High Performance Computing & Cloud Computing

Programmazione Distribuita - A.A. 2020/2021

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Organizzazione della Lezione

- La conclusione di un (lungo) viaggio
- Calcolo scalabile su internet
- Modelli per il calcolo distribuito
- High Performance Computing
- Cloud Computing
- Conclusioni

La struttura del corso di PD

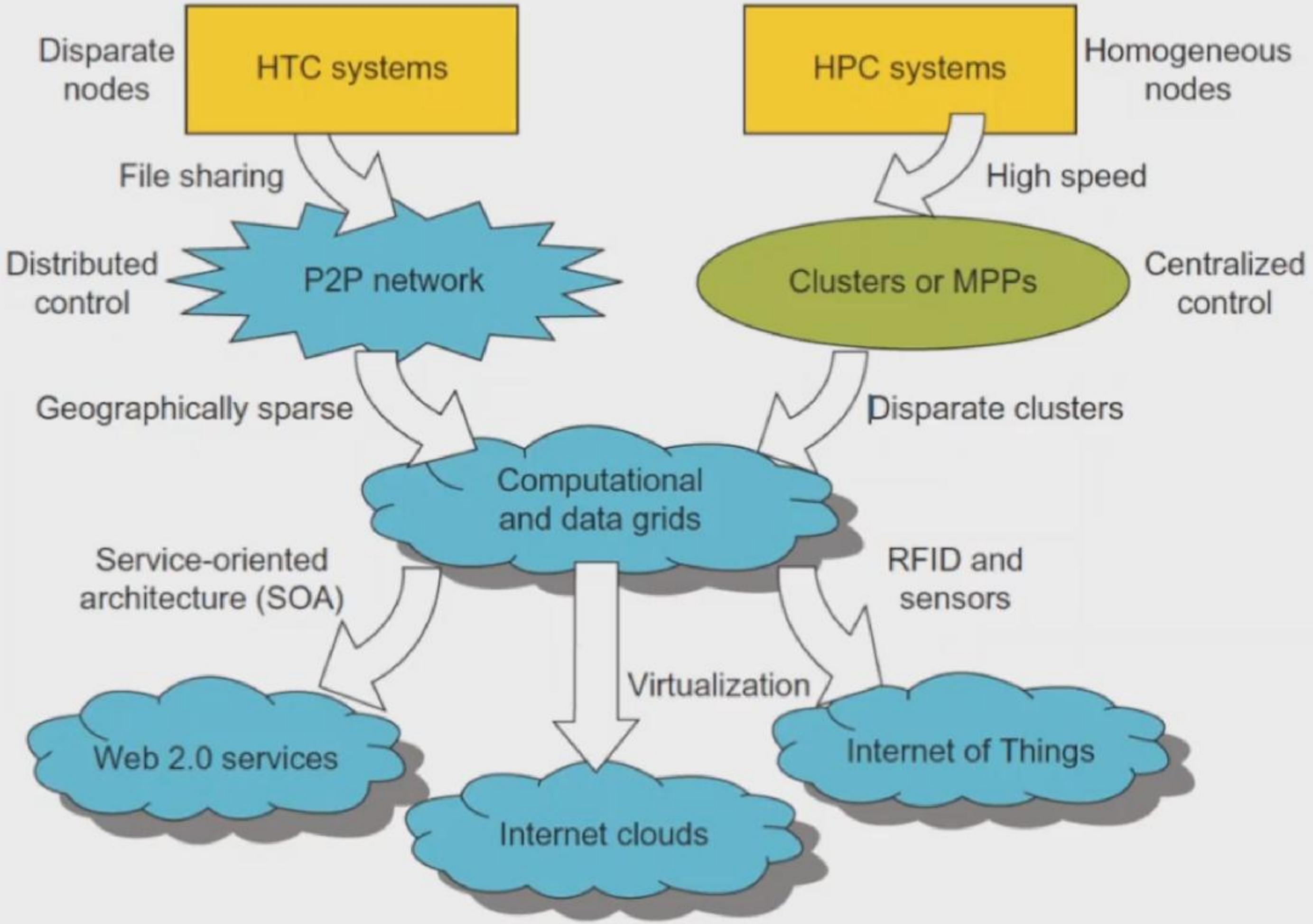
- Partendo dalla concorrenza…
  - necessaria per l'overlapping di comunicazione e computazione

La struttura del corso di PD

- Partendo dalla concorrenza…
  - necessaria per l'overlapping di comunicazione e computazione
- .. si esaminano i socket
  - soluzione efficiente, ma poco flessibile e con pochi servizi di supporto
- .. per poi passare a Remote Method Invocation
  - astrazione maggiore, familiare ai programmatori
- .. per esaminare le architetture Enterprise
  - che offrono integrazione di layer diversi (data, business, presentation, services)
- .. studiando la comunicazione orientata a messaggi (MOM)
- .. e le Architetture Orientate a Servizi
- Ed arrivare (alla fine!) a qualche cenno su HPC, Cloud e Microservices

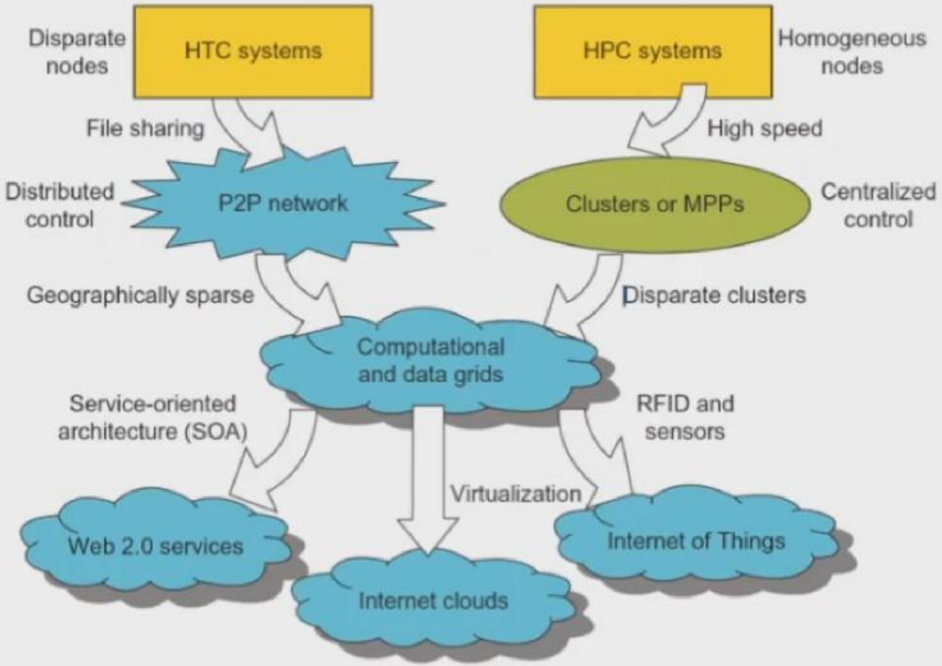
Computazioni scalabili

- Cambiamenti nel paradigma di computazione:
  - da calcolo monolitico a calcolo distribuito
- Data-intensive e network centric
- Scalabilità il punto centrale:
  - da high performance computing
  - a high-throughput computing



High Performance Computing

- Guidato dalle richieste di calcolo scientifico
  - fisica, chimica, manufacturing
- Focus sulle prestazioni pure
  - operazioni in floating point
  - Linpack benchmarking
  - HPCG and graph benchamarking
- Supercomputers
  - Top 500 list
  - sistemi omogenei e strongly coupled
  - acceleratori (GPU, ...)



