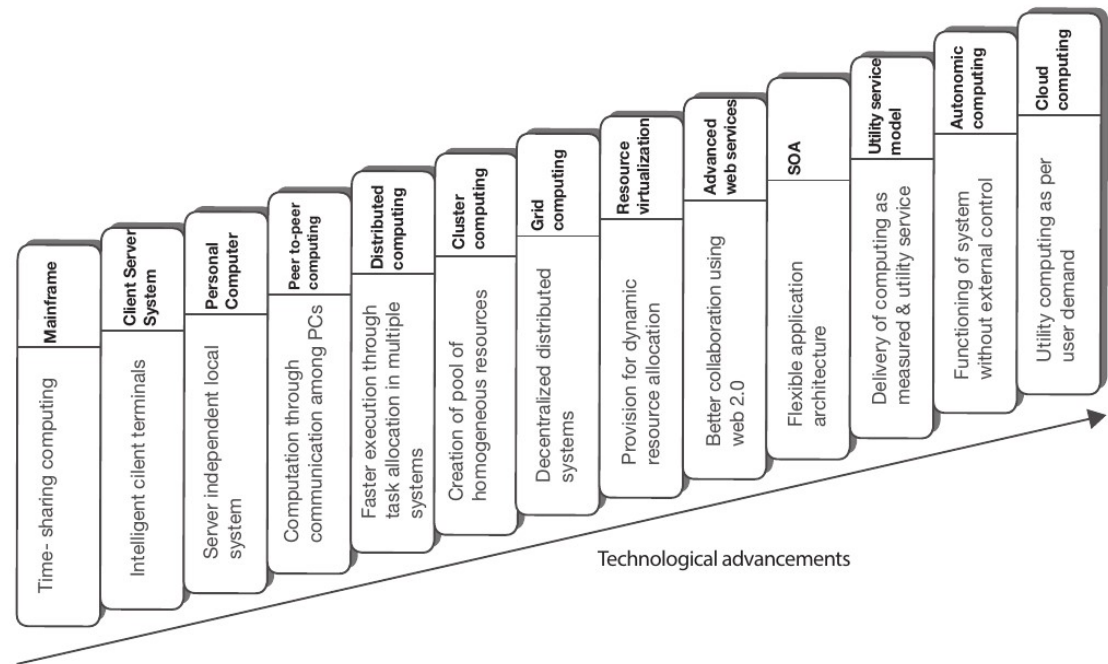
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don't worry!

