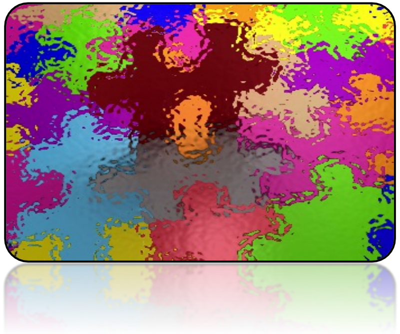
Introduction to Cloud COMPUTING

Giuliano Taffoni- I.N.A.F.

"**Introduction to Cloud Computing**"

2023 @ Università di Trieste

Outline



Intro to Cloud Computing lectures

Computing and Cloud Computing

What to expect from this course

- ✓ What is the Cloud
- ✓ Virtualization and Containers
- ✓ What is the Cloud Computing architecture and service model
- ✓ Data Management in the Cloud
- ✓ Cloud Security and economy

…and examples based on public clouds and scientific use cases.

More in details

Introduction - Computing and computing models; Distributed Computing; Cluster computing and HPC; Grid Computing; Utility computing; Towards Cloud computing.
Cloud Computing Architecture - Properties, Characteristics and Disadvantages; Role of Open Standards; Cloud stacks; Service models; Deployment models; Cloud types and usage.
Virtualization and Containers - Virtual Machines; Cloud and Virtual Machines;
Resource Management - IaaS and Examples;
Data Management - Store and access data; scalability and usability; database and data store; large scale data processing;
Cloud Security - Infrastructure Security; Data Security (storage); Identity and access; Access Control, Trust, Reputation, Risk;
Orchestration – K8s, workflows

What is computing

"Computing is the process of using computer technology to complete a given goal-oriented task. [...] Computing may encompass the design and development of software and hardware systems for a broad range of purposes" (Association of Computing Machinery, 2005)

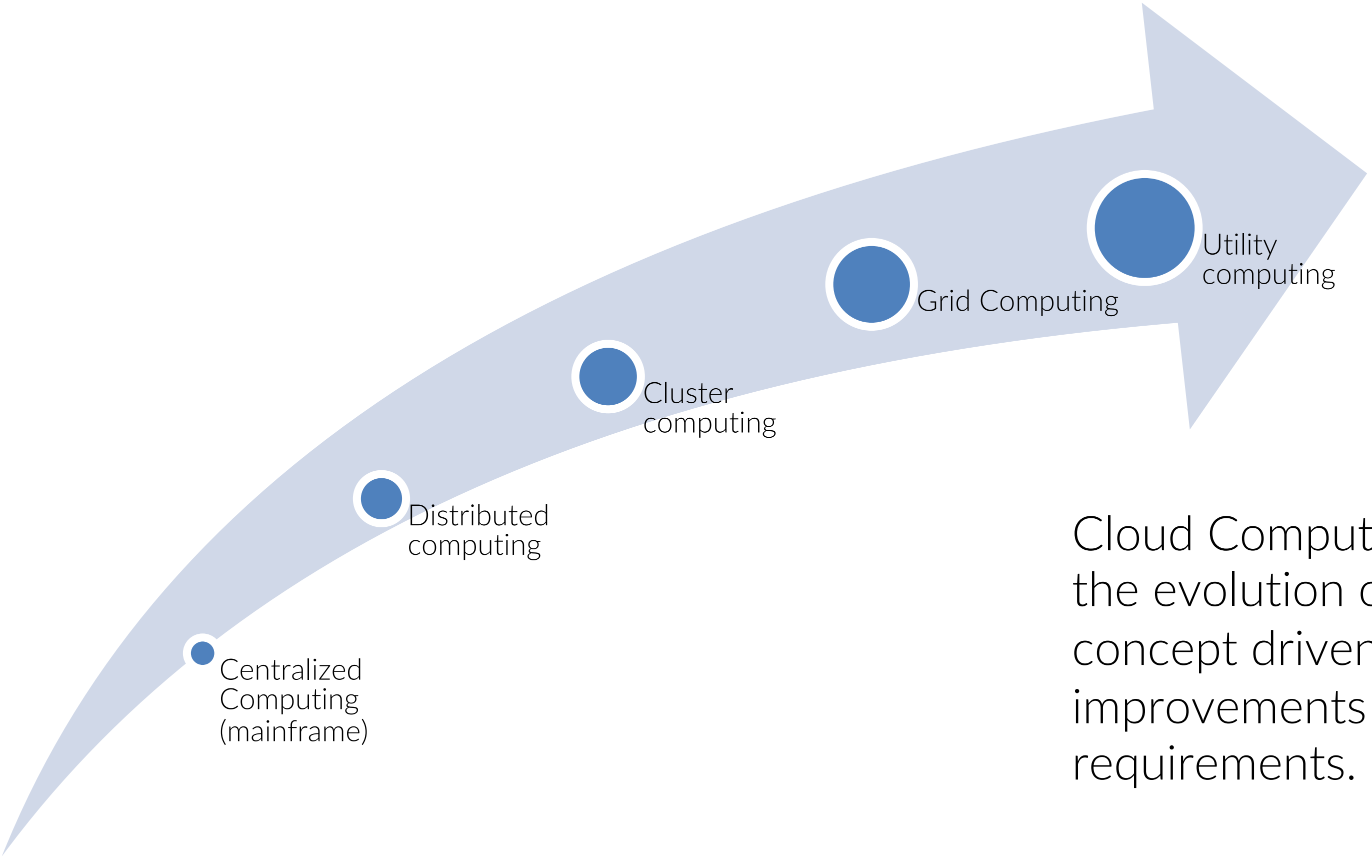
Modern computing

Each scientific instrument is critically dependent on computing for sensor control, data processing, international collaboration, and access.

Computational modelling and data analytics are applicable to all areas of science and engineering

Capture and analyse the torrent of experimental data being produced by a new generation of scientific instruments

From Distributed to Cloud



Cloud Computing is the result of the evolution of the computing concept driven by the technology improvements and by users' requirements.

Distributed Computing

From a single computer to a “network” of collaborating systems.

“*A distributed system is a collection of autonomous computers that are interconnected with each other and cooperate, thereby sharing resources such as printers and databases*” (C. Leopold)

The role of the network as a glue of multiple resources.

Distributed Computing

Some applications are inherently **distributed problems** (they are solved most easily using the means of distributed computing)

Computing intensive problems where **communications is limited** (High Throughput Computing)

Data Intensive problems: computing task deal with a large amount or large size of data.

Distributed computing allows for “**scavenging.**” By integrating the computers into a distributed system, the excess computing power can be made available to other users or applications (e.g. Condor)

Robustness: no single point of failure.
more….

