Large Scalable Systems and Architectures

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Supercomputing and Distributed Systems Camping School

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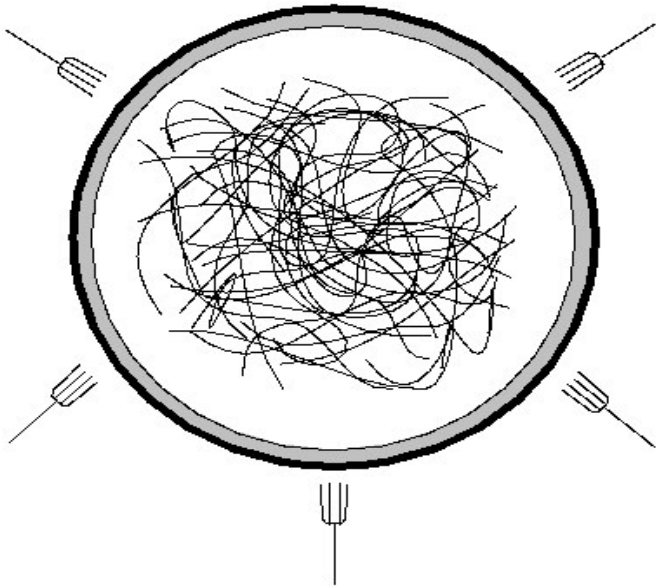
About Parallelism

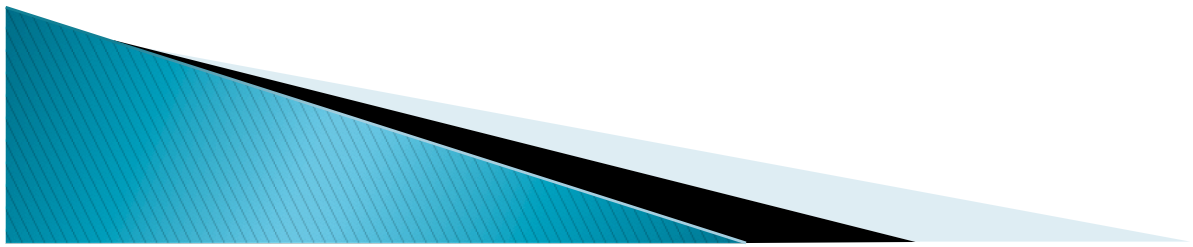


- **Concurrency** is a property of systems in which several computations are executing simultaneously, and potentially interacting with each other.

- **Implicit parallelism** is a characteristic of a programming language that allows a compiler or interpreter to automatically exploit the parallelism inherent to the computations expressed by some of the language's constructs.
- **Explicit parallelism** is the representation of concurrent computations by means of primitives in the form of special-purpose directives or function calls.

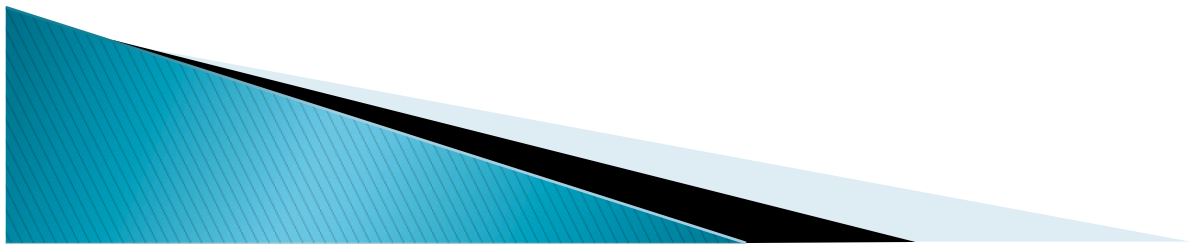
Plan

- General Concepts
- Parallel Computing
  - Basics
- Distributed Computing
- Large Scale Systems
  - Cluster
  - Grid Computing
  - Volunteer Computing
  - Cloud
- Final Comments



Scalable Systems

- Any scalable system is a distributed system.
- Parallel computing uses Scalable Systems
  - Many instructions are carried out simultaneously–concurrently.
  - High Performance Computing (HPC) implies Parallel Computing
- Scalable Systems may be describe in terms of Scalable Architectures.

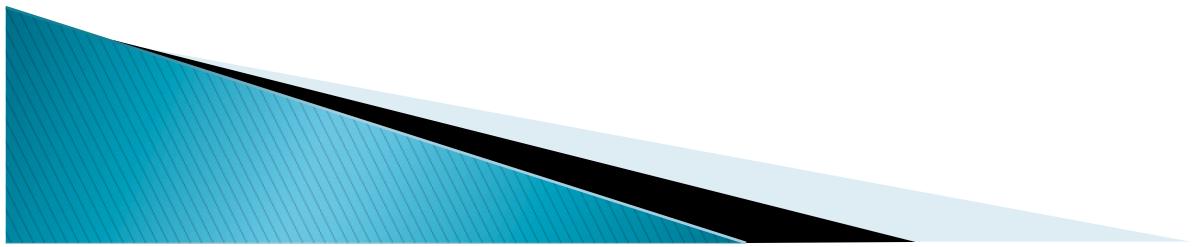


Scalable Architectures

- Scalable Architectures (hardware point of view) have the characteristics of Scalable Systems.
  - Concurrency, Distribution
- Scalable Architectures support Parallel Computing.
- Of course, Parallel Computing implies parallelism.
- Obviously, Parallel Computing demads Parallel Machines.

Parallel Computing

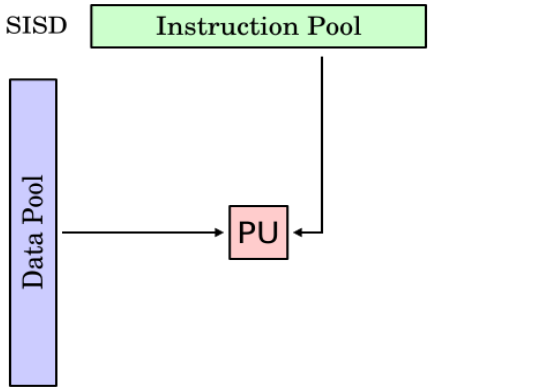
- Parallel Computing exploit Concurrency
  - In “system” terms, concurrency exists when a problem can be decomposed in sub problems that can safely executed at same time (in other words, concurrently)

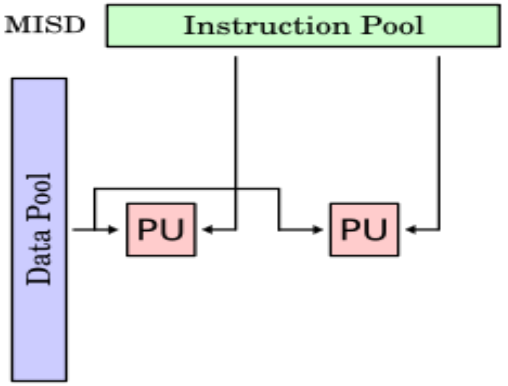


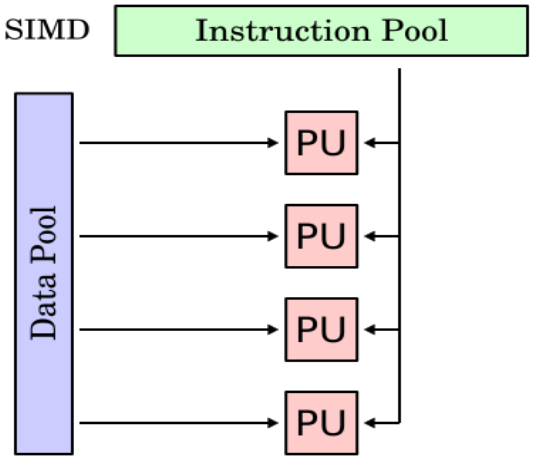
Flynn's Taxonomy

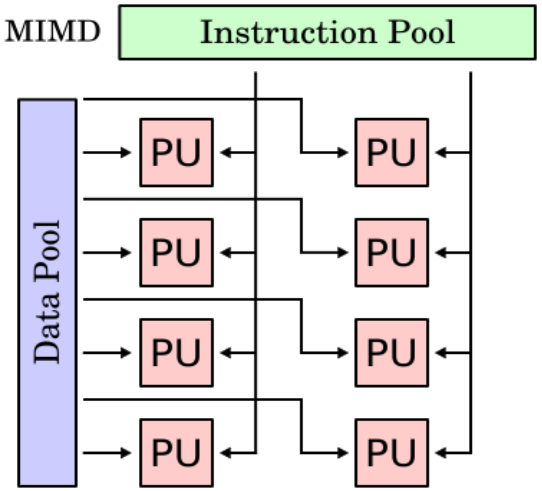
	SINGLE INSTRUCTION	MULTIPLE INSTRUCTIONS
SINGLE DATA	SISD	MISD
MULTIPLE DATA	SIMD	MIMD

