17-EURE-0004

Meet-up #Innovation #Research DIGITAL Sciences & Technologies

UNIVERSITÉ CÔTE D'AZUR

DIGITAL SYSTEMS FOR HUMANS
GRADUATE SCHOOL AND RESEARCH

Sobriété énergétique des réseaux informatiques

Frédéric Giroire (I3S/Inria)

Inria

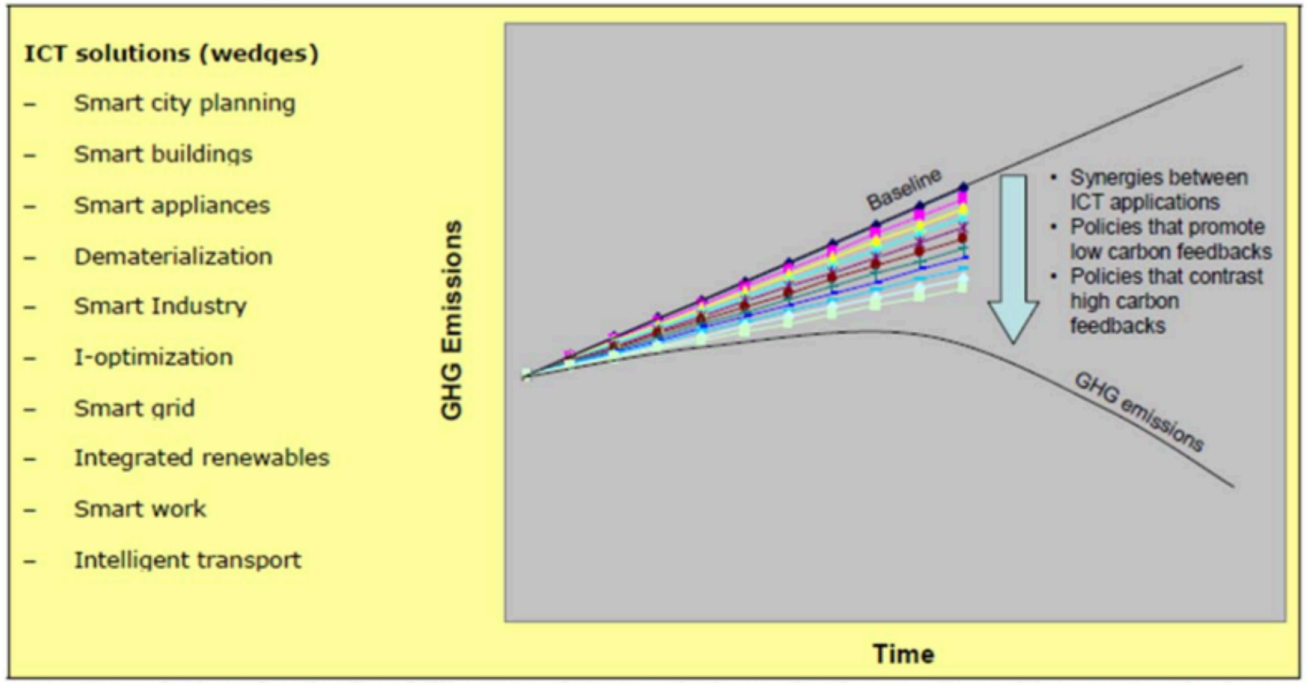
i3S sophia antipolis

LEAT LABORATOIRE D'ELECTRONIQUE ANTENNES ET TELECOMMUNICATIONS

Gredeg Groupe de recherche en Droit, Economie et Gestion

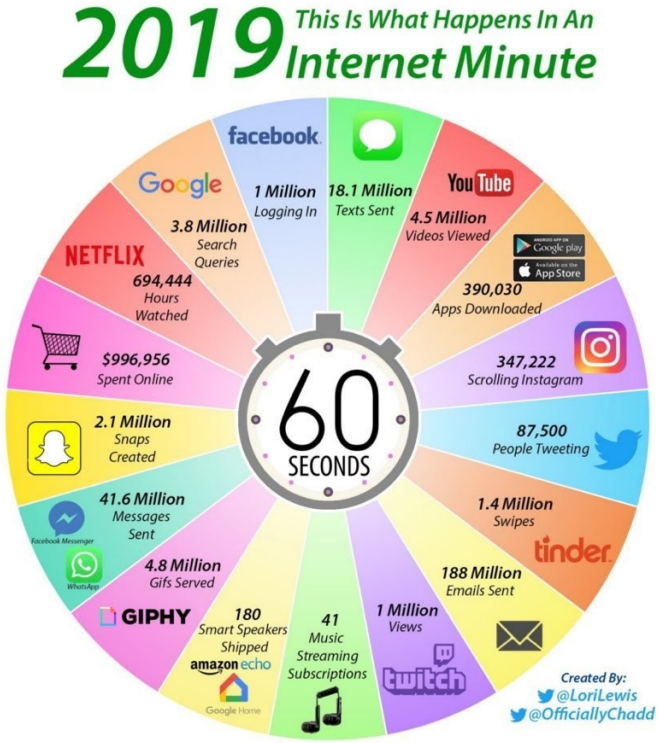
Energy consumption of ICT

- General feeling a few years ago: ***ICT Solutions will achieve systemic changes everywhere.*** It will soon save more energy that it is consuming.



Energy consumption of ICT

A crazy amount of data.

