The Cloud computing paradigm

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IaaS-PaaS-SaaS and beyond

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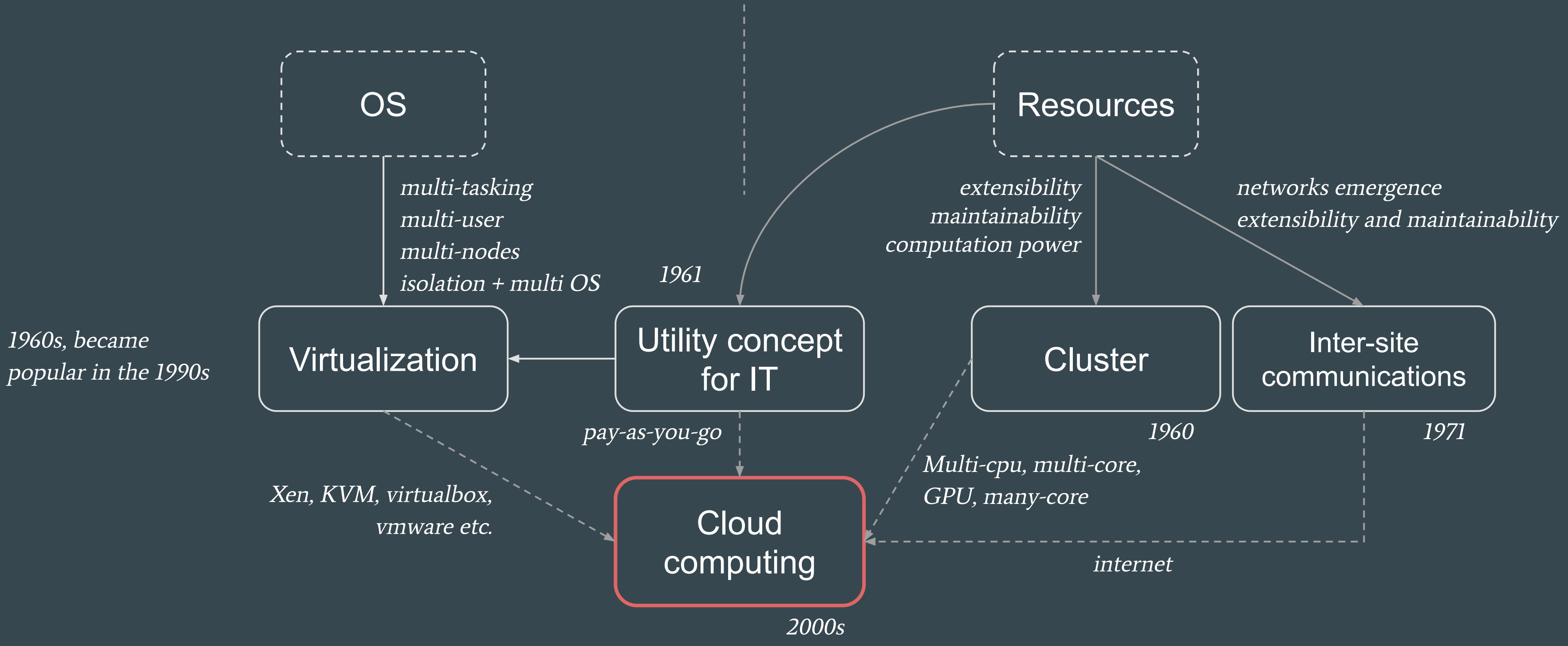
The path to the utility computing

