Simulating green networks with Ecofen

Bogdan CORNEA, Anne-Cecile ORGERIE, Laurent LEFEVRE

Green Days, Rennes 2014

Outline

Context
- energy consumption in data centers

Objectives
- calculate energy profiles of wired networks

Approach
- simulation and the energy module

Simulation results
- obtaining global and complete energy profile

Conclusions & ongoing work
- simulating energy consumption in large-scale systems
- tools for the HPC community

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Context

- Nearly every field relies on connected devices
- Energy consumption => key economical & environmental factor

Estimation for 2015	Energy [TWh]	Million tons of oil eq.	Total saving [milliard EUR / year]
No savings	50	11	-
With (expected) savings	25	5.5	7.5

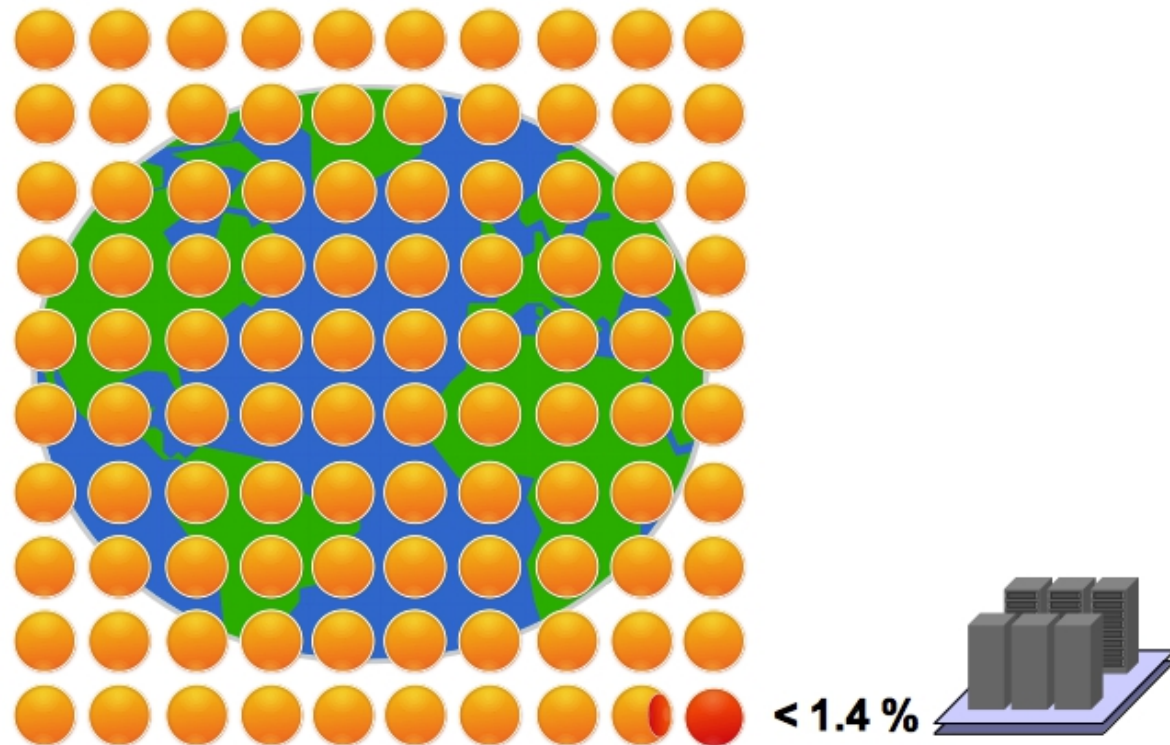Author: Institute for Energy and Transport (IET), European Comission
Date: april 2013
Source: http://iet.jrc.ec.europa.eu/energyefficiency/ict-codes-conduct/energy-consumption-broadband-communication-equipment

Context

- Platforms: Computation, Communication, Cooling
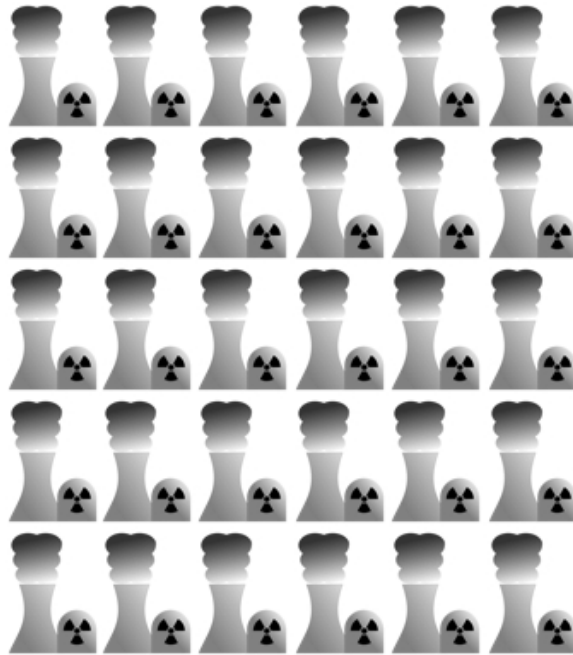- Data center power usage

~ 30 GW

< 1.4 %

Source 1: Google Inc. Data center electricity consumption.
Source 2: J. Koomey. 2011
Source 3: Glanz