High Performance Computing Systems

Fugaku at RIKEN #1

158,976 nodes / 7,299,072 cores
Manufacturer: Fujitsu
CPU: A64FX 48C (48+8 cores) 2.2GHz
with SVE vectorial instruction
Network: TOFU interconnect D
Rmax: 415 PFlop/s

HPC5 at ENI S.p.A. #6

1820 nodes / 669,760 cores
Manufacturer: Dell EMC
CPU: Intel Xeon Gold 6252 24C 2.1GHz
Accelerators: 4x NVIDIA Tesla V100 GPUs
Network: Mellanox HDR Infiniband
Rmax: 35 PFlop/s

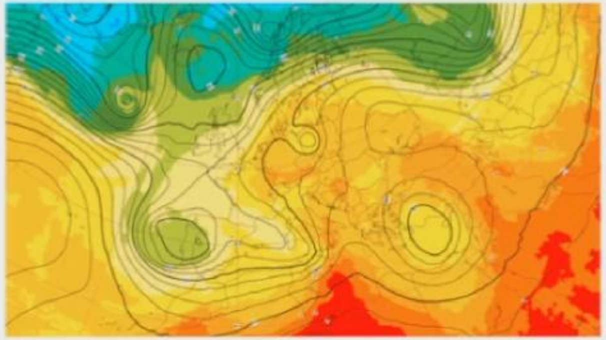
Marconi-100 at CINECA #9

980 nodes / 347,776 cores
Manufacturer: IBM
CPU: 2x16 cores IBM POWER9 AC922 at 3.1 GHz
Accelerators: 4x NVIDIA Volta V100 GPUs
Network: Mellanox IB EDR DragonFly++
Rmax: 22 PFlop/s

High Performance Computing Applications

Identify oil reservoirs / ENI spa

Deep Learning / CINECA



Weather forecast / ECMWF

Naval design / CINECA

Aerodynamic simulation
Dallara Automobili

Drug discovery
DOMPE spa

"(...) The geophysical and seismic information we collect from all over the world is sent to HPC5 for processing. Using this data, the system develops extremely in-depth subsoil models, and on the basis of these, we can determine what is hidden many kilometres below the surface: indeed, this is how we found Zohr, the largest gas field ever discovered in the Mediterranean." Source ENI: https://www.eni.com/en-IT/operations/green-data-center-hpc5.html

High Performance Computing Programming

- Modelli di programmazione HPC
- Per multicore
  - Esempio: OpenMP

```
int *a, *b, *c;
// ...
#pragma omp parallel for shared(a, b, c) private(i) schedule(static, n_per_thread)
for(i=0; i<n; i++) {
  c[i] = a[i]+b[i];
}
```

- Per acceleratori
  - Esempio: OpenCL

```
__kernel void saxpy_kernel(float alpha, __global float *A, __global
float *B, __global float *C)
{
    int index = get_global_id(0);
    C[index] = A[index] + B[index];
}
```

High Performance Computing Programming

- Per comunicazione tra nodi
  - Esempio: MPI

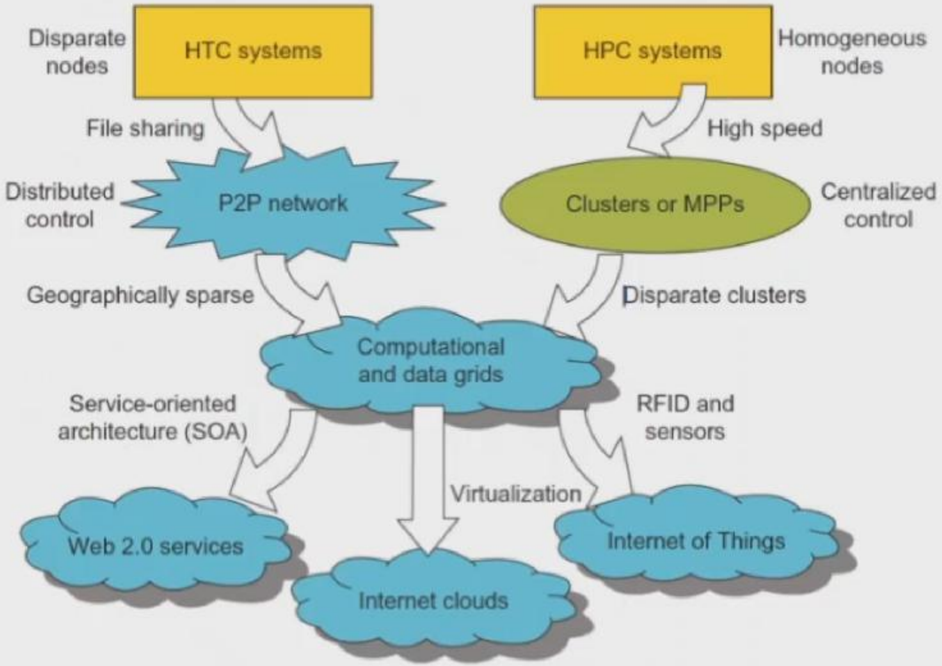
```
MPI_Init (&argc, &argv);
MPI_Comm_size (MPI_COMM_WORLD, &total_proc);
MPI_Comm_rank (MPI_COMM_WORLD,&rank);
// . . .
// scatter phase
MPI_Scatter(a, n_per_proc, MPI_INT, ap, n_per_proc, MPI_INT, MASTER, MPI_COMM_WORLD);
MPI_Scatter(b, n_per_proc, MPI_INT, bp, n_per_proc, MPI_INT, MASTER, MPI_COMM_WORLD);

// compute vector add locally
for(i=0;i<n_per_proc;i++)
  cp[i] = ap[i]+bp[i];

// gather phase
MPI_Gather(cp, n_per_proc, MPI_INT, c, n_per_proc, MPI_INT, MASTER, MPI_COMM_WORLD);
```

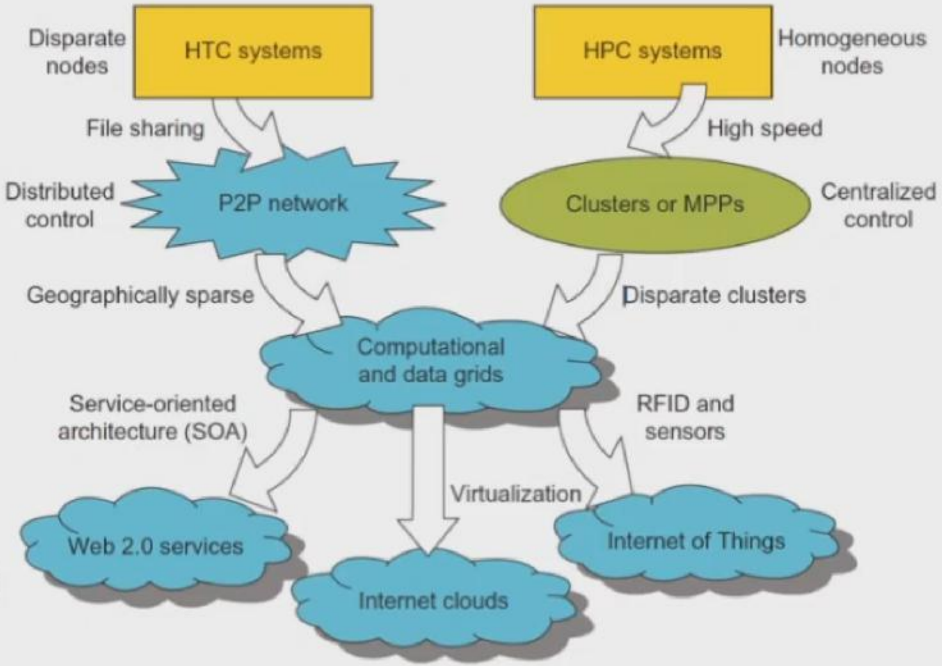
Piattaforme di calcolo

- Reti P2P: file sharing
  - distribuite, non strutturate
  - calcolo cooperativo
  - best effort (at best!)
- Calcolo massivo con HPC
  - nodi omogenei
  - sistemi strettamente accoppiati
- Computational grid
  - verso cluster di nodi semi-eterogenei
  - il calcolo come utility
    - elettricità, acqua



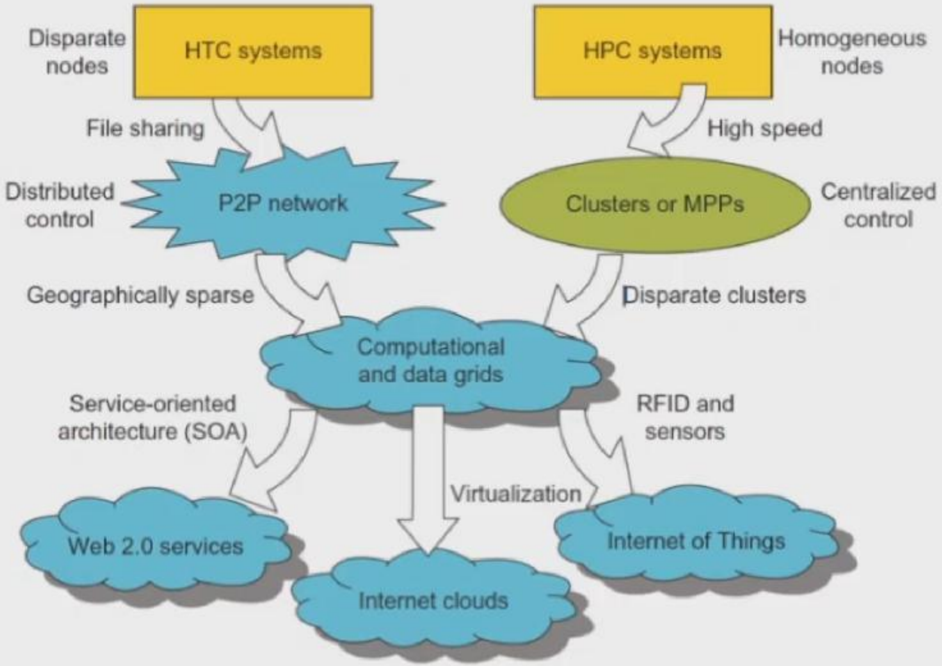
High Throughput Computing

- Focus sulla quantità di dati che possono essere calcolati
- Ricerche su Internet e web services
  - audience e dimensione è quella di Internet
- Scalabilità estrema
- Goal: non i FLOPS ma il numero di tasks completati per unità di tempo
  - task vs data parallelism
  - il task e' un utente