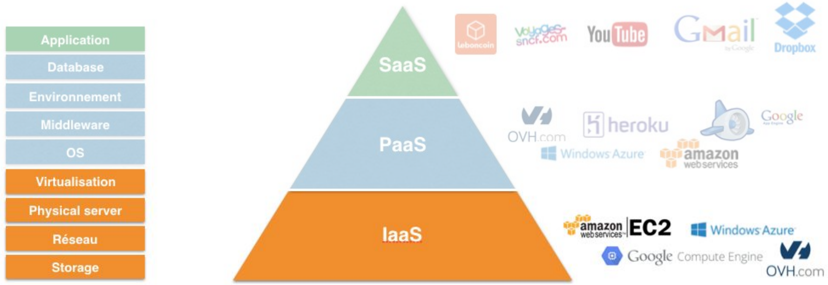


The Cloud computing and beyond

From the success of Internet to the Cloud Computing

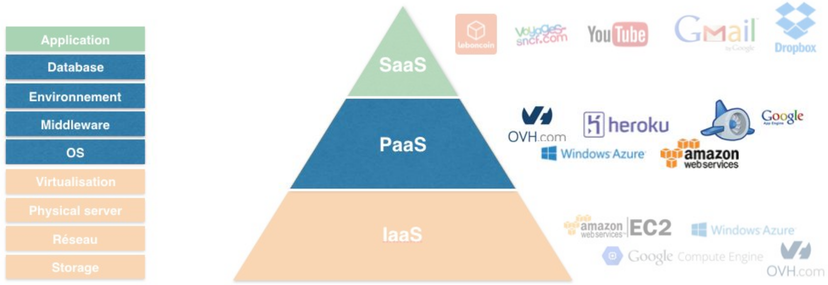
- **Late 90s - Early 2000s:** Advent of Internet and emergence of website with global audiences, with economical challenges
- To cope with users' requests
  - Datacenters are created to host large amount of computing resources
  - Complex software stacks emerge (LAMP)
  - Fault tolerance is required (High availability, Service Level Agreements, ...)
- Emergence of **outsourcing** service offering, where a third party company will handle some technical/economical aspects of a business process
- Over the course of time these service offering will sediment and stratify in 3 main layers : *Infrastructure, Platform and Application* [Youseff 2010]

IaaS Level

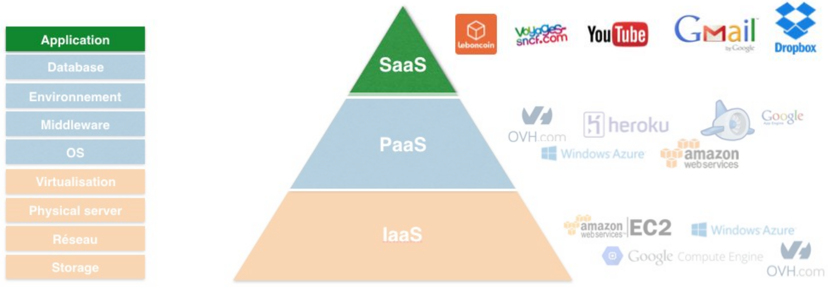


- Lowest layer of the Cloud Computing model
- Abstract low level aspects of datacenters:
    - *Servers*
    - *Networking*
    - *Storage*
    - *Locations*
- Providers offer computing resources
- Users consume at will the providers' resources

PaaS Level



- Abstract the complexity of development software stacks (tuning configuration, high availability mode, backups, SLA management)
- Providers offer configured environments that can be consumed at will by users
- Users use these environments that to develop their applications
- Middle layer of the Cloud Computing model



SaaS Level

- Abstract the hardware and software running behind a service
- Providers offer an on-premise service that requires no configuration
- Users consume at the service
- Highest layer of the Cloud Computing model

XaaS

- Everything-as-a-Service!
- Examples:
  - Network
  - Analytics, AI
  - Functions
  - Business process
  - Transport
  - Drone
  - Games
  - etc.