Comparing Flynn's Taxonomy*







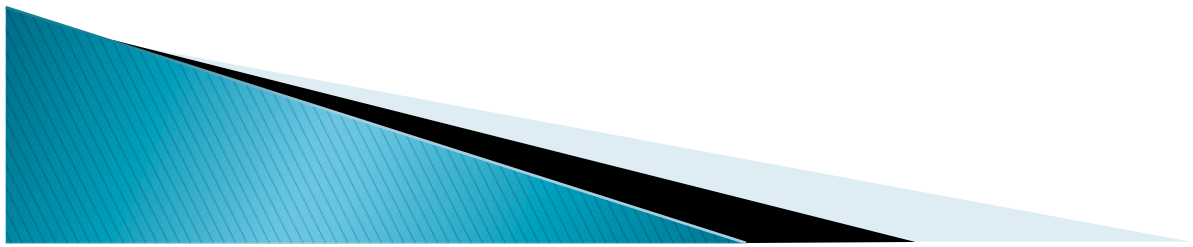


* Proposed by M. Flynn in 1966

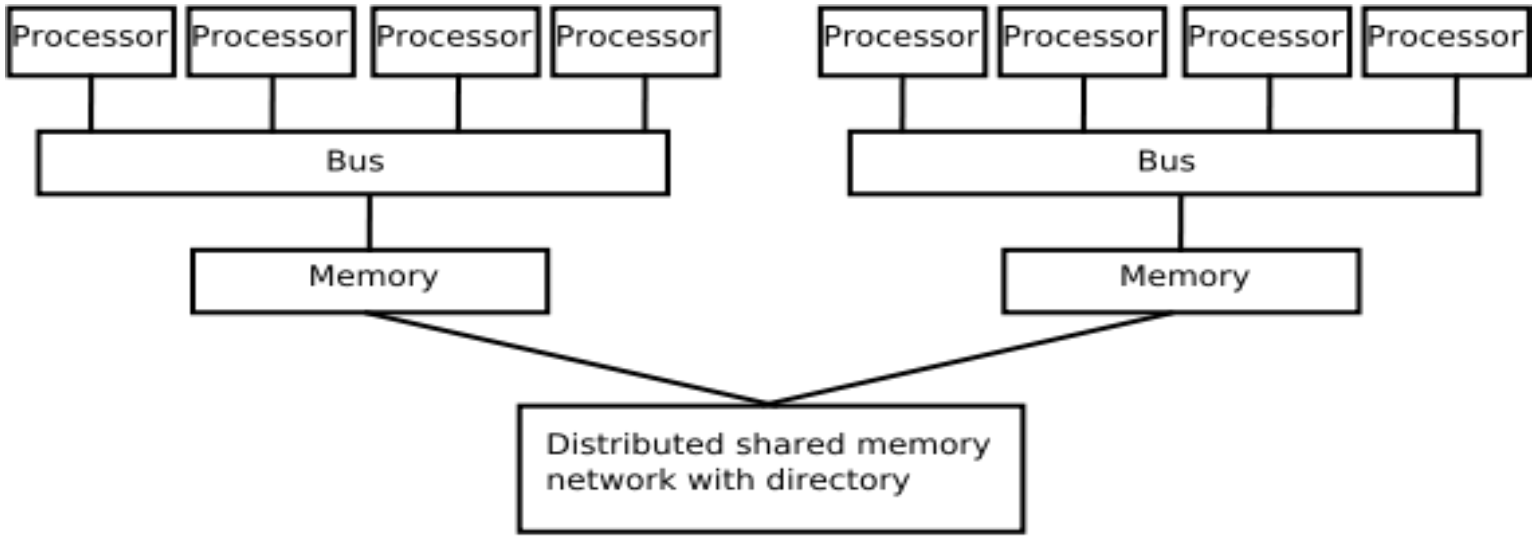
Further Taxonomy

(Derivate from MIMD for distributed memory programming)

- SPMD (Single Program, Multiple Data streams or Single Process, Multiple Data)
  - Multiple autonomous processors simultaneously executing the same program on different data.
  - It is the most common taxonomy.
- MPMD (Multiple Program Multiple Data)
  - Multiple autonomous processors simultaneously operating at least 2 independent programs.



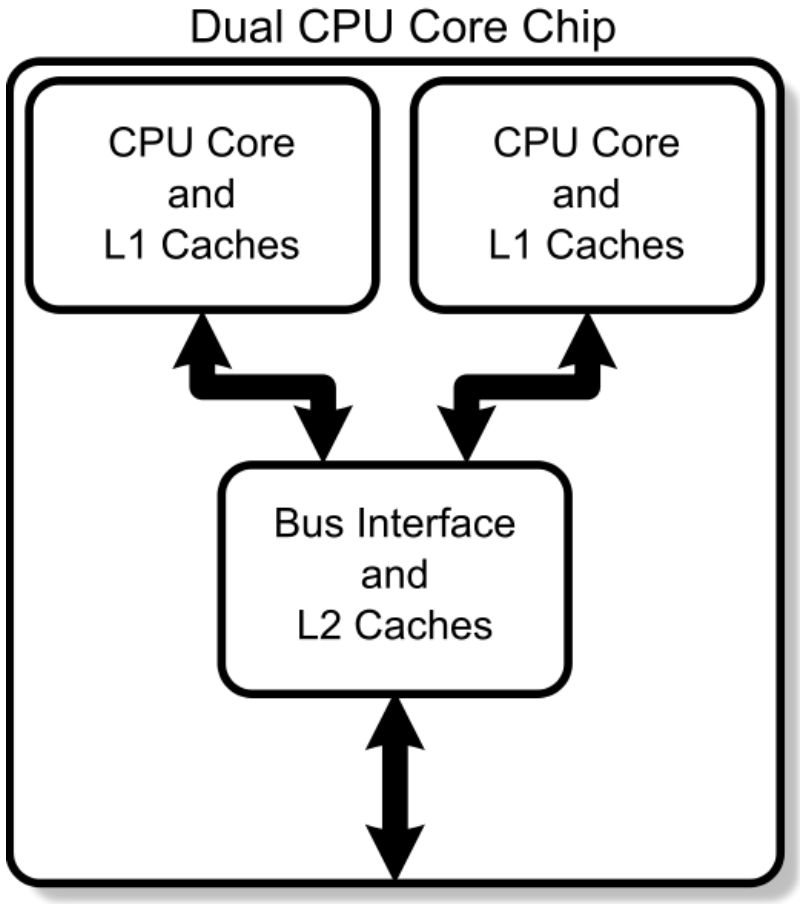
The Distributed Shared Memory Access



- Main Memory in Parallel Machines is a hybrid between shared memory and distributed memory.
- Distributed memory systems have Non-Uniform Memory Access (NUMA) architecture