Nuovi paradigmi di calcolo

- Service Oriented Architecture
  - disaccoppiamento ed eterogeneità
- RFID, GPS, sensori
  - Internet of Things (IoT)
- Internet cloud
  - 1984: The network is the computer (Sun)
  - 2008: The data center is the computer (D. Patterson)
  - Now: The cloud is the computer



Classificazioni del Calcolo

- Calcolo monolitico,
  - centralizzato
- Calcolo parallelo
  - strettamente accoppiato
- Calcolo distribuito
  - debolmente accoppiato
  - con nodi autonomi
- Calcolo su cloud
  - "utility/service computing"

Calcolo concorrente

Famiglie di sistemi distribuiti

- Computational grids
  - tipicamente per applicazioni scientifiche
  - strettamente accoppiate (grid) o no (P2P)
- Obiettivi di design di un sistema distribuito:
  - Efficienza (uso del parallelismo, FLOPS o Job throughput)
  - Affidabilità: QoS
  - Adattabilità a diversi workload di dimensioni variegate, e a difersi modelli di servizio
  - Flessibilità nella realizzazione di applicazioni in HPC (science) e HTC (business)

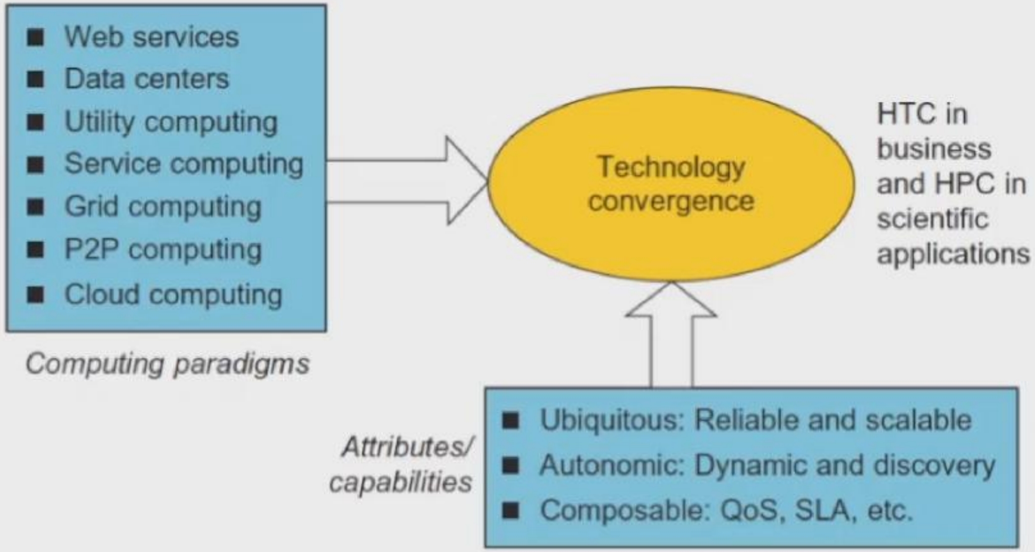
Applicazioni di HPC e HTC

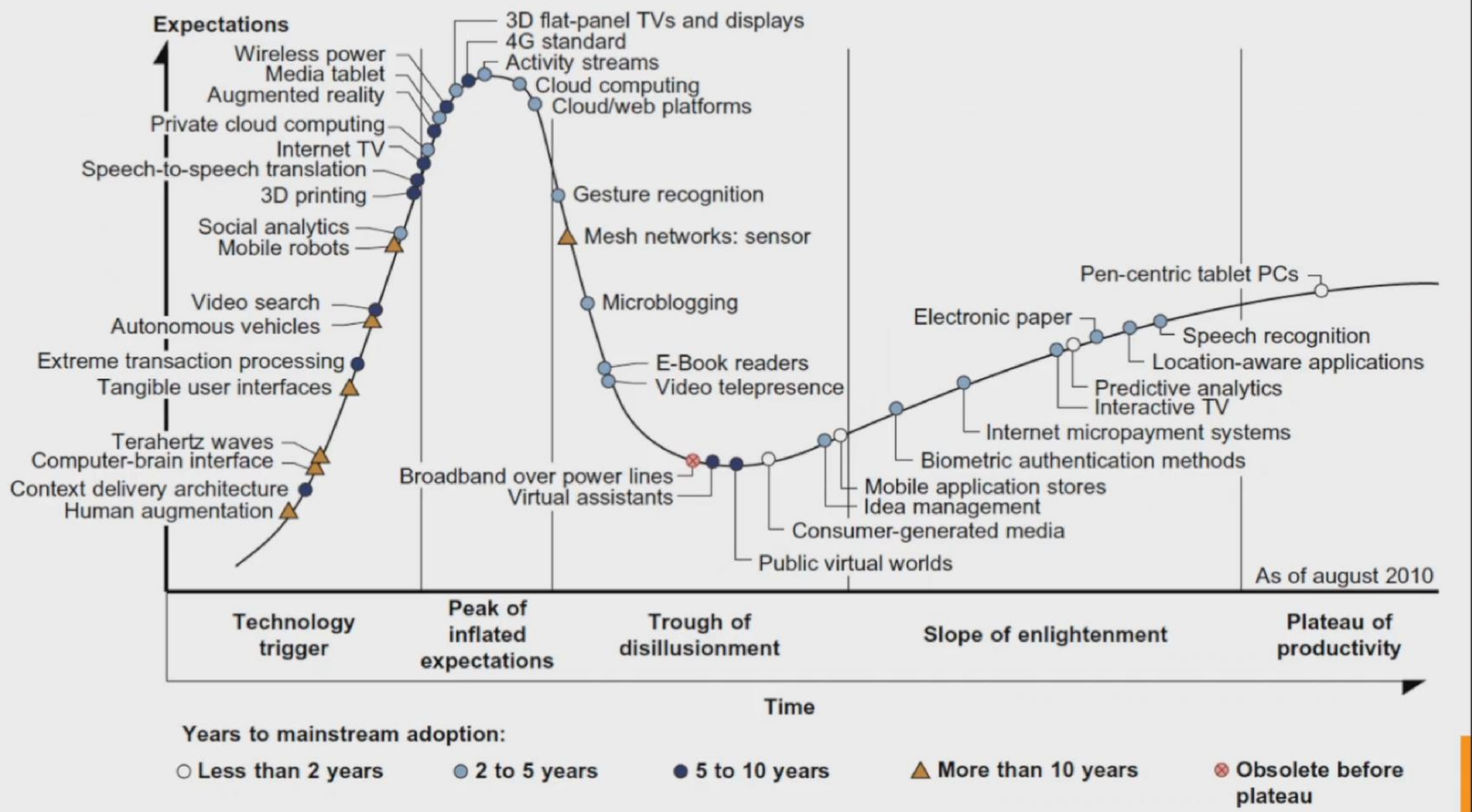
Table 1.1 Applications of High-Performance and High-Throughput Systems

Domain	Specific Applications
Science and engineering	Scientific simulations, genomic analysis, etc.
	Earthquake prediction, global warming, weather forecasting, etc.
Business, education, services industry, and health care	Telecommunication, content delivery, e-commerce, etc.
	Banking, stock exchanges, transaction processing, etc.
	Air traffic control, electric power grids, distance education, etc.
	Health care, hospital automation, telemedicine, etc.
Internet and web services, and government applications	Internet search, data centers, decision-making systems, etc.
	Traffic monitoring, worm containment, cyber security, etc.
	Digital government, online tax return processing, social networking, etc.
Mission-critical applications	Military command and control, intelligent systems, crisis management, etc.