HPC vs Cloud computing

HPC vs Cloud

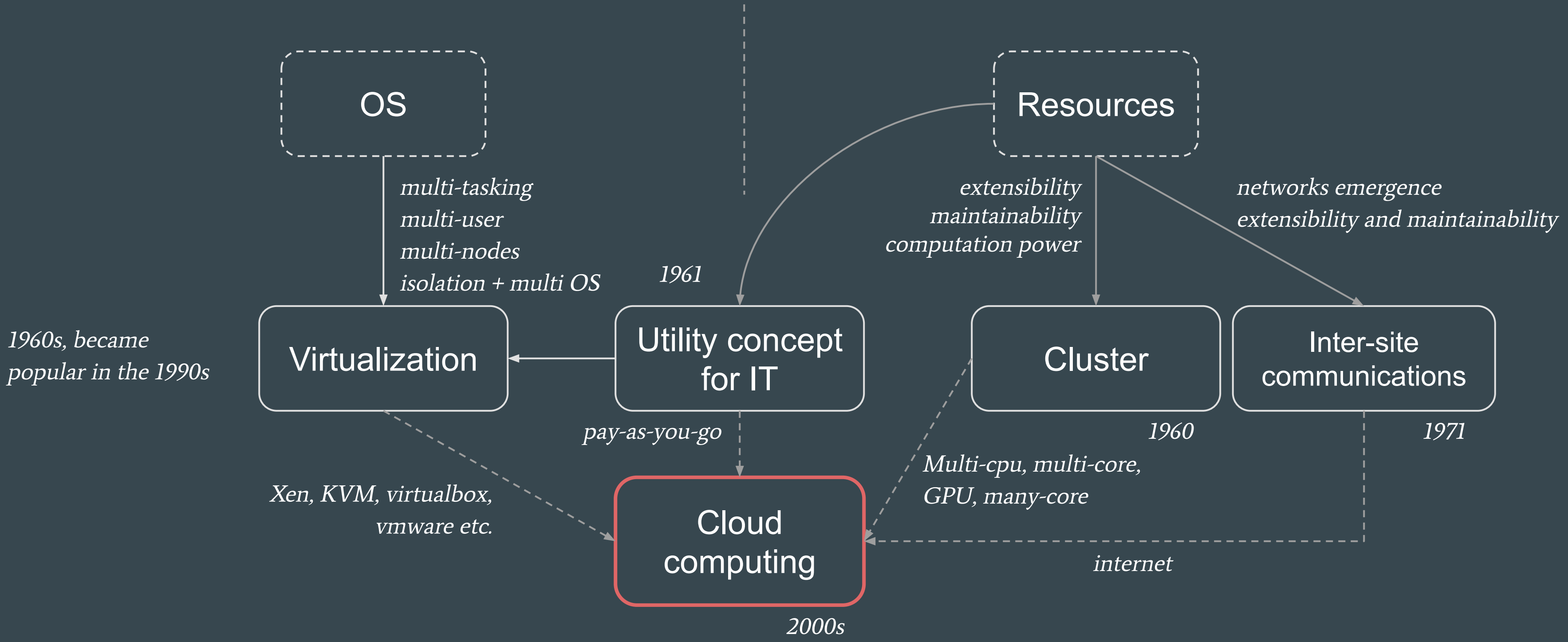
From HPC viewpoint

- Be as close as possible from the best possible performance of the machine
- Reduction of all overheads resulting in very low-level programming models and tools
- No consolidation to avoid interferences between jobs
- High bandwidth network (Infiniband)

