Cloud Computing
- Overview -

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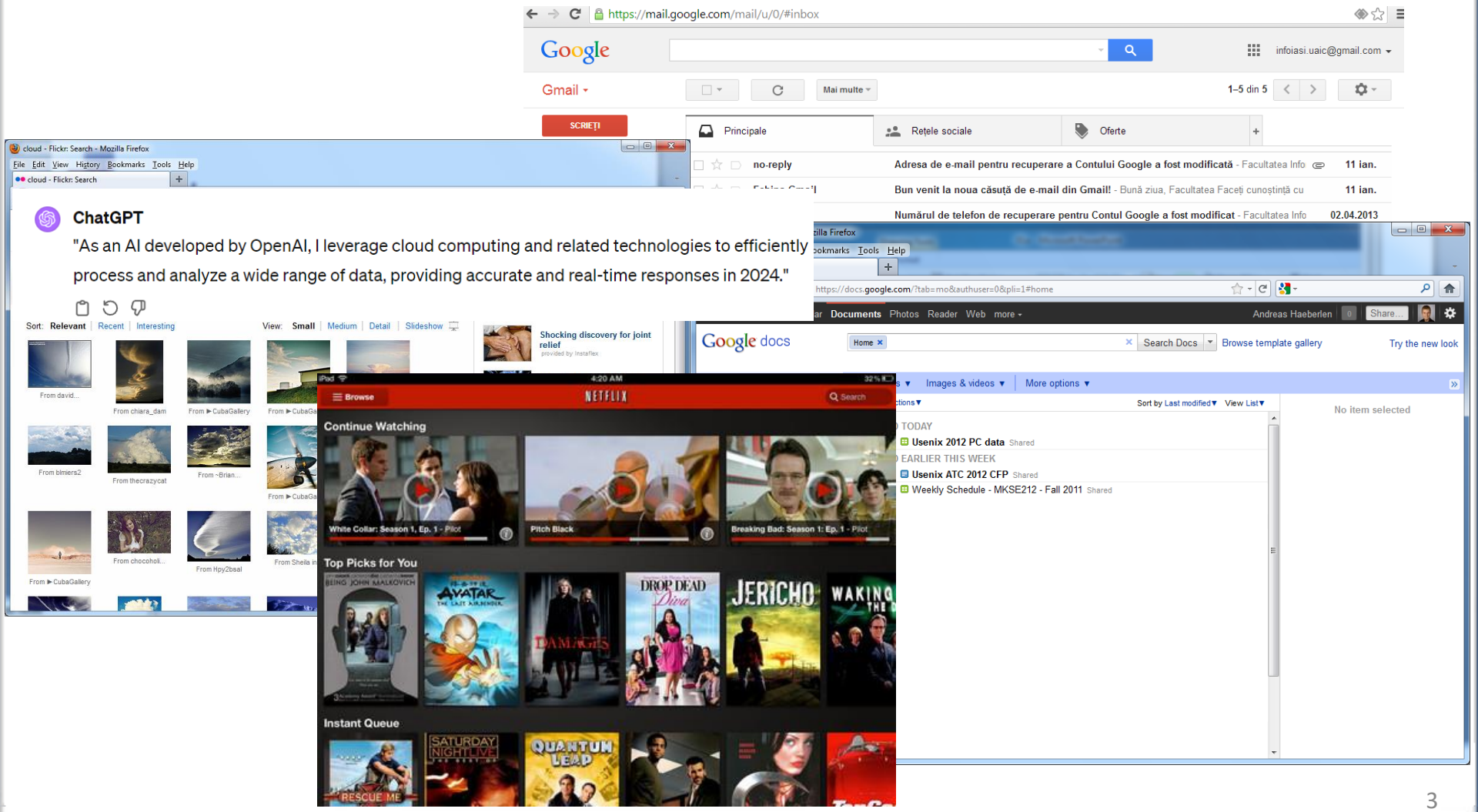
Content

- Why Cloud Computing?
- History & Evolution
- Grid/Cluster computing – general aspects
- Cloud Computing – definitions
- Grid versus Cloud
- Cloud Computing - aspects

Cloud Computing

- Do you use Cloud Computing?



Cloud Computing

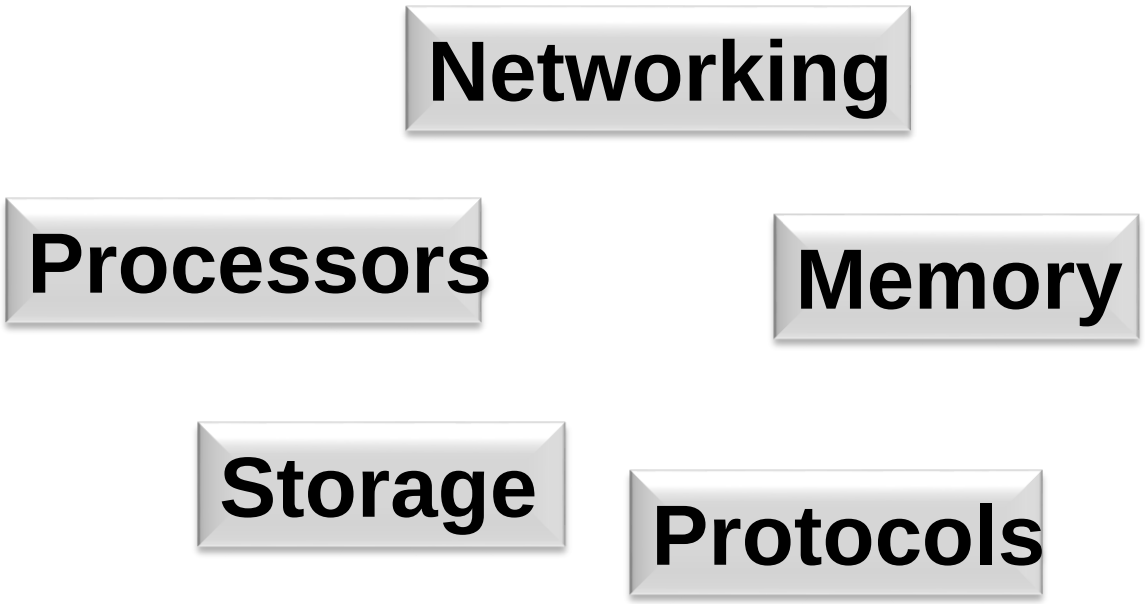
- Cloud computing “in your pocket”?

Why Cloud Computing?

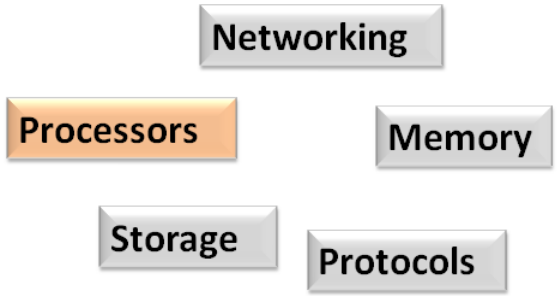
- Understanding the basic principles
  - How something scalable can be built?
  - Various development environments
- What is behind a Cloud Platform?
  - How does it work? Advantages? Disadvantages?
  - Technologies: Web Services, SOA, Ajax, XML, NoSQL, MapReduce,….
- Would you like to build the ‘next’ Facebook or ‘next” ChatGPT?
  - Scalability, efficiency, fault tolerance, security,…
- Knowing the impact on society
  - Vulnerabilities, security issues,
- Anticipating a possible future
- How do we reach Cloud Computing? (Now☺)

History & Evolution

- 1945-1985: “computers were large and expensive”
- … improvements:

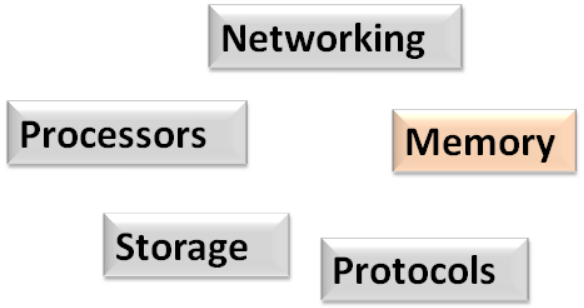


History & Evolution



- Microprocessor industry (8-biti, 16, 32, 64,…) has evolved rapidly
- Computers have become
  - Smaller
  - Cheaper
  - Faster
- "…from machine that cost 10 million dollars and executed 1 instruction per second (IPS) we have come to machines that cost 1000 dollars and are able to execute 1 billion instructions per second, a price/performance gain of 1013"
- "In 2019, Google announced that its *Sycamore quantum* computer had completed a task in 200 seconds that would take a conventional computer 10,000 years."
  - IBM's 127-qubit Eagle processor (Nov 2021) https://www.newscientist.com/article/2297583-ibm-creates-largest-ever-superconducting-quantum-computer/

History & Evolution

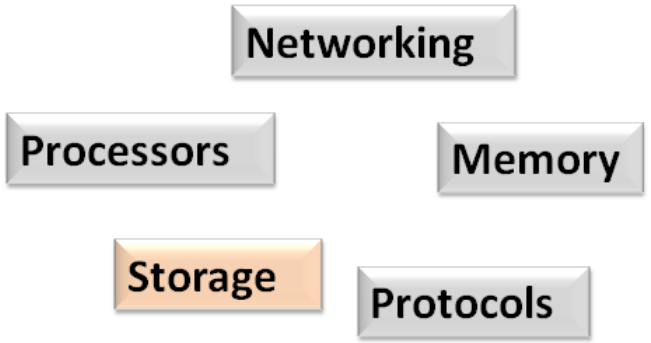


Year	Cost ($/MB)	Capacity (average)
1977	$32,000	16K
1987	$250	640K-2MB
1997	$2	64MB-256MB
2007	$0.06	512MB-2GB+
2014	$0.0091	8GB->…
2024	$0.000…	32Gb->

[http://www.cs.rutgers.edu/~pxk/]

[http://www.statisticbrain.com/average-historic-price-of-ram/]

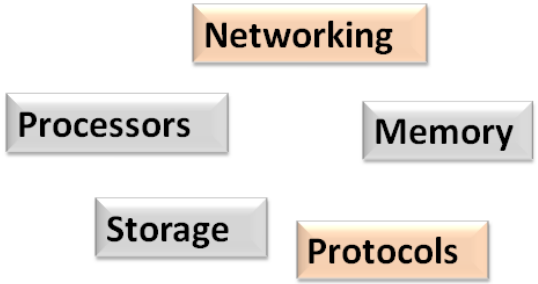
History & Evolution



- 1977: 310KB floppy drive ~ $1480
- 1987: 40 MB drive ~ $679
- 2008: 750 GB drive ~ $99
- 2024: 3-4TB drive ~ $100
- *"Areal density is a measure of the quantity of information bits that can be stored on a given length of track, area of surface, or in a given volume of a computer storage medium - TPI (tracks per inch) or bits per inch."*
- *"Recording density increased over 60,000,000 times over 50 years"*

[http://www.cs.rutgers.edu/~pxk/]