Utility Computing

- Modello di business in cui il client riceve calcolo per un canone
- Cloud e Grid
- Convergenza tecnologica




Expectations
3D flat-panel TVs and displays
4G standard
Activity streams
Cloud computing
Cloud/web platforms
Wireless power
Media tablet
Augmented reality
Private cloud computing
Internet TV
Speech-to-speech translation
3D printing
Social analytics
Mobile robots
Video search
Autonomous vehicles
Extreme transaction processing
Tangible user interfaces
Terahertz waves
Computer-brain interface
Context delivery architecture
Human augmentation
Gesture recognition
Mesh networks: sensor
Microblogging
E-Book readers
Video telepresence
Broadband over power lines
Virtual assistants
Public virtual worlds
Consumer-generated media
Idea management
Mobile application stores
Biometric authentication methods
Internet micropayment systems
Interactive TV
Predictive analytics
Location-aware applications
Speech recognition
Electronic paper
Pen-centric tablet PCs
As of august 2010
Technology trigger
Peak of inflated expectations
Trough of disillusionment
Slope of enlightenment
Plateau of productivity
Time
Years to mainstream adoption:
Less than 2 years
2 to 5 years
5 to 10 years
More than 10 years
Obsolete before plateau

Gartner Hype Cycle for Emerging Technologies, 2017

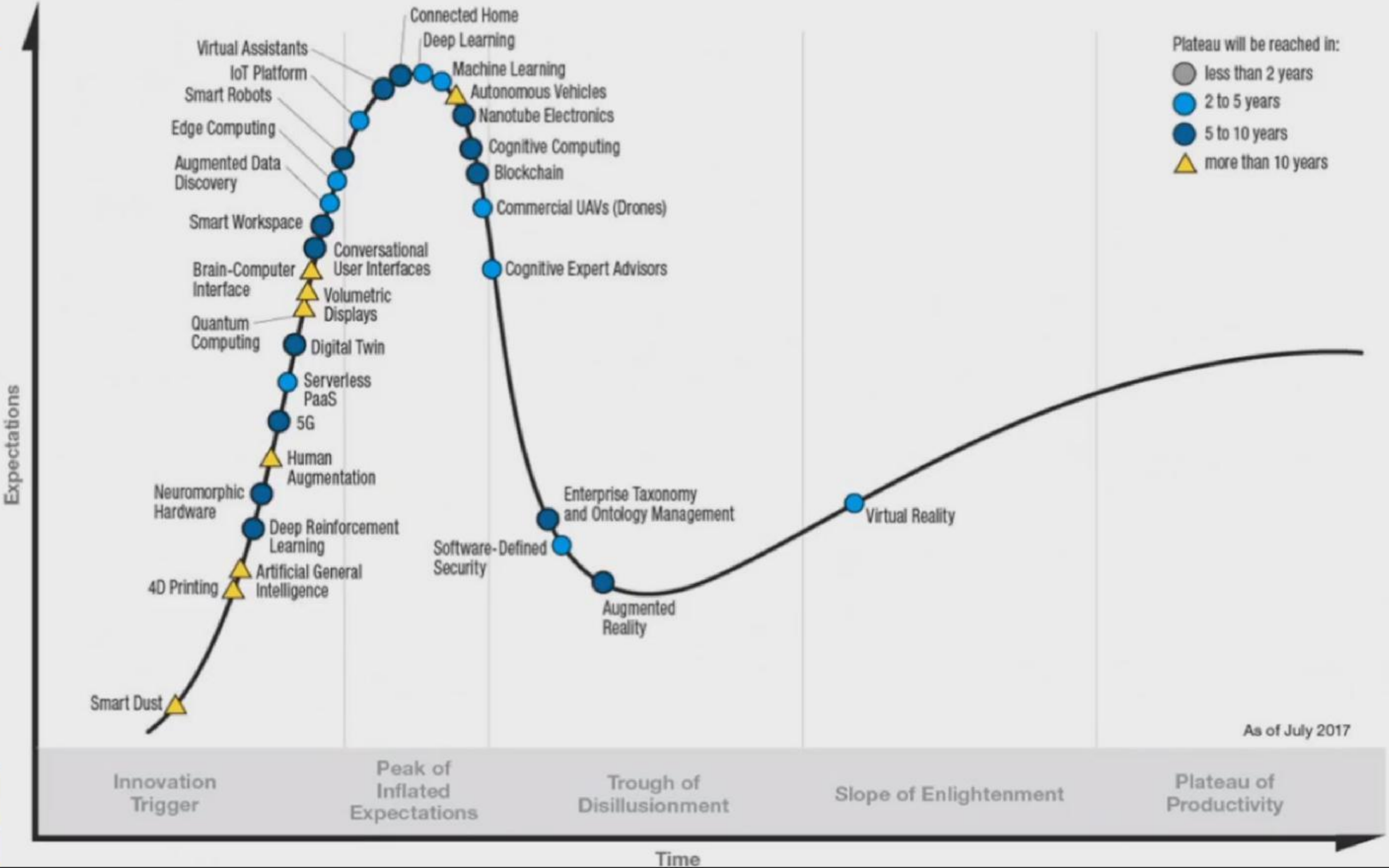
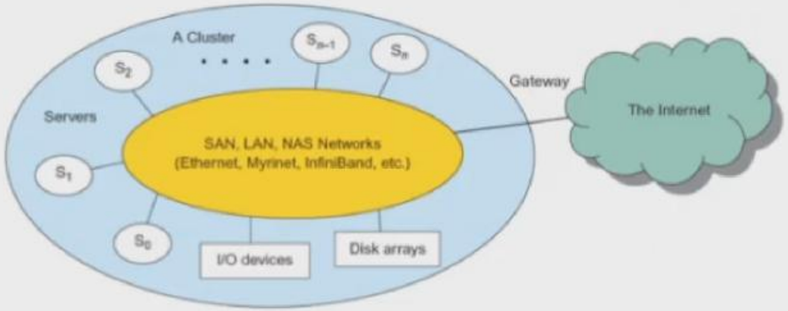


Table 1.2 Classification of Parallel and Distributed Computing Systems

Functionality, Applications	Computer Clusters [10,28,38]	Peer-to-Peer Networks [34,46]	Data/ Computational Grids [6,18,51]	Cloud Platforms [1,9,11,12,30]
Architecture, Network Connectivity, and Size	Network of compute nodes interconnected by SAN, LAN, or WAN hierarchically	Flexible network of client machines logically connected by an overlay network	Heterogeneous clusters interconnected by high-speed network links over selected resource sites	Virtualized cluster of servers over data centers via SLA
Control and Resources Management	Homogeneous nodes with distributed control, running UNIX or Linux	Autonomous client nodes, free in and out, with self-organization	Centralized control, server-oriented with authenticated security	Dynamic resource provisioning of servers, storage, and networks
Applications and Network-centric Services	High-performance computing, search engines, and web services, etc.	Most appealing to business file sharing, content delivery, and social networking	Distributed supercomputing, global problem solving, and data center services	Upgraded web search, utility computing, and outsourced computing services
Representative Operational Systems	Google search engine, SunBlade, IBM Road Runner, Cray XT4, etc.	Gnutella, eMule, BitTorrent, Napster, KaZaA, Skype, JXTA	TeraGrid, GriPhyN, UK EGEE, D-Grid, ChinaGrid, etc.	Google App Engine, IBM Bluecloud, AWS, and Microsoft Azure

Compute Clusters

- Integrati e strettamente accoppiati
- Gestione unica



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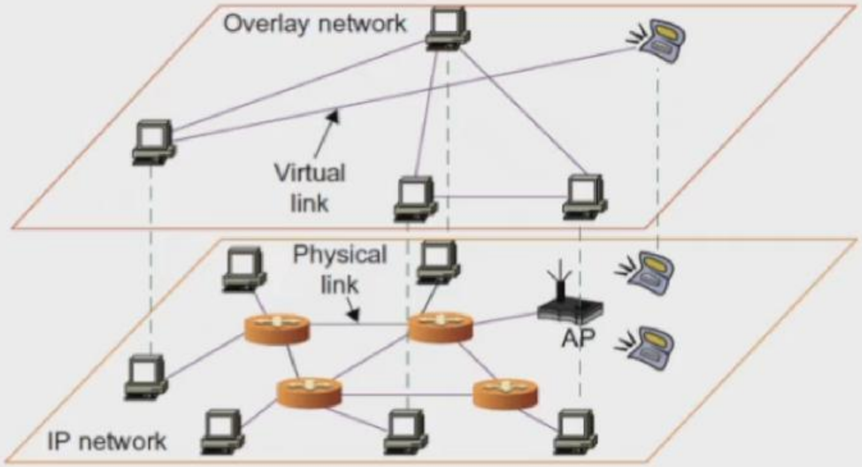
Peer-to-Peer Networks