Context

~ 30 GW

< 1.4 %

Google ~ 0.26 GW
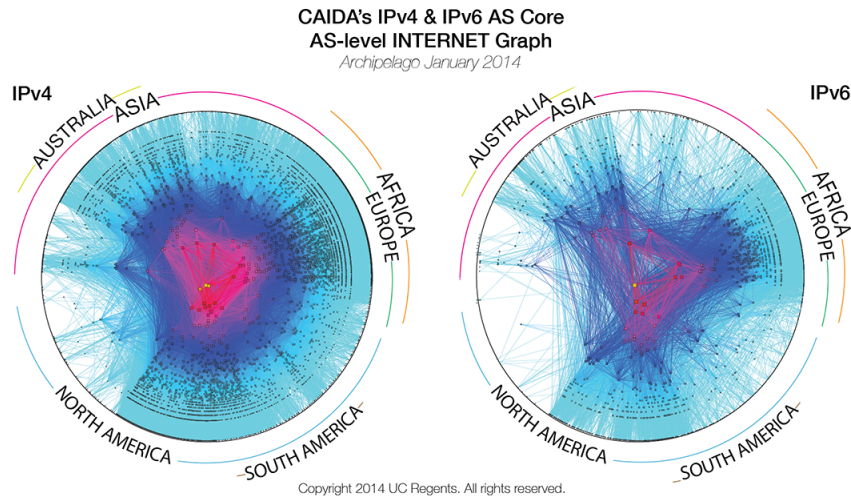
Source: Glanz 2012

Context

- Data center power

90 % is wasted

- No network means no usage, no progress.

Context

Network energy? **Wired** or Wireless

CAIDA's IPv4 & IPv6 AS Core
AS-level INTERNET Graph
Archipelago January 2014

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- Focus on wired networks
  - Backbone of mobile carriers
  - Interconnect of HPC or Cloud

Challenges

Evaluating

- the <u>end-to-end</u> energy consumption of large-scale wired networks
- Context: Cloud computing

Comparing the energy

- of various network protocols & strategies

Simulating

- Green leverage at large-scale

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Objectives

- Simulation approach

- Providing energy profiles of wired networks

- Using green levers
  - Adaptive Link Rate
  - Switching On/Off
  - Sleep.

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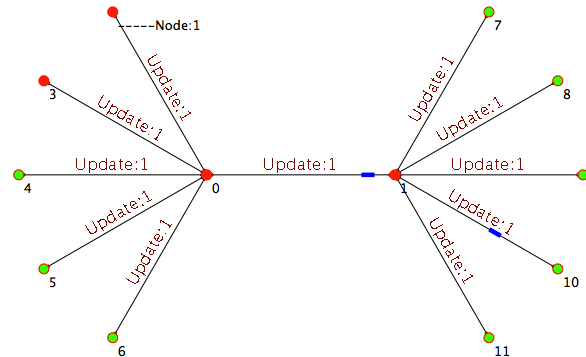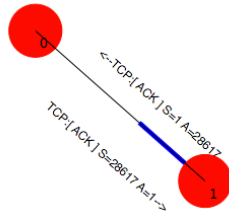- obtaining global and complete energy profile

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Approach: Network simulations

Testing

- Algorithms
- Protocols
- Resources
- Topologies

Source: [netanim]

Reproducible experiments

- Scenarios
- Specific use cases

Downside

- How realistic are the models for emerging technologies?
- Can we achieve fast and large scale simulations?

