MODÉLISER LA CONSOMMATION ÉNERGÉTIQUE DE L'INTERNET DES OBJETS ET DES RÉSEAUX ÉLECTRIQUES INTELLIGENTS

Anne-Cécile Orgerie

Entretiens Jacques Cartier 2018
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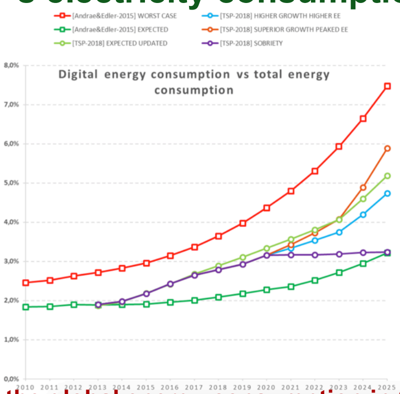
Outline

- Context
- Edge clouds & IoT use-case
- End-to-end energy consumption
- Towards generic energy models for smart systems…
- Conclusions

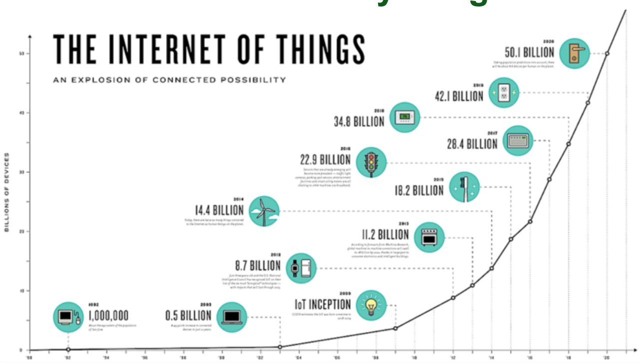
ICT's electricity consumption



THE SHIFT PROJECT

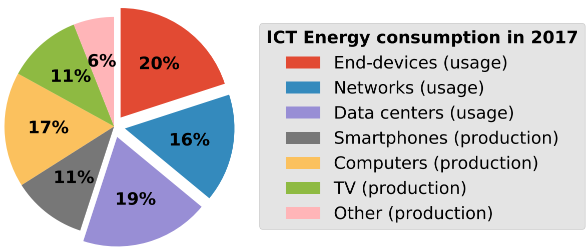
3% of the global energy consumption in 2018.

Internet of many things



Source: Cisco

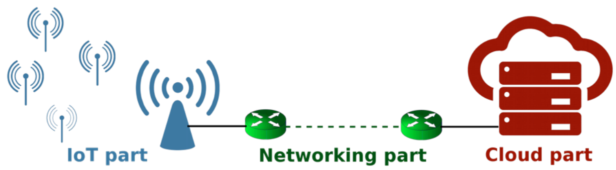
Distribution of ICT energy consumption



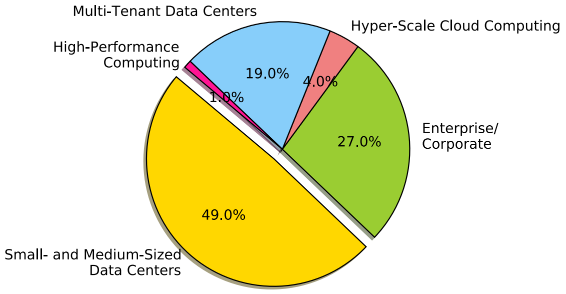
THE SHIFT PROJECT

Rapport Lean ICT : Pour une sobriété Numérique, 2018
https://theshiftproject.org

Cloud architecture



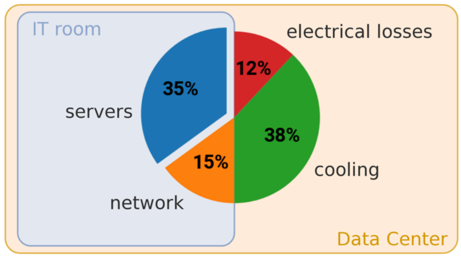
Data center's energy consumption



Estimated U.S. data center electricity consumption by market segment (2011)

Source: Data Center Efficiency Assessment, NRDC White paper, 2014.