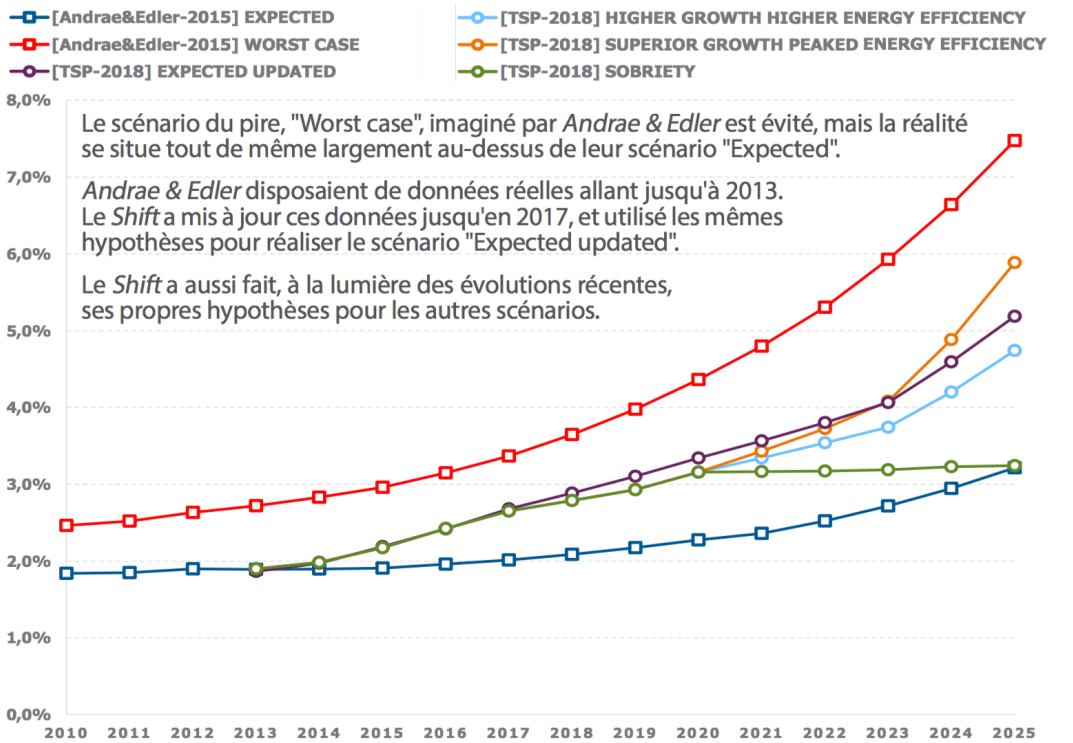


At the same time: 2,000 sold smartphones and 100 tons of DEEE. Just in France 3.4 tons.

All these data are handled by data centers and networks

Slide of Laurent Lefèvre – EJC 2019

Energy consumption of ICT

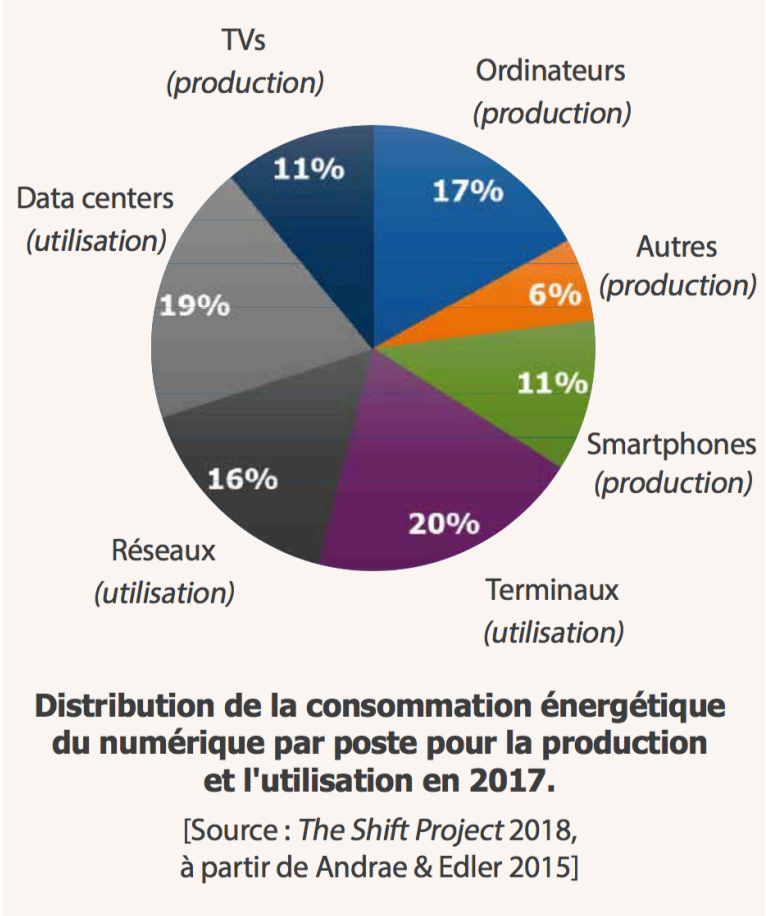


Évolution de la consommation énergétique mondiale du numérique entre 2010 et 2025, rapportée à la consommation énergétique mondiale totale

[Source : scénarios et calculs *The Shift Project* 2018, à partir de Andrae & Edler 2015]

Can something be done to stop or at least slow down this tendency?

Energy Consumption of ICT



Distribution de la consommation énergétique du numérique par poste pour la production et l'utilisation en 2017.

[Source : *The Shift Project* 2018, à partir de Andrae & Edler 2015]

Terminals + Networks + Data centers (Usage) = 55 %

We want to act on this part.

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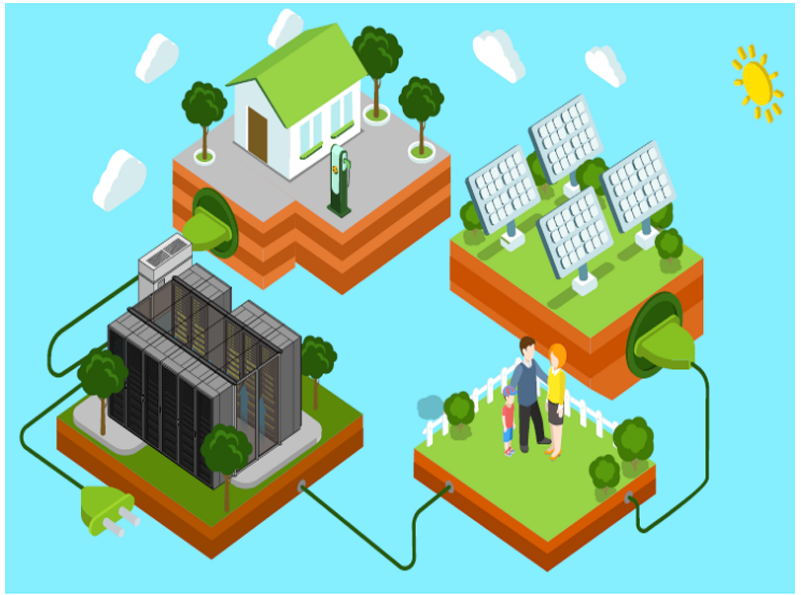
Green IT

- Green IT or sustainable computing or green computing, is a concept that aims to reduce the ecological, economic, and social footprint of information and communication technologies (ICT).

- First attempt around 2001. Then, large tendency of all actors: Data center owners and researchers.

- Study on cooling, hardware, and application management.



Green IT

- All actors over-dimension
  - Data center and application hosts: More servers and racks.
  - Network operators: Larger pipes.
  - Hardware manufacturers: More powerful machines.

- Quality of Experience of Users is number 1 criteria.

=> Waste at all levels!