Approach:
Network simulator: NS-3

Discrete event-driven simulator

- Event: physical activity
- Order: scheduled by occurrence

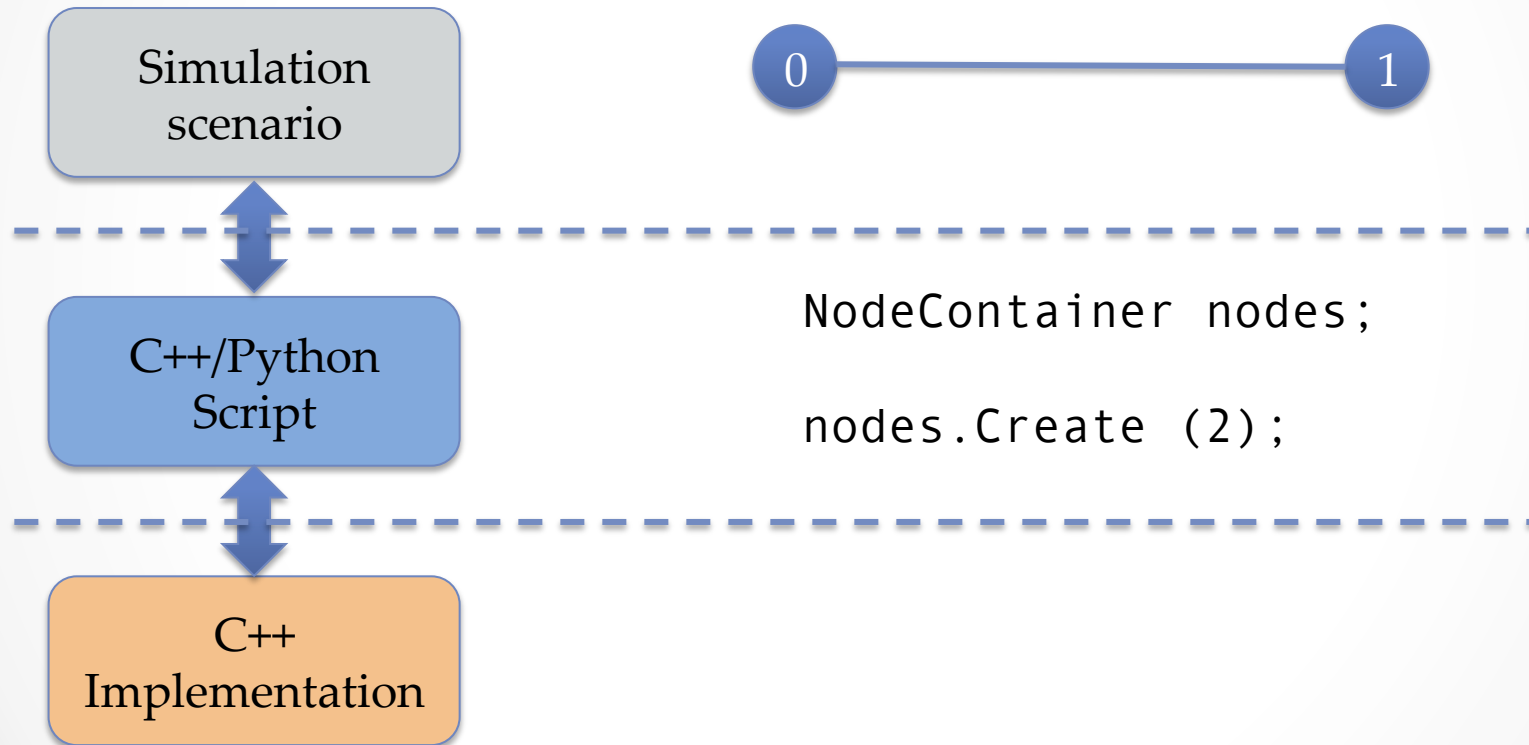A real project:

- Known and used in research

Approach:
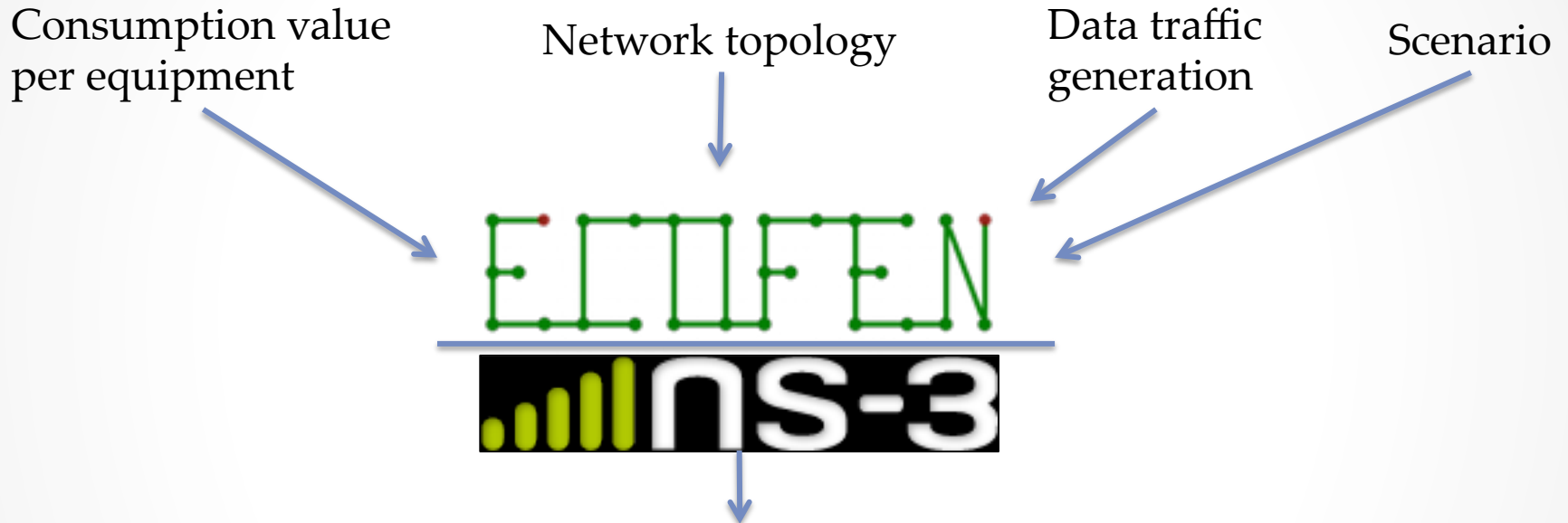# Network simulator: NS-3

Technical aspects

- C++, very modular
- Implemented protocols at multiple layers
  - TCP,UDP
  - MAC (802.11, 802.3, TDMA)
  - Ad-hoc routing
  - Sensor network
  - Other protocols: multicast, satellite, etc.