How to measure energy efficiency?



Courtesy of David Guyon

PUE: Power usage effectiveness

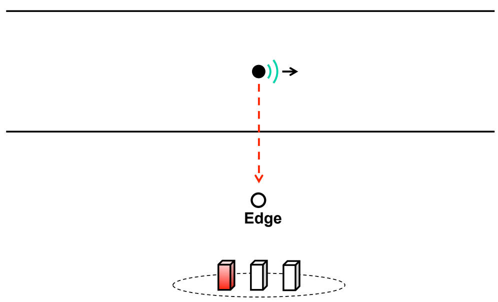
$$PUE = \frac{Total\ Facility\ Power}{IT\ Equipment\ Power}$$

the green grid

"*Green Grid Data Center Power Efficiency Metrics: PUE and DCIE*", Green Grid White Paper, 2008.

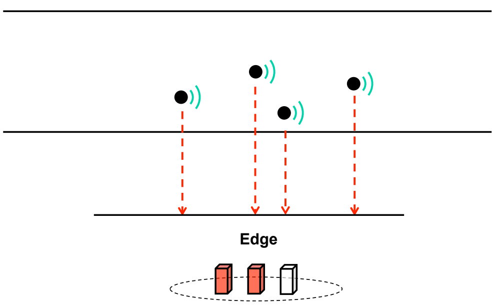
Model

Edge Model



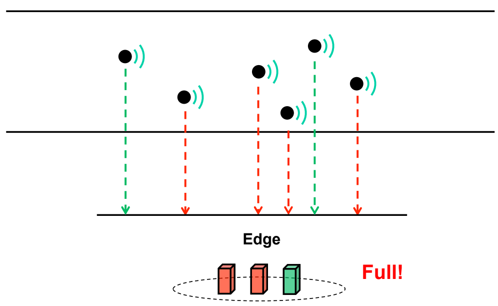
Courtesy of Yunbo Li

Edge Model



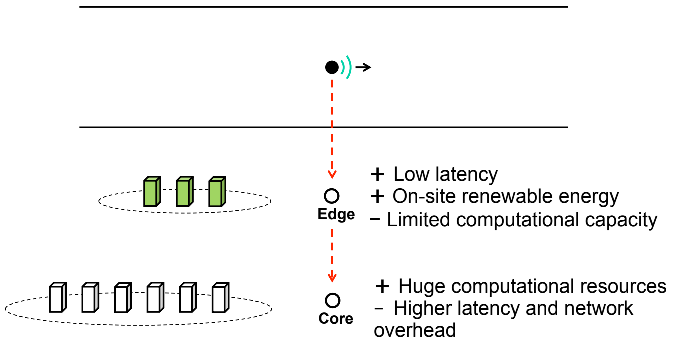
Courtesy of Yunbo Li

Edge Model



Courtesy of Yunbo Li

Edge-Core Model



Costs of running on edge/core cloud for a given application?

Depends on:

- Application's characteristics (generated traffic)
- Application's required QoS (response time, security, etc.)
- Cloud computing capacities:
  - Resource availability
  - Computing & storage capacities
  - Virtual technology (containers, VM configuration, etc.)
- Network bandwidth

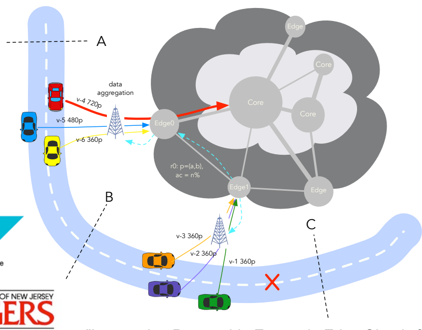
Performance/energy trade-off

Model

… later!