- Rete di sistemi molto debolmente connessi
- Calcolo tra peer, assolutamente collaborativo
- Basato su un overlay network



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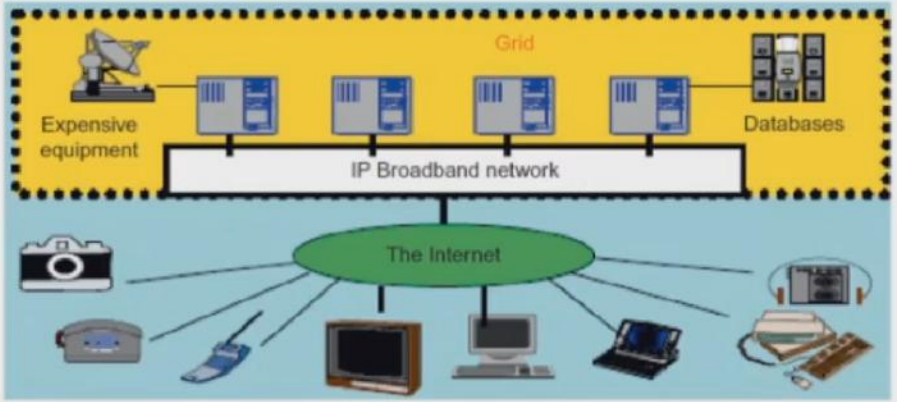
Cosa si fa con il P2P

Table 1.5 Major Categories of P2P Network Families [46]

System Features	Distributed File Sharing	Collaborative Platform	Distributed P2P Computing	P2P Platform
Attractive Applications	Content distribution of MP3 music, video, open software, etc.	Instant messaging, collaborative design and gaming	Scientific exploration and social networking	Open networks for public resources
Operational Problems	Loose security and serious online copyright violations	Lack of trust, disturbed by spam, privacy, and peer collusion	Security holes, selfish partners, and peer collusion	Lack of standards or protection protocols
Example Systems	Gnutella, Napster, eMule, BitTorrent, Aimster, KaZaA, etc.	ICQ, AIM, Groove, Magi, Multiplayer Games, Skype, etc.	SETI@home, Geonome@home, etc.	JXTA, .NET, FightingAid@home, etc.

Data/Computational Grids

- Infrastruttura che connette, computer, software, middleware, strumenti e utenti
- Piattaforme virtuali



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Cloud Platforms

- Cloud computing è realizzato da un pool di risorse offerte da computer virtualizzati
- Una cloud può offrire supporto a workload di tipo diverso
  - da batch style, backend
  - a workload interattivi e che gestiscono l'utente
- Caratteristiche:
  - calcolo ridondante
  - self-recovering
  - modelli di calcolo (e framework) altamente scalabili
  - tolleranti ai malfunzionamenti

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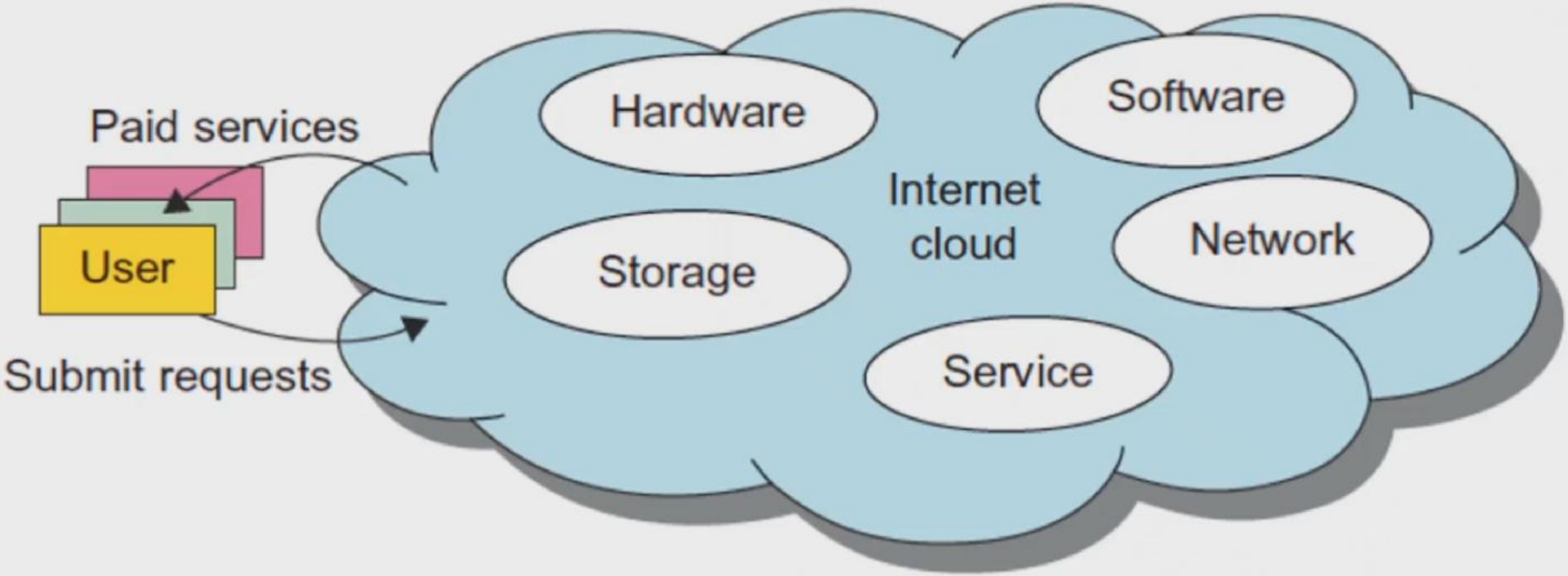
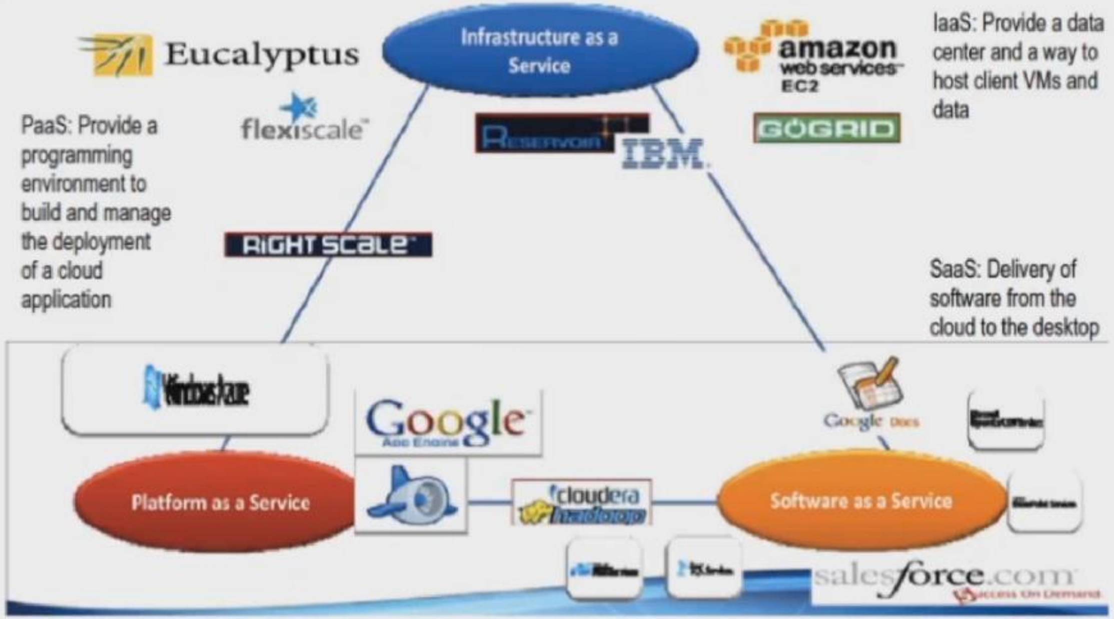
Pool di risorse