- Maintained
  - Research community can contribute

No energy module (for wired networks) available natively in NS3

Approach:
Network simulator: NS-3

| Simulation scenario |

0 ————————— 1

| C++/Python Script |

```
NodeContainer nodes;

nodes.Create (2);
```

| C++ Implementation |

Approach:
NS-3: Energy module

Consumption value per equipment

Network topology

Data traffic generation

Scenario

[Label] [time in s] [label] [node id] [label] [power in W]					
Time	0	Node	0	Power	2.94
Time	0	Node	1	Power	154.48
Time	0.01	Node	0	Power	2.94
Time	0.01	Node	1	Power	154.48
Time	0.02	Node	0	Power	2.94
Time	0.02	Node	1	Power	154.48

Approach:
NS-3: Energy module

Defining nodes

```
NodeContainer nodes;

nodes.Create(2);
```

Define the energy
reporting tool

```
nodes.Get(0)->ReportEnergy (1.0 , 0.0 , 11.000);
```

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Energy values

Configuring the simulator

Device	State / Action	Value	Unit	Energy model	Link Rate
NIC	On	1.82	W	basic	1 Gbps
	Off	0.7	W		
port	Idle	1.12	W	complete	
	Off	0	W		
	Send/Recv byte	3.4	nJ		
	Send/Recv packet	197.2	nJ		
NIC	Switch On/Off	0.91×10^{-3}	J	complete	
		0.5×10^{-3}	s		
port	Switch On/Off	0.56×10^{-3}	J	complete	
		0.5×10^{-3}	s		

Simulation results

Focuses on the features of Ecofen

1. Constant data transfer (over TCP):
   o Migrating VMs

2. Random-size data transfers (over TCP):
   o Network global dynamic analysis

   o NIC dynamic analysis

   o A one minute Cloud snapshot

   o Green levers on network devices: end-to-end and complete

Migrating VMs

Scenario:
- 2 x NIC + switch; TCP;
- Transfer size: 1.5GB;
- Link rate: 100 Mbps
- Energy model: linear
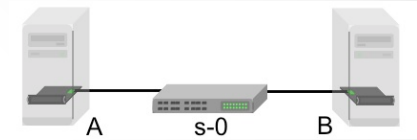
Power/Time:
- End-to-end view
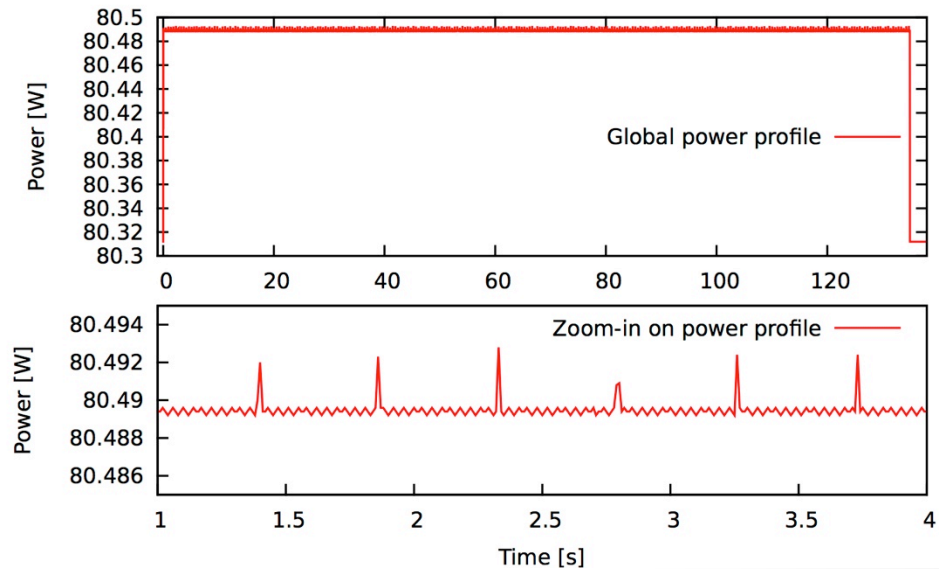
Energy:
Bw*: 54/80/100/112 Mbps
Link rates: 100/1000 Mbps
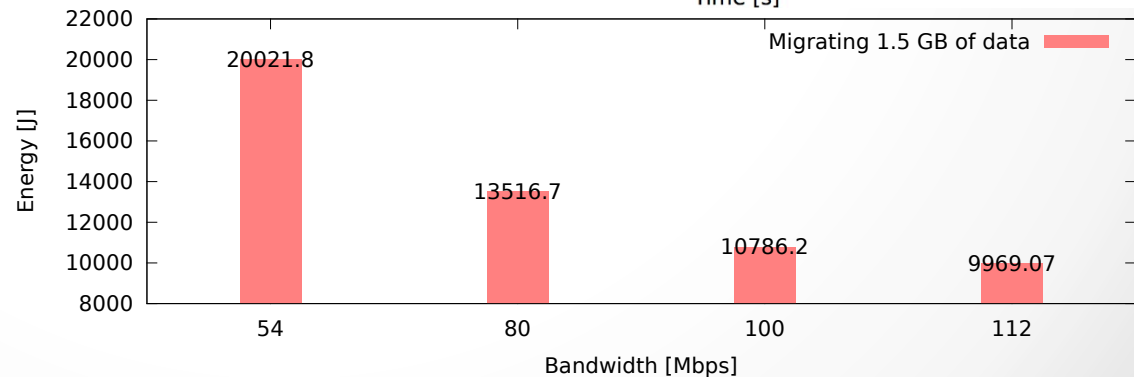
* Constraint of libvirt / Kvm+qemu