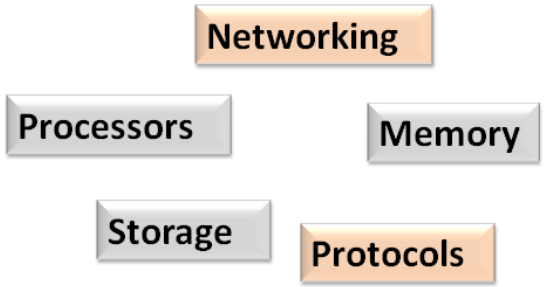
History & Evolution



1961-1972: first communication's attempts using packet-switching

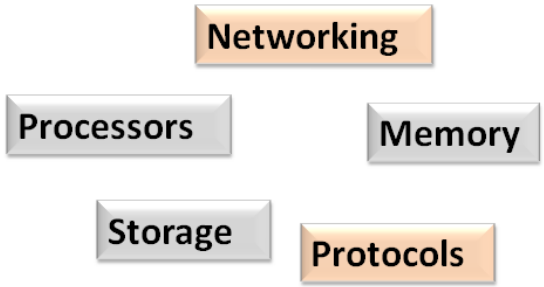
- 1961: Kleinrock – proposed a theoretical model
- 1964: Baran – implemented the communication among US military computers
- 1967: ARPAnet was projected by Advanced Research Projects Agency
- 1969: first operational node ARPAnet, a network formed by 4 computers
- 1972:
  - public demonstration of ARPAnet technologies
  - NCP (Network Control Protocol) – the first host-host protocol
  - First program for electronic mail (e-mail)
  - The sign @ is introduced
  - ARPAnet contains 15 nodes

History & Evolution



- **1972-1980: The *Internetworking* concept appeared. Also, proprietary networks appeared.**
- 1973: DARPA (Defense Advanced Research Projects Agency) – interconnected networks; Robert Metcalf (Hardvard) developed Ethernet technology that allowed data transfer using coaxial cable
- 1974: Cerf and Kahn – proposed a communication protocol entitled TCP (Transmission Control Protocol)
- 1978: TCP/IP protocols stack was standardized via RFC (Request For Comments) documents
- In the late 70s: proprietary networks stacks appeared: DECnet, SNA, XNA
- 1979: ARPAnet contained 200 nodes

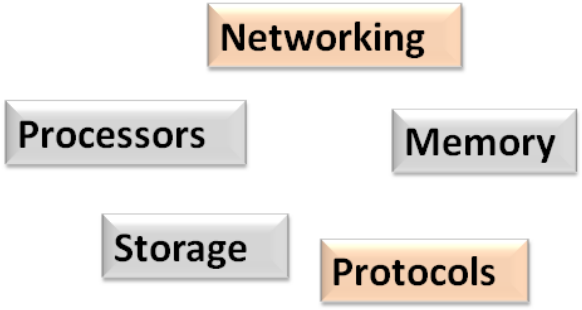
History & Evolution



- **1980-1990: new protocols, the network number was increasing, Internet**
- 1983: TCP/IP was used
- 1982: SMTP (Simple Mail Transfer Protocol) was defined
- 1983: DNS (translation of host name into IP address and vice versa) appeared
- 1985: FTP(File Transfer Protocol) protocol appeared
- 1986: **Internet backbone appeared**
- 1988: some congestion control mechanisms for TCP

were introduced

History & Evolution



LAN – speed:

- Original Ethernet: 2.94 Mbps
- **1985**: thick Ethernet: 10 Mbps; 1 Mbps with twisted pair networking
- **1991**: 10BaseT - twisted pair: 10 Mbps
- **1995**: 100 Mbps Ethernet
- **1998**: 1 Gbps (Gigabit) Ethernet
- **1999**: 802.11b (wireless Ethernet) standardized
- **2001**: 10 Gbps introduced
- **2005**: 100 Gbps (over optical link)
- **2024**: … Gbps & Tbps (e.g. giant networks in the research and education space: Internet 2 in SUA - https://internet2.edu, GEANT in Europe - https://geant.org/)

Huge amount of data can be transferred among computers

History & Evolution

Top 10 Countries with the Fastest Mobile Internet Speeds (Mbps) - 2021

Country	Mobile Speed
United Arab Emirates	269.41
Qatar	206.80
Kuwait	191.74
China	164.14
Macau	155.75
Norway	146.02
South Korea	145.25
Denmark	143.63
Bulgaria	142.07
Iceland	139.52

Top 10 Countries with the Fastest Broadband Internet Speeds (Mbps) - 2021

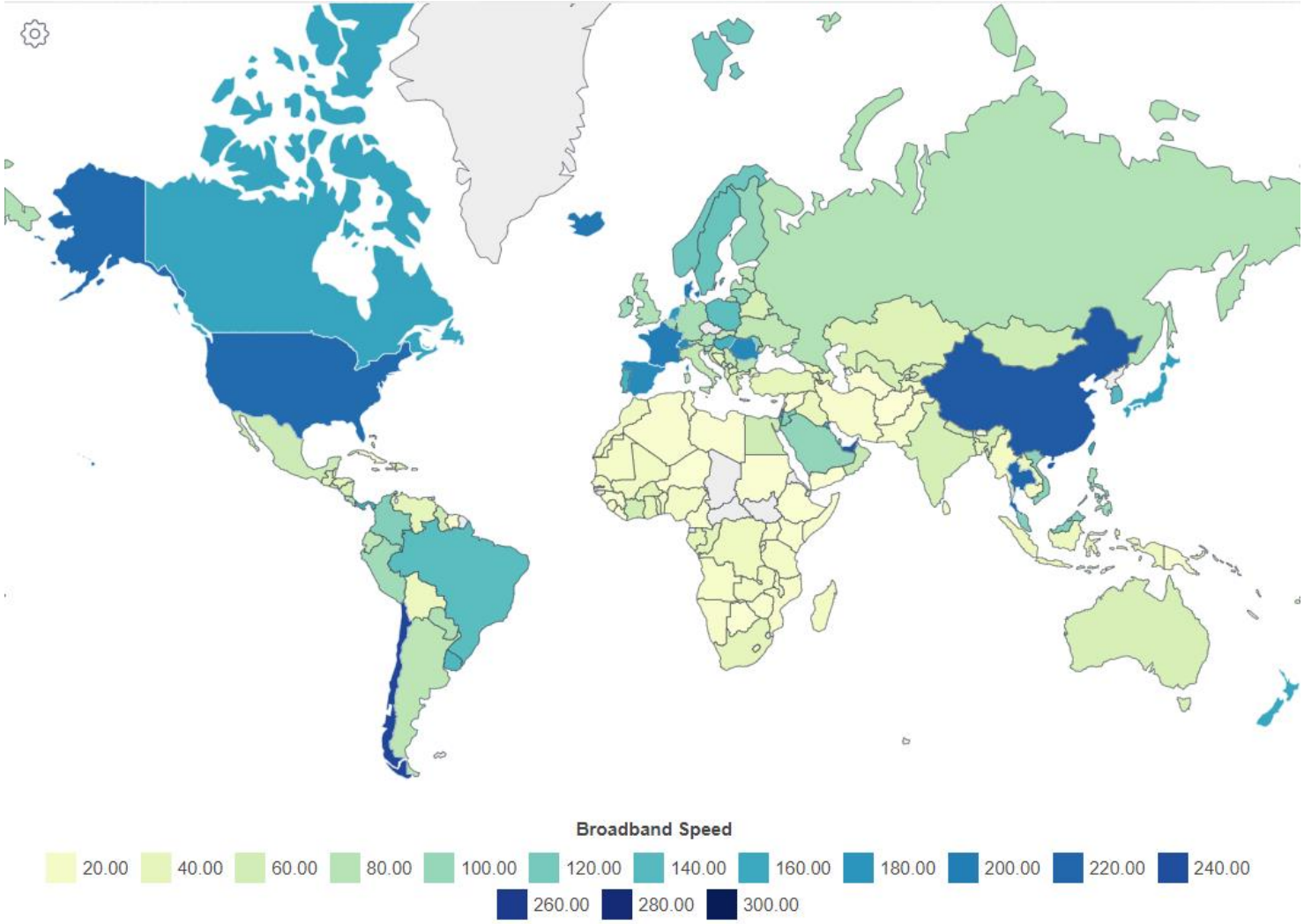
Country	Broadband Speed
Singapore	264.15
Hong Kong	263.07
Chile	248.65
United Arab Emirates	235.72
China	230.39
Thailand	218.94
United States	215.72
Denmark	206.80
Iceland	204.80
France	200.99

"According to internet speed specialists Ookla (https://www.speedtest.net/) the global average download speed on fixed broadband as of September 2021 was 113.25 Mbps on fixed broadband and 63.15 Mbps on mobile. These are both notable improvements over the scores of 85.73 Mbps broadband and 35.96 Mbps mobile just one year earlier in September 2020"

[https://worldpopulationreview.com/country-rankings/internet-speeds-by-country]

Huge amount of data can be transferred among computers

History & Evolution



[2024 | https://worldpopulationreview.com/country-rankings/internet-speeds-by-country]