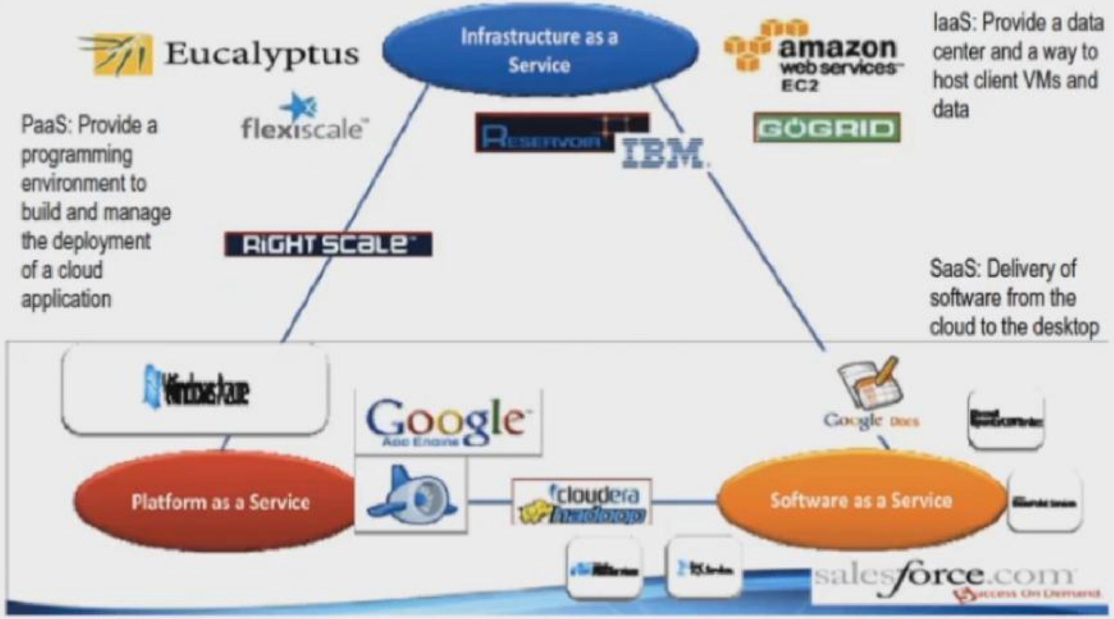
I modelli del cloud: IaaS, Paas, SaaS

- Infrastructure as a Service (IaaS):
  - l'utente noleggia un'infrastruttura



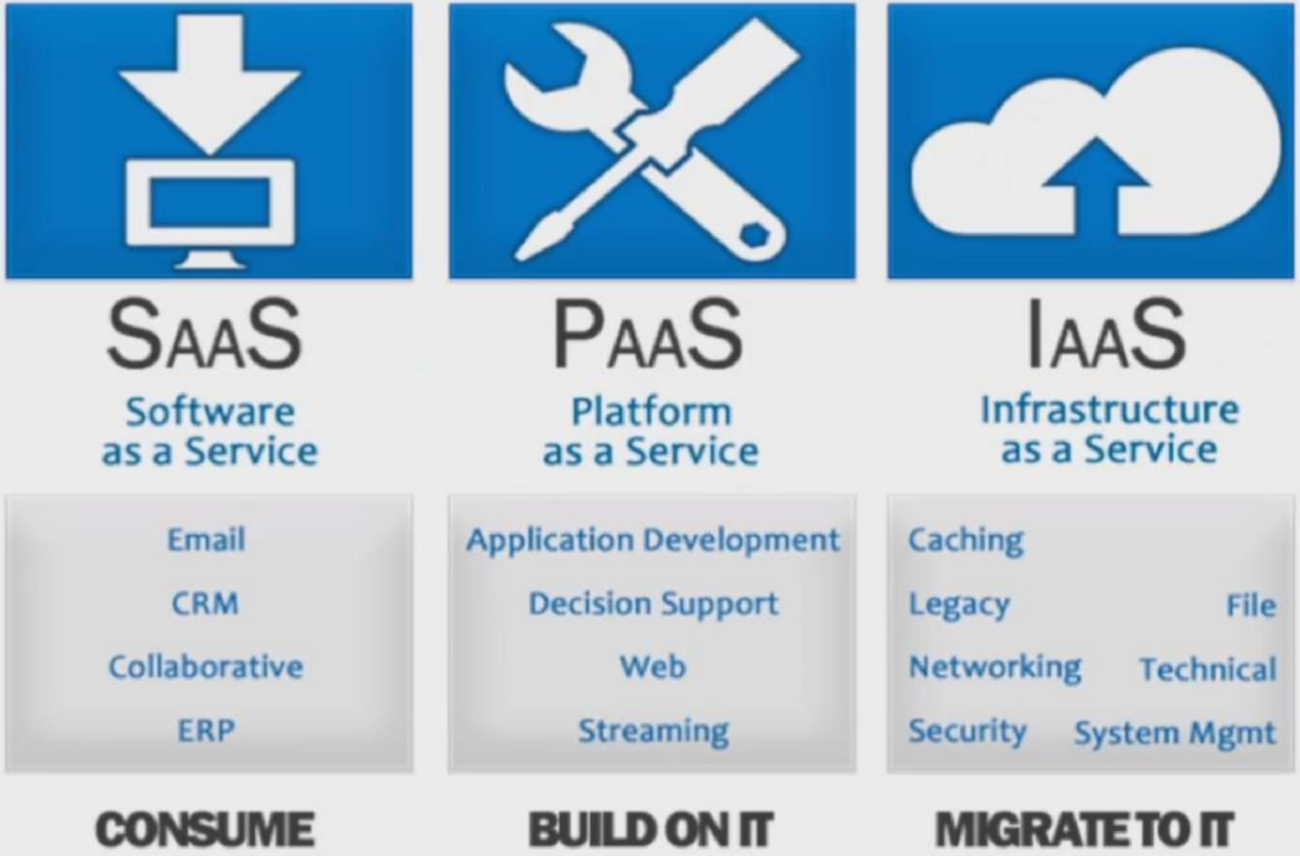
I modelli del cloud: IaaS, Paas, SaaS

- Infrastructure as a Service (IaaS):
  - l'utente noleggia un'infrastruttura
- Platform as a Service (PaaS):
  - l'utente noleggia un ambiente per poter sviluppare e eseguire applicazioni su cloud
- Software as a Service (SaaS):
  - l'utente noleggia l'uso di software fornito (via web) dal cloud