Network global dynamic analysis

Scenario:

- 5 x NIC + 5 x switch; TCP
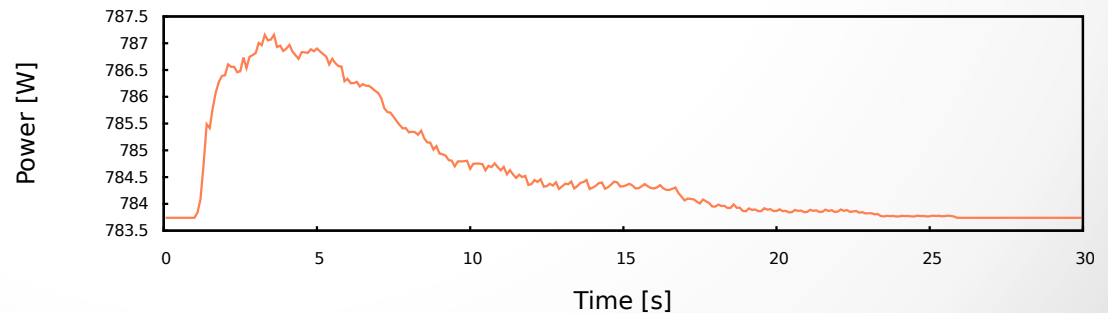- 200 transfers; random size
- Link rate: 1 Gbps
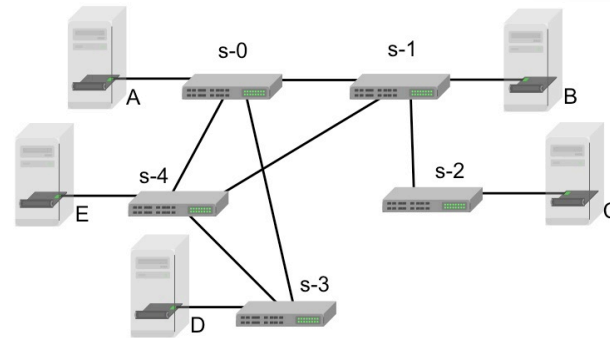- energy model: complete
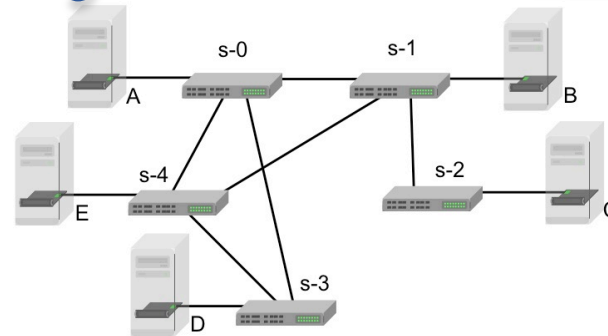
Data volume:

- Network global view
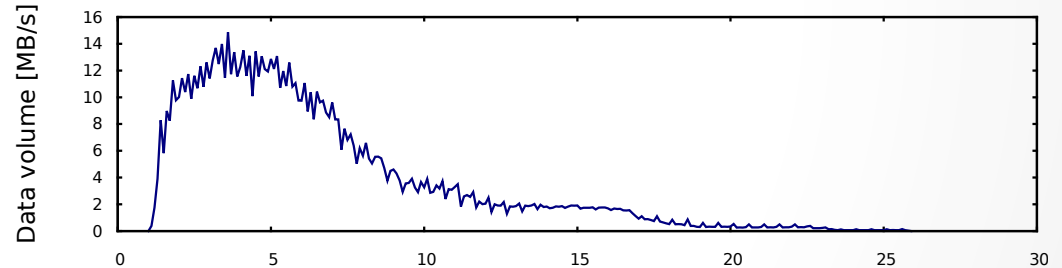
Power:

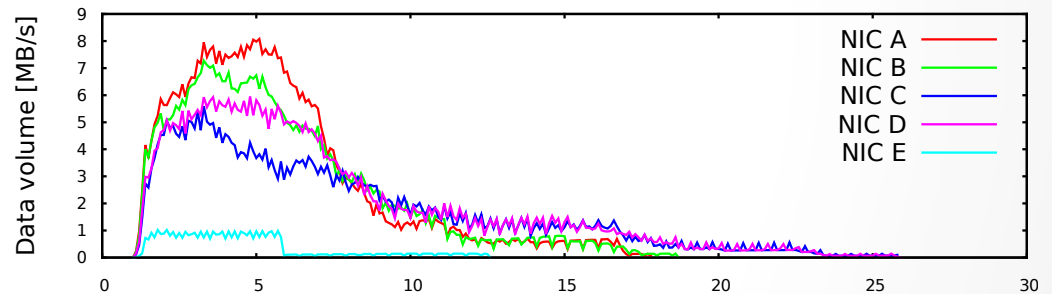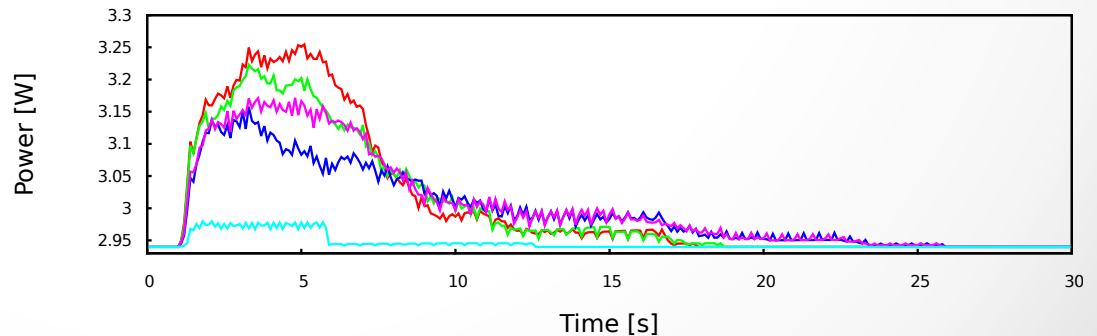- Network global view