Huge amount of data can be transferred among computers

History & Evolution

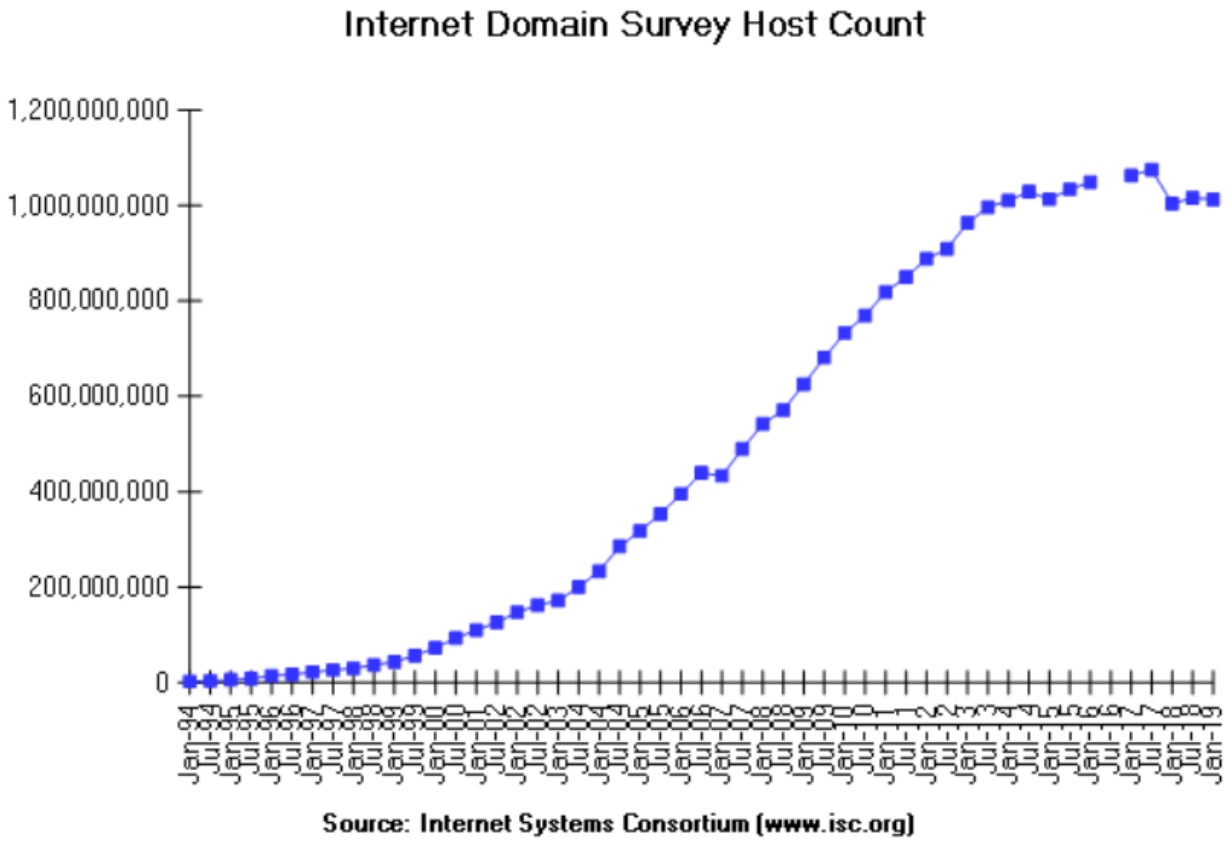
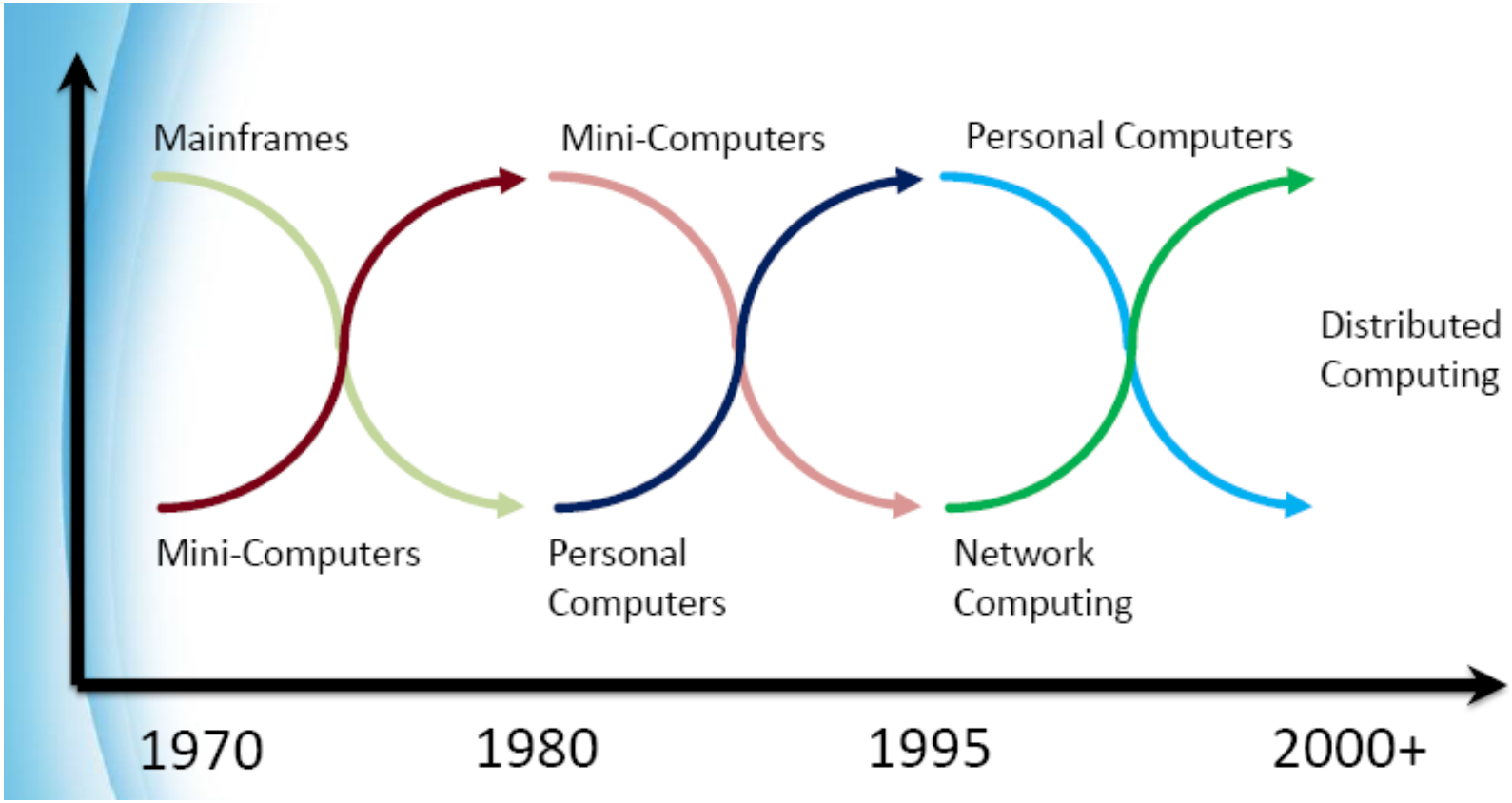


Figure. Hosts number form January 1994 till January 2019
Source: Feb 2020| https://www.isc.org/network/survey/

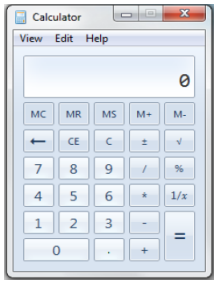
Trends

* From supercomputers to workstations that can be connected together



What means *computing?*

- Computing



- The way one thinks

In computer science?

- *"we can define computing to mean any goal-oriented activity requiring, benefiting from, or creating computing machinery. It includes the study and experimentation of algorithmic processes, and development of both hardware and software."*

… *Computing*?

*"… computing may someday be organized as a public utility just as the telephone system is a **public utility**... The computer utility could become the basis of a new and important industry."*–John McCarthy (a professor of MIT) 1961.

*"As of now, computer networks are still in their infancy, but as they grow up and become sophisticated, we will probably see the spread of **computer utilities** which, like present electric and telephone utilities, will service individual homes and offices across the country.*–L. Kleinrock(one of the chief scientists of the original ARPANET project) 1969" –John McCarthy (a professor of MIT) 1961.

… *Computing*?

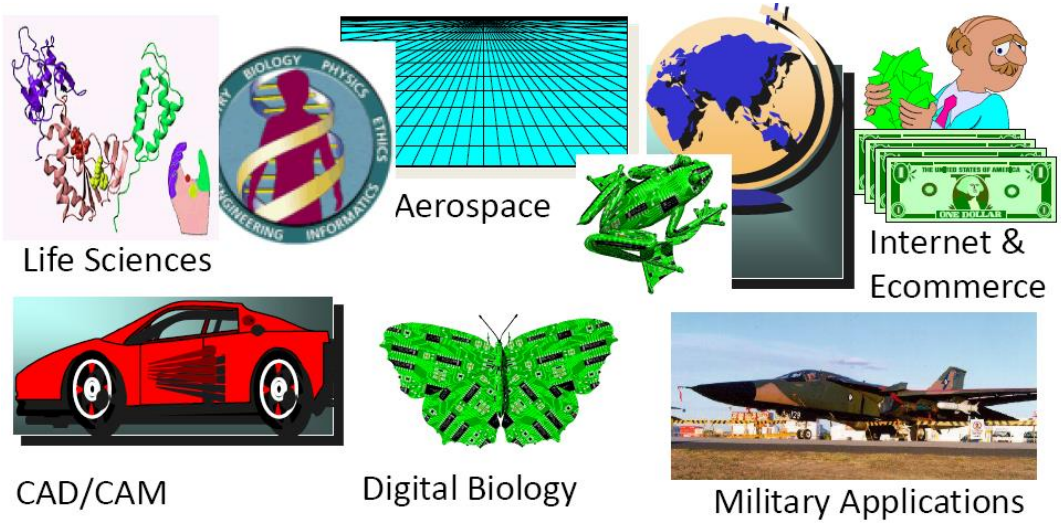
"it was transformed in a model consisting of consumer services (commodity computing) and can be provided in a manner similar to traditional utilities "

Fifth *utility -> Utility Computing* or "*Computing as a Utility*"

Computing Power ?

Required:

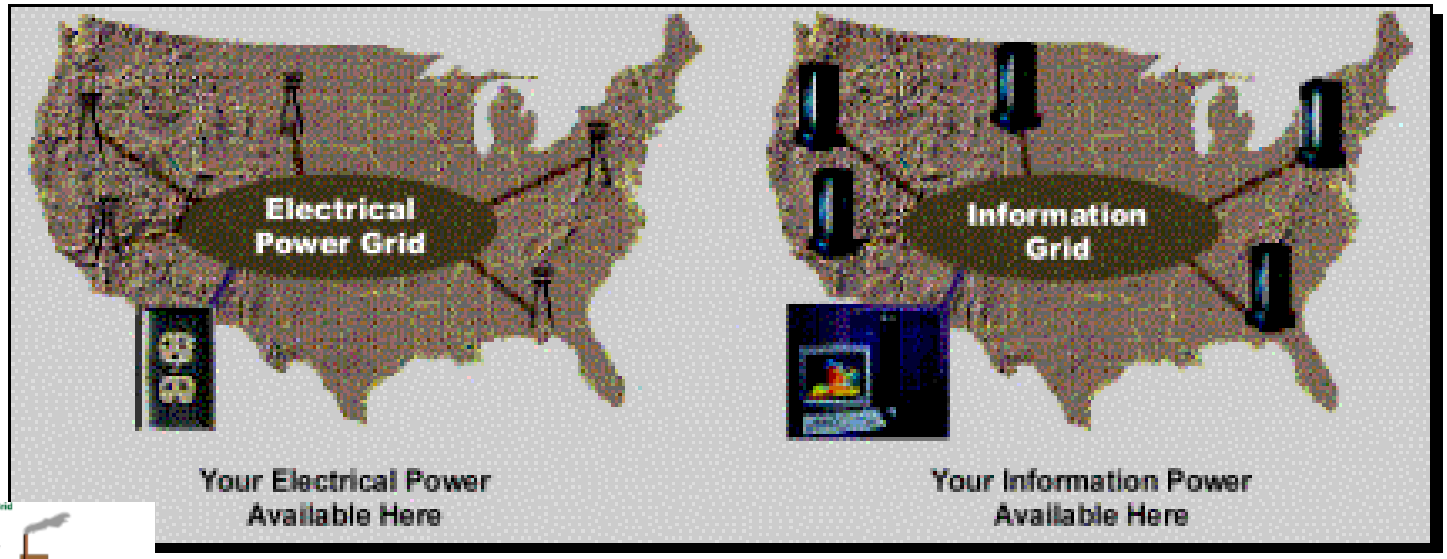
- solving problems involving modeling, simulation and analyzes

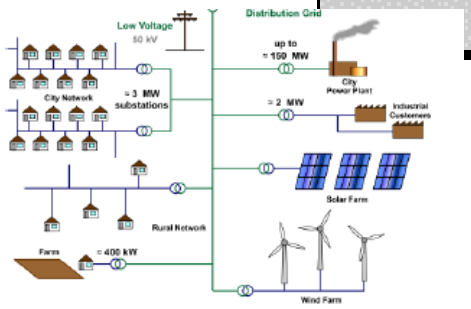


- Using unoccupied resources:
  - in the 90s almost 90% of a processor power was not used
  - the possibility to solve a wide variety of problems at affordable prices
  - cost/performance report in relation with a super-computer (HPC - high performance computer) => ….