Distributed Computing

Fault tolerance - if a node fails the whole system still work
each node play a partial role (partial inputs and outputs)
check node status

Resource sharing – between users and between sites

Load Sharing and balance - to distribute computing on different nodes to share loading to the whole system

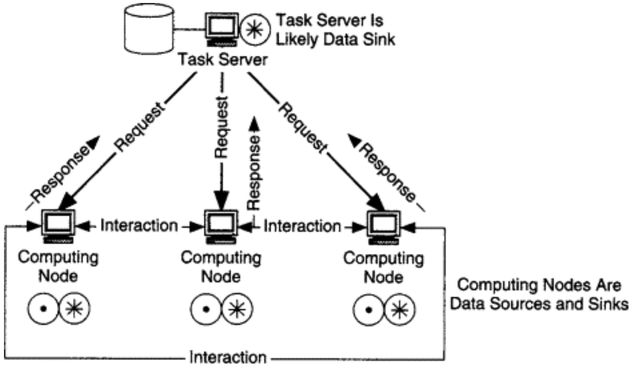
Scalability - Easy to expand

Performance - More resources involved

DD Architecture

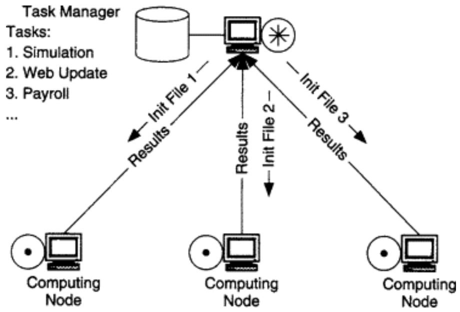
"interconnect processes running on different CPUs with some sort of communication system."

client-server: resource management centralized at a server



3-Tier architecture: move the client intelligence to a middle tier to simplify application development.

Peer-to-Peer: responsibilities are uniformly divided among all machines, known as peers that serves both as client and servers



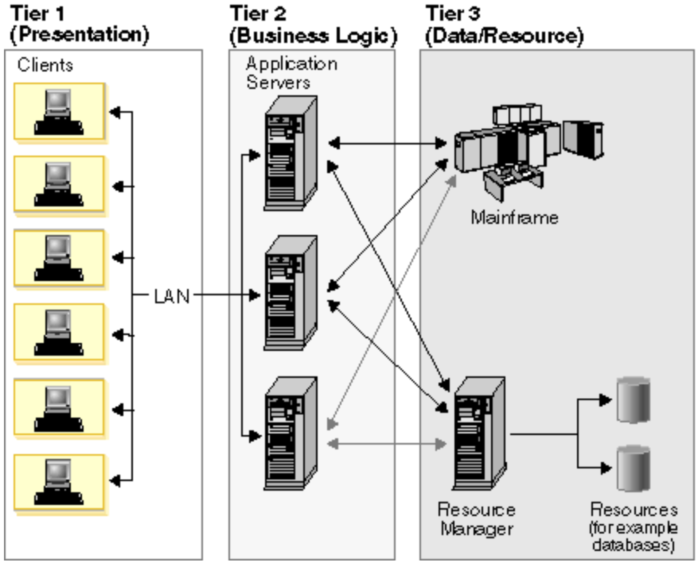
DD Architecture

"interconnect processes running on different CPUs with some sort of communication system."

client-server: resource management centralized at a server

3-Tier architecture: move the client intelligence to a middle tier to simplify application development.

Peer-to-Peer: responsibilities are uniformly divided among all machines, known as peers that serves both as client and servers



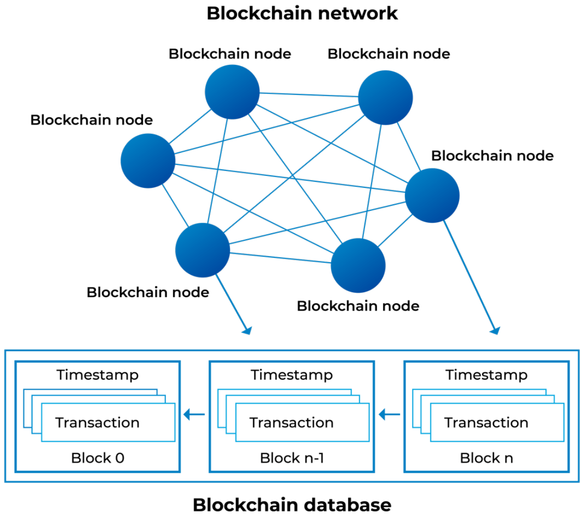
DD Architecture

"interconnect processes running on different CPUs with some sort of communication system."

client-server: resource management centralized at a server

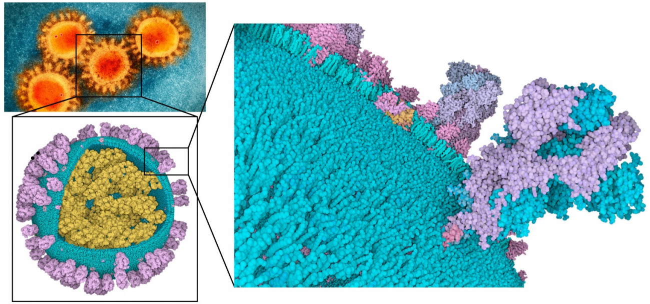
3-Tier architecture: move the client intelligence to a middle tier to simplify application development.

Peer-to-Peer: responsibilities are uniformly divided among all machines, known as peers that serves both as client and servers



Distributed applications

OpenPandemics - Covid19



High Availability Systems
Distributed databases
High Throughput Computing

...even the World Wide Web is a distributed system.

Apache hadoop

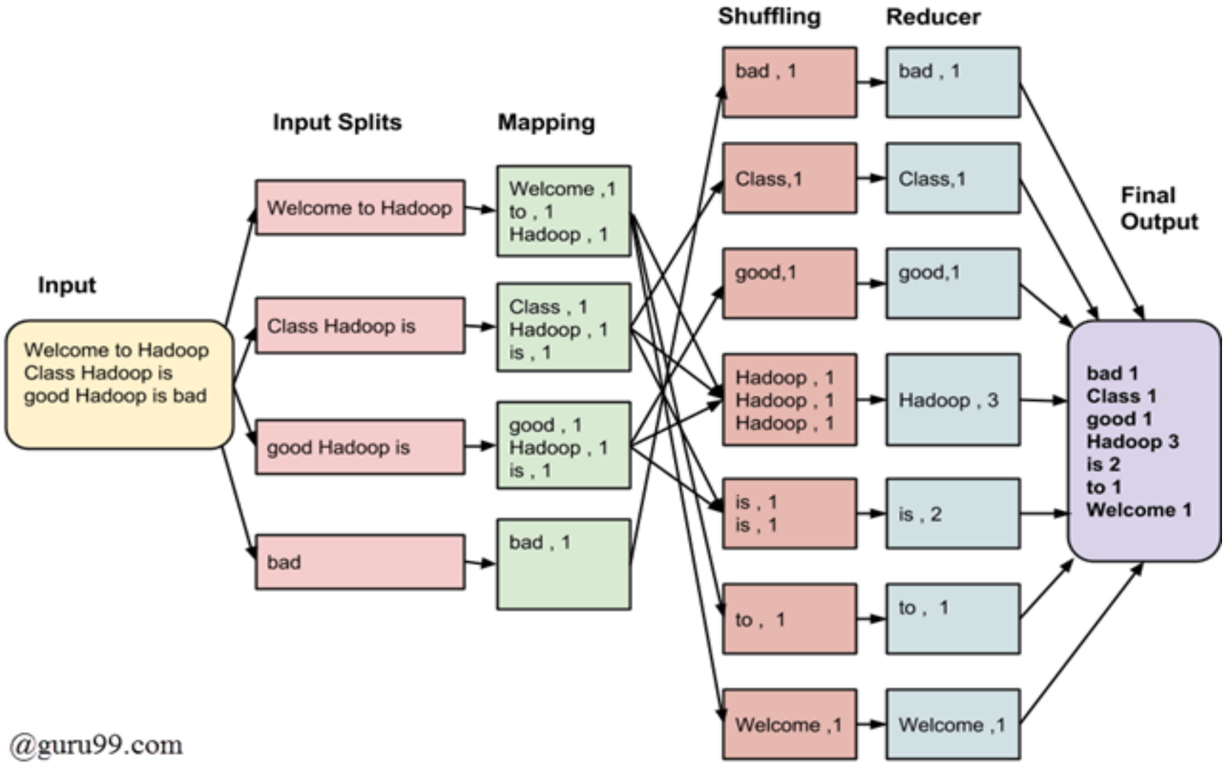
Apache Hadoop system implements a distributed scalable computing model for data analytics