Green IT: 4 main principles

- **Shutdown:** reduce the number of unnecessarily powered resources!
- **Dimensioning (slowdown):** adapting the performance of resources to real needs!
- **Optimize:** modify applications and services to make them greener!
- **Consolidate / Aggregate:** relocate/group services and applications on a reduced number of physical resources

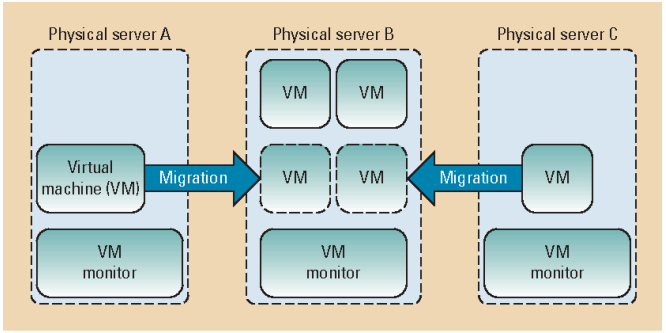
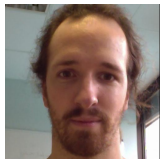


Figure 1. The virtual machine consolidation approach. The resource

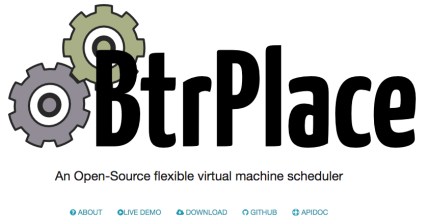
A myriad of methods: Node Shutdown, Node Hibernation. Node Suspend To Ram, DVFS: Dynamic Voltage and Frequency Scaling, NTV: near threshold voltage, AVX: Advanced Vector Extensions, Low Power Idle, Adaptive Link Rate, Green scheduling policies, Energy budget aware scheduling, Power Capping, Green Programming, Simple / Double precision computing...

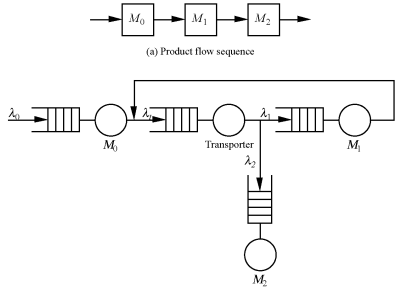
Green IT @ Univ. Côte d'Azur

- BtrPlace: tool to consolidate Data Center applications.
  Constraint programming.
  Main author: Fabien Hermenier (ex I3S)



- Renewable energy powered DCs.
  Models and performance analysis.
  Sara Alouf (Inria)





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Green Networks

- Networking research community.
  - Pioneering work [Gupta et al. SIGCOMM 2003]
  - Strong interest from 2008

- Internet Service Providers (ISP).

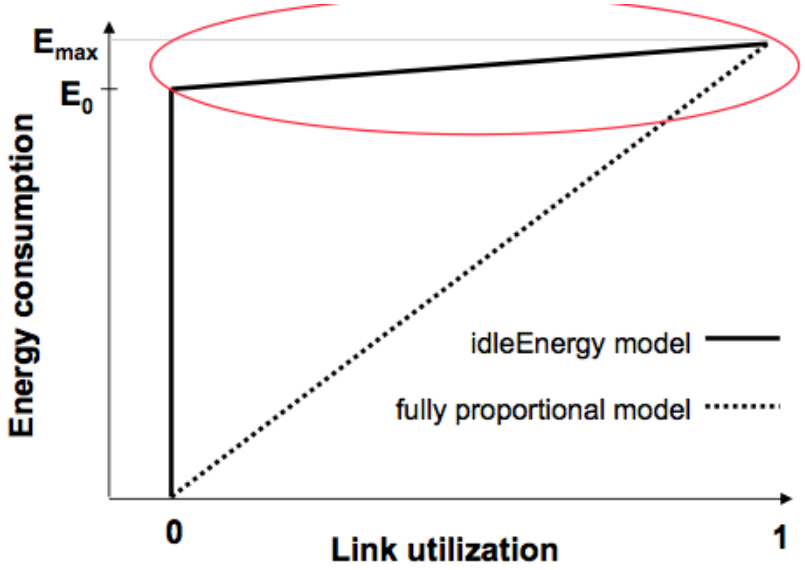
3.7 TWh ~ 0.5 billion US$

9.9 TWh ~ 1.5 billion US$

- Politics. Challenge of the European Commission: a 20% improvement in energy efficiency by 2020.

Green Networks

Measurements campaigns on routers: small influence of the traffic load on energy consumption on [Chabarek et al. Infocom08]:



—> To save energy: **switch-off** interfaces, chassis.

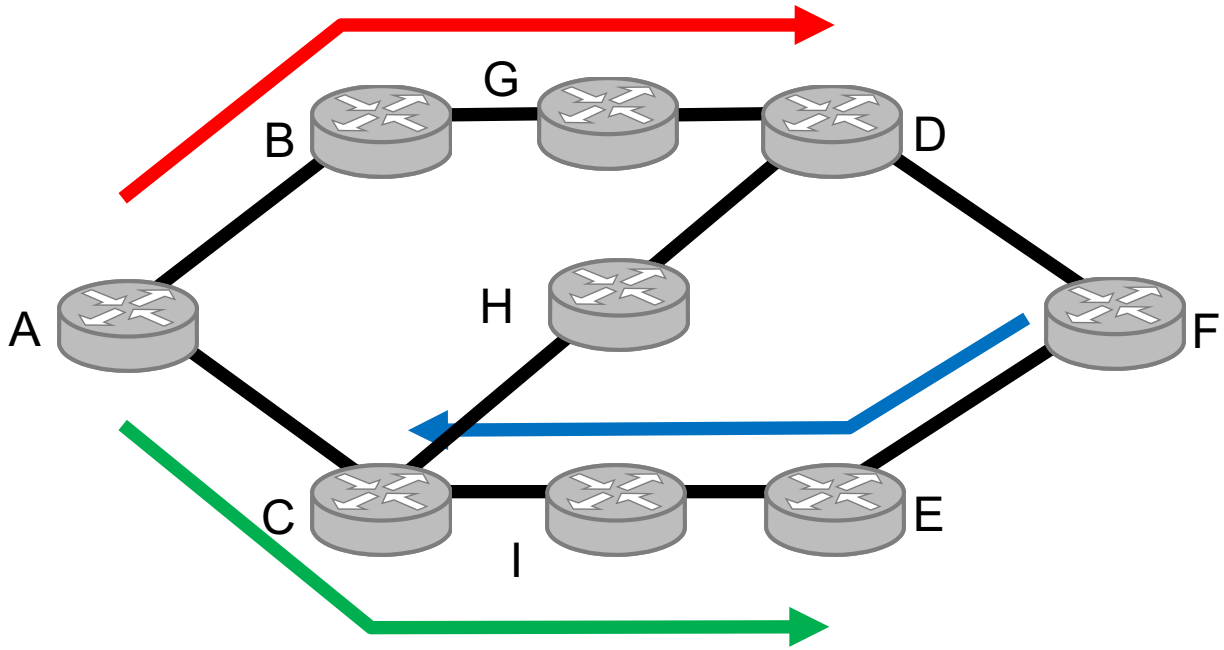
Energy Aware Routing (EAR)

Path between:

A and D

F and C

A and E



Legacy routing: using shortest paths.