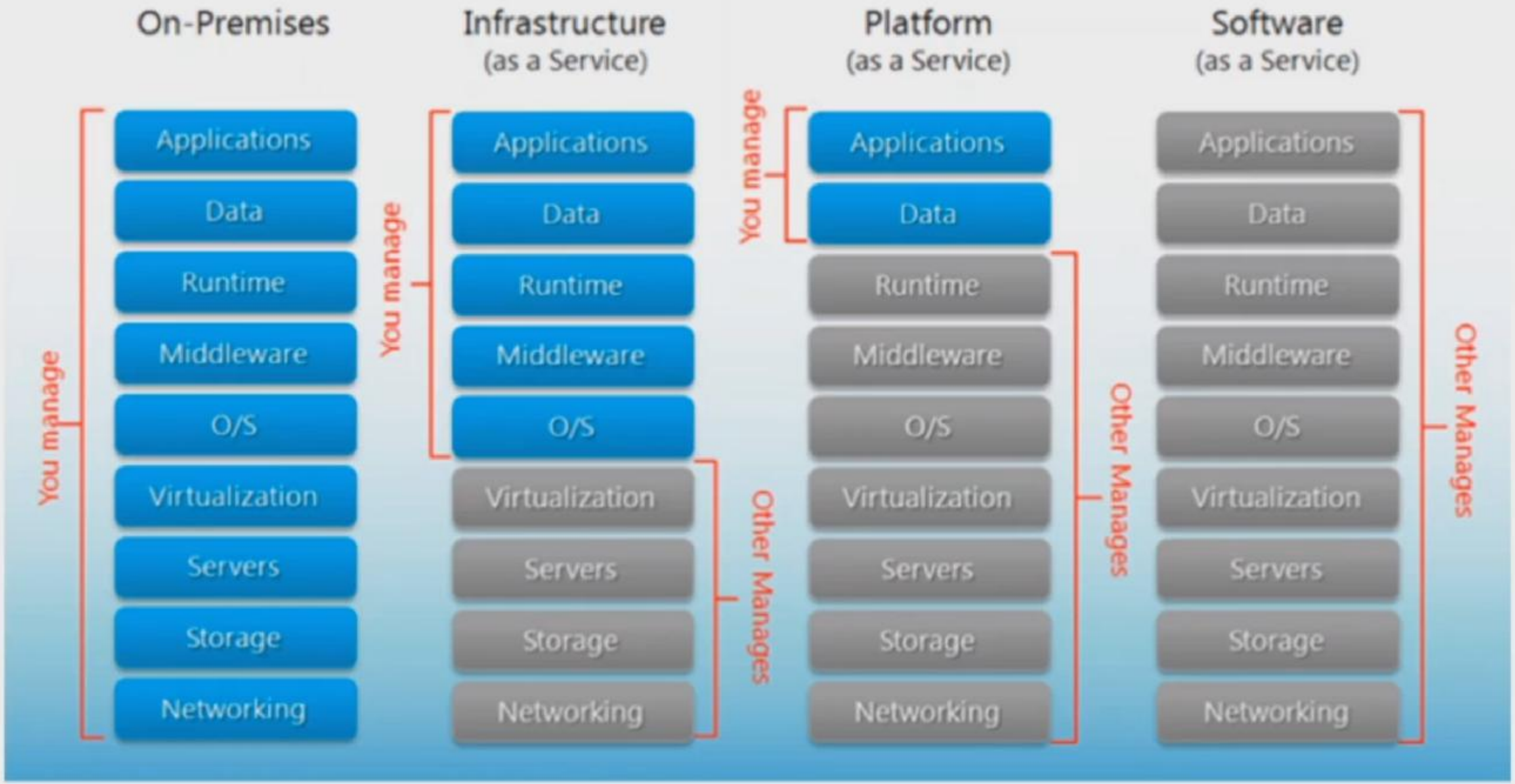


SAAS, PAAS, IAAS

- Un confronto



Separazione delle Responsabilita



Perché il cloud? 8 ragioni

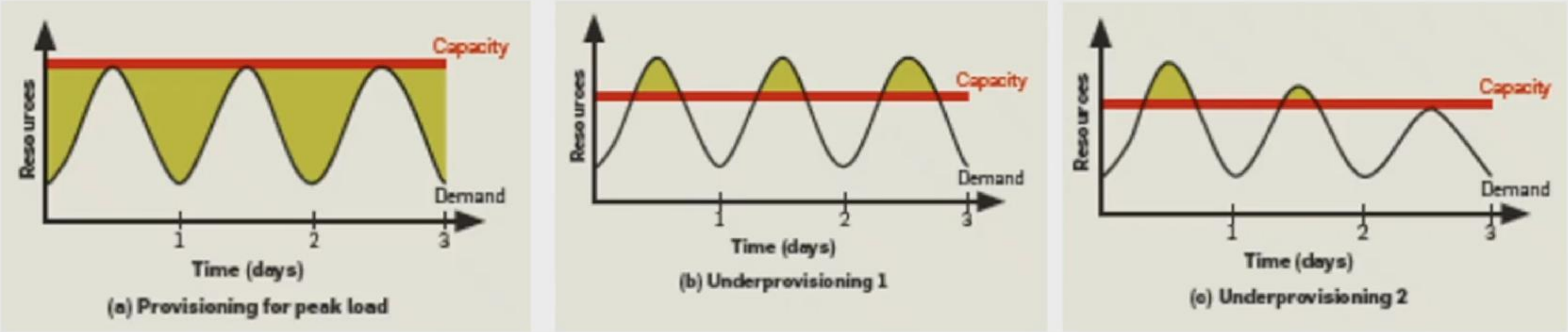
1. Spazi specificamente disegnati per il calcolo con protezione e efficienza energetica
2. Condivisione di capacità di calcolo tra numerosi utenti, migliorando la utilizzazione
3. Separazione del costo di manutenzione dal costo di sviluppo applicazioni
4. Riduzione nel costo di calcolo, notevole rispetto al paradigma tradizionale
5. Ambienti di programmazione scalabili (big data)
6. Service discovery e content distribution
7. Privacy e security
8. Modelli di costo e di business ritagliati su necessità (on-demand)

Un approfondimento: Elasticity

- Fornire nuove risorse di calcolo da poter impiegare, in tempo brevissimo (minuti) invece che di settimane
- L'utilizzo delle macchine nei centri di calcolo nel mondo è tra il 5% e il 20%
  - Progettate per picchi di carico (fattore da 2 a 10 volte superiore al carico normale)
- Un esempio:
  - un servizio che richiede 500 server di picco (mezzogiorno) ma 100 a mezzanotte, con un carico normale di 300 server.
- Se paghiamo per poter gestire i picchi, paghiamo 500 x 24h al giorno, sottostimando l'uso delle risorse
  - normalmente di un fattore stimato intorno a 1.7 volte il costo pay-as-you-go

Esempio di non-elasticità (over- under-provisioning)

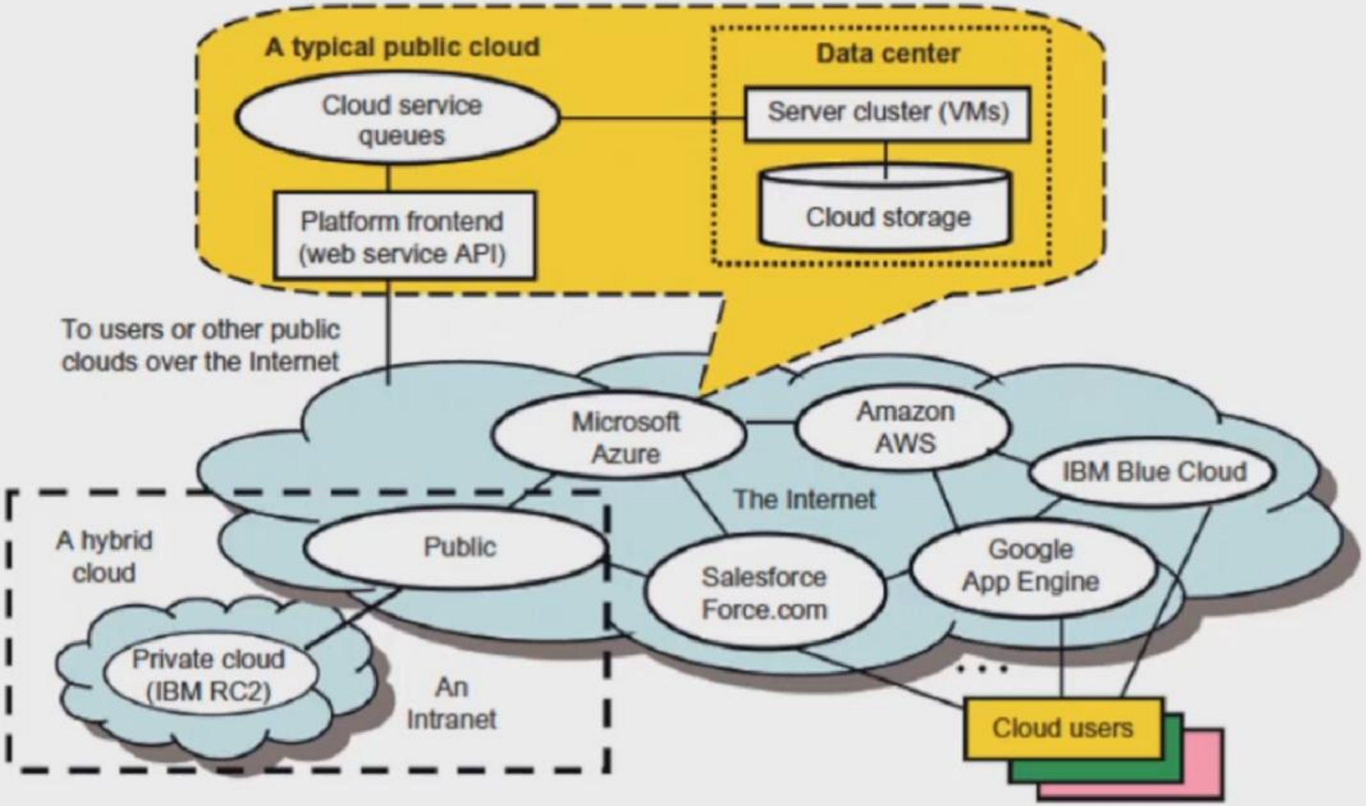
- Mancanza di elasticita nel provisioning delle risorse



Cloud Computing e modelli di servizio

- Il Cloud come risorsa per l'economia
  - porta benefici a tutta la industria dei servizi
  - nuovo paradigma
  - particolare attenzione alla dinamicità della risposta alle necessità (altrettanto dinamiche)
- Nuovi player che entrano in gioco sul panorama mondiale grazie al Cloud
  - Da un lato, Microsoft, Apple, Oracle
  - Dall'altro, Google, Amazon …