A distributed file system (HDFS) manages large numbers of large files, distributed (with block replication) across the storage of multiple resources

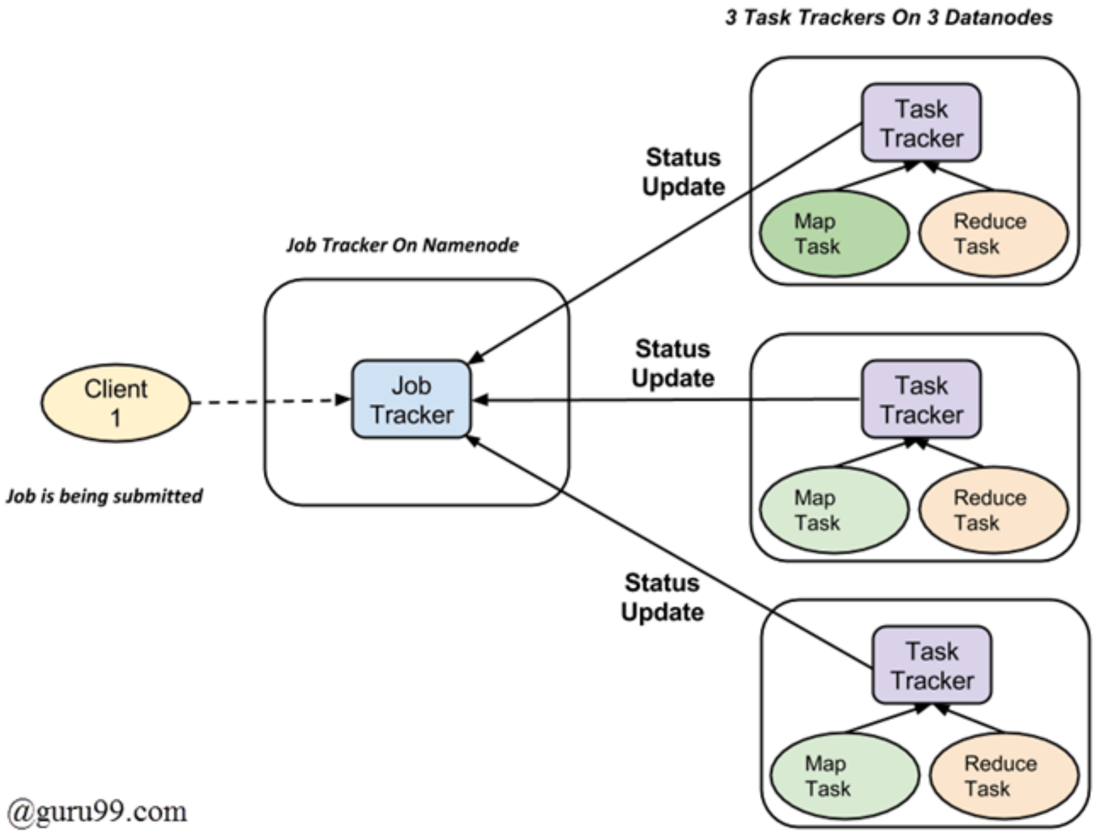
Tools for high-level programming model for the two-phase MapReduce model (e.g. PIG)

Can be coupled with streaming data (Storm and Flume), graph (Giraph), and relational data (Sqoop) support, tools (such as Mahout) for classification, recommendation, and prediction via supervised and unsupervised learning.

MapReduce Example



MapReduce work



multiple tasks onto multiple data nodes

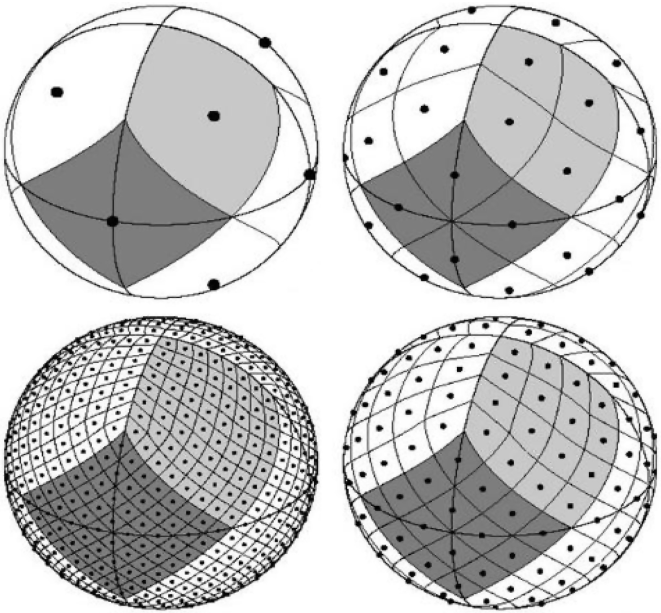
job tracker - coordinate and scheduling

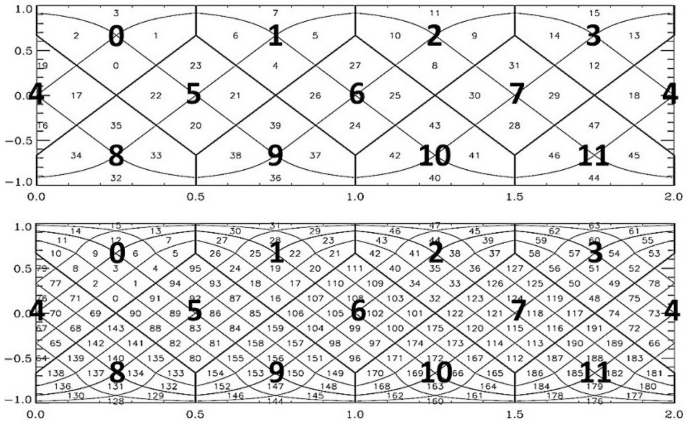
Task tracker sends the progress and 'heartbeat'

job tracker keeps track of the overall progress. In the event of task failure, the job tracker can **reschedule** it on a different task tracker.