Scenario

Application-driven approach



Data stream analysis from cameras embedded on vehicles to detect objects on the road

IMT Atlantique
Bretagne-Pays de la Loire
École Mines-Télécom

THE STATE UNIVERSITY OF NEW JERSEY
RUTGERS

"Leveraging Renewable Energy in Edge Clouds for Data Stream Analysis in IoT", Y. Li, A.-C. Orgerie, I. Rodero, M. Parashar and J.-M. Menaud, p 186-195, IEEE/ACM CCGrid 2017.

Evaluation metrics

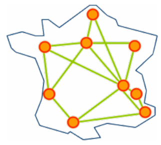
- Application accuracy (detection probability)
- Service performance (response time)
- Energy consumption
- *Green energy consumption*

Application details

- Haar classifier (in OpenCV) to analyze video streams for object detection
- Videos encoded in H.264 at 25 fps in 3 resolutions (360p, 480p, 720p)
- Analysis of about 1 frame over 3 (8 fps)
- 5 minutes videos for the experiments

	resolution	bit rate
360p	640 x 360	514 kb/s
480p	720 x 480	706 kb/s
720p	1280 x 720	1176 kb/s

Wattmeters



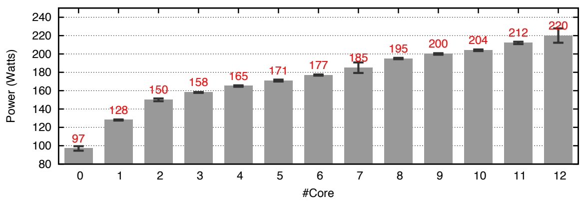
Grid'5000

"*The Green Grid'5000: Instrumenting a Grid with Energy Sensors*", M. Dias de Assunção, J.-P. Gelas, L. Lefèvre and A.-C. Orgerie, INGRID 2010.

Servers' power profile

- x86 servers with 12 physical cores (2.3 GHz), 32 GB RAM
- KVM-based virtualization layer

Grid'5000



"*Opportunistic Scheduling in Clouds Partially Powered by Green Energy*", Y. Li, A.-C. Orgerie and J.-M. Menaud, IEEE GreenCom 2015.

Experimental methodology

1. Application benchmarking on real infrastructure
2. Extrapolated results based on simulation

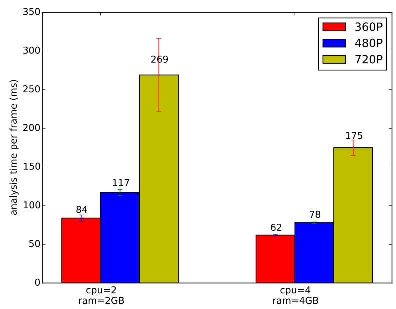
Using:

- Servers monitored by wattmeters

Grid'5000

Experiments

Analysis time on different VM sizes



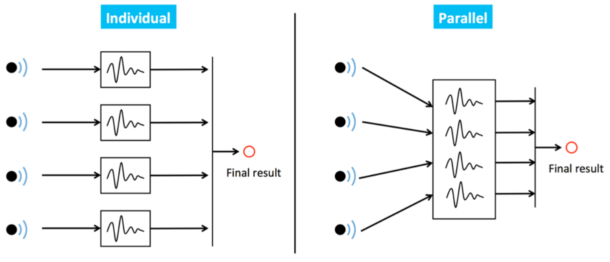
Small VM Medium VM

Medium VM better, but not linear scalability

Depends on applications' elasticity

Real measurements based on 10 runs for each experiment.