Grid Computing

- The Grid concept appeared in the 90s (Foster and Kesselman)
  - In analogy with *electric power grids ~ 1910*





Grid Computing

- Foster and Kesselman (1998): "*A computational grid is a hardware and software infrastructure that provides dependable, consistent, pervasive, and inexpensive access to high-end computational capabilities.*"
- *"The Grid is an emerging infrastructure that will fundamentally change the way we think – and use – computing. The word Grid is used by analogy with the electric power grid, which provides pervasive access to electricity and, like the computer and a small number of other advances has had a dramatic impact on human capabilities and society. Many believe that by allowing all components of our information technology infrastructure – computational capabilities, databases, sensors, and people – to be shared flexibly as true collaborative tools, the Grid will have a similar transforming effect, allowing new classes of application to emerge."* (Foster and Kesselman 2004)

Grid Computing

- Distributed computing architecture originally designed scientific projects and then the industrial ones
- Offers the existance of a software and hardware infrastructure which allows: permanent and affordable access in a consistent manner to computing resources
- Offers various mechanism to process data in a distributed manner
- Allows the execution of tasks on multiple machines that can be viewed as a single computer
- Offers support for searching and retrieving information, regardless of their physical location
- Offers the context to create VO - *virtual organizations* – which shares application, data in an open and heterogeneous environment in order to solve various complex problems

It is shared: *Computing/processing power, Data storage/networked file systems, Communications and bandwidth, Application software, Scientific instruments*

Grid Computing|Initiative

- GridPP (UK Computing Grid for Particle Physics) - http://www.gridpp.ac.uk/
  - Contributes with over 40.000 PCs as part of the largest Grid in the world- LCG (LHG Computing Grid)

    LHG = Large Hadron Collider (CERN, din 2007)
  - It was part of EuroGrid project
- Worldwide LHC Computing Grid (WLCG) - provide global computing resources for the storage, distribution and analysis of the data generated by the LHC
- WLCG combines the computing resources - 900 000 computer cores from over 170 sites in 42 countries, producing a massive distributed computing infrastructure that provides more than 12 000 physicists around the world with near real-time access to LHC data, and the power to process it.
- It runs over 2 million tasks per day and global transfer rates regularly exceeded 60 GB/s.
- **https://home.cern/science/computing/grid**

Grid Computing

- Terminology:
  - *Grid middleware* – software level providing the required functionalities needed for heterogeneous resources sharing and creating a virtual organization
  - *Grid infrastructure* – refers to the combination of hardware and Grid middleware which transforms disparate and heterogeneous computing resources in a virtual infrastructure that offers the view of a single machine to the end user
  - *Utility computing* – Grid Computing and applications are provided as services (e.g. *hosting* solutions for VO, et. al.)
    - Utility computing is based on business *pay-per-use* model

Grid Computing| Architecture

- Grid Architectures use simultaneously a large number of resources (hardware, software, logical)
- Resource – a sharing entity that can be present in a Grid infrastructure:
  - Computation: PDA, PC, workstation, server, cluster,…
  - Storage: hard disk, RAID, NAS, …
  - I/O type: sensors, networks, printers etc.
  - Logical: timers, job scheduling, logging and tracing instruments, …
- Obs. Systems as: scientific instruments or HPC can be part of a Grid
- A Grid architecture focuses on interoperability issues, communication protocols between suppliers and the resource used in order to establish sharing relationships

Grid Computing| Architecture

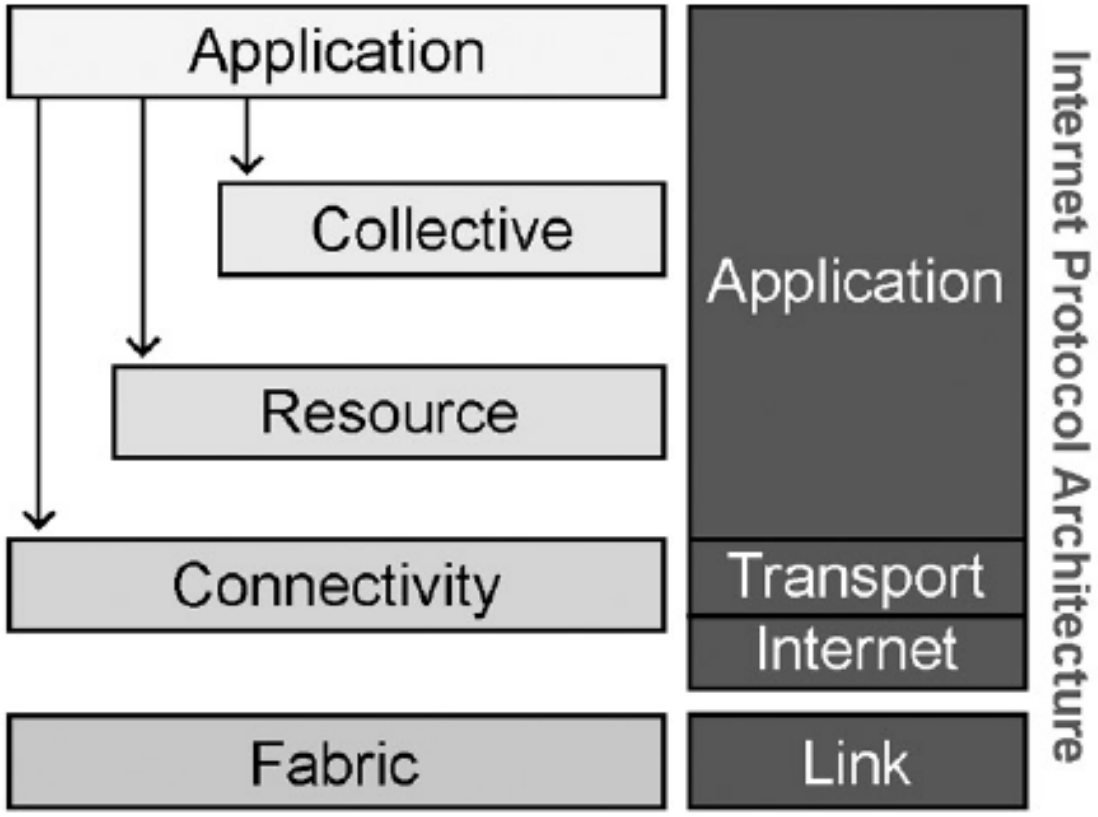
- Generic Grid architecture

"Coordinating multiple resources": ubiquitous infrastructure services, app-specific distributed services

"Sharing single resources": negotiating access, controlling use

"Talking to things": communication (Internet protocols) & security

"Controlling things locally": Access to, & control of, resources



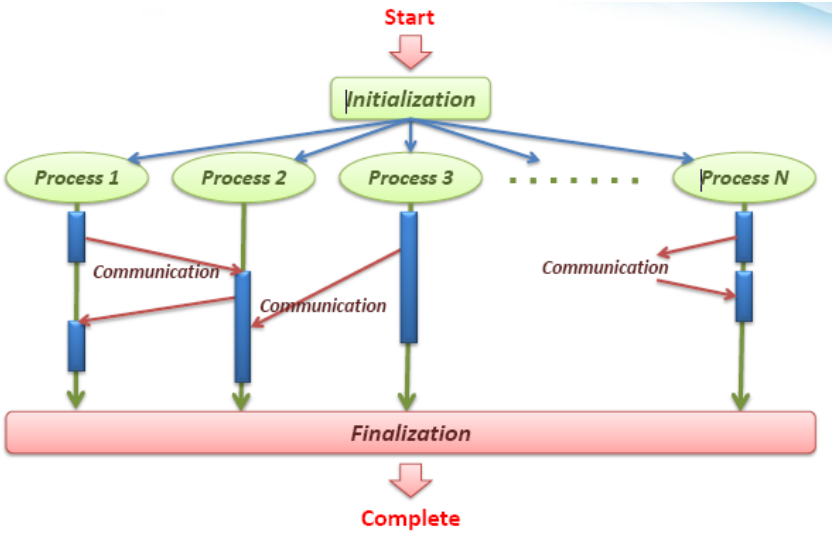
Grid Computing|Classification

- Classifications:
  - In relation to the type of managed resources
    - Compute Grid – used to share computing resources (e.g. CPU) - Examples: intensive graphic processing
    - Data Grid – focused on storage, management and sharing of distributed and heterogeneous resources
    - Application Grid – focused on application management and transparently providing remote access to software and libraries; Example: grids in the bioinformatics field or earth science
    - Service Grid – resulting from Grid and SOA convergence, offers support to share services in an efficient manner
  - In relation to the resource sharing domain:
    - Cluster Grid
    - Enterprise Grid
    - Utility Grid Services
    - Partner/Community Grids

Grid Computing|Classification

- **Cluster Grid**
  - Enables full use of computer resources (*mainframe*s, PCs, laptops, *smartphone*s, ...)
  - Cluster = set of computers– from a LAN – which form a unique computing resource

▪Obs. Clusters offer no implicit sharing of resources (improves computing capacity and storage level), and may be considered the first step towards Grid Computing



Typical flow for parallel executions

[A. S. Tanenbaum, M.Steen, DISTRIBUTED SYSTEMS]

Grid Computing|Classification

- **Enterprise Grid**
  - Facilitates resource sharing among multiple departments within an organization (even a virtual one)
    - Politics for resource management
  - It is called *intra grid* or *campus grid*
  - Example: Novartis - Pharmaceutical company
    - Held in 2003 an infrastructure consisting of thousands of desktop
    - Pilot Grid Project : 2003, Basel (Elvetia), 50 *PC*s "*Grid enabled*" connected to the existing nodes (Goal: determining the protein structure)
      - In each node there was an agent that checks the system load
      - => Result: a week of running in Enterprise Grid led to results that could be obtained in 3.18 years
    - 2700 PCs (Basel, Viena, Cambridge)

Grid Computing|Classification

- **Utility Grid**
  - The Grid environment is developed and managed by a service provider
  - The usage of computing power or storage services is in *pay-per-user manner*
  - Functionality: the user does not have the Grid, he has no control over operations
    - Data and various computing operations are transmitted and then the result is expected
    - => security and *privacy problems*
    - *=> reliability problems*
    - => unnecessary IT infrastructure investments
    - => Utility Computing offers scalability and flexibility on request
  - Examples:
    - Sun Grid Compute Utility from 2006
      - *Pay-per-use*: 1$/CPU per hour
      - Latter it offered support for applications
    - HP Labs offers Utility Computing for DreamWorks

Grid Computing|Classification

- **Partner/Community Grid**
  - Provides support for building VO layering on shared IT infrastructure
  - The architecture can be viewed as a collection of independent resources (e.g. Cluster Grids) that are interconnected in a global Grid middleware
  - *Partner grids* – are established among companies and universities that have a common goal
    - It defines sharing politics for resources
  - Community Grids – relay on the donation of resources (often from private individuals)
    - Example: SETI@HOME

- **Vision: Open Global Grid**
  - Represents a collection of heterogeneous Grids geographically distributed over a wide area – continent or planet
    - Global Use Policy
    - General protocols for resource sharing
    - => no additional configuration is required for access

Grid Computing| Evolution

- Generation 1 – Globus project (Goble & Foster)
  - Applications requiring high computing power
  - Includes protocols (LDAP, FTP) and heterogeneous development tools
  - Support for access and files transfer
  - Use Internet technologies, but ignore the Web
  - Employed mainly in academic environment
  - Sharing resources is achieved via GridFTP
  - Implementations: …Legion, Condor, Unicore, ….