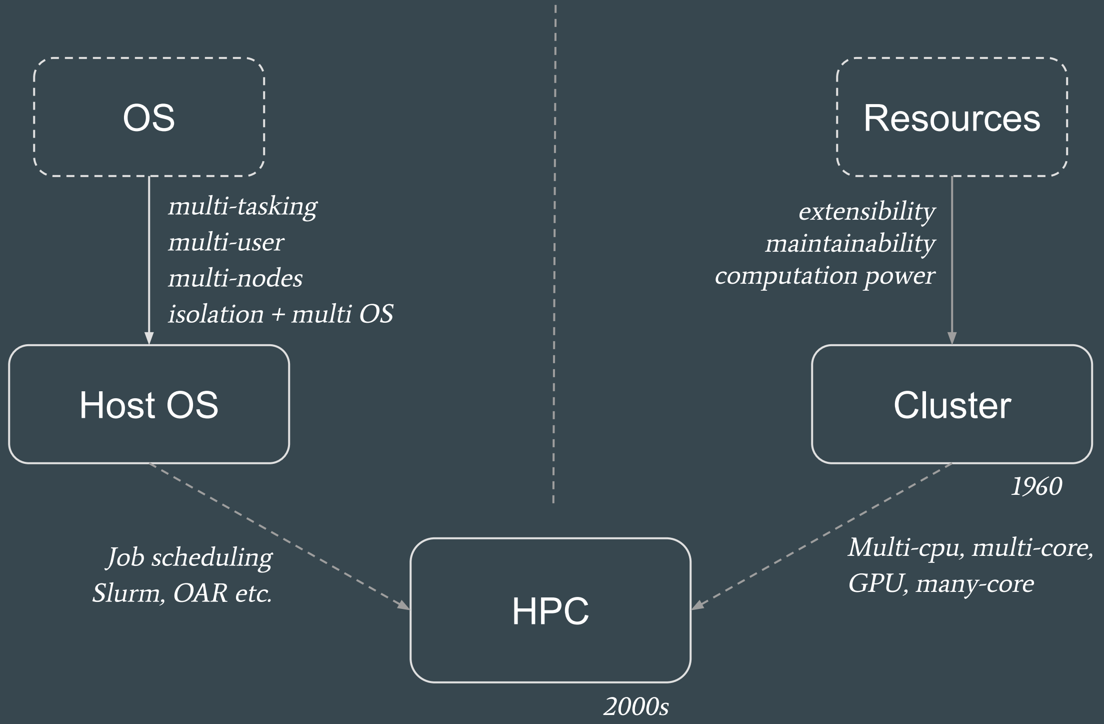
From Cloud viewpoint

- Flexibility and utility is the first-class citizen
- Economic model “pay-as-you-go” and consumes only what you need
- Resources are used at their maximum (or even more, over-provisioning) thanks to consolidation and migration of VMs
- High overhead due to VMs and interferences on host machines
- Often virtualized network

The path to the cloud computing