Service configuration

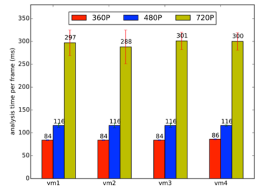


One VM per stream

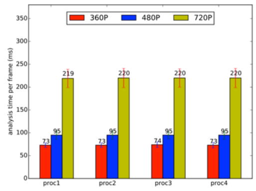
A VM for several streams

Courtesy of Yunbo Li

Several small VMs vs. one large VM



(a) Analysis time for 4 identical VMs with 1 data stream each on the same PM

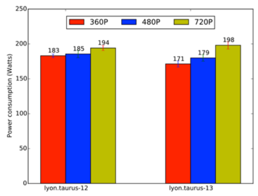


(b) Analysis time for each of the 4 data stream processes in a large VM

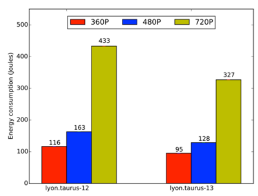
Better performance with one large VM
Large VM less easy to consolidate, repair, etc.

Depends on application's resource usage

Power and energy consumption



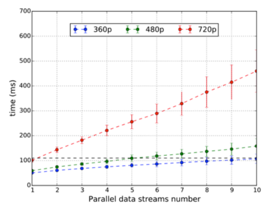
(c) Power consumption for 4 small VMs on Taurus-12 and 1 large VM on Taurus-13 for the same amount of computation



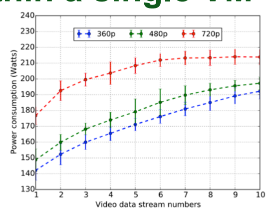
(d) Energy consumption for analyzing a 5 mn video on Taurus-12 with 4 small VMs and on Taurus-13 with 1 large VM

Power consumptions almost equivalent
Better energy consumption with large VM

Consolidation within a single VM



(e) Analysis time with parallel data streams in a large VM



(f) Power consumption with parallel data streams in a large VM

8 frames per second to analyze: 0.125 ms per frame max
A large VM can handle: 11 360p streams, 5 480p streams and 1 720p stream.

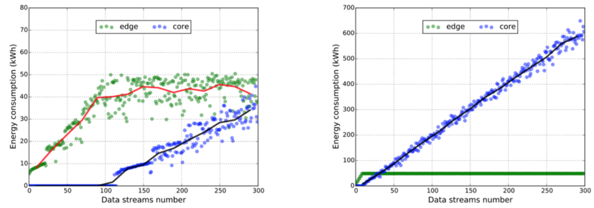
Depends on required application accuracy.

Simulations

Cloud configurations

- **Core cloud**
  - 100 servers
  - 100 ms latency with the edge devices
- **Edge cloud**
  - 5 servers
- **Unused resources are switched off.**

Energy consumption at edge & core

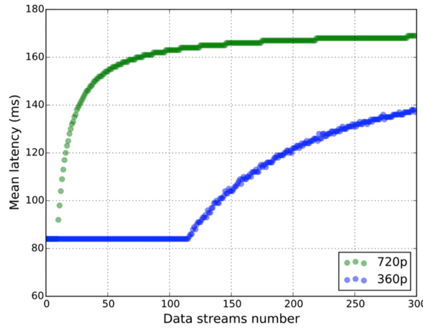


(a) Energy consumption with resolution 360p (b) Energy consumption with resolution 720p

Edge can handle: 112 *360p* data streams and 16 *720p* data streams.

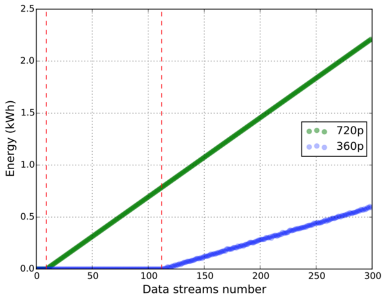
Depends on servers' architecture.