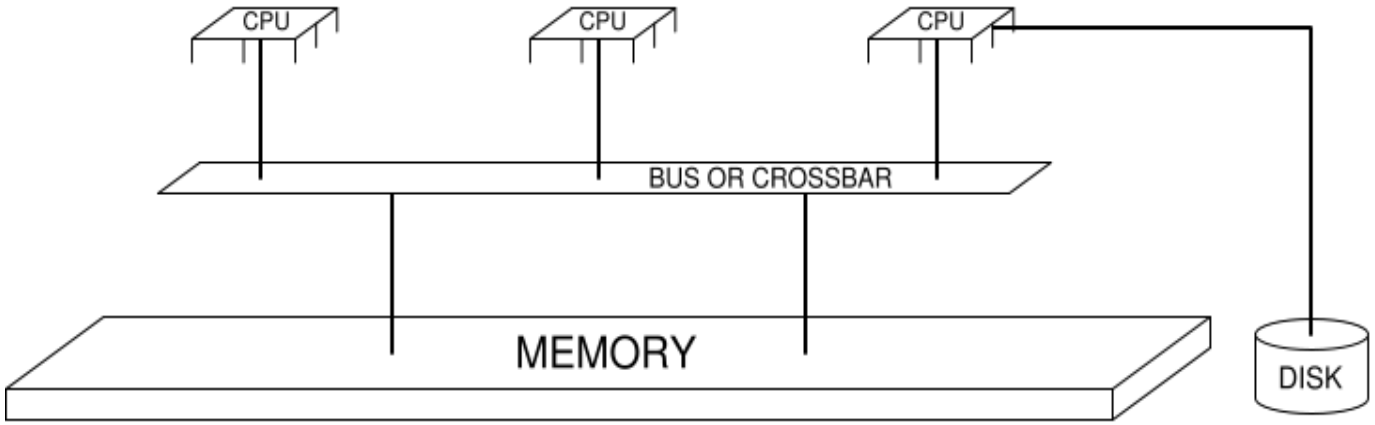
Multicores

- Multicore Computer:
  - Multicore Processor includes multiple execution units (cores)
  - Intel's Dual Core, Intel's QuadriCore
  - Play Station 3



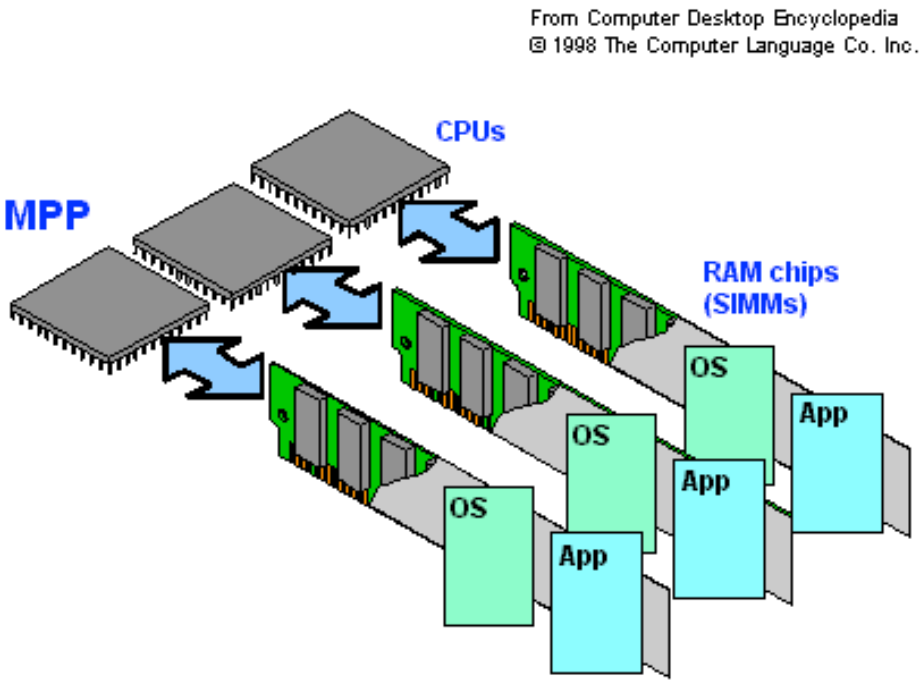
Symetric Multiprocessing

- Symmetric multiprocessors:
  - A symmetric multiprocessor (SMP) is a computer system connected to a main shared memory.
  - Intel's Xeon.
  - Sun Microsystems UltraSPARC.



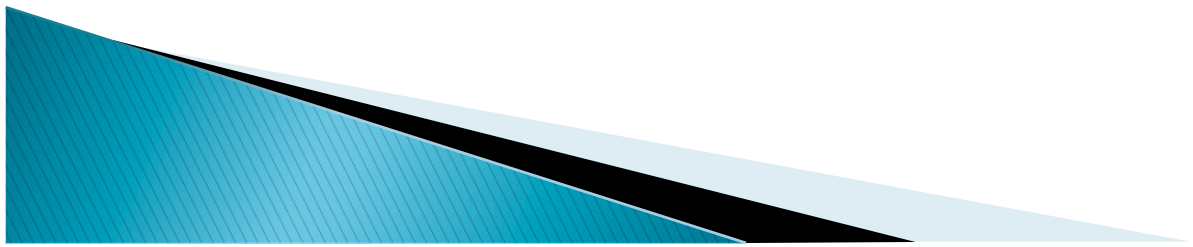
Massive Parallel Processing (MPP)

- Computer system with many independent arithmetic units or entire microprocessors, that run in parallel
- MPPA is a MIMD (Multiple Instruction streams, Multiple Data) architecture, with distributed memory accessed locally, not shared globally



Others Parallel Computers

- Reconfigurable Computing with Field-Programmable Gate Arrays (FPGA).
- General-Purpose Computing on Graphics Processing Units (GPGPU).
  - Programmin with CUDA and OpenCL (i.e.)
- Application-Specific Integrated Circuits (ASIC).
- Vector Processors. (SIMD)