Grid Computing| Evolution

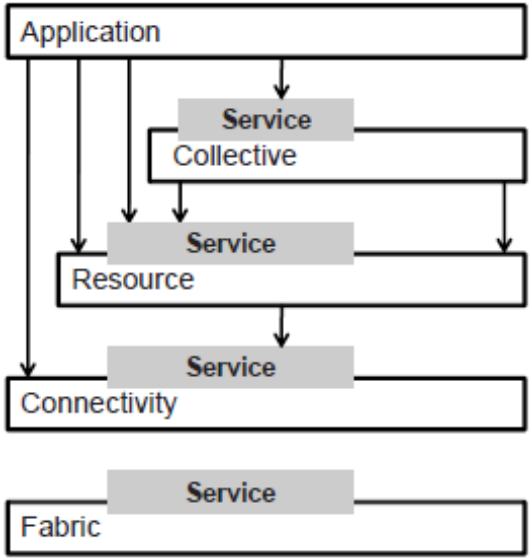
- Generation 2 – OGSA (*Open Grid Services Architecture*)
  - There is convergence of Service-oriented computing (SOC) and Grid Computing

"Service-oriented Computing (SOC) is a new computing paradigm that utilizes services as the basic construct to support the development of rapid, low-cost and easy composition of distributed applications even in heterogeneous environments. The visionary promise of Service-Oriented Computing is a world of cooperating services where application components are assembled with a little effort into a network of services that can be loosely coupled to create flexible dynamic business processes and agile applications that may span organisations and computing platforms." (Papazoglou et al. 2006)

- We notice the interoperability and sharing vision of SOC at application lever versus Grid computing vision mainly at hardware level
  - Generation 1: Grid Computing architecture consists of protocols and services used to describe and share available physical resources
  - By using Web Services Standard (such as: WSDL, SOAP, BPL4WS,…) Grid protocols and Services can be described in a standardized manner

Grid Computing| Evolution

- Generation 2 – OGSA (*Open Grid Services Architecture*)



- Using the same standards => it was possible the convergence between Grid Computing and SOC => besides hardware and system resources, the applications have become shareable

- OGSA:

"Building on concepts and technologies from both the Grid and Web Services communities, OGSA defines a uniform exposed service semantics (the *Grid Service*); defines standard mechanisms for creating, naming, and discovering transient Grid service instances; provides location transparency and multiple protocol bindings for service instances; and supports integration with underlying native platform facilities." (Foster et al. 2002)

Implementation

- Generation 2 – OGSA (*Open Grid Services Architecture*)

  Grid services must be:

  – **Dynamic and volatile** – set of composed services that can be invoked or removed "on the fly"

  – **Ad-hoc** – there is no central location or central control

  – **Widespread**– orchestrating a large number of services (> 100) should be performed anytime

  – **Available** – potentially long-term (e.g. a simulation can take weeks)

  – OGSI (Open Grid Service Infrastructure)

    - OGSA Infrastructure - "accommodates" interactions between Grid resources and Web Services
    - Model implemented by Globus Toolkit 3.0

    » OGSI was replaced by WSRF (Web Service Resource Framework): WS- Security, WS- Management and other standards for Web Services => Globus 4.0

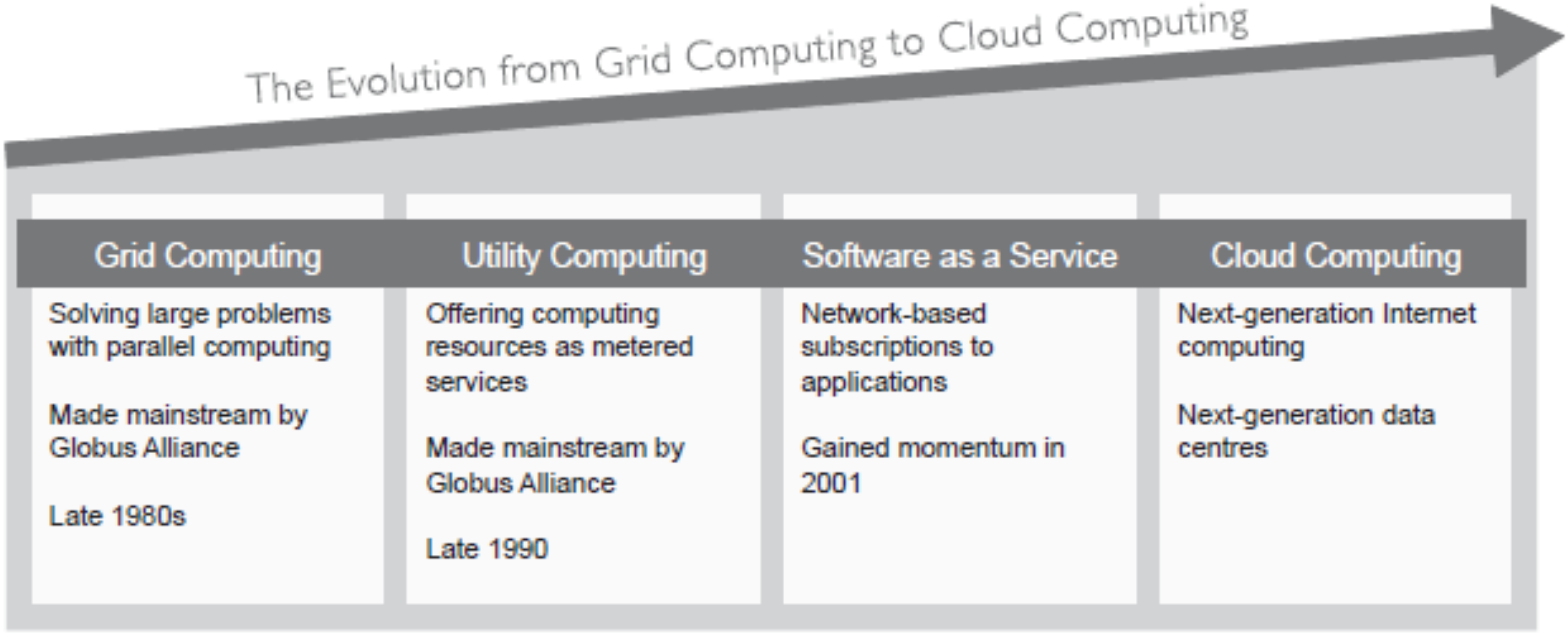
Grid Computing| Evolution

- **Generation 3 – present and future**
  - Convergence of Grid Computing and SaaS (Software-as-a-Service) paradigm
  - SaaS
    - Designates software that is owned, delivered and managed by a provider
    - It is used in the *pay-per-use* principle via a Web browser or APIs
    - Versus traditional software
      - The user pays for the time of use
      - The user does not have the software, he does not invest in the infrastructure or licenses
    - History: Application Service Provisioning (ASP) – appeared in 1988
      - It was a step for IT outsourcing and it came with the idea of Web applications that could be provided by a central supplier (one-to-many delivery model)
        - The main problem: the inability to provide personalized services
        - Issues regarding scalability, robustness, …

Grid Computing| Evolution

- Generation 3 – present and future
- ASP problems can be solved by using Grid Computing + Web Services
  - Web Services allows services personalization
  - Grid Environment offer flexibility and scalability

  => *many-to-many delivery model*



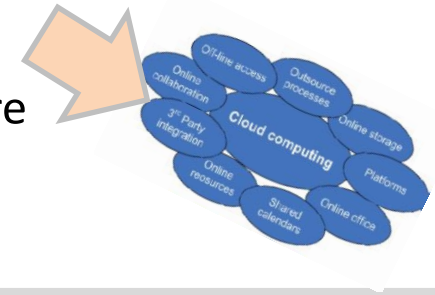
The Evolution to Cloud Computing (adapted from IBM 2009)

[Grid and Cloud Computing - A Business Perspective on Technology and Applications, 2010]

Present and future

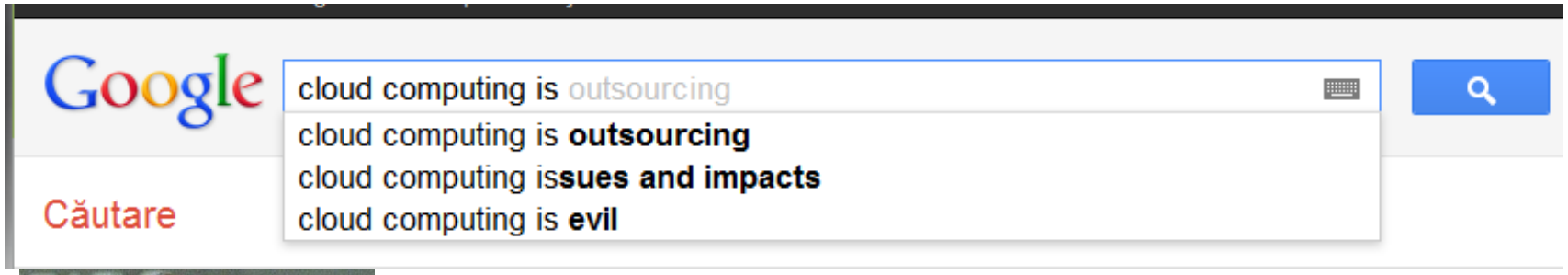
Overview

- Two directions of evolution:
  - Grid Computing
    - Mature technology
    - It provides computational power in *pay-per-use manner* => new business models for *utility computing*
    - There were many initiatives at hardware level: Sun, IBM, etc.
  - There were many initiatives at software level -> SaaS
    - Microsoft, SAP et. al.
- ? **Next step…**
  - A scalable , robust and reliable physical infrastructure,
  - Services that provide developers access to infrastructure by manipulating abstracted interfaces
  - SaaS running on a flexible and scalable infrastructure



Cloud Computing

- What is?