Hadoop in Astronomy

Hierarchical Equal Area iso-Latitude Pixelization (HEALPix).





(a)

(b)

Hadoop & Spark, « cross-match » of source catalogues

André Schaaff, François-Xavier Pineau
CDS, Centre de Données astronomiques de Strasbourg
Noémie Wali
UTBM, Université de technologie de Belfort-Montbéliard

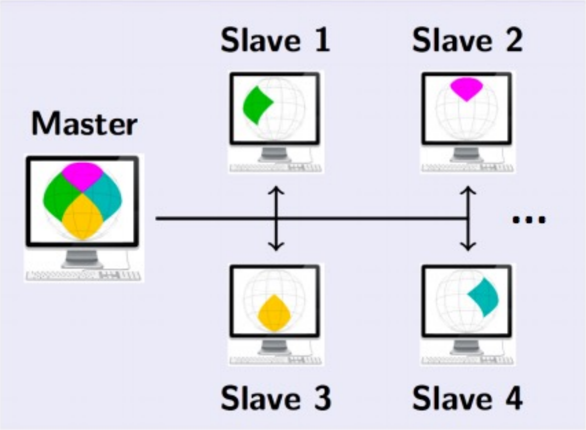
Special thanks to Julien Nauroy, Université de Paris Sud

IVOA Cape Town, GWS session 2

CENTRE DE DONNÉES ASTRONOMIQUES DE STRASBOURG

Data distribution and processing

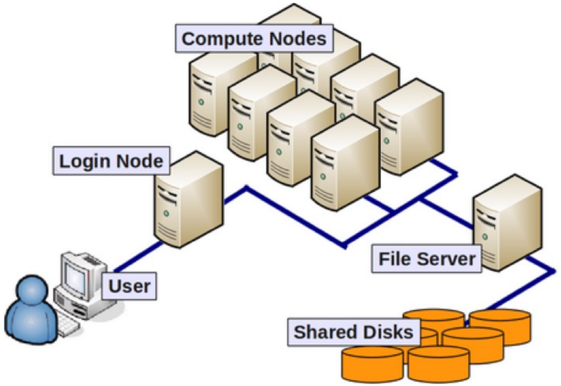
- With Hadoop / Spark, the data is distributed over several nodes
- Distribution ?
- How to optimise it ?



Cluster Computing

A computer cluster is a group of **linked** computers, working together closely so that in many respects they form a single computer. The components of a cluster are commonly, but not always, connected to each other through fast local area networks.

Clusters are usually deployed to improve **performance** and/or **availability** over that provided by a single computer, while typically being much more cost-effective than single computers of comparable speed or availability.



Cluster Classification

High availability clusters (HA) (Linux)

- Mission critical applications
- High-availability clusters (also known as Failover Clusters) are implemented for the purpose of improving the availability of services which the cluster provides.
- provide redundancy
- eliminate single points of failure.

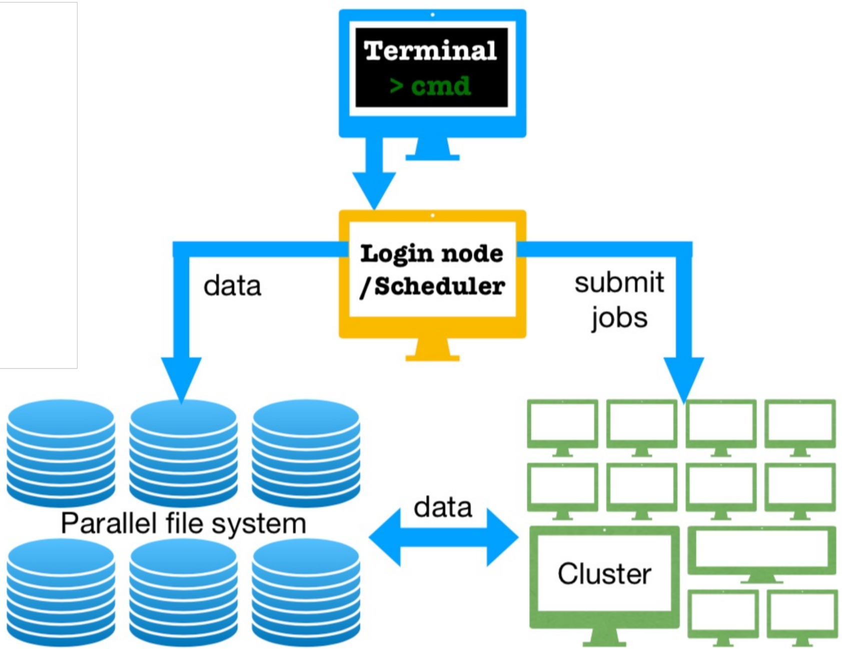
Network Load balancing clusters

- operate by distributing a workload evenly over multiple back end nodes.
- Typically the cluster will be configured with multiple redundant load-balancing front ends.
- all available servers process requests.
- Web servers, mail servers,..

HPC Clusters

- Low Latency Network
- Message passing libraries
- Parallel Filesystem
- HPC system software

Using a Cluster



Batch systems - shell script - application environment - Not suitable for interactive jobs - queue with a limited computing time - filesystem structure: home, scratch, data

Cluster computing is…

Cost-effective

Much cheaper than a super-computer with the same amount of computing power!

Resilient

When the supercomputer crashes, everything crashes, when a single/few nodes in HPC fail, cluster continues to function.

Multi user

Multi-user shared environment: not everyone needs all the computing power all the time.

higher utilization

can accommodate variety of workloads (#CPUs, memory etc), at the same time.

Scalable

Can be expanded, partitioned or shrunk, as needed.