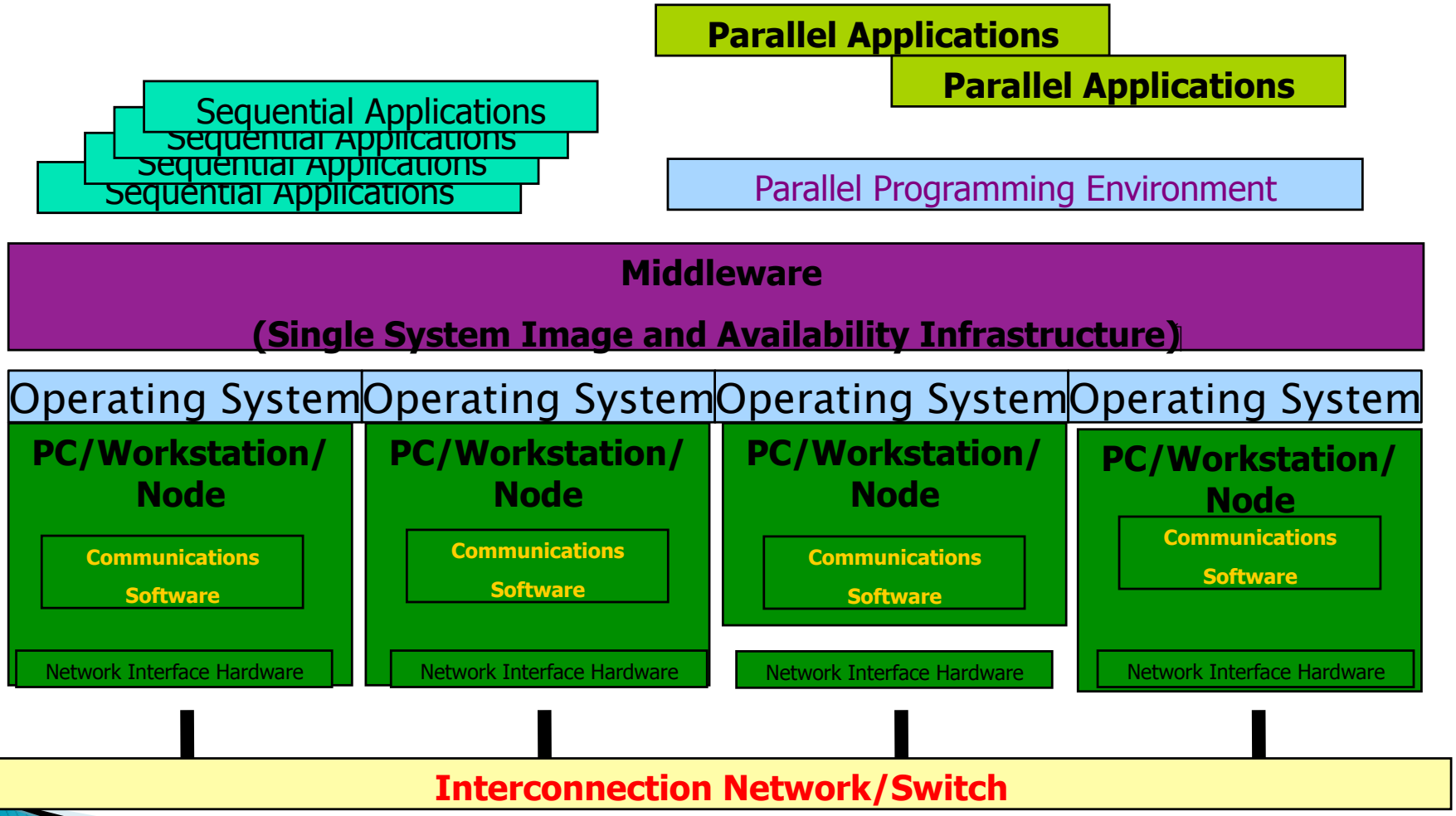
Distributed Computers

- **Distributed computing:**
  - Distributed Computing is a Distributed Memory Multiprocessor System connected by a network.
  - Distributed computers are highly scalable!
  - Cases of Distributed Computing:
    - Cluster computing (Parallel Distributed Computing)
    - Grid Computing

Large Scale Architectures

- Large Scale Architecture (LSA) allows to trait large scale problems.
  - LSAs need Large Scale Sotware
  - LSAs are distributed systems.
    - Cluster Computing Platform
    - Grid Computing Infrastructure
  - The Fault tolerance is a critical problem in LSA systems.

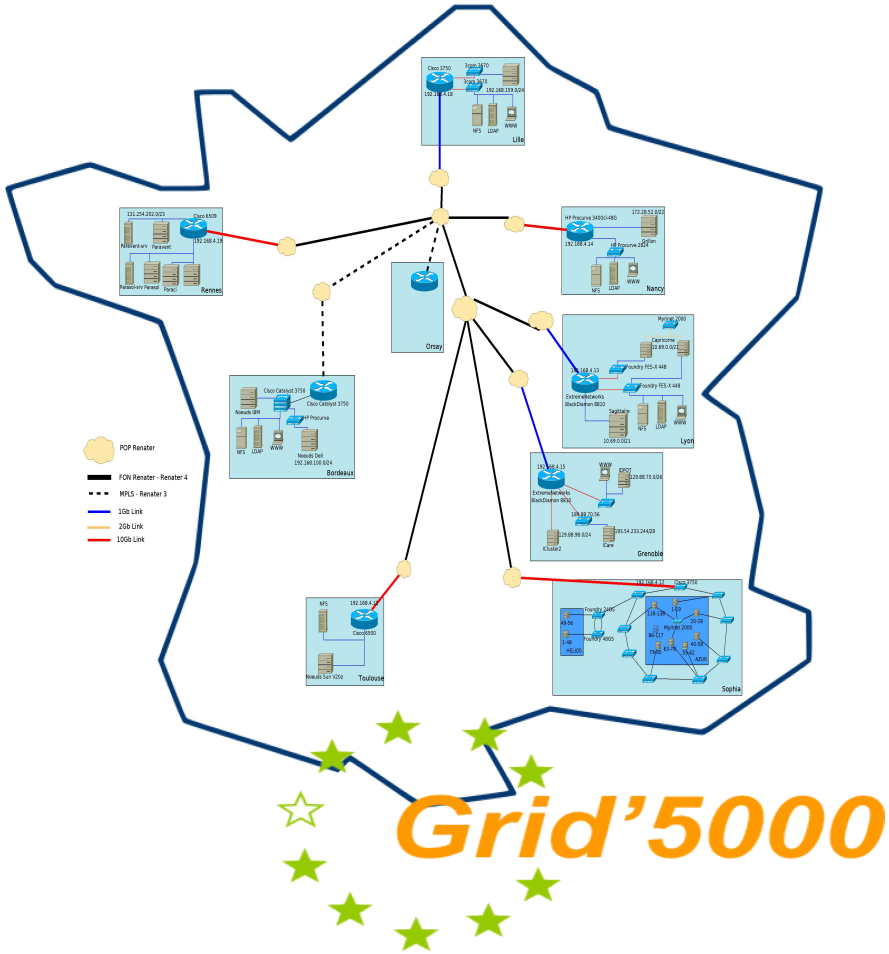
Cluster Computing Architecture



Grid Computing

- Grid Computing implies technology, technics and methodology to support Parallel*/ Distributed Computing.
- Grid Computing needs Grid Computing Infrastructure and dedicated and high disponibility networks or interconexion.
- Different Types or Possibilities:
  - Experimental Testbeds
  - Production Grids
  - Lightwigth Grids
  - Desktop Grid Computing (May be Lightwith too)