Public, Private e Hybrid Cloud

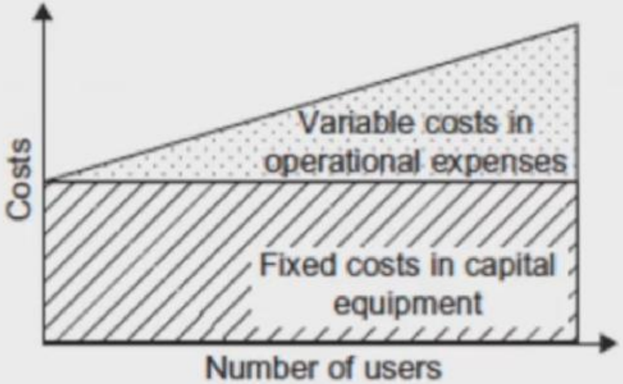


Il modello di utilizzo del Cloud

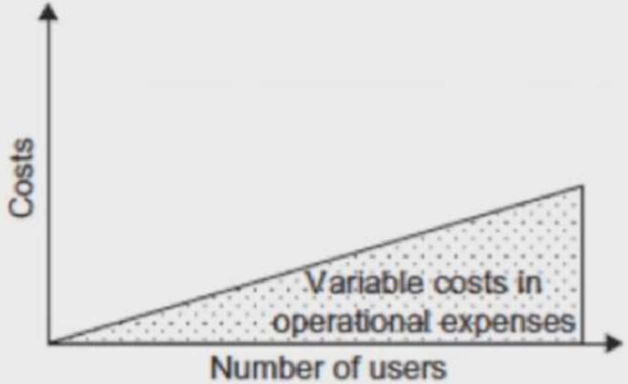
Classical Computing	**Cloud Computing**
(Repeat the following cycle every 18 months)	(Pay as you go per each service provided)
Buy and own	**Subscribe**
Hardware, system software, applications to meet peak needs	- - - -
Install, configure, test, verify, evaluate, manage	**Use** (Save about 80-95% of the total cost)
- - - -	- - - -
Use	(Finally)
- - - -	**$ - Pay for what you use**
Pay $$$$$ (High cost)	based on the QoS

Modelli di costo

- Il cloud sposta il costo da Capital expenses (CAPEX) a Operational Expenses (OPEX)
- CAPEX: costi fissi, investimenti notevoli, immobilizzazione di risorse
  - 1 utente o 100000 non fa (quasi) differenza
- OPEX: costi variabili che dipendono dal numero di utenti

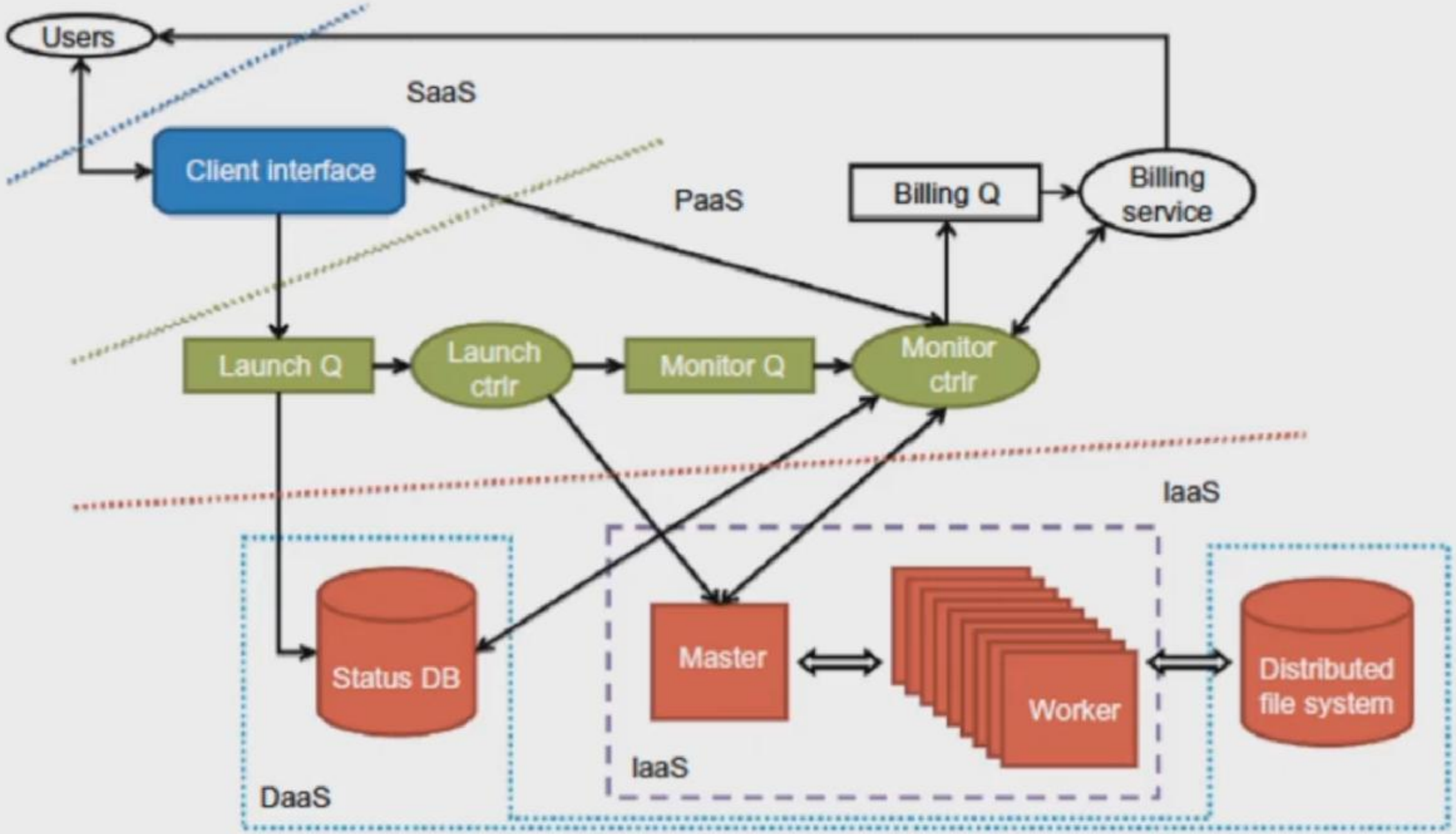


(a) Traditional IT cost model



(b) Cloud computing cost model

Modelli di servizio: IaaS, PaaS e SaaS



Esempi di IaaS

Table 4.1 Public Cloud Offerings of IaaS [10,18]

Cloud Name	VM Instance Capacity	API and Access Tools	Hypervisor, Guest OS
Amazon EC2	Each instance has 1–20 EC2 processors, 1.7–15 GB of memory, and 160–1.69 TB of storage.	CLI or web Service (WS) portal	Xen, Linux, Windows
GoGrid	Each instance has 1–6 CPUs, 0.5–8 GB of memory, and 30–480 GB of storage.	REST, Java, PHP, Python, Ruby	Xen, Linux, Windows
Rackspace Cloud	Each instance has a four-core CPU, 0.25–16 GB of memory, and 10–620 GB of storage.	REST, Python, PHP, Java, C#, .NET	Xen, Linux
FlexiScale in the UK	Each instance has 1–4 CPUs, 0.5–16 GB of memory, and 20–270 GB of storage.	web console	Xen, Linux, Windows
Joyent Cloud	Each instance has up to eight CPUs, 0.25–32 GB of memory, and 30–480 GB of storage.	No specific API, SSH, Virtual/Min	OS-level virtualization, OpenSolaris

Esempi di PaaS

Table 4.2 Five Public Cloud Offerings of PaaS [10,18]

Cloud Name	Languages and Developer Tools	Programming Models Supported by Provider	Target Applications and Storage Option
Google App Engine	Python, Java, and Eclipse-based IDE	MapReduce, web programming on demand	Web applications and BigTable storage
Salesforce.com's Force.com	Apex, Eclipse-based IDE, web-based Wizard	Workflow, Excel-like formula, Web programming on demand	Business applications such as CRM
Microsoft Azure	.NET, Azure tools for MS Visual Studio	Unrestricted model	Enterprise and web applications
Amazon Elastic MapReduce	Hive, Pig, Cascading, Java, Ruby, Perl, Python, PHP, R, C++	MapReduce	Data processing and e-commerce
Aneka	.NET, stand-alone SDK	Threads, task, MapReduce	.NET enterprise applications, HPC

Esempi di SaaS

- Software applicativo utilizzato via browser HTML
- Alcuni esempi:
  - Google Gmail, Docs, Photos, etc.
  - Microsoft Office365
  - Customer Relationship Management software da Salesforce.com

Conclusioni

- La conclusione di un (lungo) viaggio
- Calcolo scalabile su internet
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