HPC Clusters on top500

HPC clusters are heterogeneous environments where the computing power is given by CPU and Accelerators…but not all of them ;-)

https://www.top500.org

Rank	System	Cores	Rmax (PFlop/s)	Rpeak (PFlop/s)	Power (kW)
1	**Frontier** - HPE Cray EX235a, AMD Optimized 3rd Generation EPYC 64C 2GHz, AMD Instinct MI250X, Slingshot-11, HPE DOE/SC/Oak Ridge National Laboratory United States	8,699,904	1,194.00	1,679.82	22,703
2	**Supercomputer Fugaku** - Supercomputer Fugaku, A64FX 48C 2.2GHz, Tofu interconnect D, Fujitsu RIKEN Center for Computational Science Japan	7,630,848	442.01	537.21	29,899
3	**LUMI** - HPE Cray EX235a, AMD Optimized 3rd Generation EPYC 64C 2GHz, AMD Instinct MI250X, Slingshot-11, HPE EuroHPC/CSC Finland	2,220,288	309.10	428.70	6,016
4	**Leonardo** - BullSequana XH2000, Xeon Platinum 8358 32C 2.6GHz, NVIDIA A100 SXM4 64 GB, Quad-rail NVIDIA HDR100 Infiniband, Atos EuroHPC/CINECA Italy	1,824,768	238.70	304.47	7,404

HPC vs HTC

High Performance (Capability)

High Throughput (Capacity)

Fine-grained Applications
- **Many-node**
- **Few concurrent runs**
- **High interconnect use**

Course-grained Applications
- **Single-node**
- **Many concurrent runs**
- **No interconnect use**

HTC applications

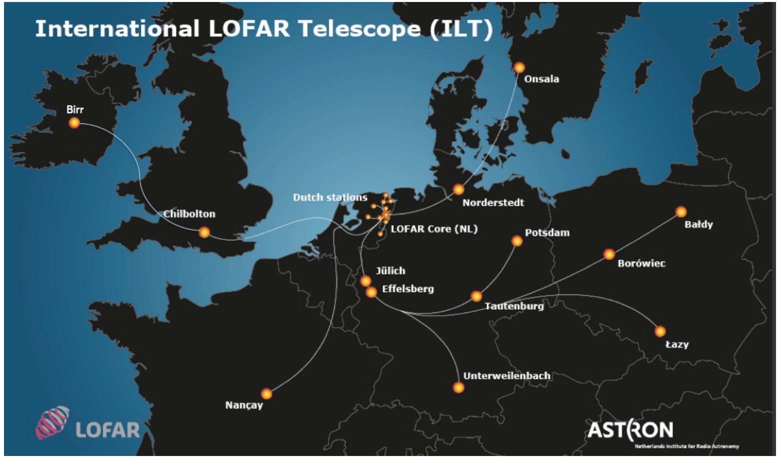
- divide the problem up into smaller **independent** parts;
- get system to process as many of these small parts as possible in parallel (i.e. at the same time);
- combine the partial results produced by the system to give the overall result.

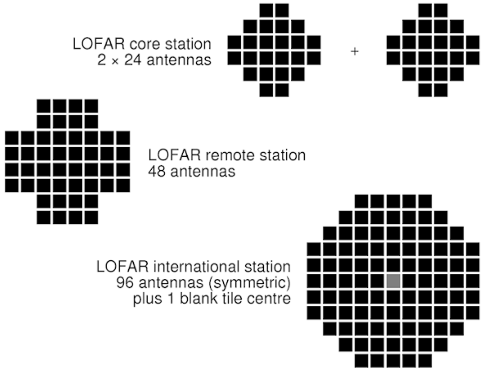
Can I partion my data?

Are the small parts independent?

Do you estimate the overhead of partition the data?

HTC example



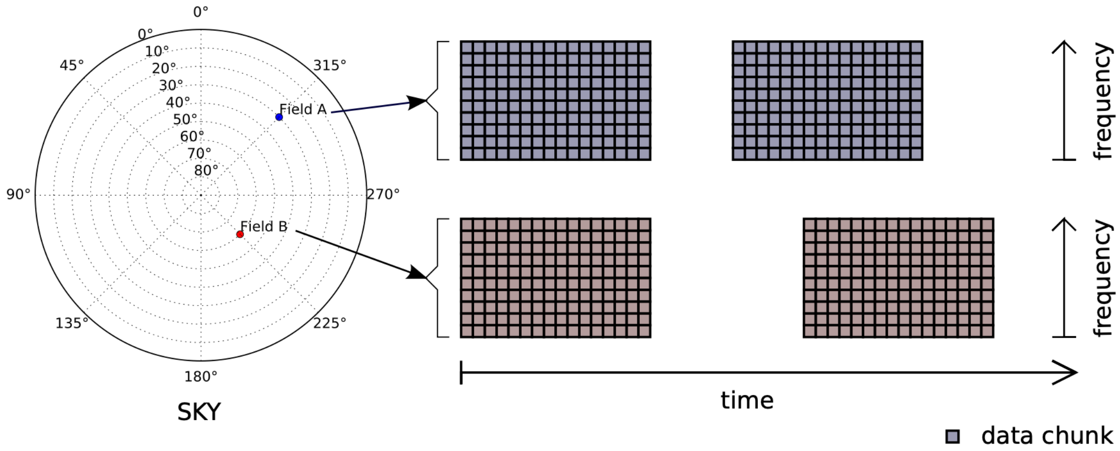


- Needs to process large datasets (several TBs)
- Datasets can be divided in pieces that can be processed independently.

LOFAR Pipeline parallelism

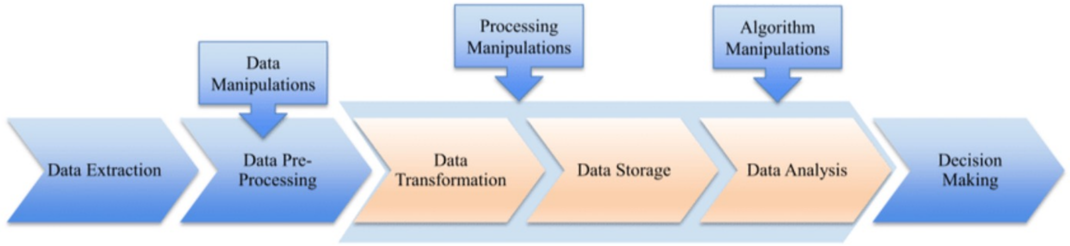
Each 8 hours observation is 115 MHz to 175 MHz in 371 separate sub-bands. Each sub-band was originally composed of 64 spectral channels, and the initial scan-time was set to 1 second. We need to process 320 observations.

SKY+TIME+FREQUENCY data parallelism

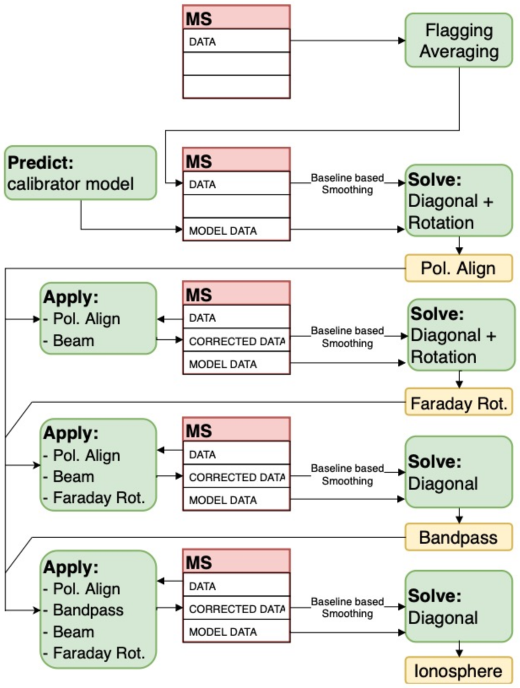


Data reduction PIPELINE

A pipeline is a set of processes and tools used to collect raw data from multiple sources, analyse it and present the results in an understandable format.