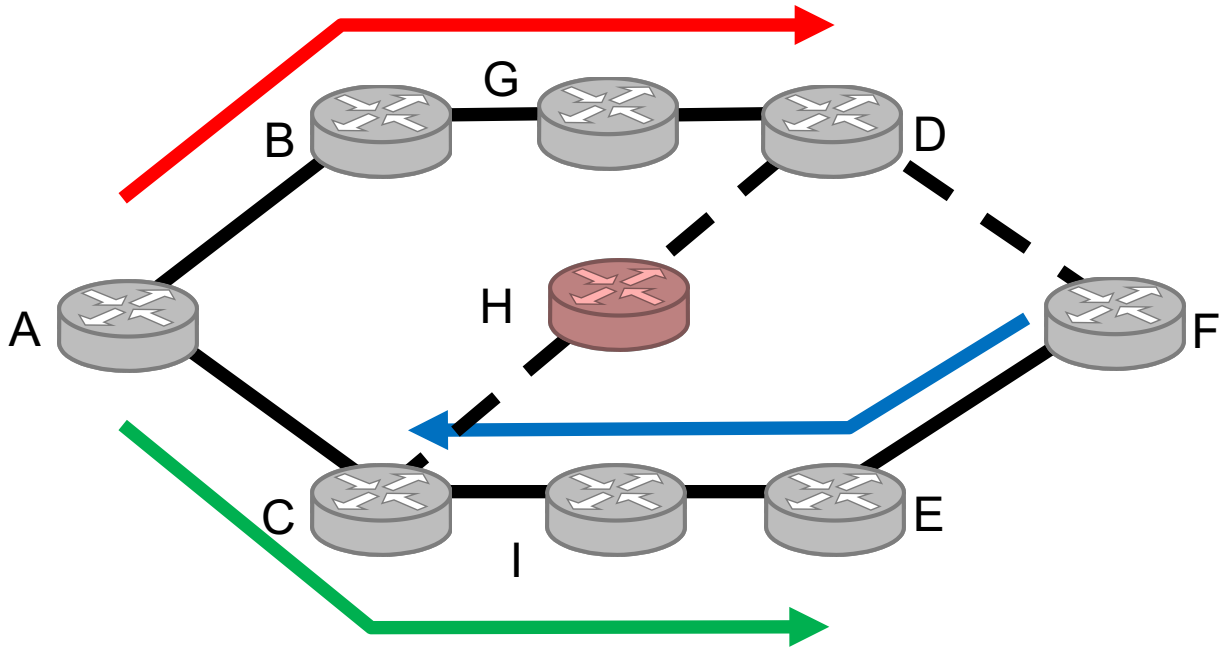
Energy Aware Routing (EAR)

Path between:

A et D

F et C

A et E



Shortest path routing

Putting unused network equipments (routers and/or links) into sleep mode

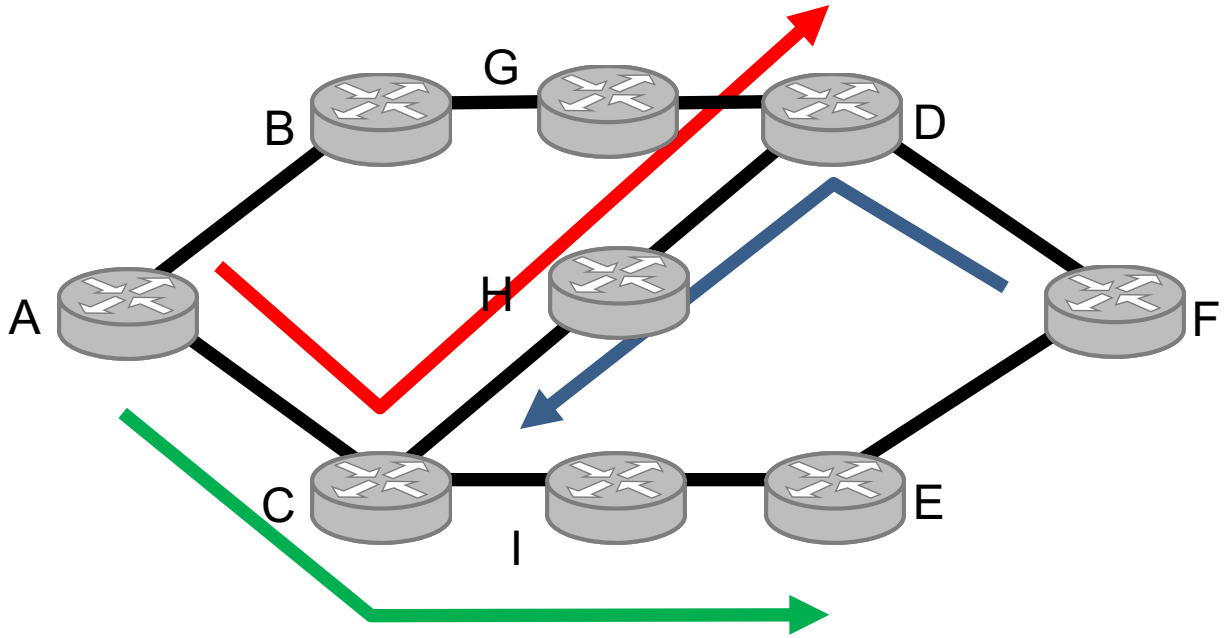
Energy Aware Routing (EAR)

Path between:

A et D

F et C

A et E



EAR: Routing requests while minimizing the number of active network equipments

Energy Aware Routing (EAR)

Path between:

A et D

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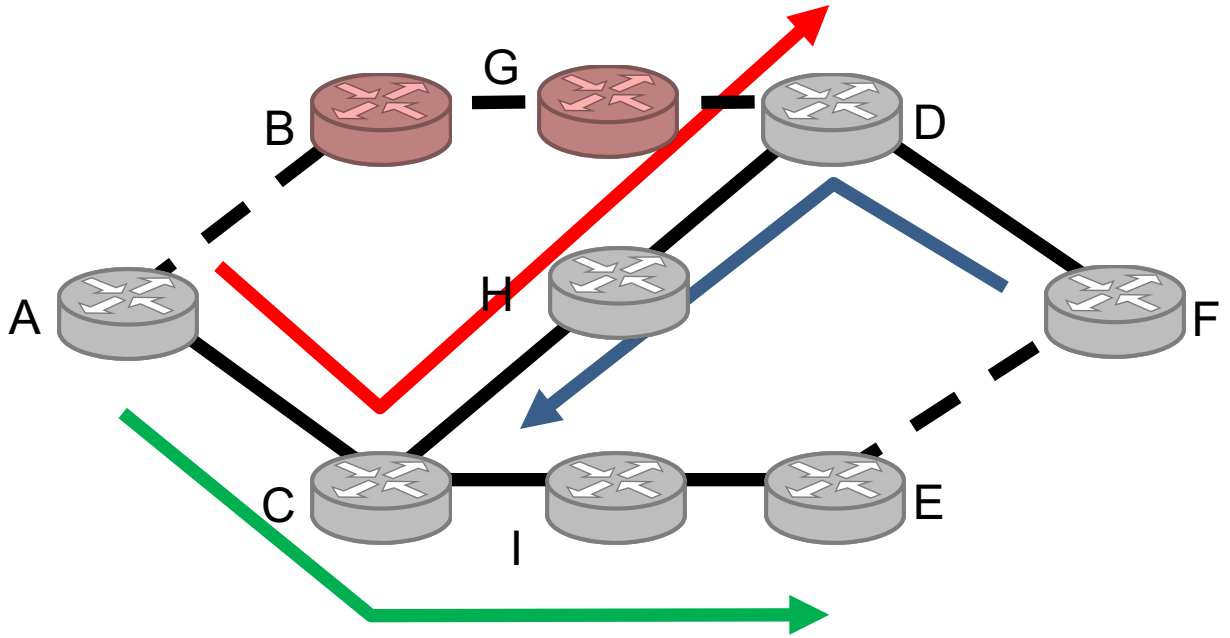
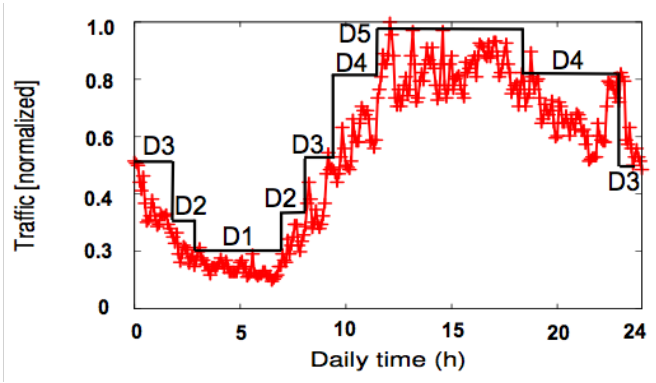


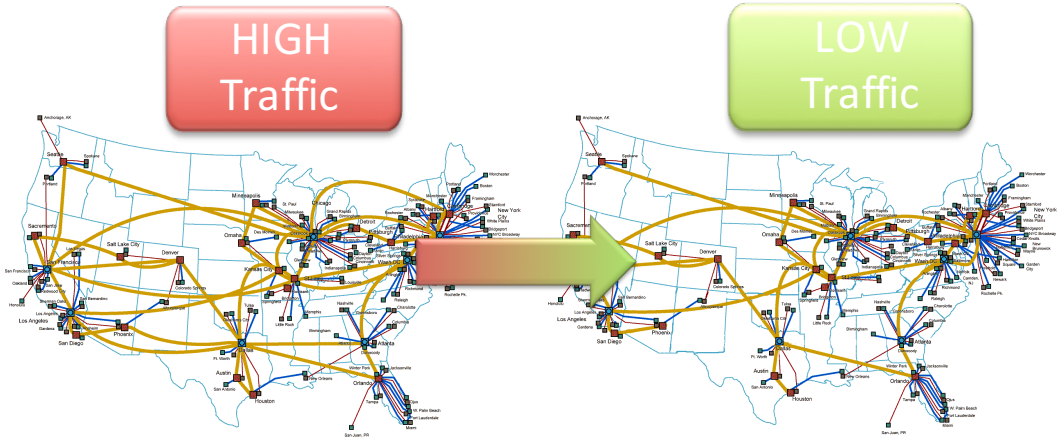
Energy Aware Routing

EAR: Routing requests while minimizing the number of active network equipments

Energy Efficiency

- Core of solutions for energy efficiency: dynamic adaptation of resource usage to traffic changes.

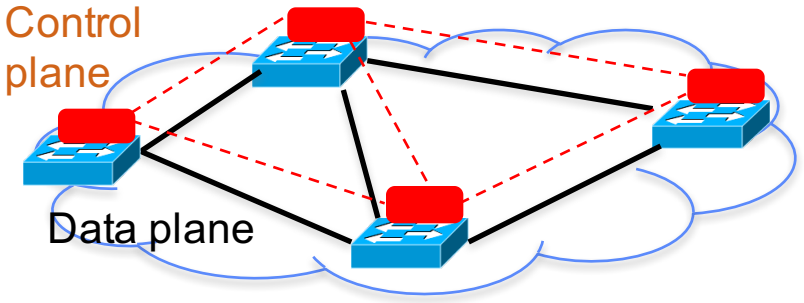




Other applications: energy efficient data centers (virtual machine assignment), wireless networks (base-station assignment)…

Legacy networks

However, network operators reluctant to change the routing.



- **Router=closed systems.** Any change has to be done **manually.**

- Networks are managed by complex **configurations.**

—> Important difficulties to deploy new protocols

-> Energy efficient solutions not yet successfully implemented in networks.

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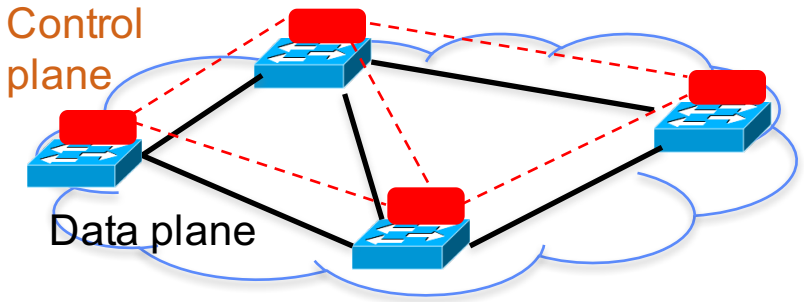
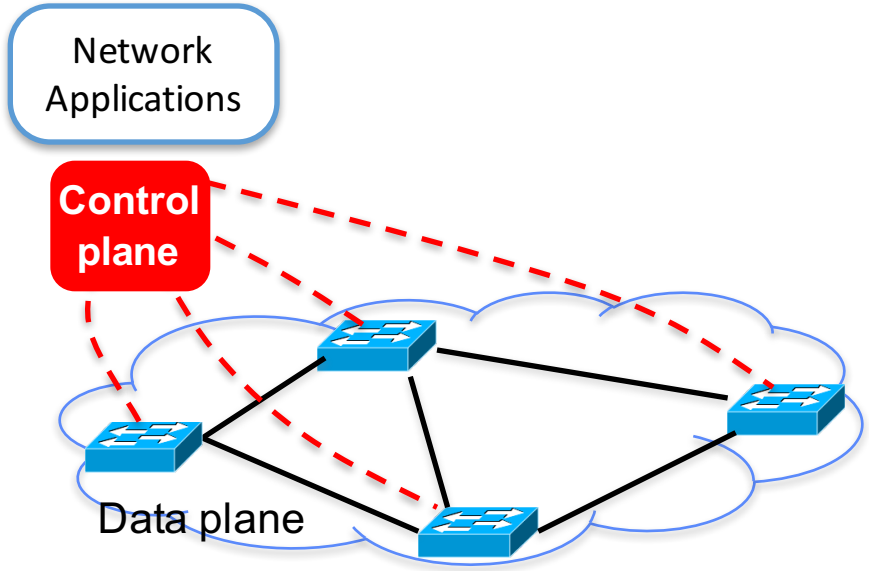
A new context: Software Defined Networks