The path to HPC



Convergence HPC Cloud

- From HPC viewpoint
  - Get user-friendly tools
  - Get better flexibility for users
  - Being able to consolidate servers
  - E.g. containers
- From Cloud viewpoint
  - GPUs, powerful CPUs etc
  - Adding a HPC offer to the Cloud
  - Less consolidation
  - Lighter virtualization (containers)

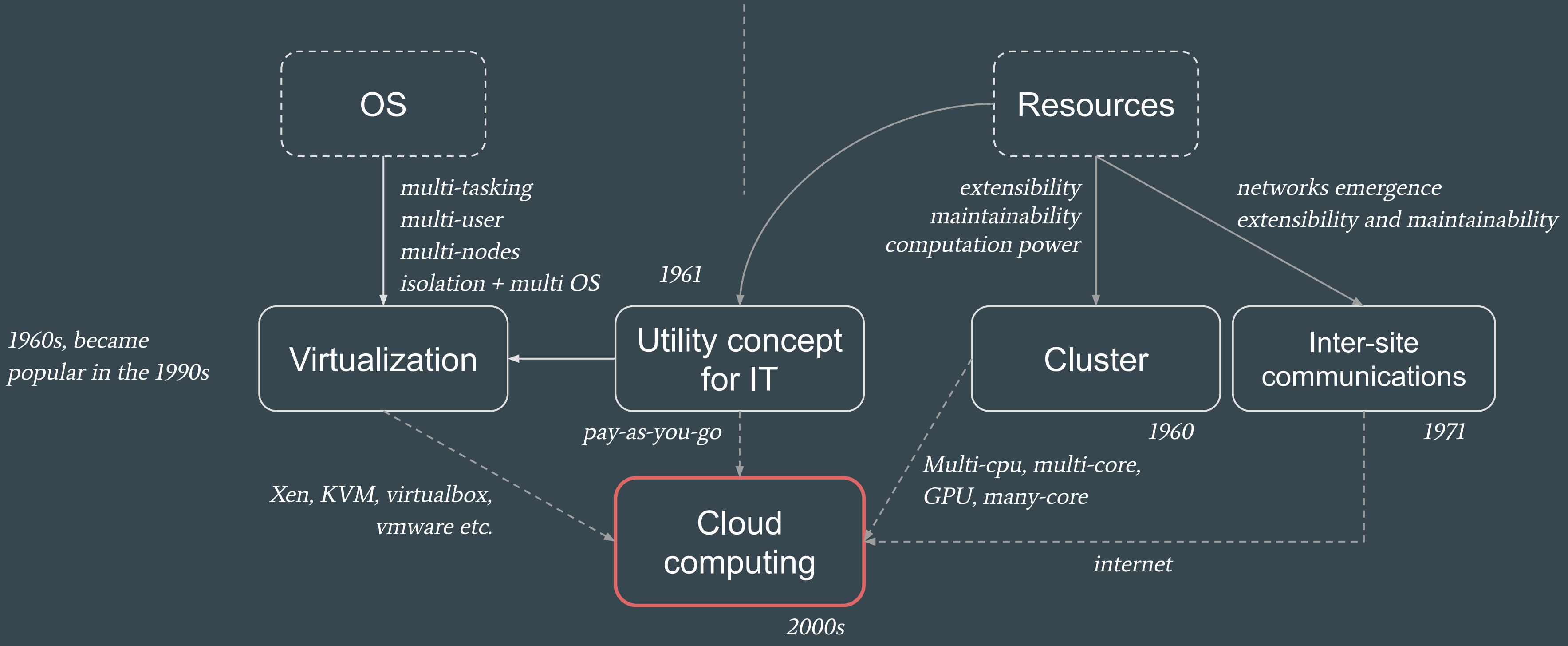
[2019 Mercier]