LOFAR Pipeline HTC



Compute Time on single node each observation:

Run on calibrator ~ 2/3 h

Run on target image ~12/24 h

FINAL OUTPUT

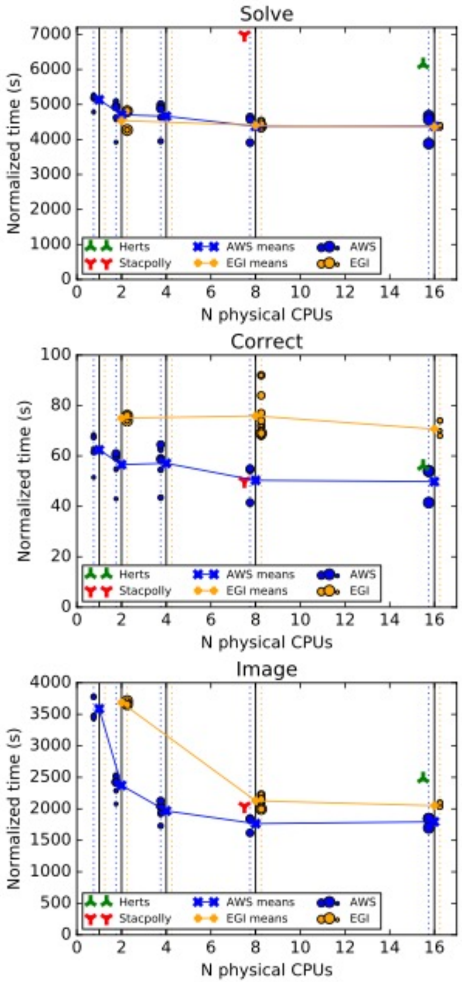
~100GB of data in MS format

CAN BE SPLITTED IN FREQ (~100)

How much time can we save?

What is the bottle neck?

LOFAR Test on single node



High Perfomance Data Analysis

The ability of increasingly powerful HTC systems to run **data-intensive problems** at larger scale, at higher resolution, and with more elements (e.g., inclusion of the carbon cycle in climate ensemble models)

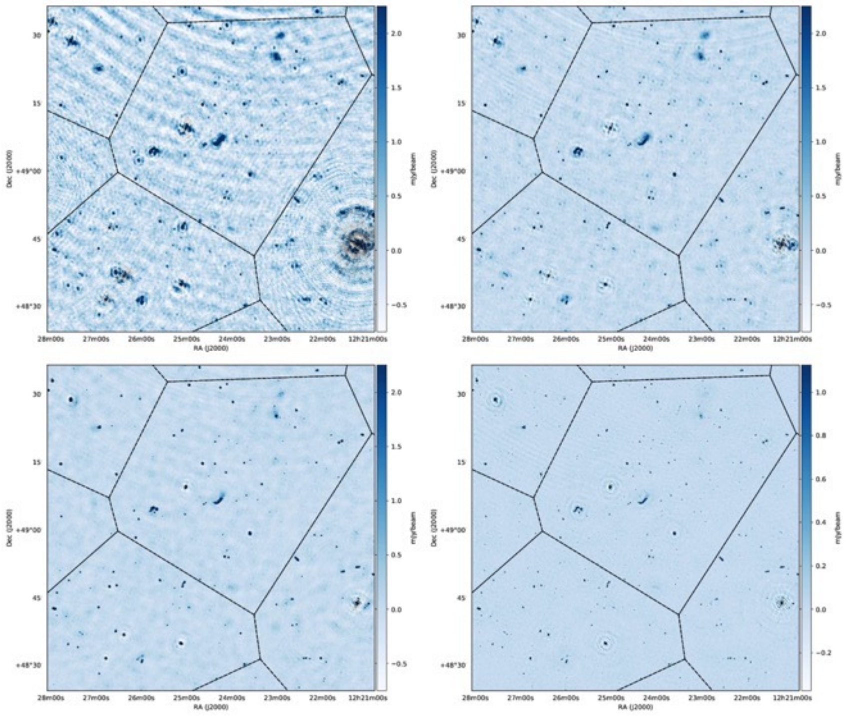
The proliferation of **larger, more complex scientific instruments and sensor** networks, from "smart" power grids to the Large Hadron Collider and Square Kilometer Array.

The growth of stochastic **modeling, parametric modeling and other iterative** problem-solving methods, whose cumulative results produce large data volumes.

The availability of **newer advanced analytics methods and tools**: MapReduce/Hadoop, graph analytics (NVIDIA IndeX), semantic analysis, knowledge discovery algorithms (IBM Watson), COMPS and pyCOMS, and more

The escalating need to perform advanced analytics **in near-real time** a need that is causing a new wave of commercial firms to adopt HPC for the first time

Sizing the problem



Compute Time on single node:

- Run ~8/12 g no snapshots no

FINAL OUTPUT

- 10TBs of data

Sizing the problem

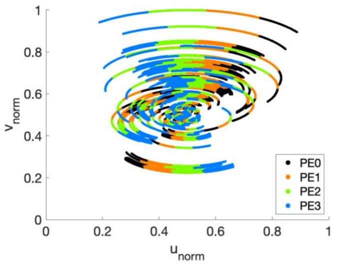
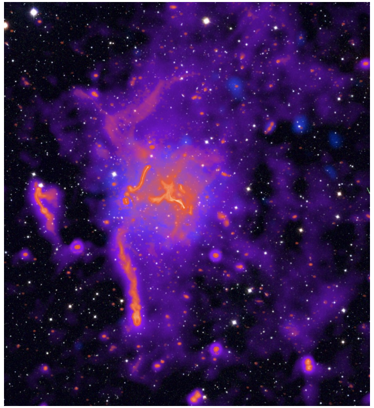


Figure 3 2D distribution of the observational data among four processing units (indicated as PE#). Subsequent time slices are assigned to each processor. Each processor owns data distributed on the whole (u, v) plane.



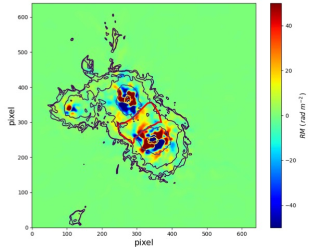


Fig. 11. Faraday depth map obtained using the cluster simulation (Wittor et al. 2019a) - see text fr details. The contours are from the density field in Fig. 10, and the selected bridge region is highlighted in red. Every pixel is ~ 16 kpc long.