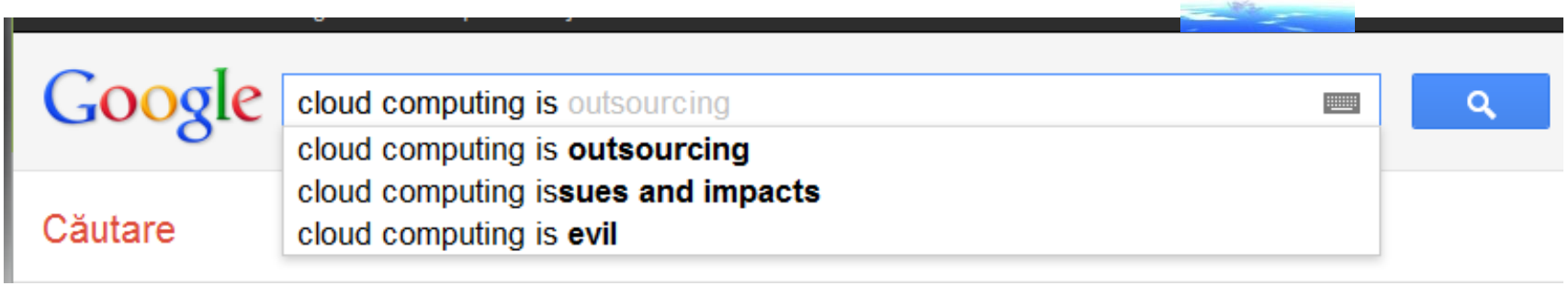


Larry Ellison, founder of Oracle

"We've redefined Cloud Computing to include *everything that we already do.* . . . I don't understand what we would do differently in the light of Cloud Computing other than change the wording of some of our ads."

Cloud Computing

- What is?



Richard Stallman
Creatorul GNU

•"cloud computing is evil"
•"I think that marketers like cloud computing because it is devoid of substantive meaning. The term's meaning is not substance, it's an attitude: 'Let any Tom, Dick and Harry hold your data, let any Tom, Dick and Harry do your computing for you (and control it).' Perhaps the term 'careless computing' would suit it better."

Cloud Computing

Definition from the end user perspective:

- "the idea of delivering personal (e.g., email, word processing, presentations.) and business productivity applications (e.g., sales force automation, customer service, accounting) from centralized servers" (Merrill Lynch)

Definition that contains architectural aspects:

- "a service model that combines a general organizing principle for IT delivery, infrastructure components, an architectural approach and an economic model – basically, a confluence of grid computing, virtualization, utility computing, hosting and software as a service (SaaS)"

Cloud Computing

Definition that contains both architectural and final use aspects:

- "Cloud Computing refers to both the applications delivered as services over the Internet and the hardware and systems software in the datacenters that provide those services. The services themselves have long been referred to as Software as a Service (SaaS). The datacenter hardware and software is what we will call a Cloud. When a Cloud is made available in a pay-as-you-go manner to the general public, we call it a Public Cloud; the service being sold is Utility Computing. We use the term Private Cloud to refer to internal datacenters of a business or other organization, not made available to the general public. Thus, Cloud Computing is the sum of SaaS and Utility Computing, but does not include Private Clouds. People can be users or providers of SaaS, or users or providers of Utility Computing." (Berkeley Lab, 2009)

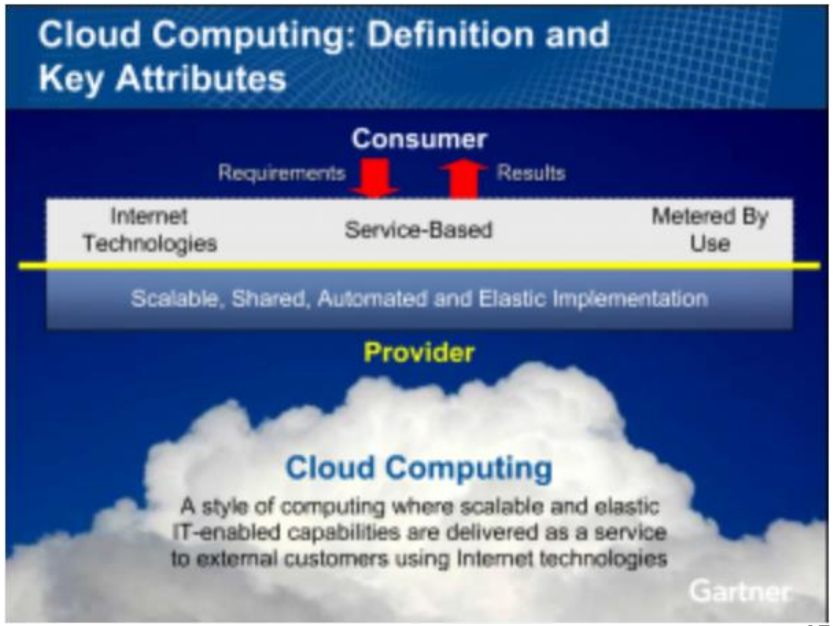
Cloud Computing

Definitions

"a large-scale distributed computing paradigm that is driven by economies of scale, in which a pool of abstracted, **virtualized**, **dynamically-scalable**, managed computing power, storage, platforms, and services are delivered on demand to external customers over the Internet." (Foster et al. (2008))

- http://jameskaskade.com/?p=594

  • "a style of computing in which massively scalable IT-related capabilities are provided "as a service" using Internet technologies to multiple external customers" (Gartner)



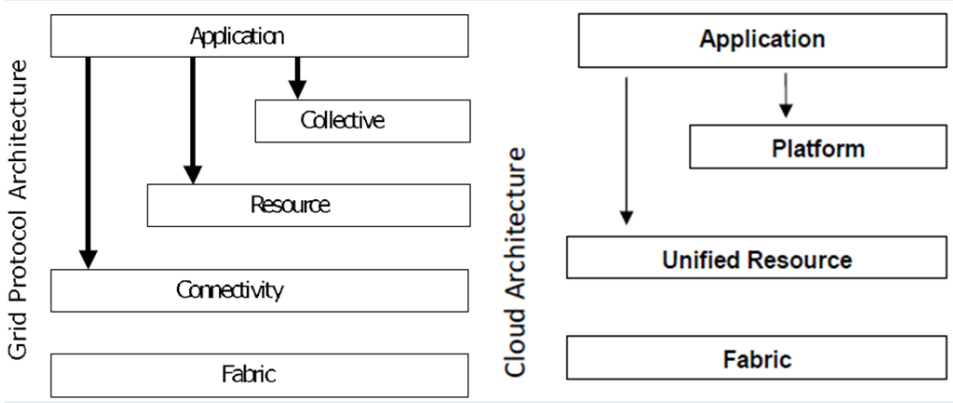
Cloud Computing

The relation with Grid Computing:

- "We argue that Cloud Computing not only overlaps with Grid Computing, it is indeed evolved out of Grid Computing and relies on Grid Computing as its backbone and infrastructure support. The evolution has been a result of a shift in focus from an infrastructure that delivers storage and compute resources (such is the case in Grids) to one that is economy based aiming to deliver more abstract resources and services (such is the case in Clouds)." (Foster et al., 2008)

Cloud Computing

Versus Grid Computing

	Grid Computing	Cloud Computing
Business Model (Traditional: pay only once for the unlimited use of the software)	Grid: project oriented, negotiation, allocate resources depending on the level of the provided services	Cloud: the pay is allocated depending on the consumption (computing, storage, ..)
Arhitectura 	Fabric Level – consists in resources, similar to Grid Unified Resource Level – resources that have been encapsulated (e.g. virtualization) – cluster or virtual system, file system logic, etc. Platform Level- environment to host web, develop the services, etc.	

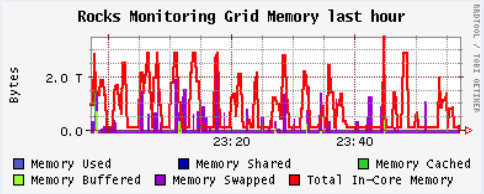
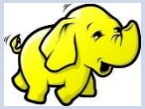
Cloud Computing

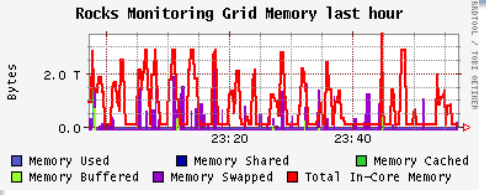
Versus Grid Computing

	Grid Computing	Cloud Computing
Computing Model	*Batch-scheduled* (*queued systems*) Assigning multiple resources/ servers for a **single** task	**Simultaneously** user shared resources, as opposed to dedicated Challenge: QoS
Exploitation pattern	Running programs for a limited amount of time	Frequently used for "long-running services"
Various relationships between resources providers	Main purpose – creating => user policies and agreements (multiple domains)	Overrides this necessity (single domain)
Different purpose	Provides infrastructure as service	Provides IaaS, PaaS, SaaS, … XaaS
Final user perspective	The Grid interfaces are based on protocols and API's oriented to expert users	Provides interfaces available in browser or API.

Cloud Computing

Versus Grid Computing

	Grid Computing	Cloud Computing
Data location – in order to achieve better scalability, the data are distributed on several computers	Based on distributed files systems (NFS, GPFS,PVFS, Lustre)	Based on modern mechanisms and frameworks
Monitoring	Monitoring tools: Ganglia (http://meta.rocksclusters.org/ganglia/) - **Grid Report for Sun, 19 Feb 2012** 	A low granularity control is achieved because virtualization and containerization (there are issues for administrators): self-maintained autonomous clouds
Programming models	Employs flux control tools to manage large quantities of data and tasks (MPICH-G2, GridRPC, …)	Employs a big range of models (e.g. AI Models (LLMs), Hadoop using Pig as programming,…) 



ROCKS

Rocks Monitoring Grid Report for Mon, 4 Mar 2013 21:17:15 -0800

Get Fresh Data

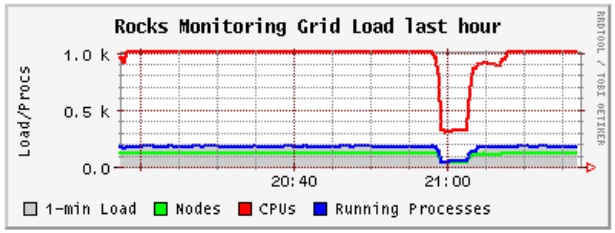
Last hour **Sorted** descending

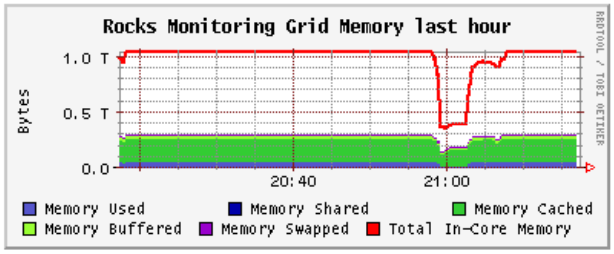
Rocks Monitoring Grid > --Choose a Source

Rocks Monitoring Grid (5 sources) (tree view)

CPUs Total: **1008**
Hosts up: **126**
Hosts down: **5**

Avg Load (15, 5, 1m):
17%, 18%, 18%
Localtime:
2013-03-04 21:17

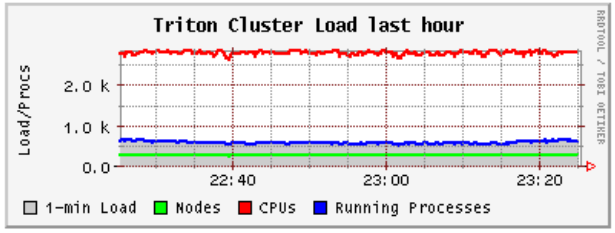


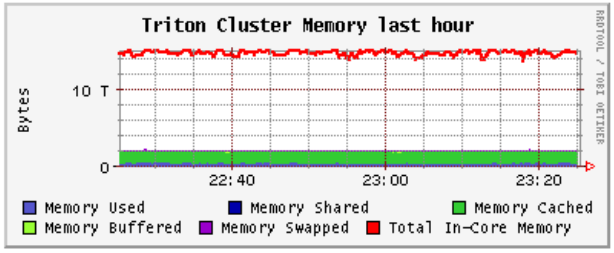


Triton Cluster (physical view)

