Green Days
@ Toulouse

Segment Routing based Traffic Engineering for Energy Efficient Backbone Networks

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CHIST-ERA STAR

Outline

- Context: energy efficiency and backbone networks
- Switching OFF/ON for energy efficiency
  - Why?
  - What?
  - How?
- Simulation
- Results
- Future work

Some messages from our planet

Ice melting: 500Gtons/year in 2011-2014

x2/x3 increase compared to averages in 2003 - 2009

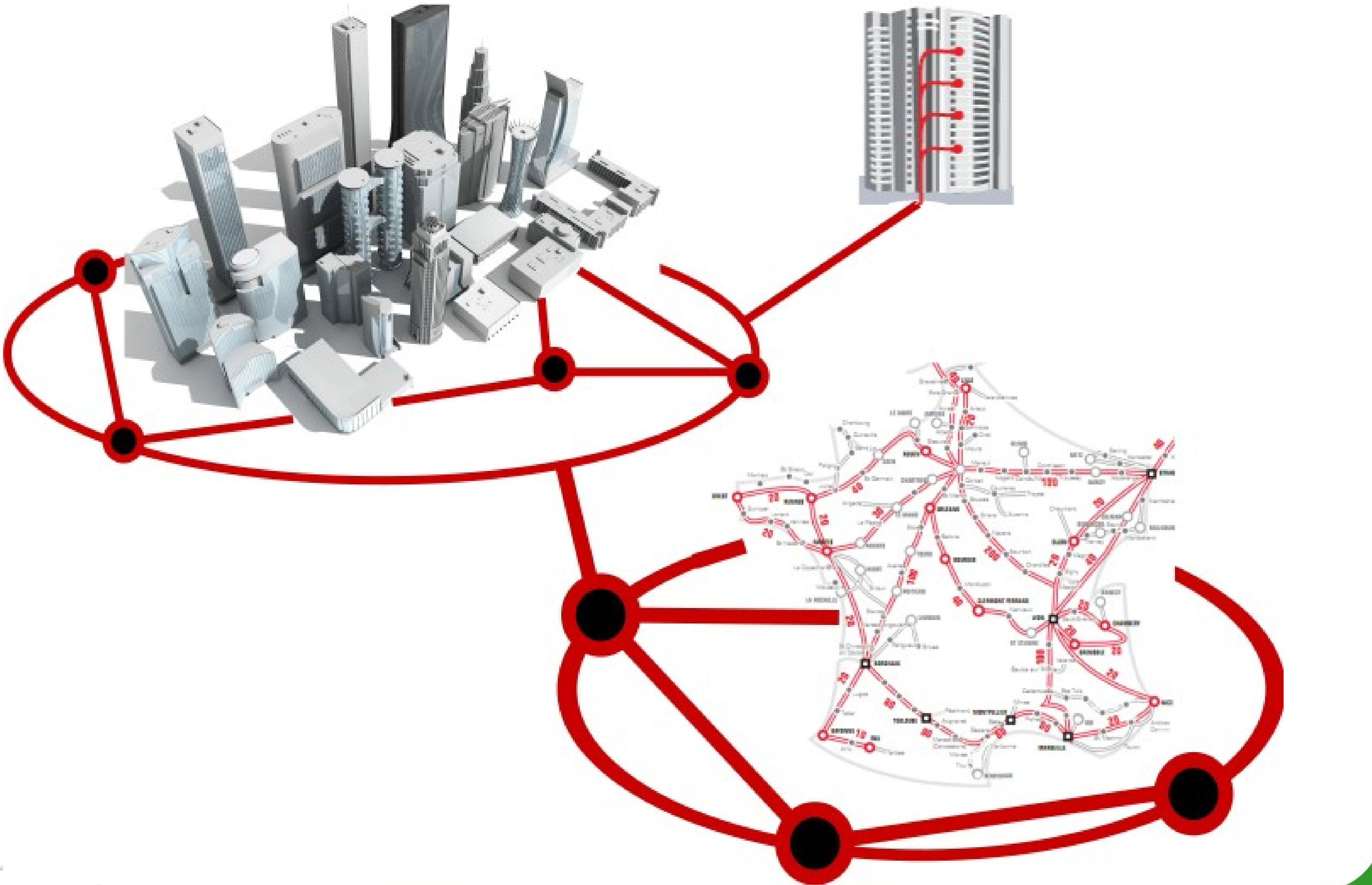
ocean rising > 1 m (2100)