DAYs

WEEKs

200TB

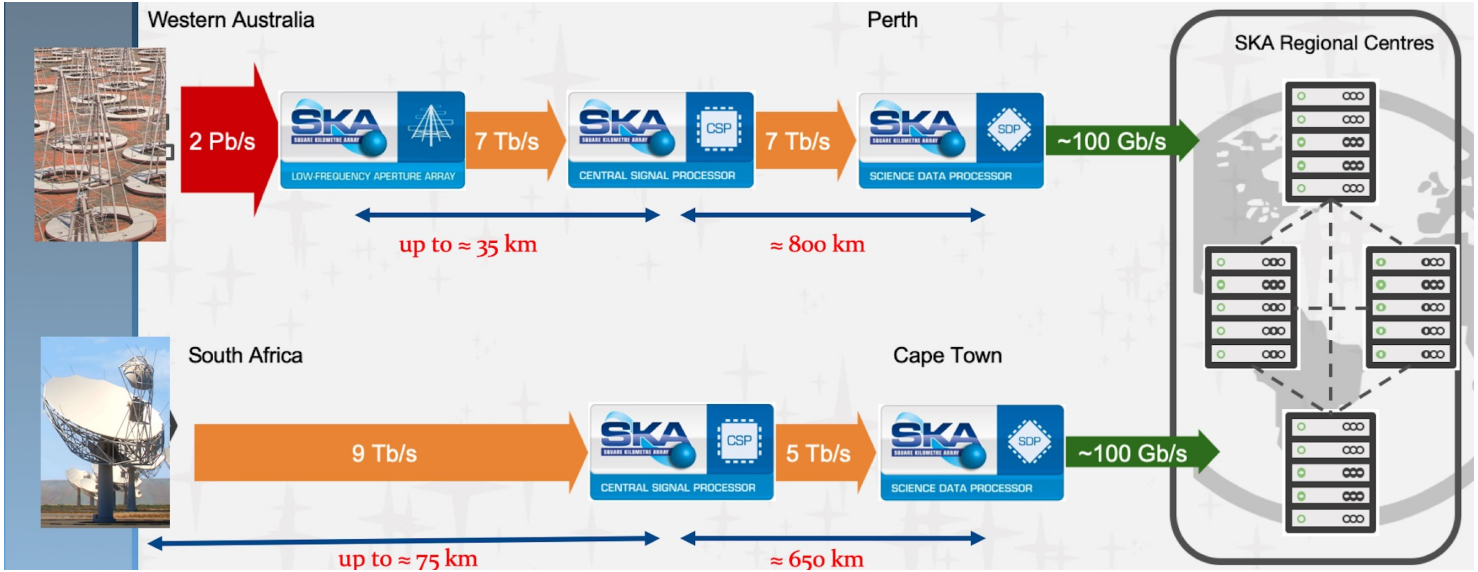
~2TB

~20TB

Download

Compute

Future challenges



700 PB/year

HPC processing

- **The computing challenge**. In order to to improve the codes' performance, multi (multi–core CPUs) and many cores (GPUs) architectures have to be exploited.

- **The memory challenge -** Huge datasets cannot be loaded in the memory of a single CPU and cannot be handled by a single processor but by distributed memory systems. Distributed computing, based on the adoption of the MPI standard, represents a feasible and effective solution.

- **The data challenge -** This addresses the management, archiving and access of the raw data, the science data products, and the final outcomes of data processing and analysis.

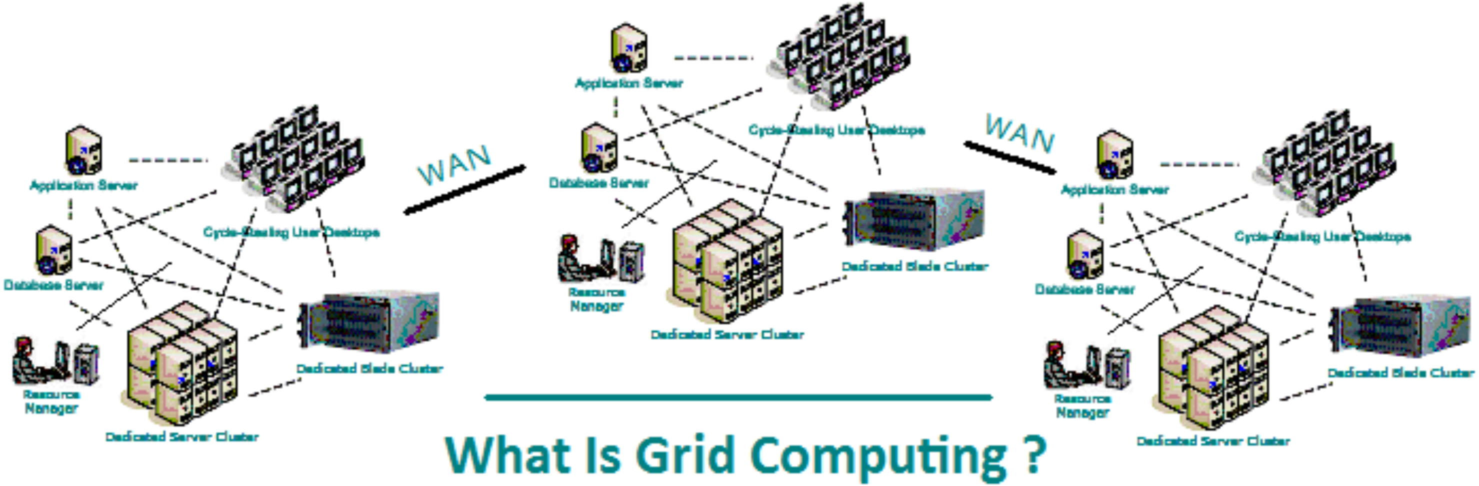
GRID Computing

“a single seamless computational environment in which cycles, communication, and data are shared, and in which the workstation across the continent is no less than one down the hall"

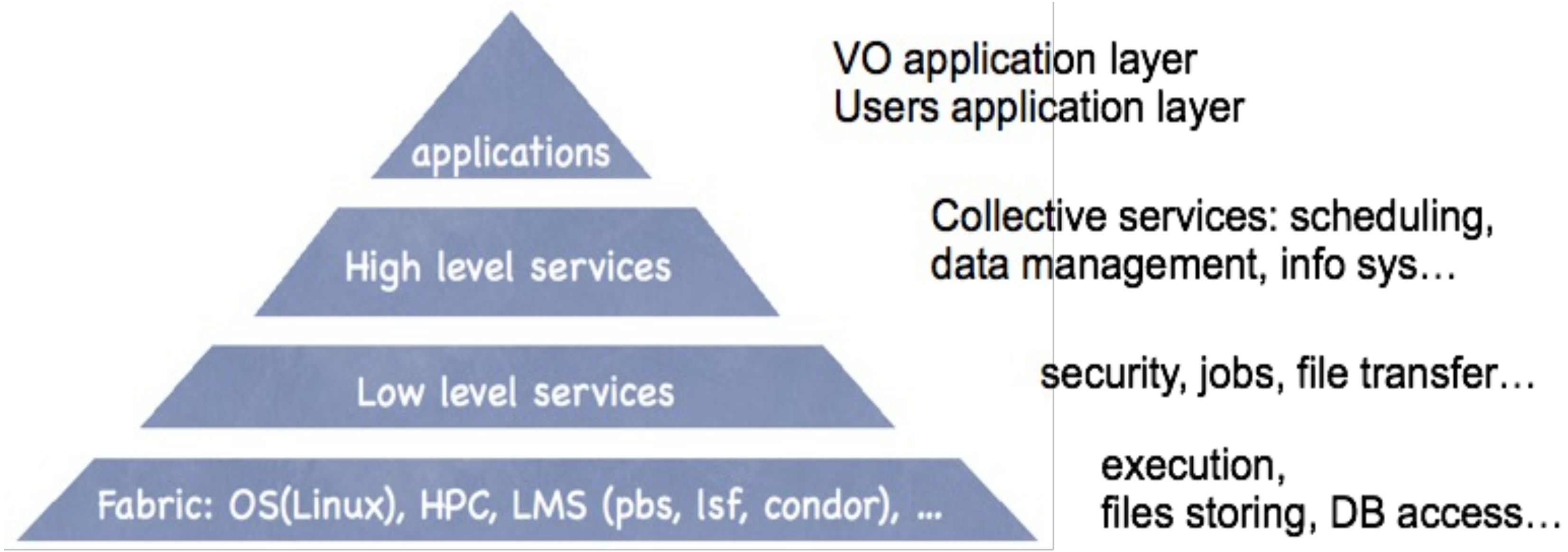
“wide-area environment that transparently consists of workstations, personal computers, graphic rendering engines, supercomputers and non-traditional devices: e.g., TVs, toasters, etc."