Grid vs Cloud computing

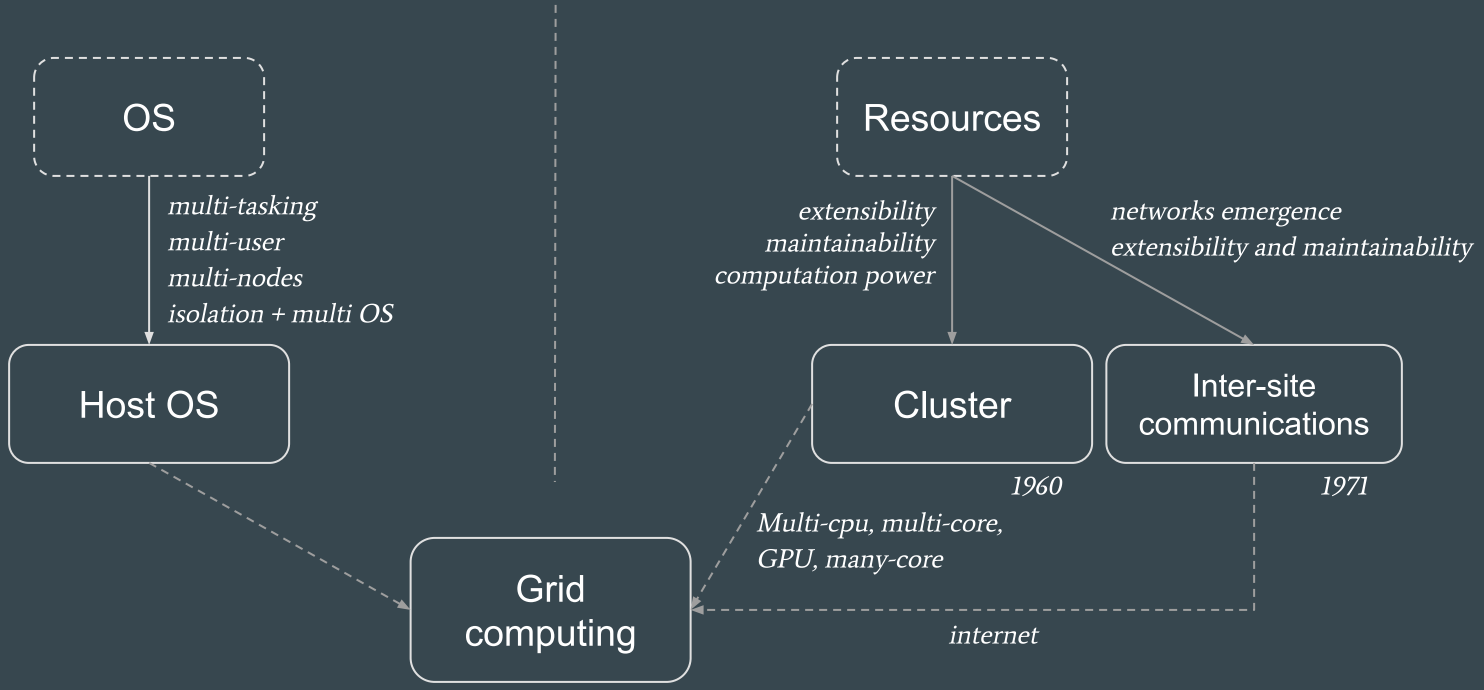
Grid computing

- 1999 - Ian Foster and Steve Tuecke
- More heterogeneous than HPC
- Multi-clusters, multi-sites
- Consolidation of nodes (multi-tasks)
- In between cloud computing and HPC

The path to the cloud computing

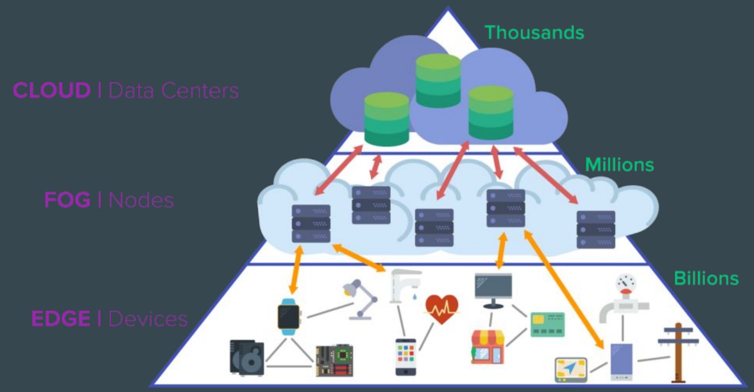


The path to the grid



Fog and Edge computing

Fog and Edge computing



Issues related to the centralized Cloud paradigm:

- Latency and bandwidth issues
- Security issues (hosting country laws)
- Fault tolerance issues

Fog and Edge computing use both the core and the edge of the network to offer resources closer to the user [2018 Mahmud] [2018 Iorga]

Fog and Edge computing

A few information

- Most cloud providers are already divided in multiple regions of clusters.
- All telecom companies, as they handle most of the core network, are interested in this topic.
- Fog and Edge computing are enabling technologies to handle 5G infrastructures where virtualized network functions have to be computed with very short response time.

The STACK team at IMT Atlantique (Inria)

How to operate large and massively geo-distributed infrastructures?

To handle Fog and Edge infrastructures a decentralized OS is needed!

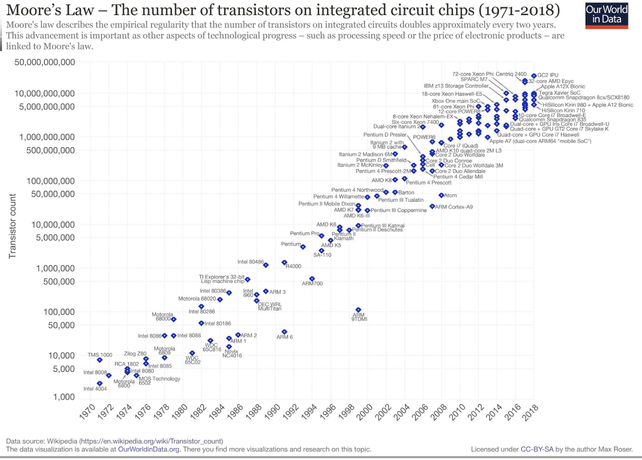
- Multi-user, multi-node, multi-region, multi-tasking
- Heterogeneous virtualizations
  - From bare-metal to VMs
- Heterogeneous resources (edge)
- Decentralized control of a large geo-distributed infrastructure
  - Fault tolerance, no SPoF