Temperature increasing (2°C – 2100) -> 4°C (50% chance – 2100)

No more oil in 50 years … more coal usage…

IT -> electricity -> CO_2 -> impact

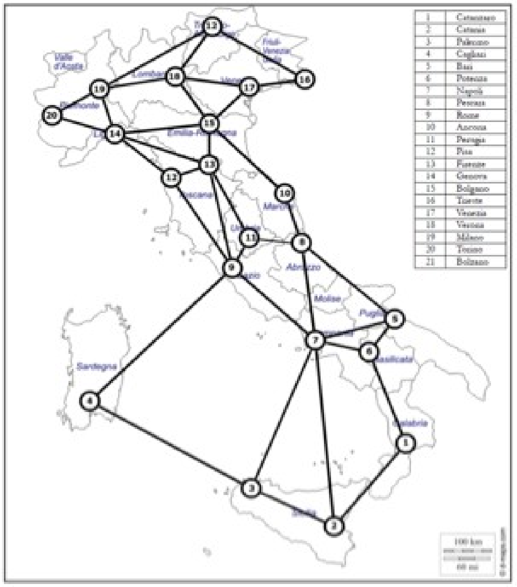
Backbone networks



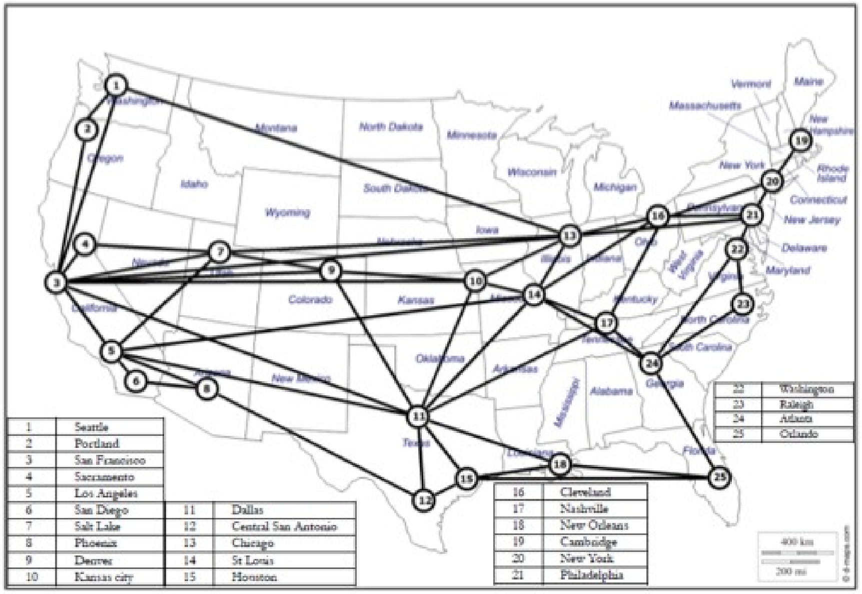
Backbone networks

- High speed core networks
- Relatively small number of nodes
- High speed ports
- The network must not be disconnected
- Based on optical fibers
- High energy consumption
- Overprovisioning