Grid Computing Feautures

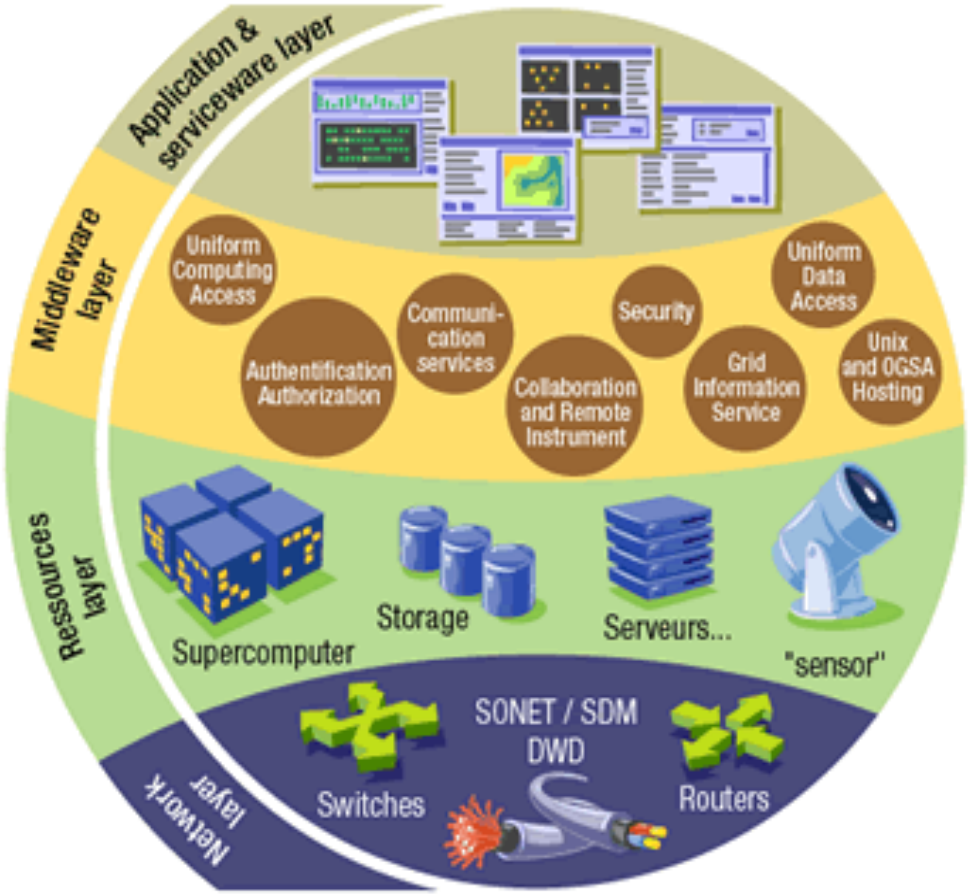


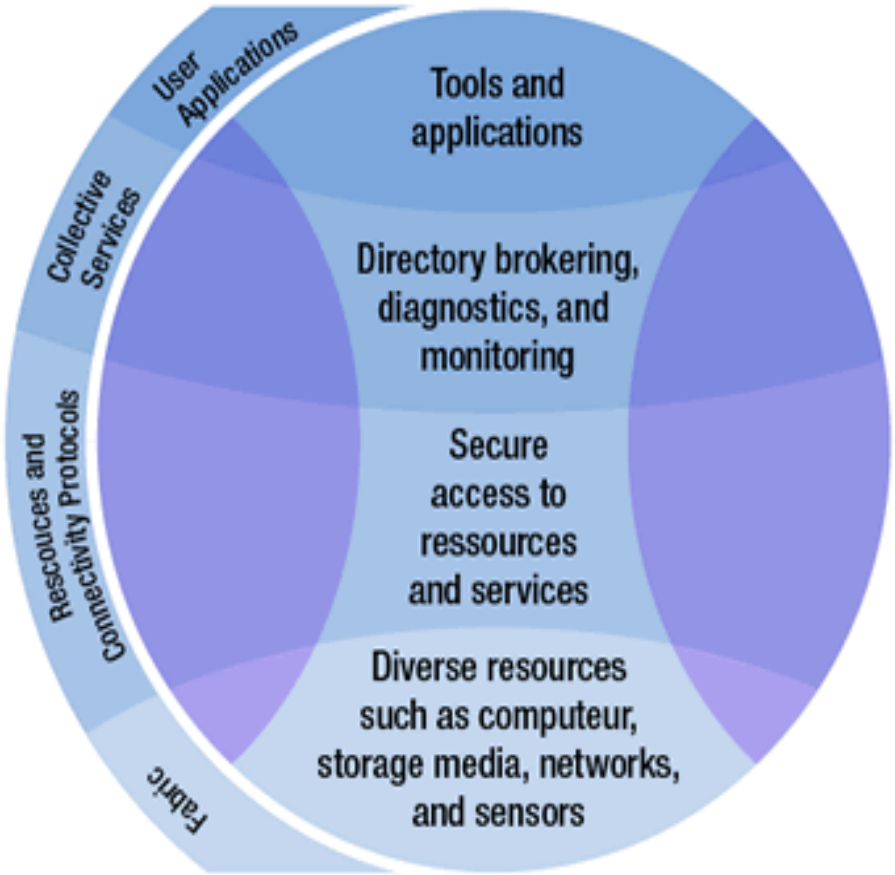
Grid'5000

- Grid Computing Features:
- Infrastructure
  - High Avalaibility
  - High Performance
  - Heterogeneity
  - Pervasive
  - Scalability
- Methodology
  - Different User Levels
  - Multi Administration
- Politics
  - Security
  - Use
  - Privacy

http://www.grid5000.fr

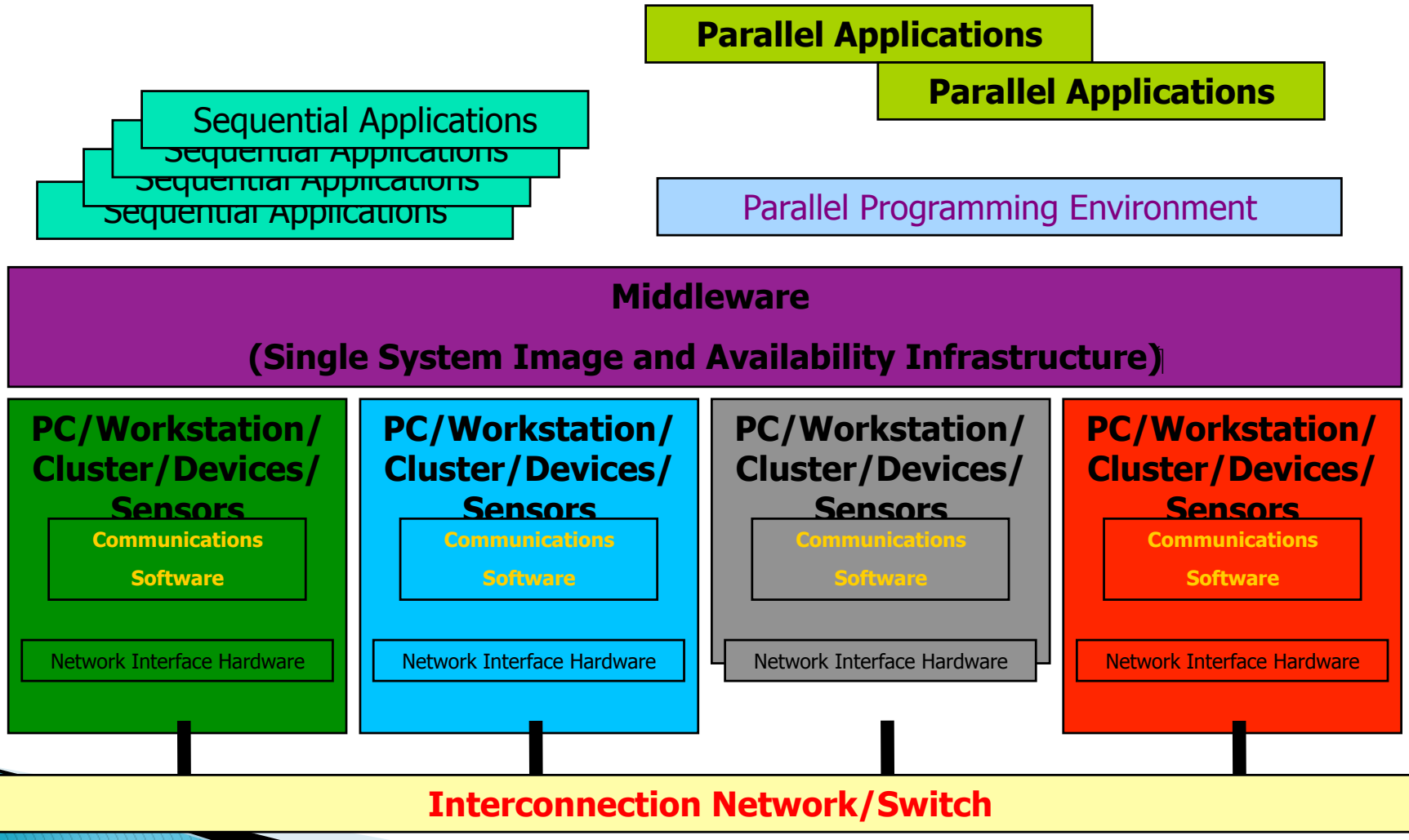
Grid Computing Architecture (Typical Diagram)