CPUs Total: **2800**
Hosts up: **268**
Hosts down: **4**

Avg Load (15, 5, 1m):
21%, 22%, 22%
Localtime:
2013-01-04 23:25

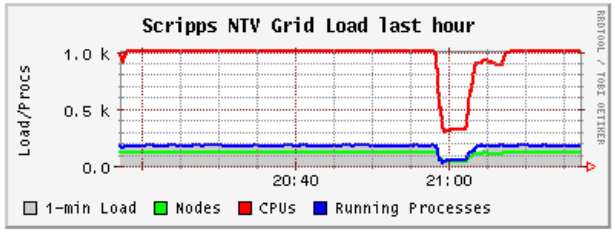


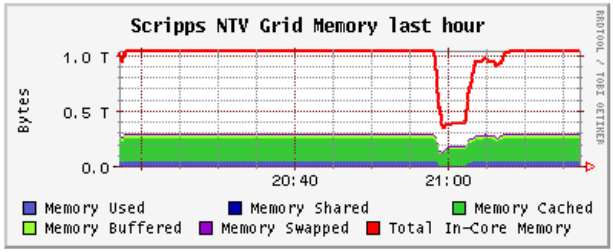


Scripps NTV Grid (tree view)

CPUs Total: **1008**
Hosts up: **126**
Hosts down: **4**

Avg Load (15, 5, 1m):
17%, 18%, 18%
Localtime:
2013-03-04 21:17





Cloud Computing

- "How big is the Cloud?" ☺

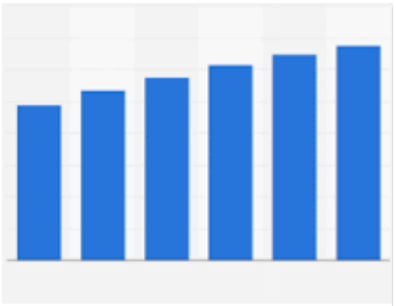
newsroom.fb.com/Key-Facts

Home

News

Key Facts

About Facebook



1.69 billion

In **2020**, the global number of **Facebook users** is expected to reach 1.69 billion, up from 1.34 million in 2014. Nov 15, 2019

www.statista.com › Internet › Social Media & User-Generated Content

Statistics

- 1.13 billion daily active users on average for June 2016

Statistics

- 1.4 billion daily active users on average for December 2017
- 2.13 billion monthly active users as of December 31, 2017
- Approximately 84.5% of our daily active users are outside the US and Canada

press@fb.com

Statistics

945 million monthly active users who used Facebook mobile products as of December 31, 2013.
757 million daily active users on average in December 2013.
Approximately 81% of our daily active users are outside the U.S. and Canada.
1.23 billion monthly active users as of December 31, 2013.

Board Members

Mark Zuckerberg, Founder, Chairman and CEO, Facebook
Marc Andreessen, Co-founder and General Partner, Andreessen Horowitz
Susan Desmond-Hellmann, chancellor of the University of California, San Francisco (UCSF)
Donald E. Graham, Chairman and CEO, The Washington Post Company
Reed Hastings, Chairman and CEO, Netflix

Cloud Computing

- "How big is the Cloud?" ☺

Facebook User Statistics

There are 3.049 Billion Monthly Active Users on Facebook

As of Q3 2023, there are 3.049 billion monthly active users on Facebook, making it the largest app in the world. This is an increase from 12 months prior in Q3 2021 when they had 2.91 billion users.

51.48% of the entire U.S. population are Facebook Users

The U.S. population currently sits at 339.9 million, with an estimated 175 million people in America that have an account on Facebook. And Facebook penetration in the U.S. is on the rise!

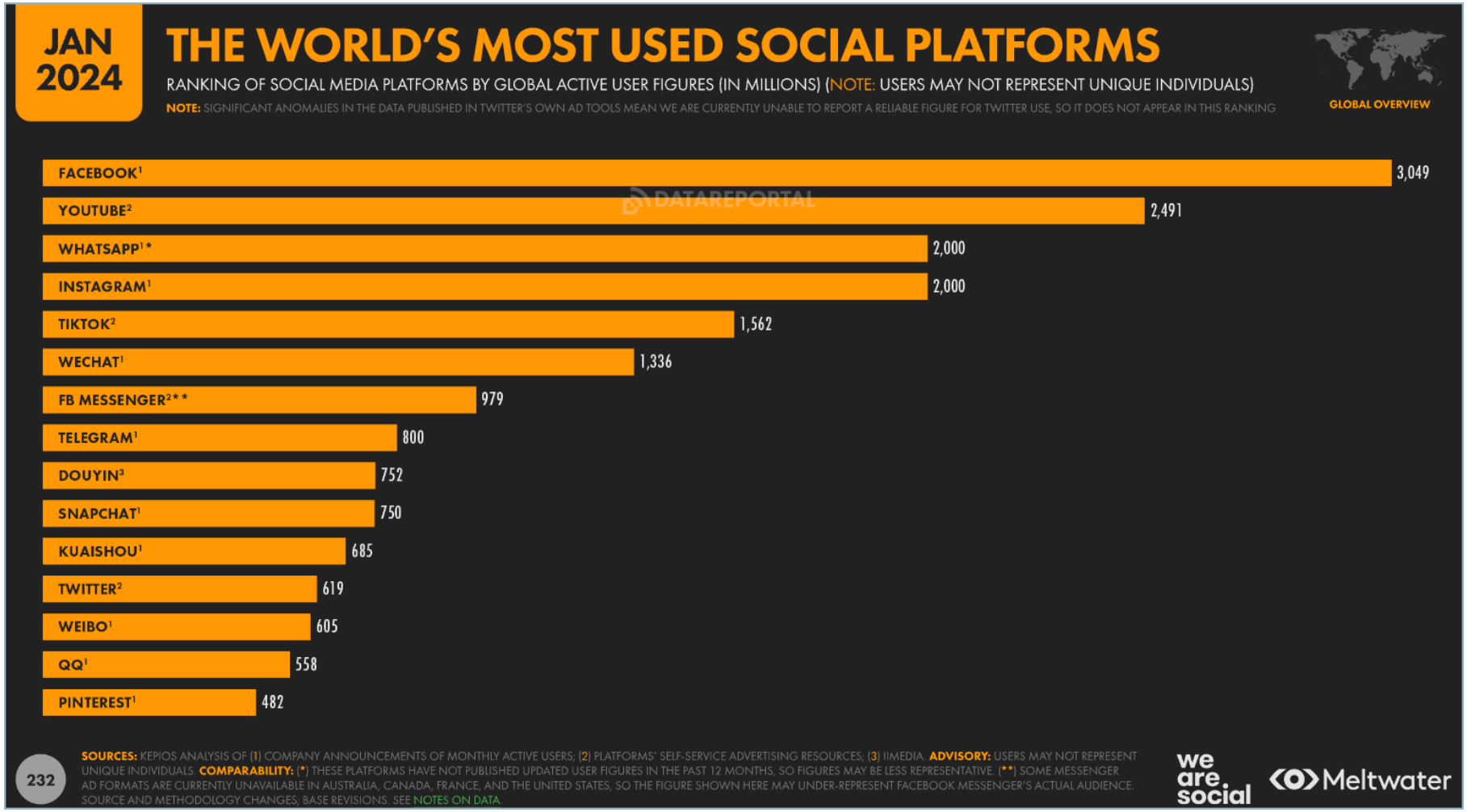
400 users sign up to Facebook every minute

In that same minute, more than 510,000 comments are made, there are 293,000 status updates, 136,000 photos are uploaded, and a whopping 4 million posts are liked. As the site constantly increases and expands, these numbers are sure to only go up.

[https://thesocialshepherd.com/blog/facebook-statistics]

Cloud Computing

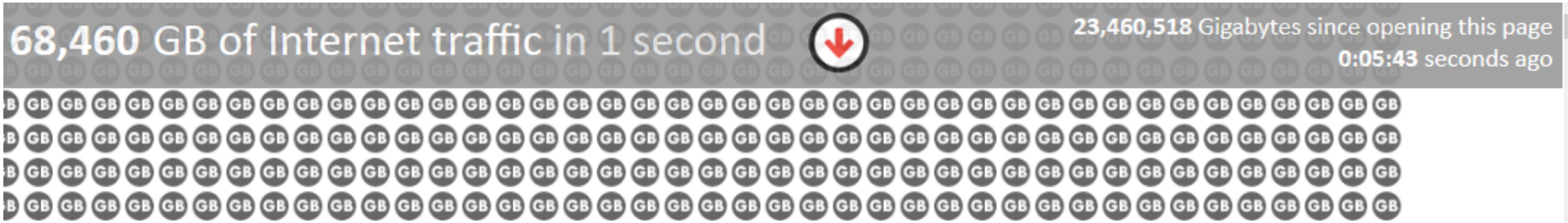
- "How big is the Cloud?" ☺



[https://www.smartinsights.com/social-media-marketing/social-media-strategy/new-global-social-media-research/]

Cloud Computing

- "How big is the Cloud?" 2019☺



[http://www.internetlivestats.com/one-second/#google-band]

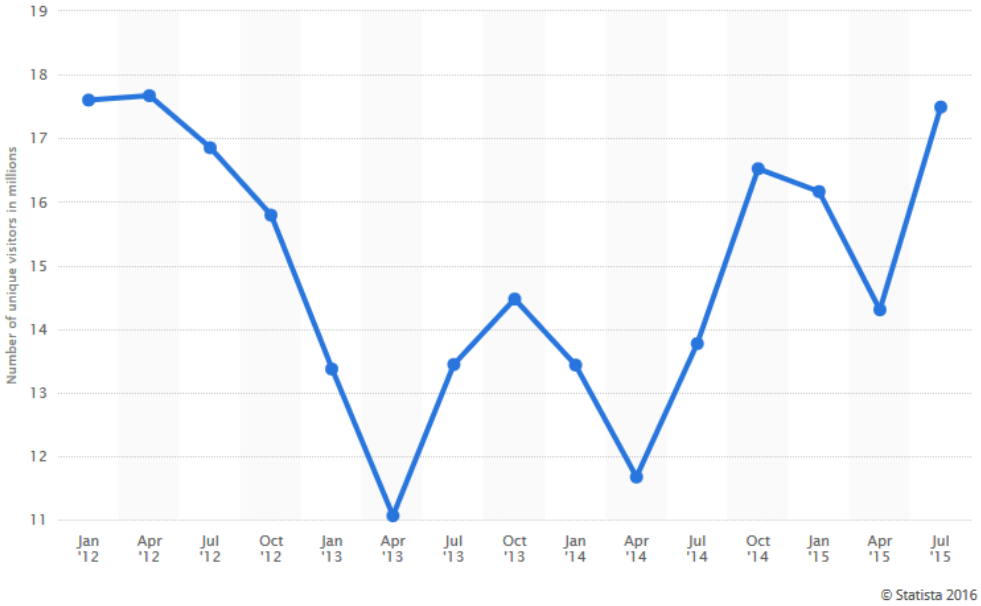
Cloud Computing

- "How big is the Cloud?" 2022☺

[http://www.internetlivestats.com/one-second/#google-band]