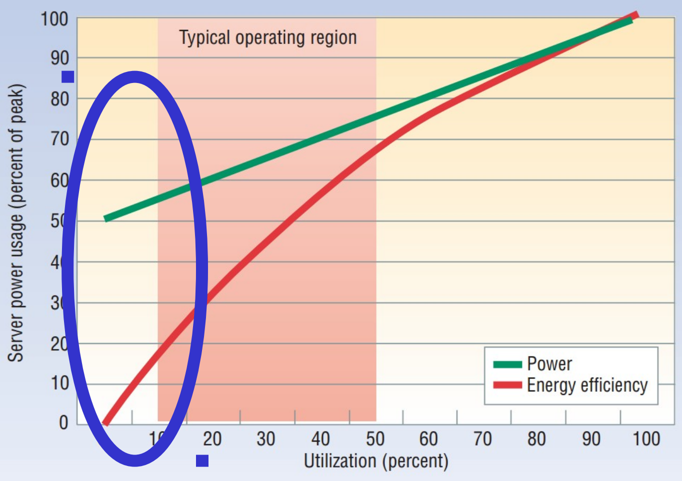
Telecom Italia



AT & T



Energy proportionality



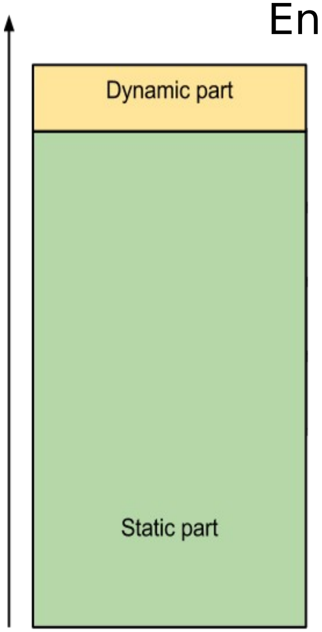
*Luiz André Barroso and Urs Hölzle, « The case for Energy-Proportional Computing », IEEE Computer, 2007