NIC dynamic analysis

Scenario:

o 5 x NIC + 5 x switch; TCP
o 200 transfers; random size
o Link rate: 1 Gbps
o energy model: complete

Data volume:
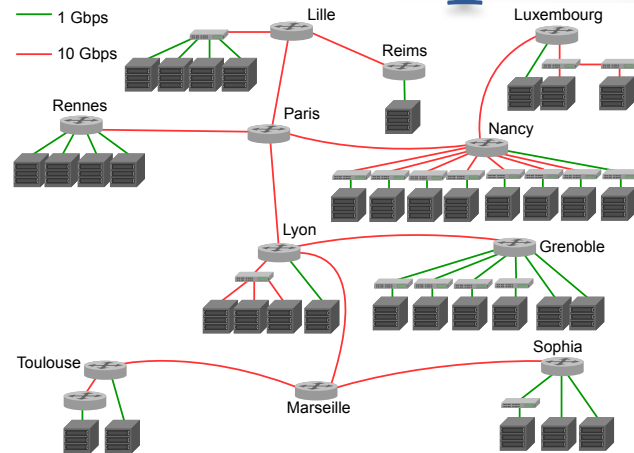
o NIC view
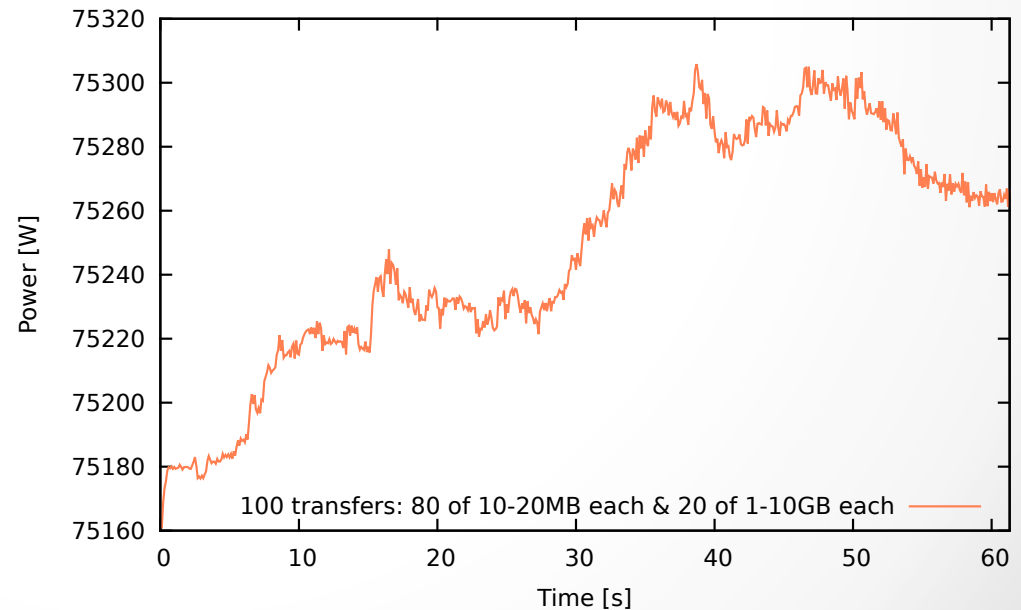
Power

o NIC view

Cloud platform snapshot

Scenario:

- Grid'5000 platform topology
- 1000+ NIC ; switches ; routers
- Link rates:
    - 1 Gbps, 10 Gbps
- 100 transfers; random size
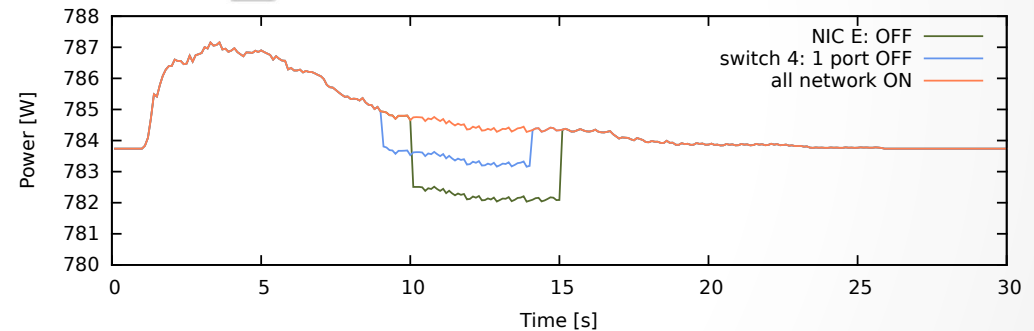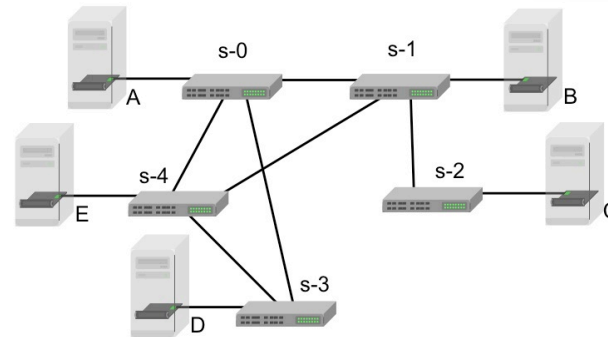- TCP
- Energy model: complete

Power

- 60s snapshot

100 transfers: 80 of 10-20MB each & 20 of 1-10GB each

Green levers on network devices

Scenario:

- 5 x NIC + 5 x switch; TCP
- 200 transfers; random size
- Link rate: 1 Gbps
- energy model: complete
- changes:
  - port switch Off
  - card switch Off

Power (top):

- Network global view

Power (bottom):

- Switch view

Green levels on network devices

Scenario:

- 5 x NIC + 5 x switch; TCP
- 200 transfers; random size
- Link rate: 1 Gbps
- energy model: complete
- changes:
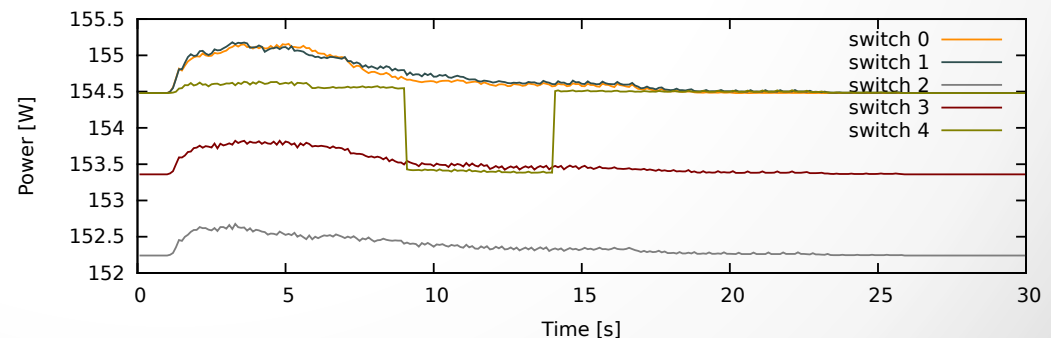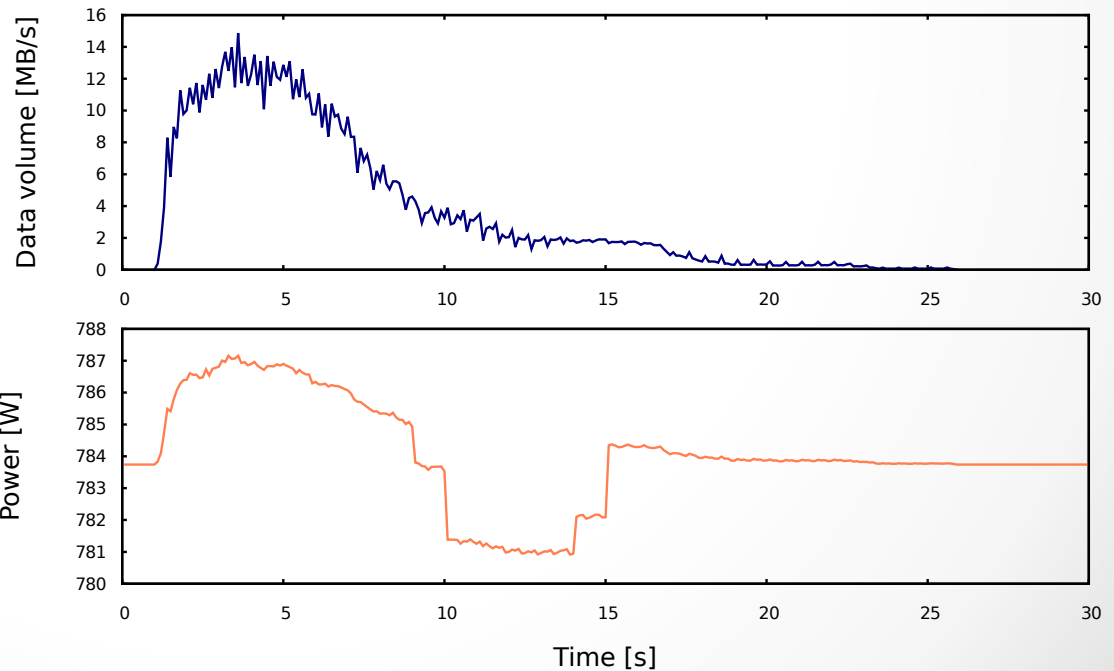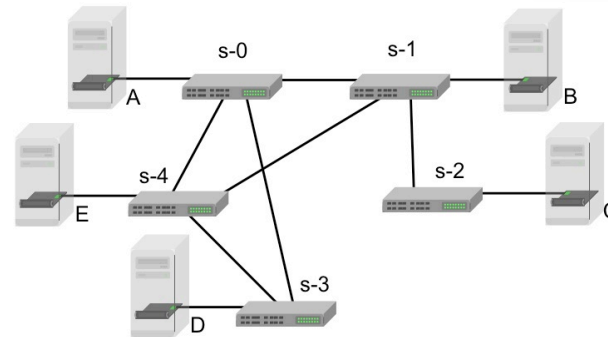 - port switch Off
  - card switch Off