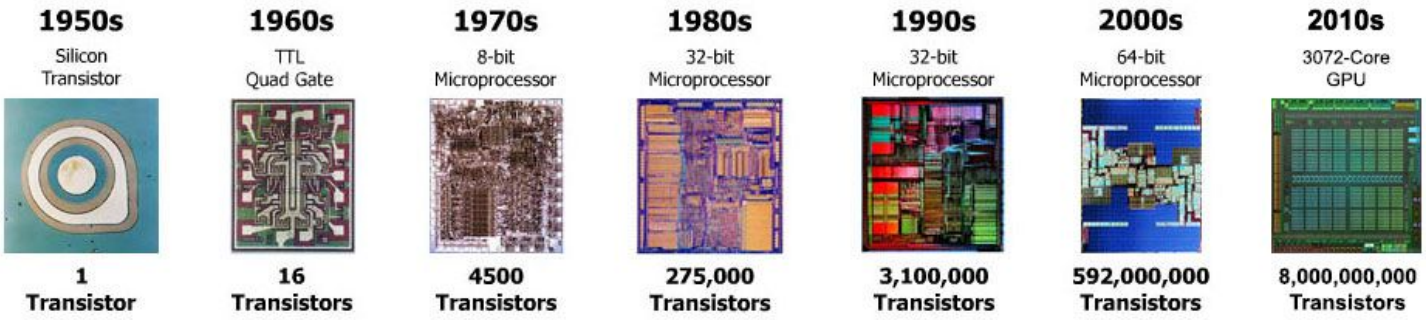
Cloud, utility, IT growth and sustainability

Growth of IT resources

Moore's law

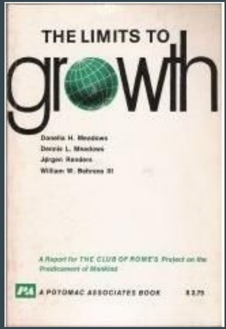
"The number of transistors in a dense integrated circuit doubles about every two years"





The limits to growth

Also true in computer science?

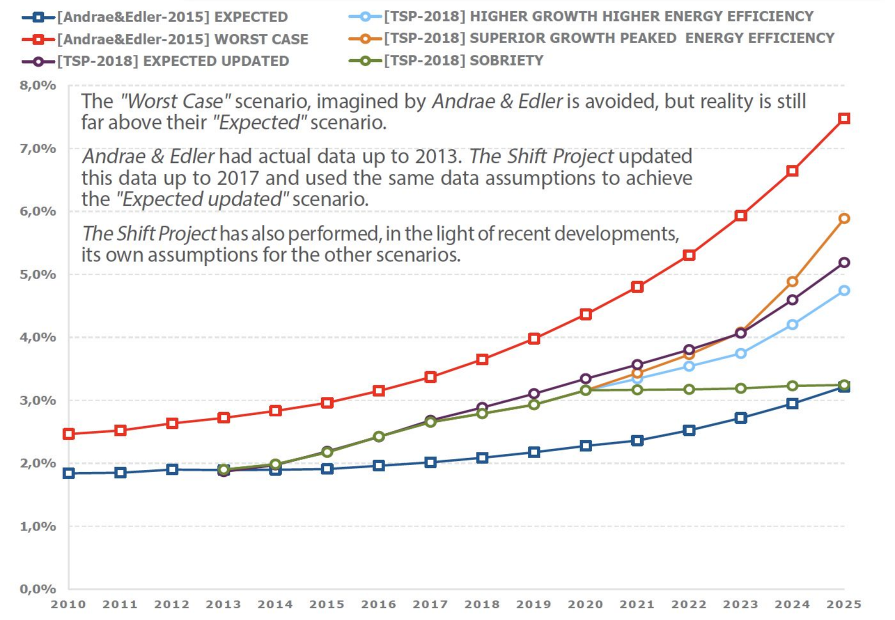


- *"Exponential never last"* Gordon E. Moore
- Physical limitations
  - Materials
  - Quantum effects
  - Heat
  - Etc.
- When will it end?
- What will be the replacement technology?
  - Quantum computing?