- **Router=closed systems.** Any change has to be done **manually.**
- Networks are managed by complex **configurations.**

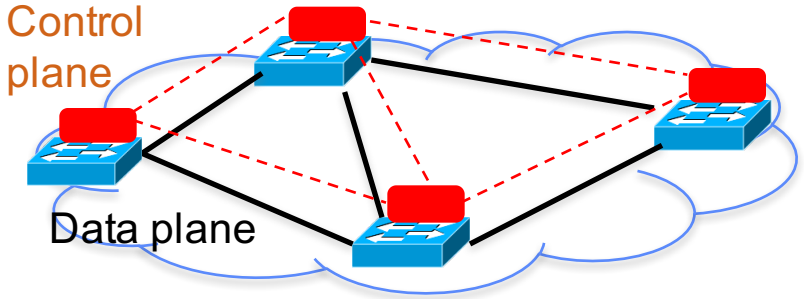
—> Important difficulties to deploy new protocols



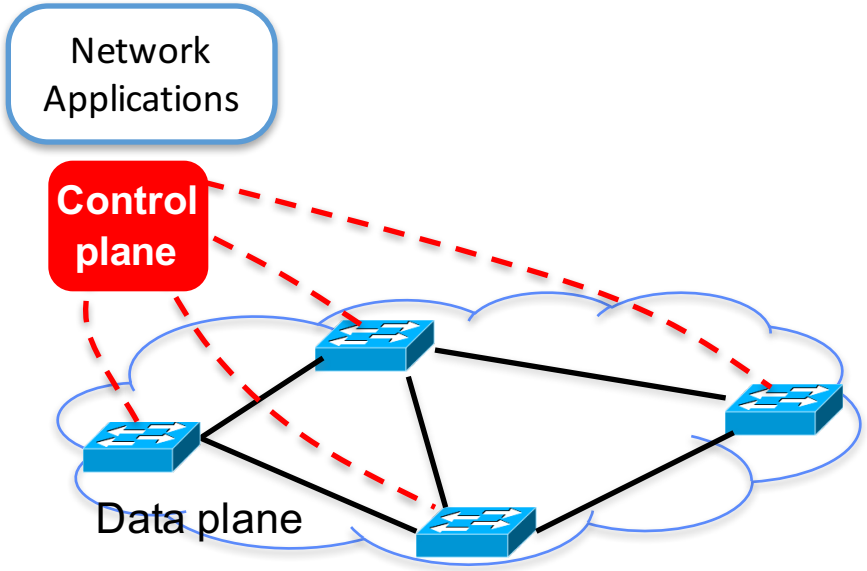
- Intelligence implemented by a **centralized controller** managing **elementary** switches
- SDN conceives the network as a **program.**

—>Allows the deployment of advanced (dynamic) protocols

Software Defined Networks



—> SDN has the potential to put into practice energy efficient solutions



- Intelligence implemented by a **centralized controller** managing **elementary** switches
- SDN conceives the network as a **program.**

—>Allows the deployment of advanced (dynamic) protocols

Software Defined Networks

- Pushed by open source communities + large software and telecommunication companies.
  - **Large eco-system:** Open Flow / Open Day Light / Open Stack / Open vSwitch
  - **Software companies:** Google B4 large scale experiment on its inter-data center networks [Jain 2013].

B4 worldwide deployment (2011)

  - **Telcos:** e.g. AT&T targets 75% of network functions as a software by 2020.

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- SDN and Energy efficiency: project between COATI and SIGNET






- Inside the axis Energy of labex UCN@Sophia

- Two Ph.D. students:
  - Nicolas Huin, 2014-2017
  - Myriana Rifai, 2014-2017


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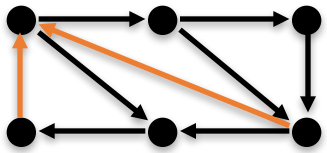


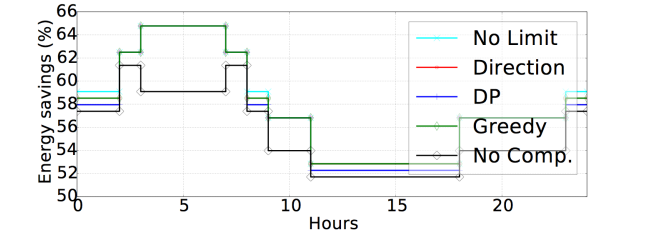
Problem: how to route using compression while minimizing energy consumption.

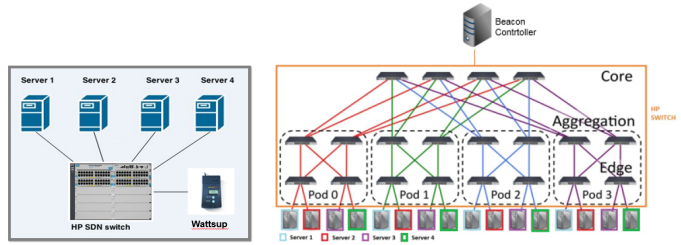
Résout problème ouvert énoncé dans [Suri et al. Algorithmica 2003]

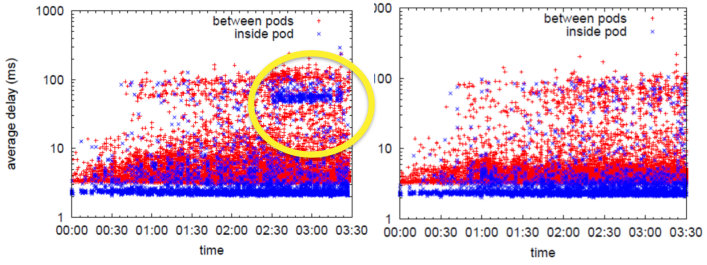
1. NP-complete (Link with Feedback Arc Set). 3-approximation. FPT Algorithms.
   [Algorithmica 2018. Short version INOC 2015]

2. Modeling with ILP and Simulations on ISP networks.
   [Computer Communications 2018 . Short version Globecom 2014]

3. Experiments for an SDN data center network.
   [Computer Networks 2018. Short version Globecom 2015]







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Network Function Virtualization

- Legacy networks implements network functions using expensive specific hardware called middleboxes.