Average application latency



Depends on edge's resources availability

Network energy consumption



Cost per-bit energy model for network

Model from: F.Jalali, K.Hinton, R.Ayre, T.Alpcan, R.S.Tucker, *``Fog Computing May Help to Save Energy in Cloud Computing*'', JSAC 34 (5), 2016.

Depends on application traffic and edge resources

Application accuracy

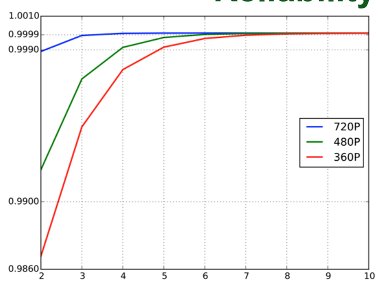
Object detection accuracy

Classes	720p	480p	360p
car	96.7%	91%	88.5%
body	97.7%	94.9%	90.7%
dog	96.1%	94.9%	90.7%
total	96.7%	92.3%	87.9%

Is it better to have 1 car with 720p resolution or 2 cars with 360p resolutions?

Data from: P. Simoens, Y. Xiao, P. Pillai, Z. Chen, K. Ha, M. Satyanarayanan, *``Scalable crowd-sourcing of video from mobile devices''*, ACM International Conference on Mobile systems, applications, and services, 2013.

Reliability



Not feasible in real-time with 1 VM

Feasible in real-time with 1 VM

Number of data streams for reaching required accuracy

# nines	720p	480p	360p
99.9%	3	4	6
99.99%	4	6	8
99.999%	5	7	11

Summary

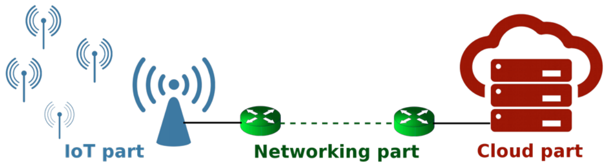
Offloading the data to process video streams at edge:

- Effectively reduces the response time
- Avoids unnecessary data transmission between edge and core
- Extends for instance the battery lifetime of end-user equipment
- *On-site renewable energy production and batteries in our scenario can save up to 50% total consumed energy consumed at the edge*

"Leveraging Renewable Energy in Edge Clouds for Data Stream Analysis in IoT", Y. Li, A.-C. Orgerie, I. Rodero, M. Parashar and J.-M. Menaud, p 186-195, IEEE/ACM CCGrid 2017.

What about the other parts?

Which part consumes the most?



"End-to-end Energy Models for Edge Cloud-based IoT Platforms: Application to Data Stream Analysis in IoT", Y. Li, A.-C. Orgerie, I. Rodero, B. Lemma Amersho, M. Parashar, J.-M. Menaud, FGCS, vol. 87, p 667-678, 2018.

Parameters of our example

IoT devices (camera)

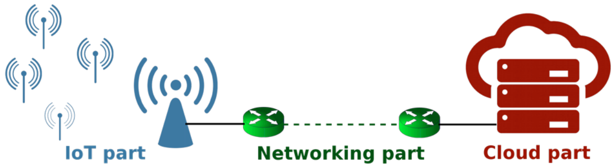
Parameter	Value
Voltage	3.3 V
Idle current	0.273 A
CCA Busy State current	0.273 A
Tx current	0.38 A
Rx current	0.313 A
Channel Switching current	0.273 A
Sleep current	0.033 A

Network devices

Parameter	Edge router	Core router
Idle consumption	4,095 Watts	11,070 Watts
Max consumption	4,550 Watts	12,300 Watts
Traffic	560 Gbps	4,480 Gbps
Energy	37 nJ/bit	12.6 nJ/bit