“[framework for] flexible, secure, coordinated resource sharing among dynamic collections of individuals, institutions, and resources"

“collection of geographically separated resources (CLUSTERS) connected by a network [...distinguished by...] a software layer, often called middleware, which transforms a collection of independent resources into a single, coherent, virtual machine”


Application Server
Database Server
Resource Manager
Dedicated Server Cluster
Dedicated Blade Cluster
WAN
Application Server
Database Server
Resource Manager
Dedicated Server Cluster
Dedicated Blade Cluster
WAN
Application Server
Database Server
Resource Manager
Dedicated Server Cluster
Dedicated Blade Cluster
What Is Grid Computing ?

It’s the software layer that glue all the resources
Everything that lies between the OS and the application



Virtual Organization

The size and/or complexity of the problem requires that people in several organizations collaborate and share computing resources, data, instruments

VIRTUAL ORGANIZATIONS

GRID MIDDLEWARE

Globus alliance (Globus Toolkit)
gLite (EGEE middleware)
Unicore (DE)
GridBus
GRIA

LHC data has been distributed on a tiered architecture based on LHC Computational Grid (gLite) and processed using the LHC Grid.

GRID Limitations

Very Rigid environment: all the resources must be installed, maintained and monitored homogeneously.

Useful for applications that requires an HTC environment, but a high level of complexity is introduced to use it efficiently

Licensing problems across different domains

Implementation limits due to the middleware used.

Political challenges associated to resource sharing

Utility Computing

It is a theoretical concept, and CC implements this concept in practice

"It is a service provisioning model in which a service provider makes computing resources and infrastructure available to customers and charges them for specific usage rather than a flat rate" (on-demand)

Low or no initial cost to get a resource (the resource is essentially rented)

Pay-per-use model
maximize the efficient use of resources minimizing costs

Utility Computing: concepts

1. Pay-per-use Pricing Business Model
2. Optimize resource utilization
3. Outsourcing
4. “infinite resource availability”
5. Access to applications or libraries
6. Automation

Utility Computing: concepts

The principle of utility computing is very simple: One company pays another company for servicing. The services include software rental, data storage space, use of applications or access to computer processing power. It all depends on what the client wants and what the company can offer.

Different model may be implemented even if the pay per use is the most common one (e.g. flat rate, metered, etc)

The pricing model is what characterize the Utility Computing

Utility Computing

Data backup

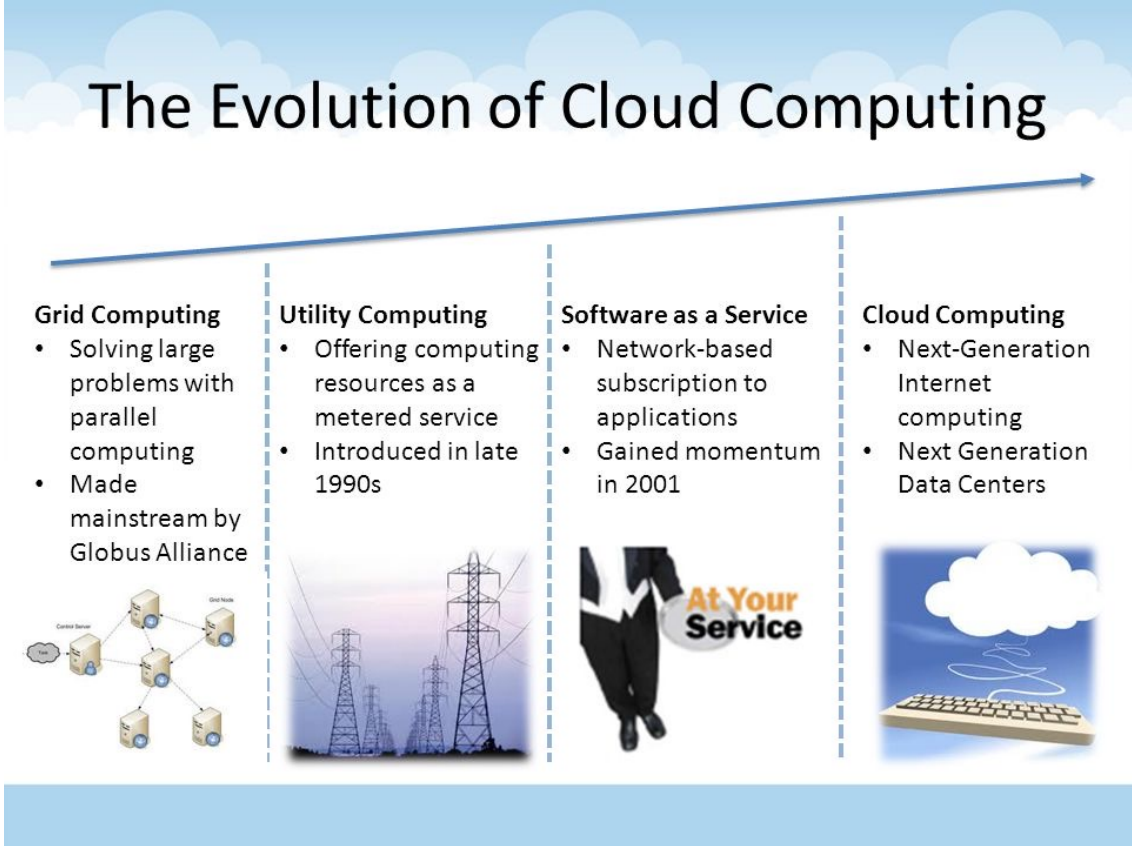
Data Security

Partners competences

Defining Service Level Agreement

Getting value from charge back

Towards Cloud



that’s all, have fun