- The NFV initiative allows functions to be run on generic hardware using Virtual Machines.

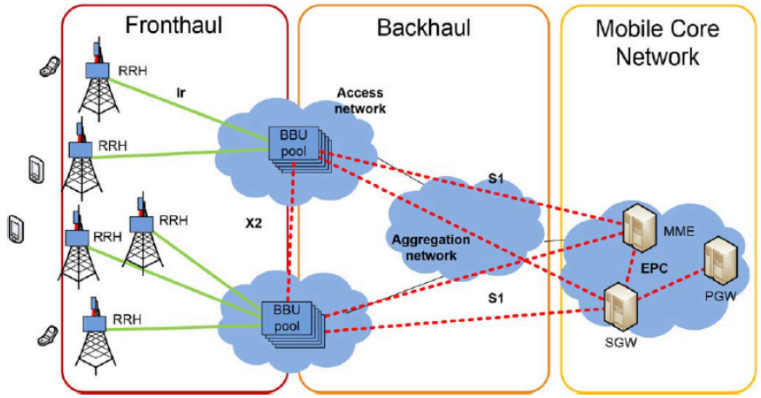
- Solve problems of cost, capacity rigidity, management complexity, and failures

NFV and Energy Efficiency

- Allows to **instantiate and scale on demand** Network Functions.

- Enables **Network Virtual Function consolidation.**

Example: 5G Cloud RAN. Baseband Units (BBUs) from multiple base stations pooled into centralized BBU Pool for statistical multiplexing gain, load balancing and cooperative processing of signals.
-> Energy efficiency + cost savings.



- Enables greater flexibility (good for energy). **Route and Network Function consolidation now possible!**

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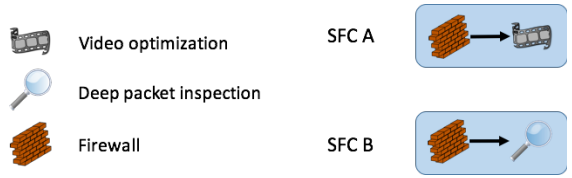
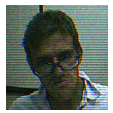


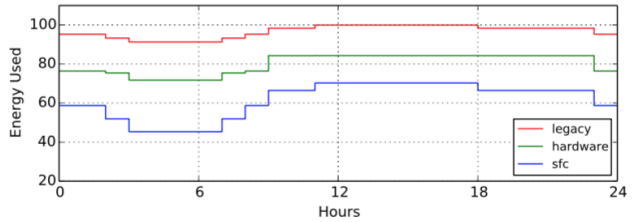
- **Service Function Chain provisionning**
  1. using **Column Generation** [Several papers including ICC 2017-2018, ToN 2018]
     -> improved the scalability of ILP models
  2. with **Approximation Algorithms** [INFOCOM 2018]
     -> *"First approximation algorithms taking into account ordering constraints."*
  3. For **Energy Efficiency** [JOCN 2018]

Service Chain	Chained VNFs	rate	% traffic
Web Service	NAT-FW-TM-WOC-IDPS	100 kbps	18.2%
VoIP	NAT-FW-TM-FW-NAT	64 kbps	11.8%
Video Streaming	NAT-FW-TM-VOC-IDPS	4 Mbps	69.9%
Online Gaming	NAT-FW-VOC-WOC-IDPS	50 kbps	0.1%

TABLE I: Service Chain Requirements [2]

NAT: Network Address Translator, FW: Firewall, TM: Traffic Monitor, WOC: WAN Optimization Controller, IDPS: Intrusion Detection Prevention System, VOC: Video Optimization Controller

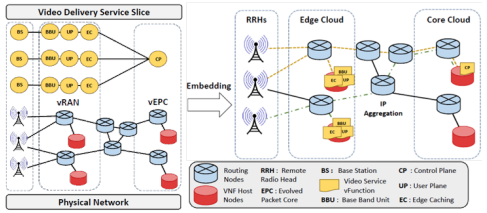


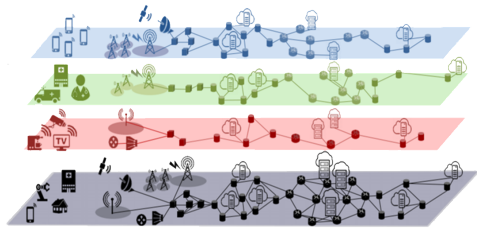


Hardware scenario: savings using dynamic routing, 20%
SFC scenario: savings using virtualization, 30 to 55%
Few function replications are needed

- **5G Network slicing** and **virtual network embedding.**

PhDs of A. Gausseran and G. di Lena
2018-2021 (I3S. Orange, Inria)





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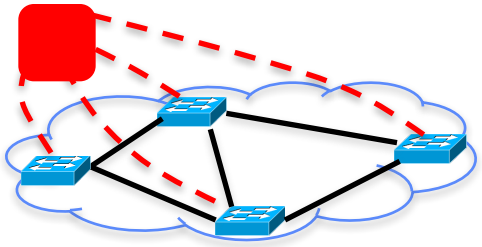
Perspectives

- Several major revolutions:
  - Diffusion in the industry of software defined networks
  - of network virtualization

1. Convergence of data center and networks
2. 5G/6G/IoT/M2M
3. IA, Data centers, and Networks

-> New challenges and new opportunities.



1. Convergence of Data centers and Networks

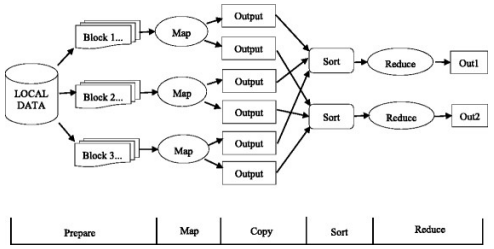
- Convergence
  - Of infrastructures and
  - Of their control with SDN.

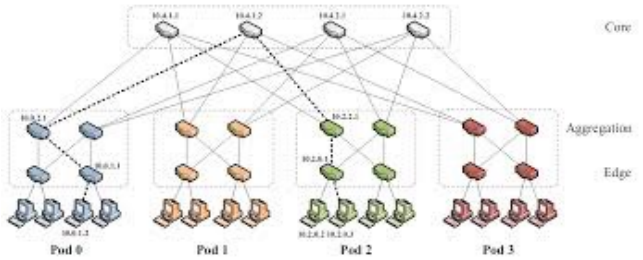
- Allows a joint optimization of applications and network traffic.