Cloud data centers
PUE = 1.7 for edge
PUE = 1.2 for core

Experimental setup



Simulations

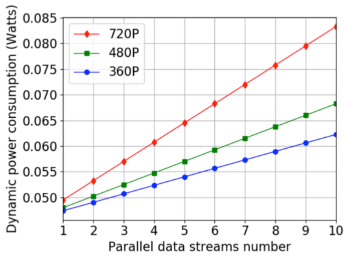
Model from literature

Real measurements

ns-3

IoT consumption per device

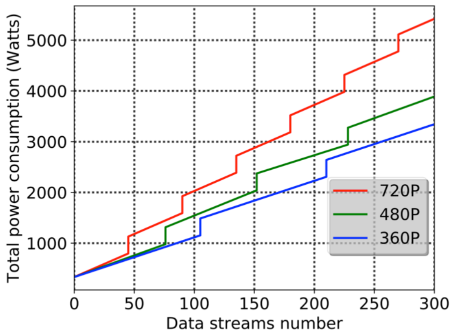
Dynamic power consumption



Overall power consumption

# devices	360p	480p	720p
1	6.907	6.908	6.909
2	12.869	12.87	12.873
3	18.831	18.832	18.837
4	24.792	24.795	24.801
5	30.754	30.757	30.765
6	36.716	36.719	36.728
7	42.677	42.682	42.692
8	48.639	48.644	48.656
9	54.601	54.606	54.62
10	60.562	60.568	60.583

IoT part including access point



Overall evaluation

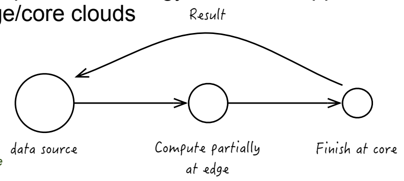
Scenario	IoT	Network	Cloud
Edge Cloud	10.96 Watts	0.07 Watts	32.3 Watts
Core Cloud	10.96	0.11 Watts	22.8 Watts

- Cost per 360p stream for each part
- Consumption when in use
- Not including all the infrastructure costs

- **IoT part**: accurate for the given scenario in an ideal case (without loss on the 802.11 network)
- **Network part**: following literature model (based on average Internet traffic, so probably underestimated)
- **Cloud part**: measured, accurate on the given servers

Conclusions

- Typical (future) application: data stream analysis for IoT devices and applications
- Real power and performance measurements on a concrete use-case
- Exploration of possible trade-offs between performance (response time and accuracy) and energy consumption (*green and brown*)
- First step towards energy-aware IoT applications relying on edge/core clouds

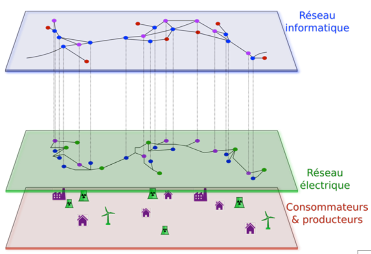


Conclusions

- **End-to-end** energy consumption
- Cloud part non negligible
- Started with the study of a given application
- Extending existing simulators with generic validated energy models
- On-going work…
  - Other IoT devices
  - Using other network protocols
- Could increase the use of renewable energy

Smart Grids

ICT infrastructure with sensors-actuators to manage the electrical Grid with multiple consumers and producers



Current ICT network
- Overprovisioning
- Intrusive system

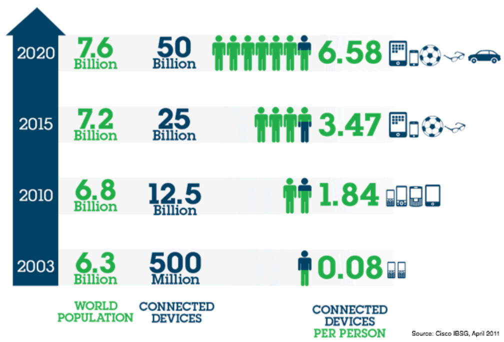
Issues:

More and more flexible load

Distributed production

Intermittent production

Internet of all the Things



http://www.supinfo.com/articles/single/4235-internet-of-things

Thank you for your attention

http://people.irisa.fr/Anne-Cecile.Orgerie