# Utility Computing Model

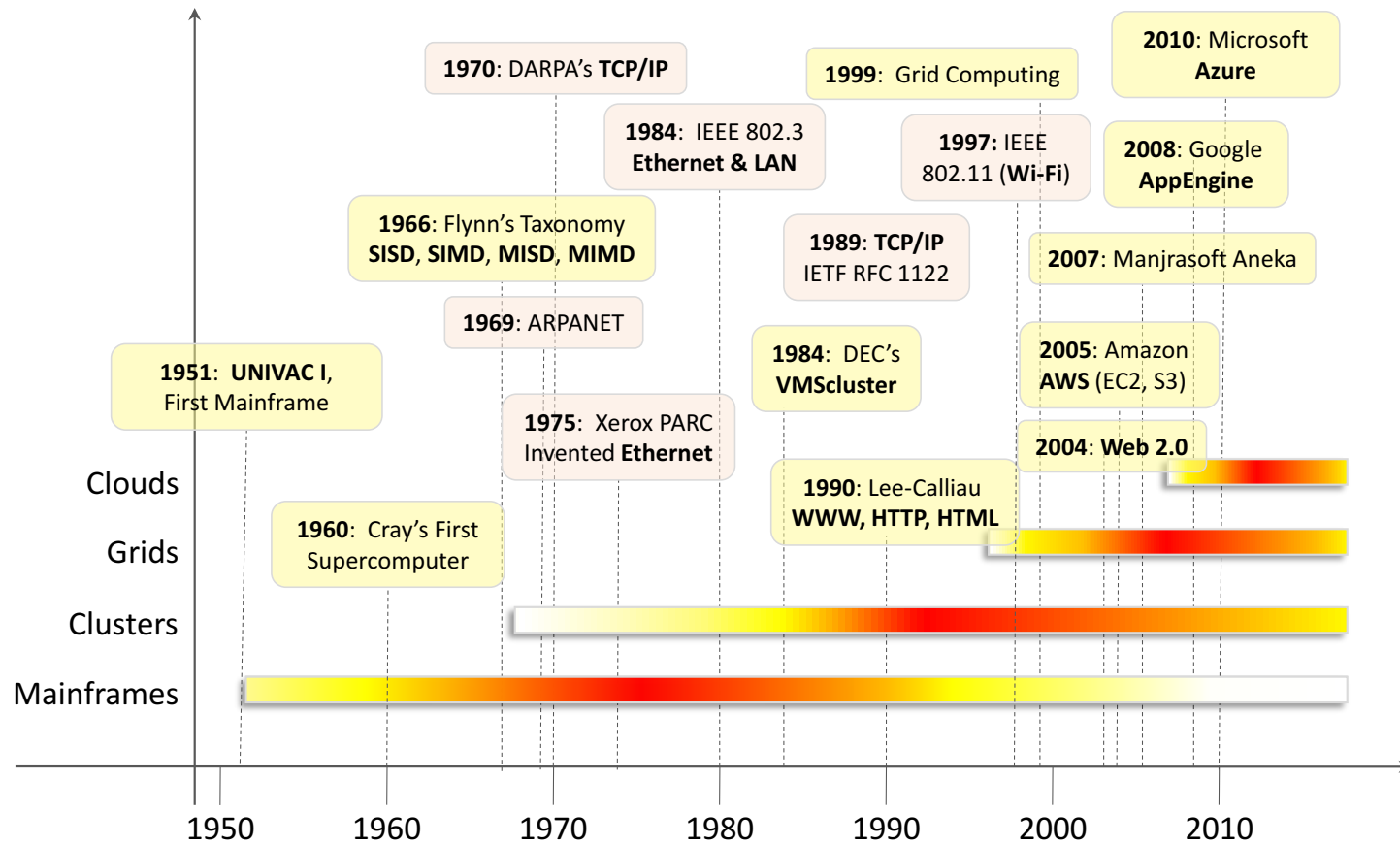
- Computing era reached a point in which we had:
  - Scalable computing infrastructure made of heterogeneous resources
  - Distributed computing environments empowered by high bandwidth networks
  - Collaborative environment across the world via web services
  - Flexible applications via SOA
- **Utility Computing**: delivering of computing resources as utility, following a pay per use model and on demand
- Crucial enabler for this model was hardware virtualization,

# Cloud Computing ... eventually

- Utility computing become cloud computing
- Each one was essential, from networking advancements to novel software development methodologies



# Timeline



# Cloud computing today

- The first commercial initiative based on cloud computing concepts was from salesforce.com in 1999
- The first large scale cloud computing service was commercialized by Amazon in 2006 that launched its Elastic Cloud Computing (EC2) and Simple Storage Service (S3)
- Soon after other big players entered in the market with similar services, e.g. Microsoft in 2009
- The term Cloud computing appeared with its present meaning for the first time in 2006, used by Google CEO Eric Schmidt in a conference

# Cloud computing in numbers

- The total expenditure worldwide reached a figure of \$210 billion at the end of 2020
- Demand for cloud services grows by 18% in 2019
- 90% of companies use some type of cloud service
- 80% of enterprises use Amazon Web Services as their primary cloud platform
- There were 3.6 billion cloud users in 2018
- The positive impact of cloud technology is almost instantaneous. 80% of companies report operation improvements within the first few months of adopting the tech