- Importance :
  - Big data : enormous quantity of data distributed in the network to be handled
  - Communications may account for more than 50% of completion time [SIGCOMM 2011].

- Revisit fundamental problems of scheduling. [Infocom2019].

Topic of a common lab.
Between Orange and Inria “Big OS”

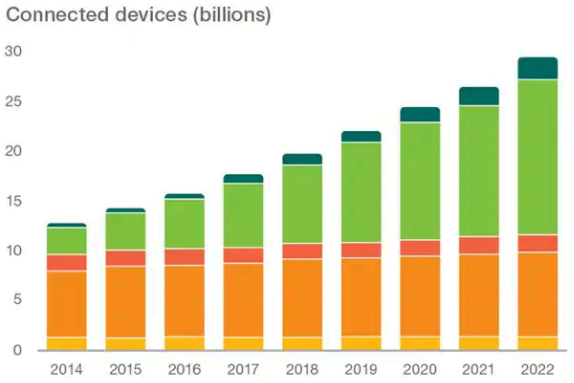




2. IOT, 5G, Cloud and Energy

Enormous expansion

- In 2021:
  - Number of connected devices = 3 times worldwide population.
  - Wireless traffic (IoT and Mobile) will represent 71 % of global IP traffic.



	2016	2022	CAGR
Wide-area IoT	0.4	2.1	30%
Short-range IoT	5.2	16	20%
PC/laptop/tablet	1.6	1.7	0%
Mobile phones	7.3	8.6	3%
Fixed phones	1.4	1.3	0%
	16 billion	29 billion	10%

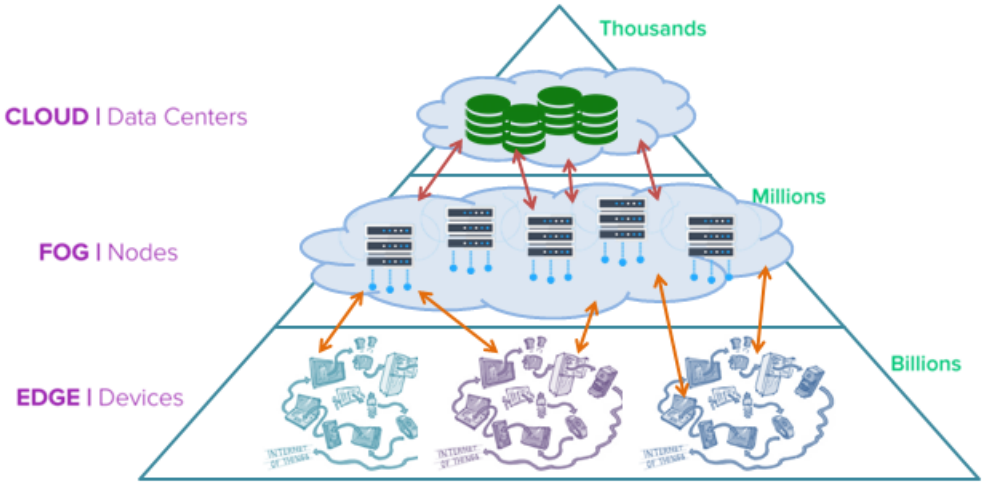
- New types of applications:
  - Very large throughput: e.g. vidéosurveillance.
  - Very low delay: augmented reality or connected cars need end-to-end latencies ≤ 20 ms.

How to limit the energy consumption of networks with tens of billions of connected devices?

Problematic to send, store, and compute everything in the cloud!

2. Mobile Edge Computing and Fog Computing

- Simple Idea: *Carry out the computations, storage, and networking as close as possible to the users.*

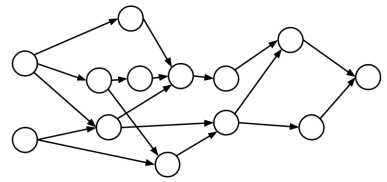


Taking advantage of distributed computations close to the edge.

- Challenges:
  - Where and when to compute, store, and send the data of IoT and mobile applications?

    In order to: minimize the energy consumption, guarantee user's QoS, secure the data…

  - Defining good models of complex applications. E.g. Video surveillance.



Application: small dynamic graph with several modules.

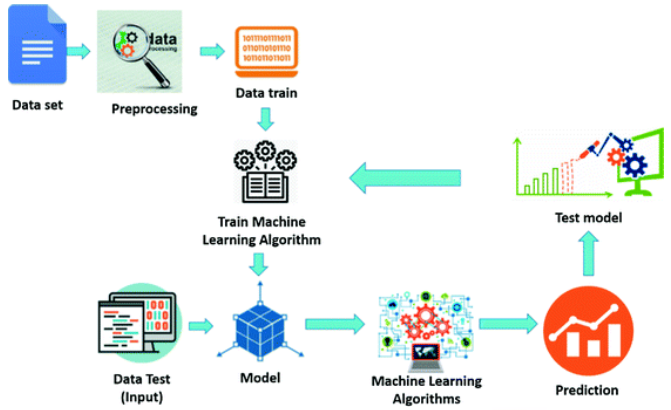
PhD financed by EUR DS4H: H. Lesfari 2019-2022

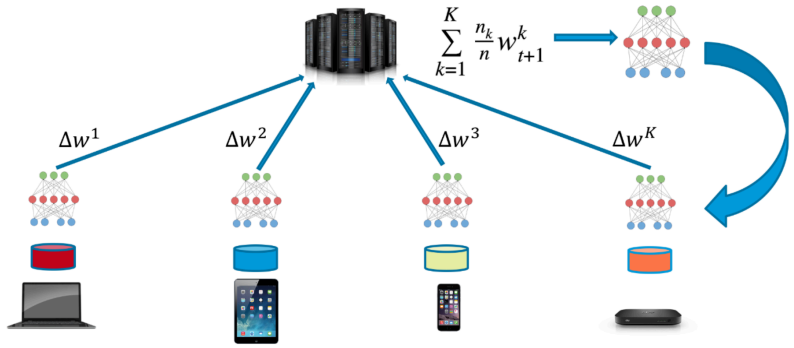
3. IA and energy

- IA: Again, first an opportunity. Having good prediction models for the future. Install and use the right amount of resources.

- Business model: Accumulate more data and we will see how to make use of it later.

- People start to think of how to reduce the impact of IA on networks and data centers:
  - E.g. Federated Learning. Not sending the data. Distributed computation.





THANKS FOR YOUR ATTENTION!