Data volume (top):

- Network global view

Power (bottom):

- Network global view
- Cumulated saving:
  Port(sw04) + NIC E

Demo NetAnim

![Myriads] Guillaume CHAPEL
Guillaume.Chapel@inria.fr

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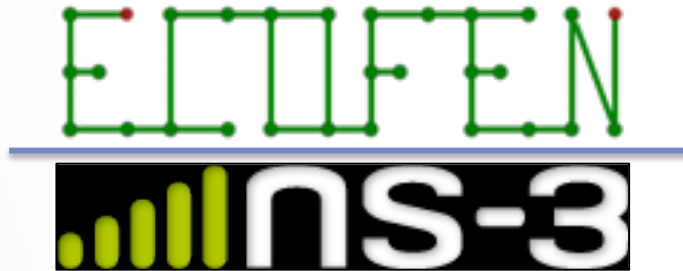
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Conclusions

- An Energy consumption model for end-to-end networks (Ecofen)

- Profile of the energy consumption
  - Global + complete

- Study the impact of green levers

Ongoing work

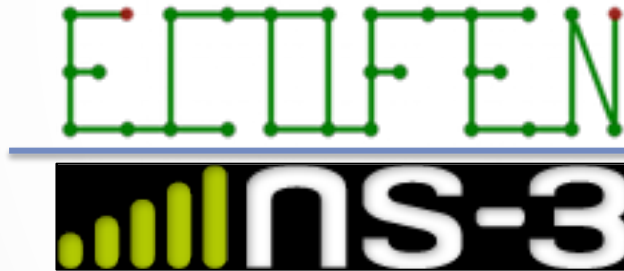- Ecofen
  - Network community: NS3

Ongoing work

- Ecofen
  - Network community: NS3

Ongoing work

- Ecofen
  - Network community: NS3

  - Integration with SimGrid (MPI)
    - Trace-based simulation
    - Full simulation

Thank you!

Simulating green networks with Ecofen

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Green Days, Rennes 2014

References

- [Orgerie] A.-C. Orgerie, L. Lefevre, I. Guerin-Lassous, and D. Pacheco, "Ecofen: An end-to-end energy cost model and simulator for evaluating power consumption in large-scale networks," in *World of Wireless, Mobile and Multimedia Networks (WoWMoM), 2011 IEEE International Symposium on a*, June 2011, pp. 1–6.

- [Glanz] J. Glanz. The Cloud Factories - Power, Pollution and the Internet. The New York Times, 22 Sept. 2012. http://www.nytimes.com/2012/09/23/technology/data-centers-waste-vast-amounts-of-energy-belying-industry-image.html?smid=pl-share

- Google Inc. Data center electricity consumption.
  http://www.google.com/green/bigpicture/#/datacenters/infographics

- [Koomey] J. Koomey. 2011. *Growth in Data center electricity use 2005 to 2010*. Oakland, CA: Analytics Press. August 1. http://www.analyticspress.com/datacenters.html

- [Oines 2013] Arnfinn Oines. Google Energy consumption. 16 Feb 2013
  http://arnfinno.wordpress.com/2013/02/16/googles-energy-consumption

Energy data:

- http://www.eia.gov/tools/faqs/faq.cfm?id=104&t=3

  o Typical nuclear power plant electricity: 2 x 500 MW = 1GW.

- http://iet.jrc.ec.europa.eu/energyefficiency/ict-codes-conduct/energy-consumption-broadband-communication-equipment

Backup slide 1

Defining nodes	`NodeContainer nodes;` `nodes.Create(2);`

(0) ———————————— (1)

Creating a comm. Link	`link.SetDeviceAttribute ("DataRate", 54);` `link.SetChannelAttribute ("Delay", 0.08);`
Install link on ports	`NetDeviceContainer dev0 = link.Install (n0n1);`

Add energy information to NIC or switch	`power.Set ("On", 6.936 );`
	 `power.Set ("Off", 0 );`
	 `power.Install (nodes);`

Add energy information to ports	`port.Set ("IdleConso", 0.11 );`
	 `port.Set ("ByteEnergy", 3.423 );`
	 `port.Install (dev0);`

Define the energy reporting tool	`nodes.Get(0)->ReportEnergy ( 1.0 , 0.0 , nodes );`

ECOFEN

.ıll ns-3