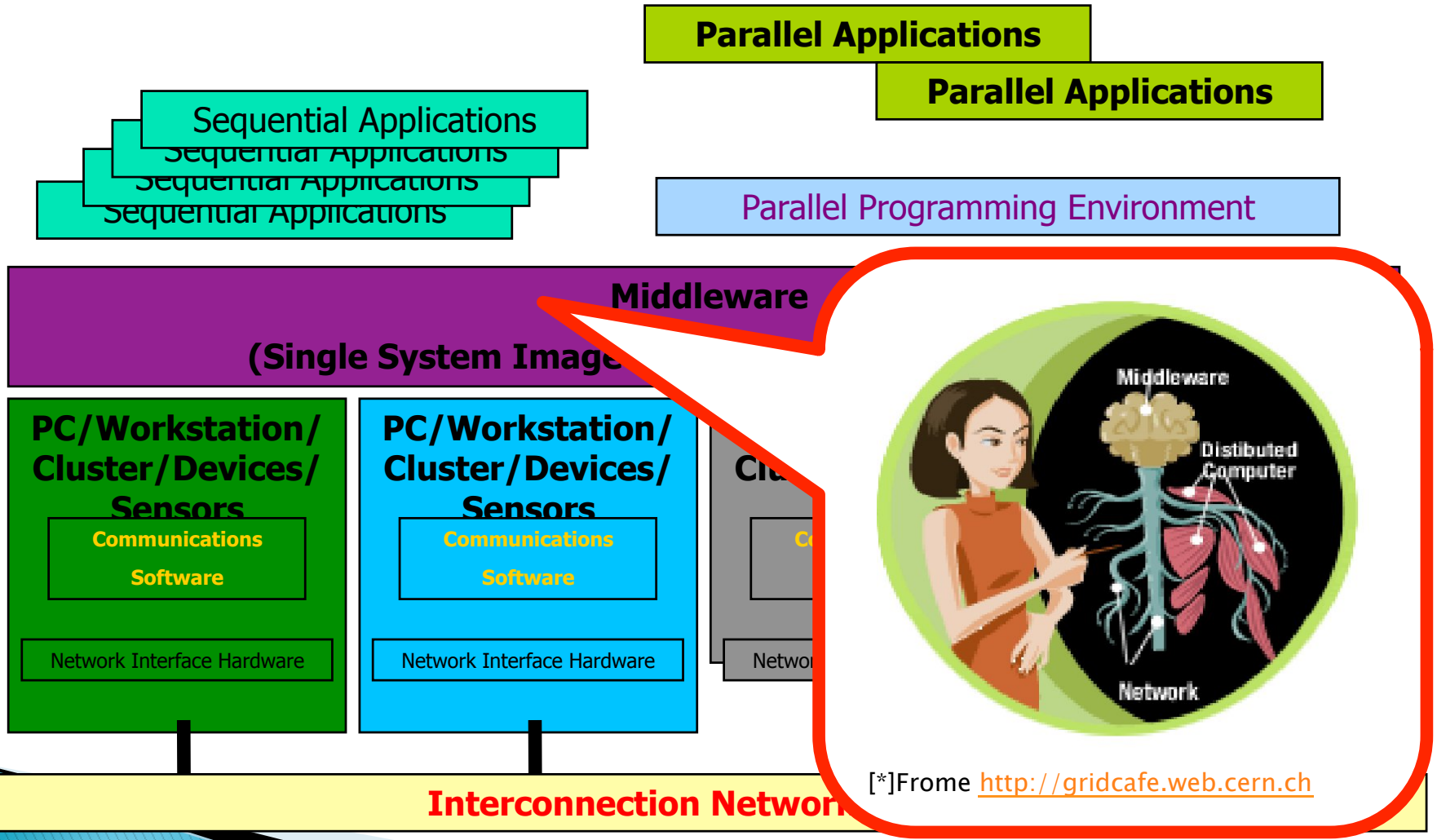


[*]From http://gridcafe.web.cern.ch

Grid Computing Architecture (Remember the Cluster Architecture)

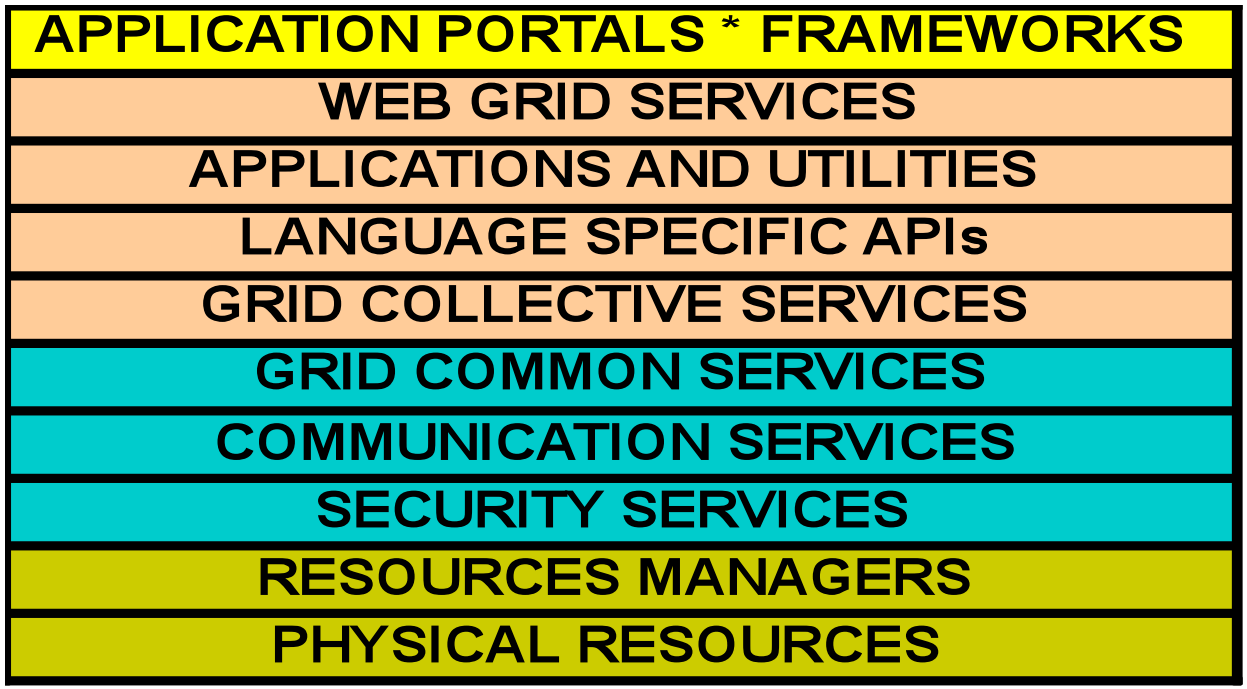


Grid Computing Architecture and the Middleware



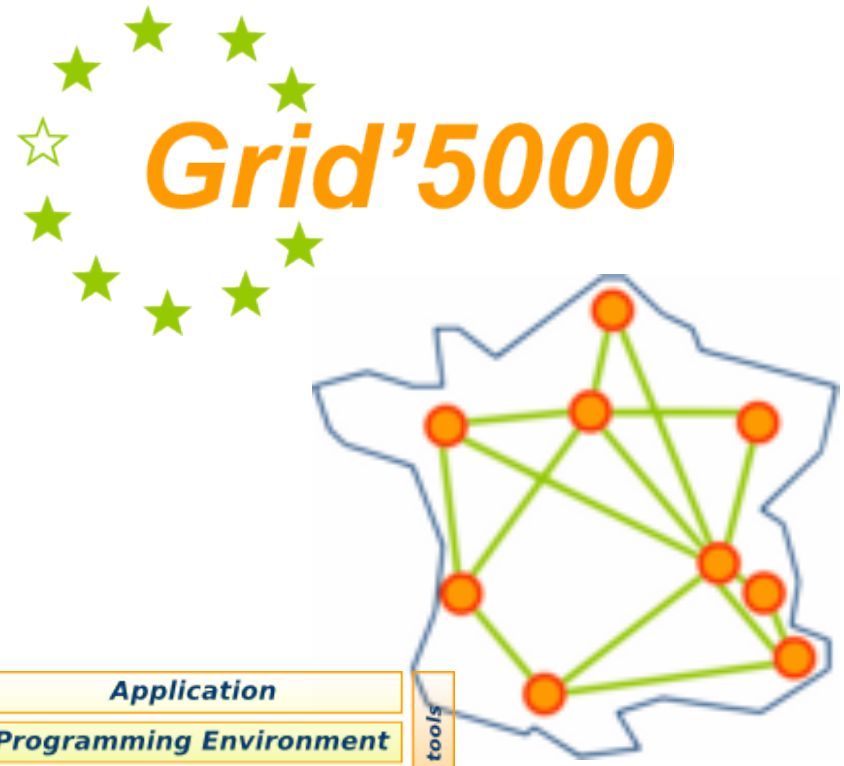
[*]Frome http://gridcafe.web.cern.ch

Grid Computing Architecture



[*]From: Grid Computing: Making The Global Infrastructure a Reality

Grid5000 (G5K)