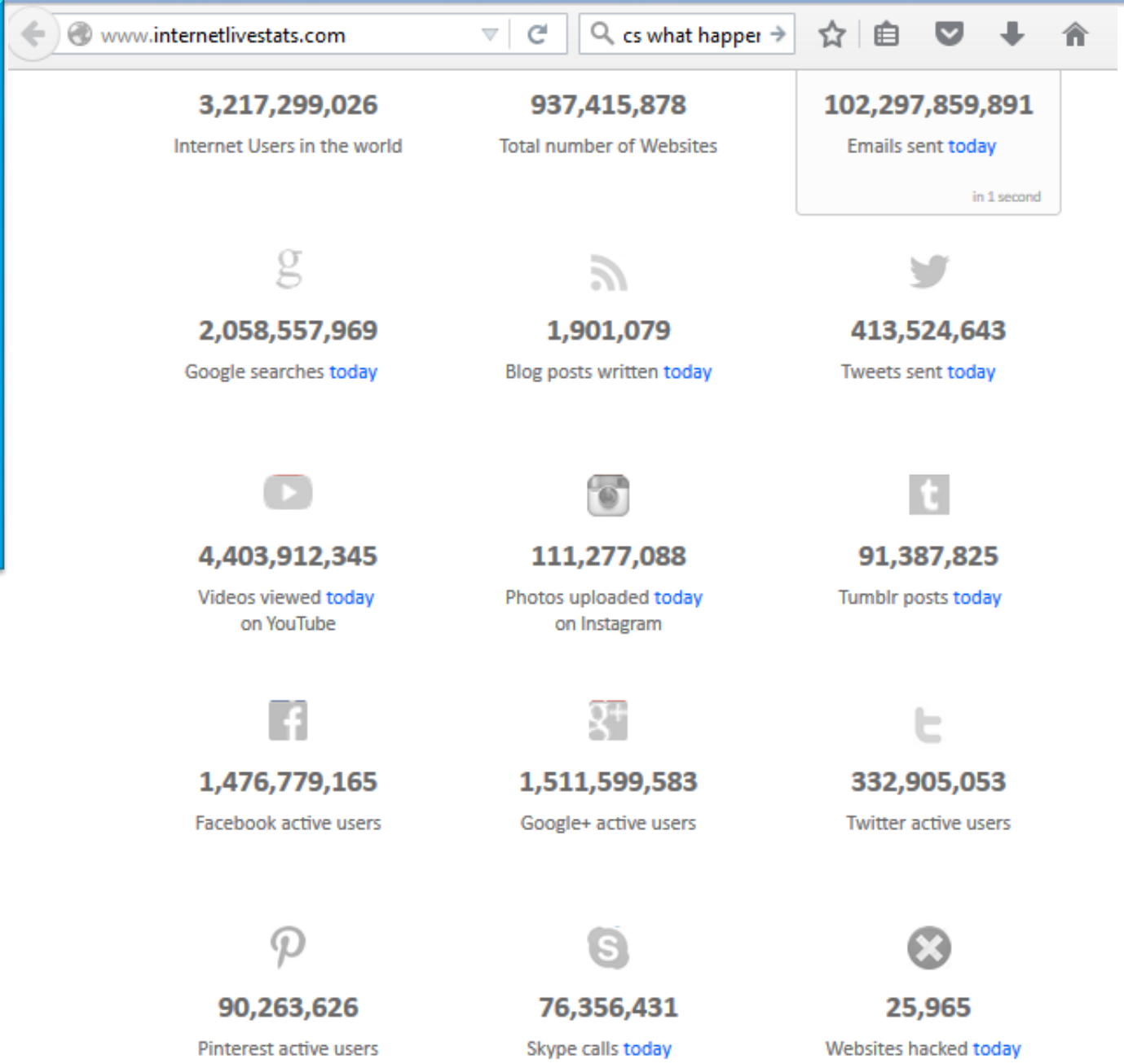
Cloud Computing

- "How big is the Cloud? " ☺

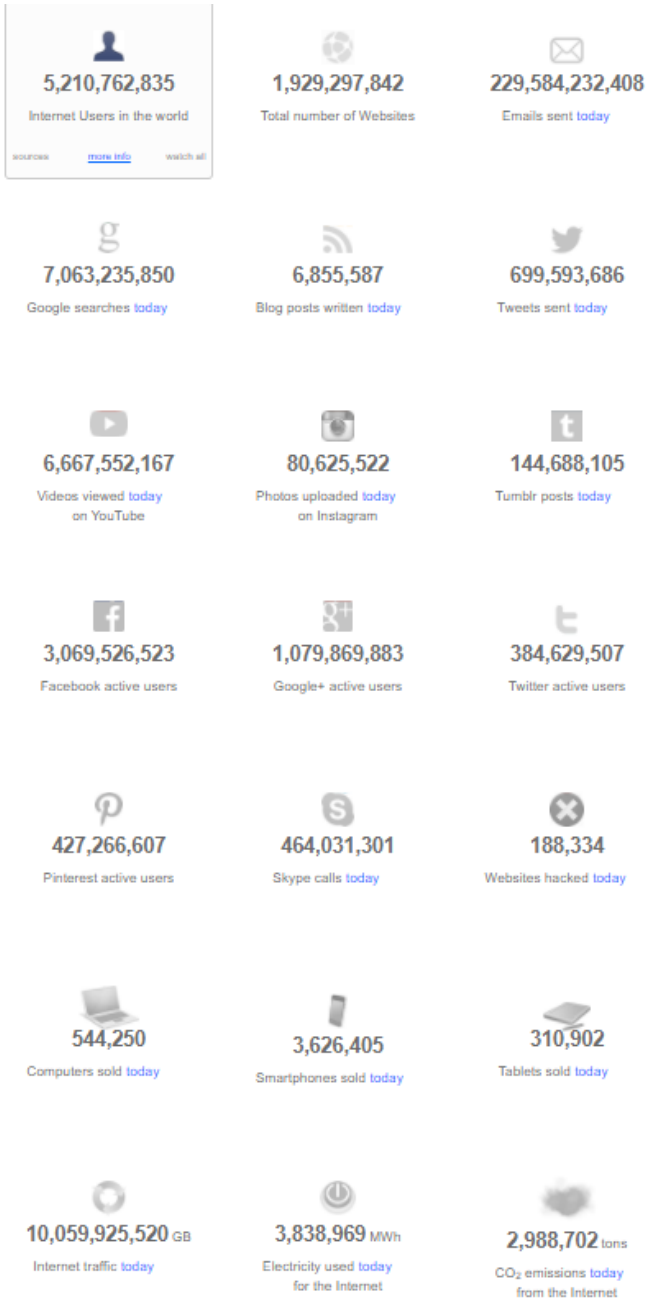


[http://www.live-counter.com/how-big-is-the-internet/]

2015



2022



Cloud Computing

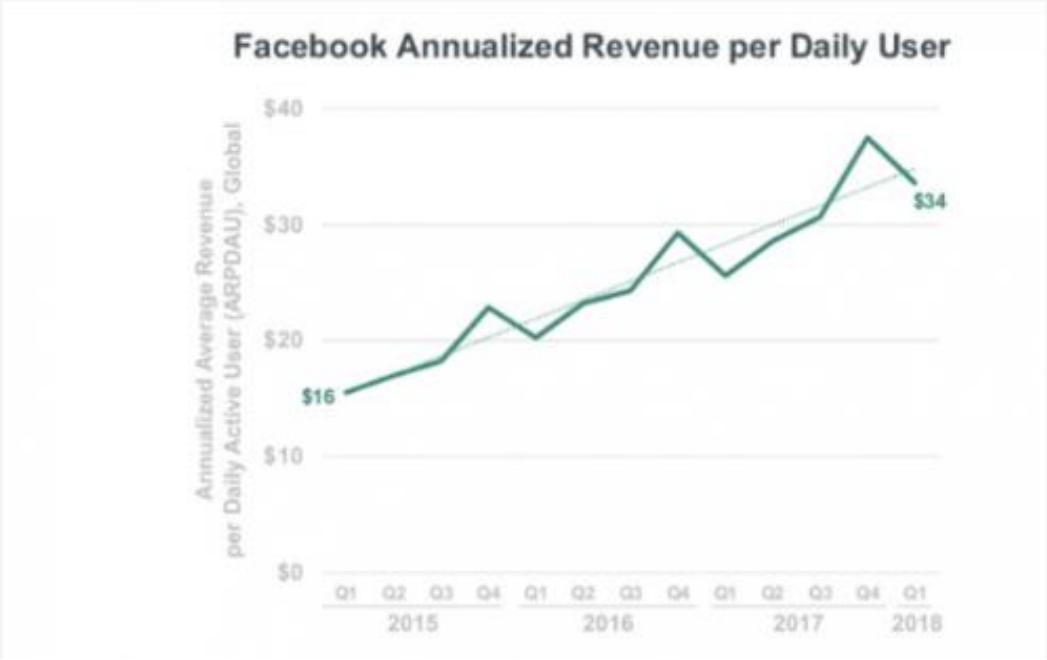
- The trend: data-centric computing
  - Big Data, AI, …
- Current currency on the Internet?
  - Users “pay” Facebook, Google, Instagram use … all actions, links, shares are recorded
  - Also, data have another dimension (besides economic)
    - Better answers to various questions, validate hypotheses on various social interactions, better LLMs,…
    - Example: Online Social Network research

Cloud Computing

3. Facebook's revenue per user has doubled in 3 years

Facebook's focus on meaningful connection has driven rising user engagement, which in turn drives monetization for the platform.

What does that look like in dollars? Facebook earned $13.2 billion in revenue in the first quarter of 2018, a 42 percent increase, year over year.



[https://blog.hootsuite.com/facebook-statistics/#general]

Cloud Computing

- At this point, near search engines, there are other BigData "players"
  - banks, academia, financial environment, government,….
  - ⇒ Everything is possible thank to the new generation of "*hardware hosting services*" ⇔ cloud and new programming models (LLMs)
- Cloud Services are deeply embedded in modern society
  - Communication: Twitter, Facebook, Skype,…
  - Media: iTunes, Netflix,….
  - Market: Amazon, eBay, stock exchanges, advertising,…
  - ….
- *True understanding ⇔ understanding the interactions between technology, systems, networks and people* ⇔ purpose of this course ☺

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Summary

- Why Cloud Computing?
- History & Evolution
- Grid/Cluster computing – general aspects
- Cloud Computing – definitions
- Grid versus Cloud
- Cloud Computing - aspects

Cloud Computing
- Overview -

Questions?