DARPA ERI Summit 2018: The End of Moore's Law & Faster General Purpose Computing, & a New Golden Age

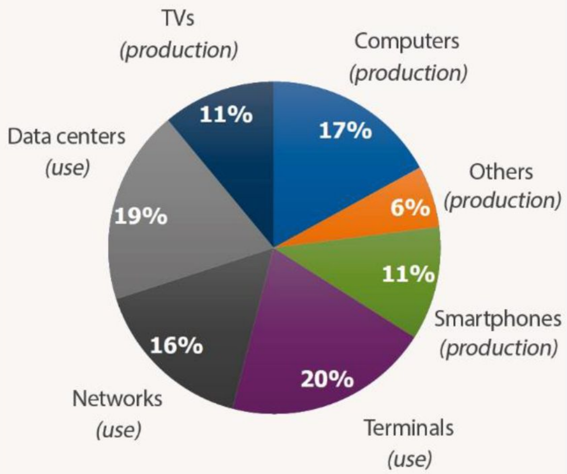
IT, energy consumption, CO2 emissions

"Since 2013 IT represents from 2.5% to 3.7% of global CO_2 emissions" [2018 Lean-ICT]



Evolution of global energy consumption of digital between 2010 and 2025, as a proportion of total world energy consumption

[Source: *The Shift Project 2018*, as of Andrae & Edler 2015]



Distribution of energy consumption per digital workstation for production and use in 2017.

[Source: *The Shift Project* 2018, as of Andrae & Edler 2015]

Sustainability and utility computing

A challenge

Do we really always need more storage and computing capacities?

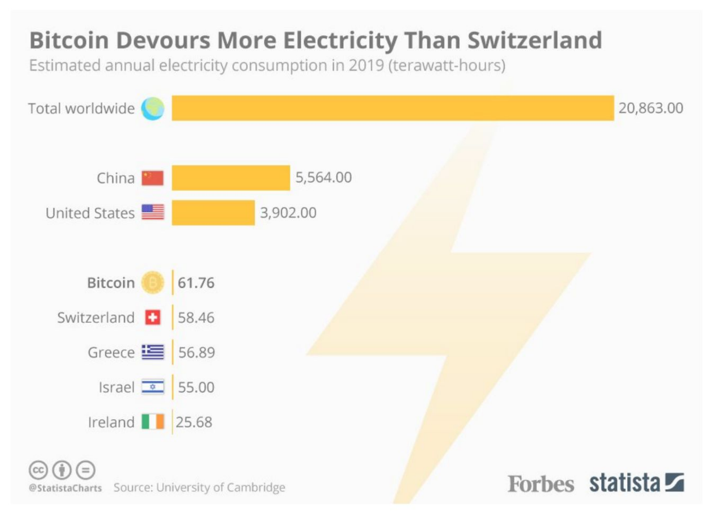
Do we really need 5G for video streaming in the bus?

Do we really need to store so much kittens videos?

Do we really need to buy new phones and new laptop while the current ones perfectly work?

Example: Bitcoin

- Bitcoin efficiency is low : 4.6 transactions per second (TPS) vs 1700 TPS for the Visa network
- Some authors estimates that bitcoin consumes more energy than medium-size countries [Bitcoin's Growing Energy Problem, Alex de Vrie, 2019]



Source: [Bitcoin Devours More Electricity Than Switzerland]

Thank you!
Questions?

References

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- [2018 Lean-ICT] Lean-ICT report, The Shift Project
- [2018 Mahmud] *Fog Computing: A Taxonomy, Survey and Future Directions*. Mahmud, Redowan and Kotagiri, Ramamohanarao and Buyya, Rajkumar. Internet of Everything 2018.
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- [2019 Mercier] *Contribution to High Performance Computing and Big Data Infrastructure Convergence*. Mercier, Michael. Thesis.