- G5K has 5000 processors distributed in 9 sites France wide, for research in Grid Computing, eScience and Cyber-infrastructures
- G5K project aims at building a highly reconfigurable, controlable and monitorable experimental Grid platform

www.grid5000.org

GISELA

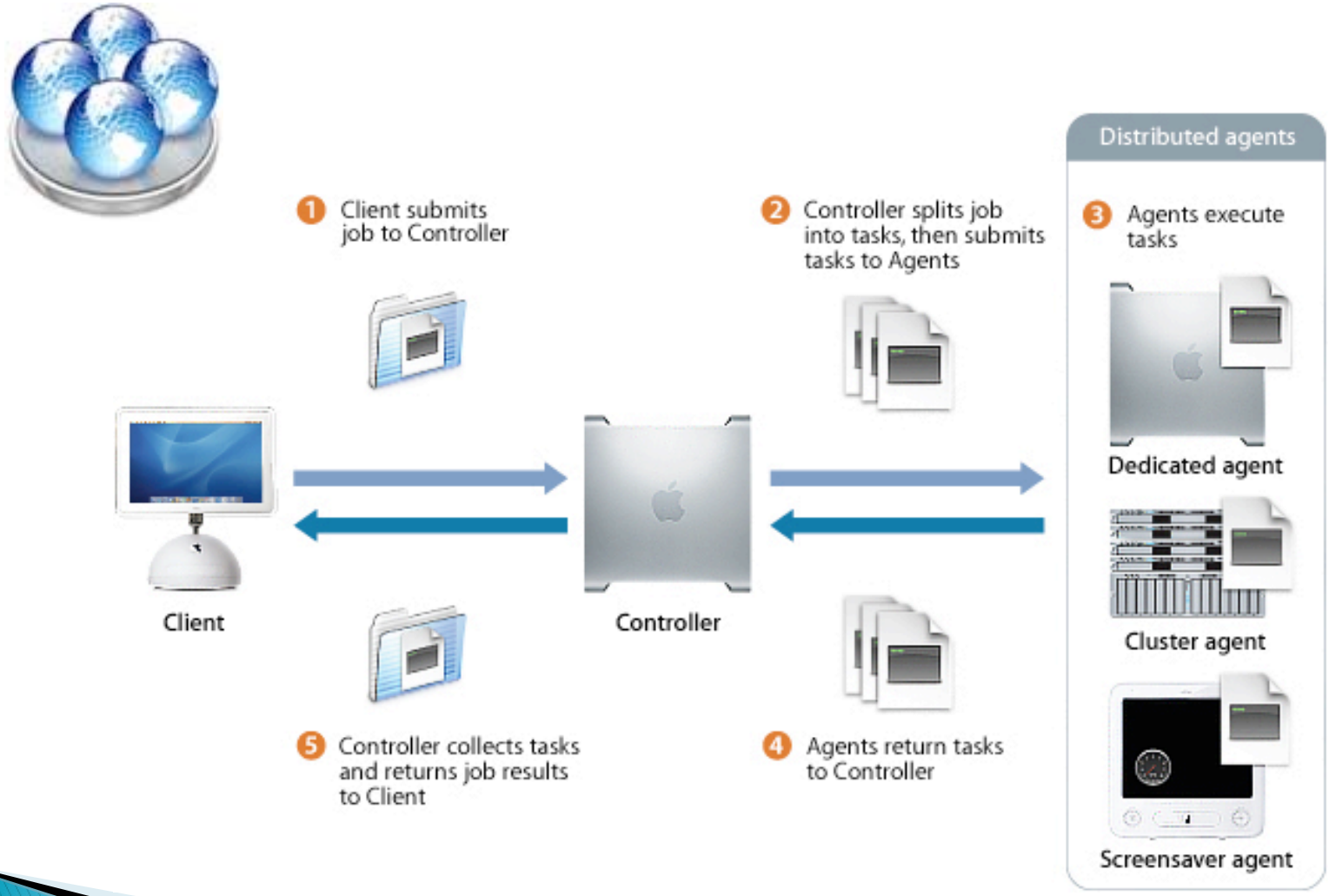

giSela
CUDI
UNAM
CUBAENERGIA
CIDETYS
UCA
UNIANDES
CEDIA
RAAP
UFCG
UFRJ
CLARA
RELNA
UdelaR
INNOVA-T
CNRS
IN2P
UPORTO
CIEMAT
INFN
Europe
Italy INFN – Catania
France CNRS, IN2P
Portugal U.PORTO
Spain CIEMAT (Coord. Institution)
Latin America and the Caribbean
Argentina INNOVA-T
Brazil UFRJ, UFCG
Chile REUNA
Colombia UNIANDES
Cuba CUBAENERGIA
Ecuador CEDIA
International CLARA
Mexico CUDI, UNAM
Panama CIDETYS
Peru RAAP
Uruguay UdelaR
Venezuela ULA

Volunteer Computing

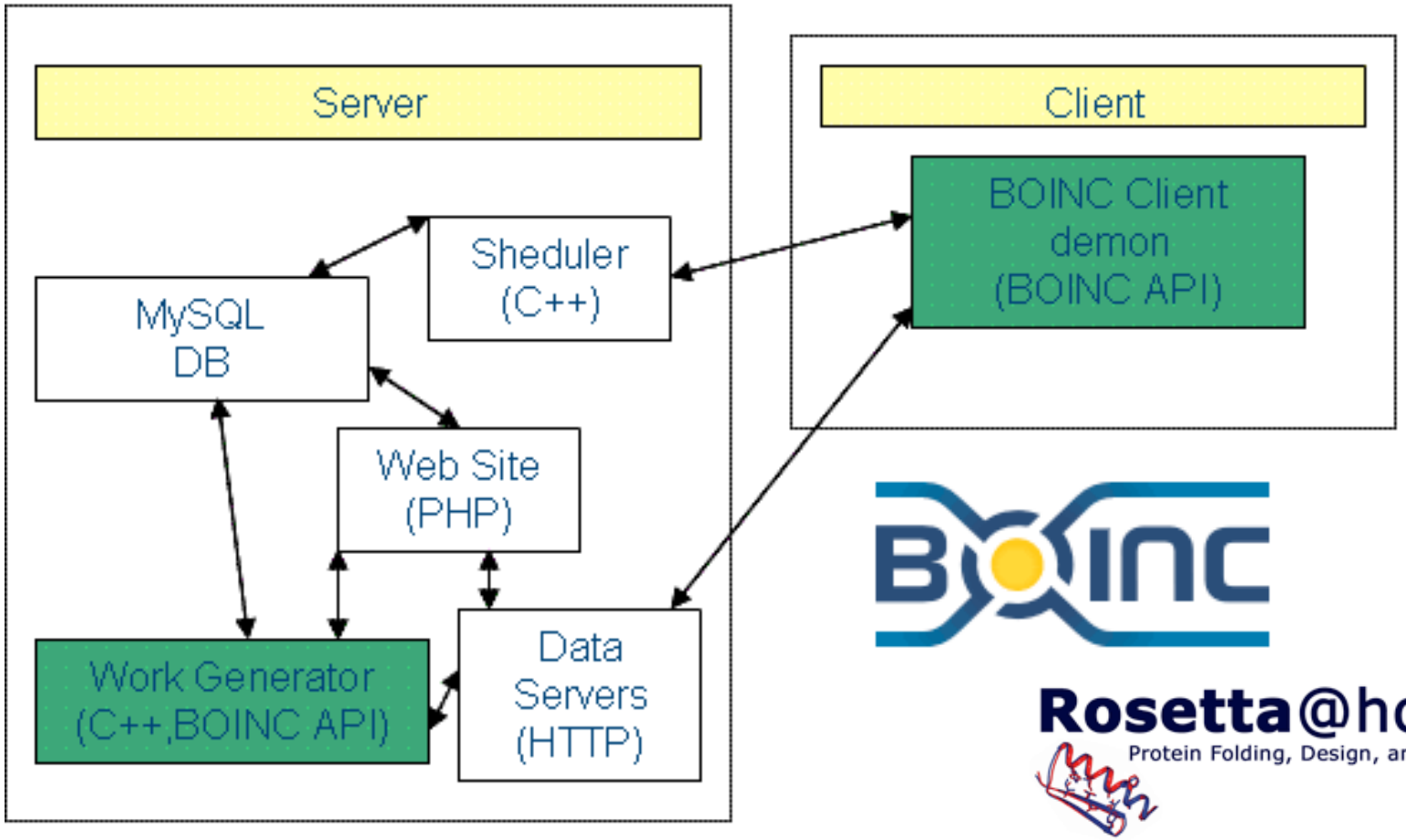
- Volunteer computing is a type of distributed computing in which computer owners donate their computing resources (such as processing power and storage) to one or more "projects".
  - •BOINC (Seti@home)
  - •Xgrid
  - •GridMP

- Associated with P2P
- Can be associated with High Throughput Computing (HTC) or High Performance Computing (HCP)

XGrid Architecture



BOINC Architecture

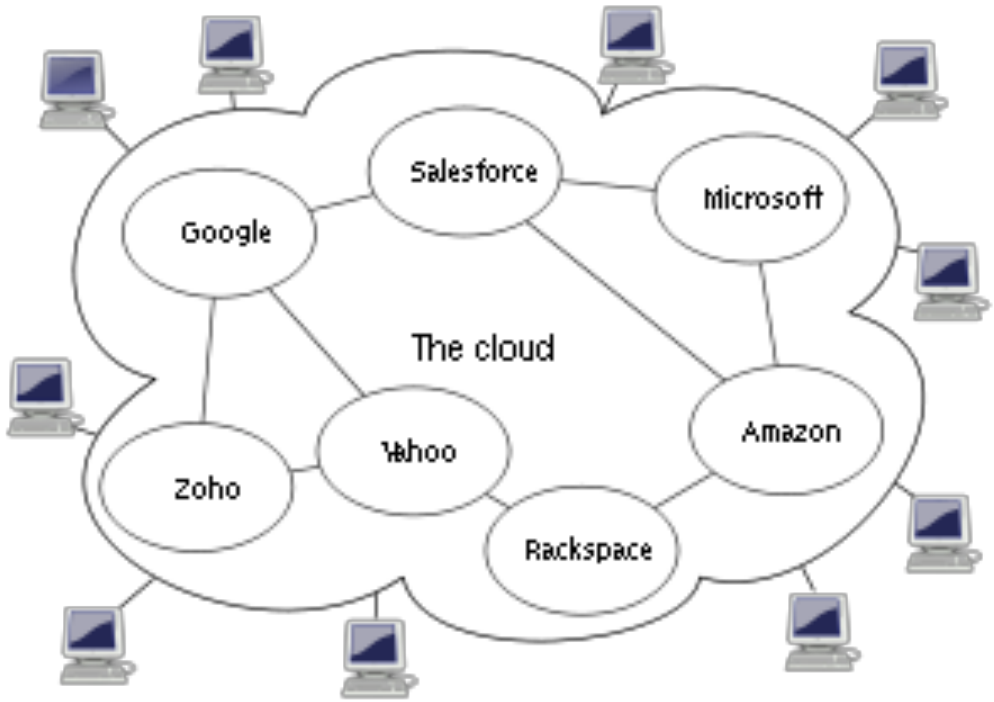


BOINC

Rosetta@home
Protein Folding, Design, and Docking

Cloud Computing

- Internet-based computing, whereby shared resources, software, and information are provided to computers and other devices on demand.
- Cloud computing describes a new supplement, consumption, and delivery model for IT services based on the Internet, and it typically involves over the-Internet-provision of dynamically scalable and often virtualized resources



Logical-Services Cloud View

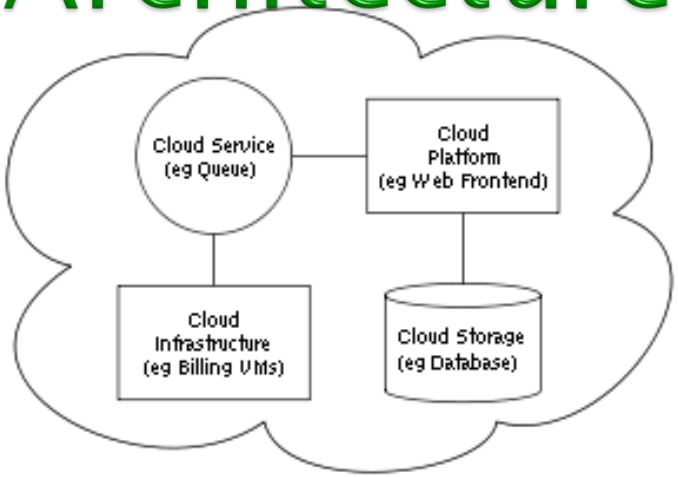
Cloud Computing Features and Issues

- **Agility**: rapidly and inexpensively re-provision technological infrastructure resources.
- **Cost**
- **Device and location independence**
- **Multi-tenancy**
  - Centralization of infrastructure in locations with lower costs
  - Peak-load capacity increases
  - Utilization and efficiency improvements for systems.
- **Reliability**: improved if multiple redundant sites are used
- **Scalability via dynamic ("on-demand"):**
  - Resources on a fine-grained, self-service basis near real-time.
  - Performance is monitored, and consistent and loosely coupled architectures are constructed using web services as the system interface.
- **Security and Safety**
- **Maintenance**: Applications are easier to maintain
- **Metering** cloud computing resources usage should be measurable and should be metered.

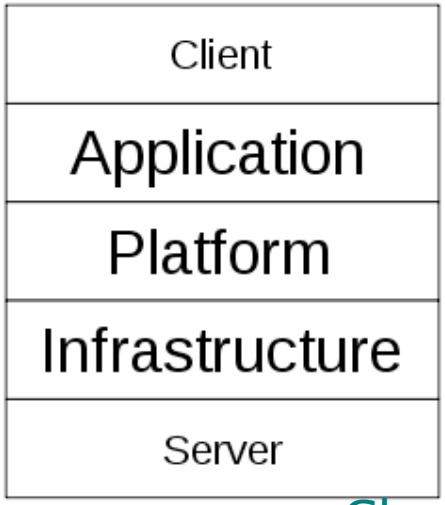
- Privacy
- Compliance (Data Protection Directives)
- Legal (Trademarks, Licenses)
- Open Source
- Security
- Safety
- Sustainability (cloud computing is often assumed to be a form of "green computing")

Cloud Computing Architecture

- Cloud computing, typically involves multiple cloud components communicating with each other over application programming interfaces, usually web services.
  - Platforms as a service
  - Infrastructure as a service



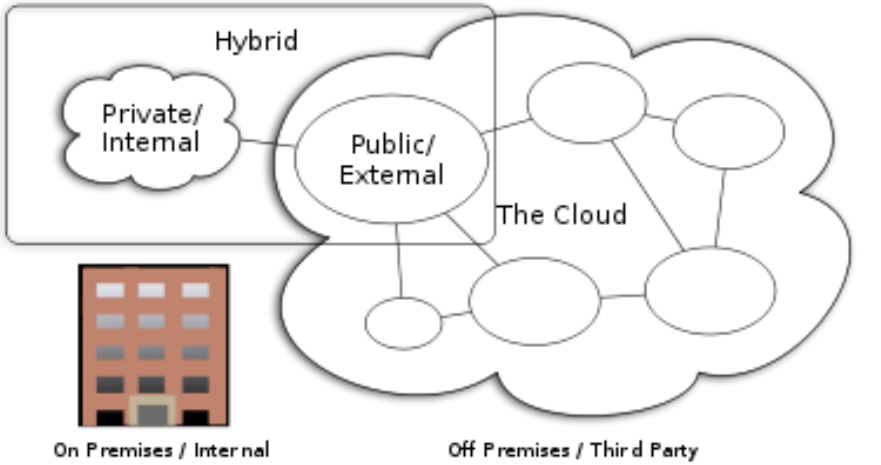
General Architecture Cloud View



Cloud Layers

Cloud Computing Deployment Types

- Private Cloud
- Public Cloud
  - Resources are dynamically provisioned on a fine-grained, self-service basis over the Internet, via web applications/web services
- Community Cloud
  - Established where several organizations have similar requirements and seek to share infrastructure
- Hybrid Cloud
- InterCloud
  - Cloud of Clouds



Cloud Computing Types

Final Comments

- Guidelines to Parallel and Distributed Programming (should) require identify Patterns
  - Finding Concurrency
  - Algorithm Structure
  - Supporting Structures
  - Implementation Mechanisms
    - Supported Platforms and Infrastructures
  - *Problems need minds, minds need applications, applications need platforms, platforms need infrastructure.*