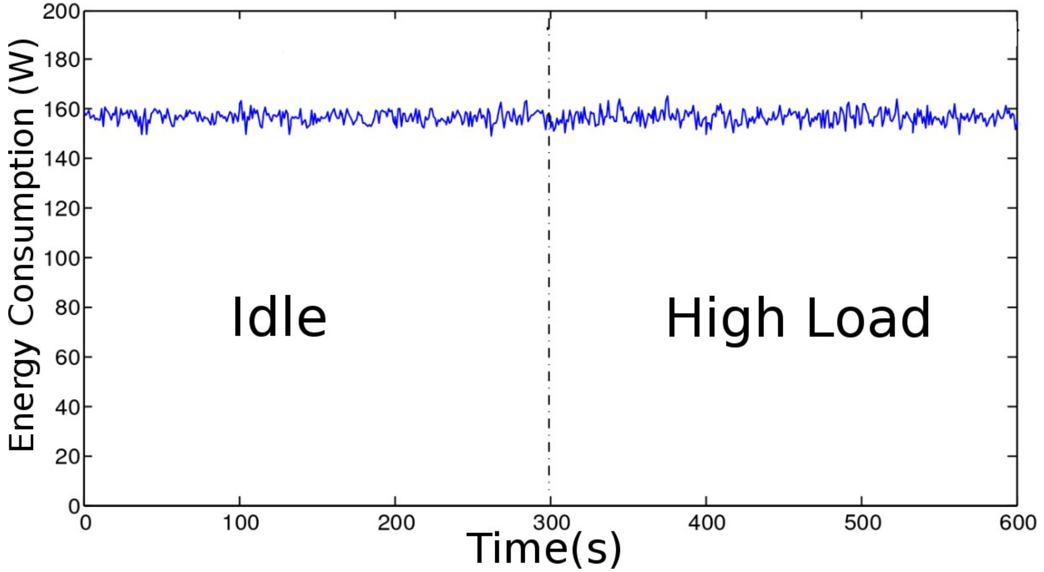
<u>Servers</u>

- Idle power consumption
- Non-linear increase of energy efficiency

<u>Network</u>

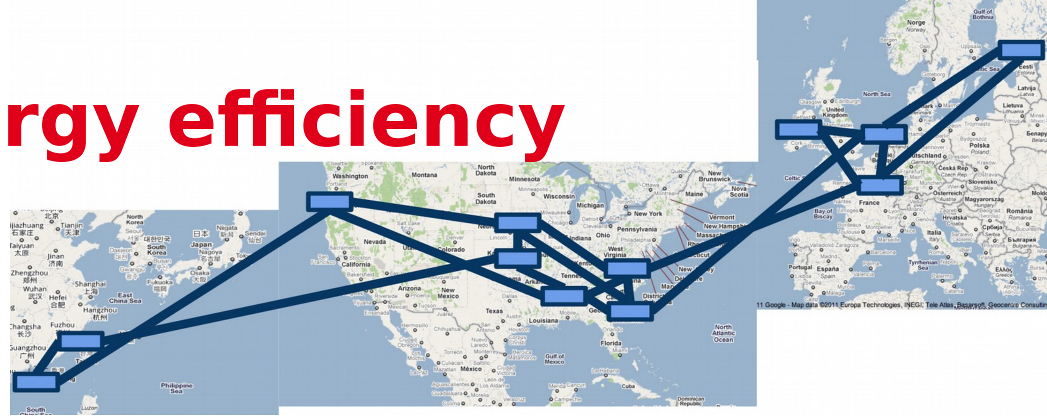
- Even less proportional
- Energy consumption almost constant



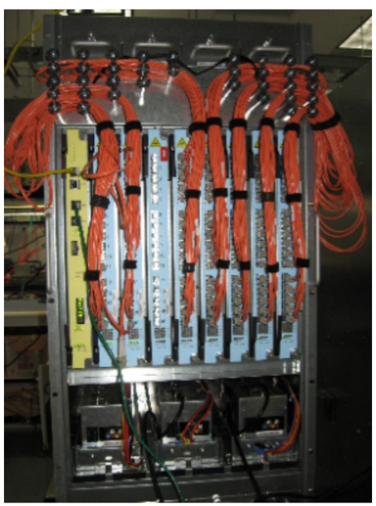


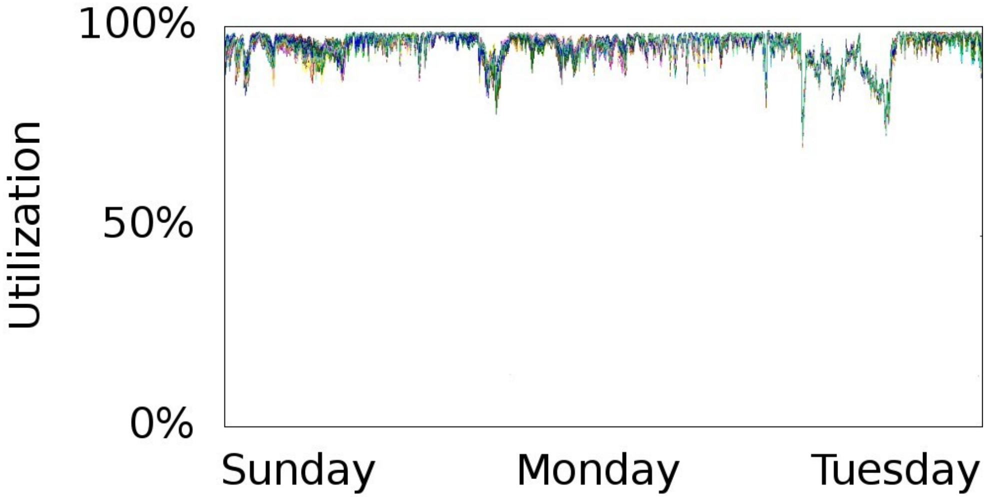
Mohammed El Mehdi Diouri. Eficacite energetique dans le calcul tres haute performance : application a la tolerance aux pannes et a la difusion de donnees. Ecole normale superieure de lyon - ENS LYON, 2013.

Increasing the energy efficiency



Google's way: increase the utilization!





*Sushant Jain, Alok Kumar et al. «B4: experience with a globally-deployed software defined wan». SIGCOMM Comput. Commun. Rev. 43, 4 (August 2013), 3-14.

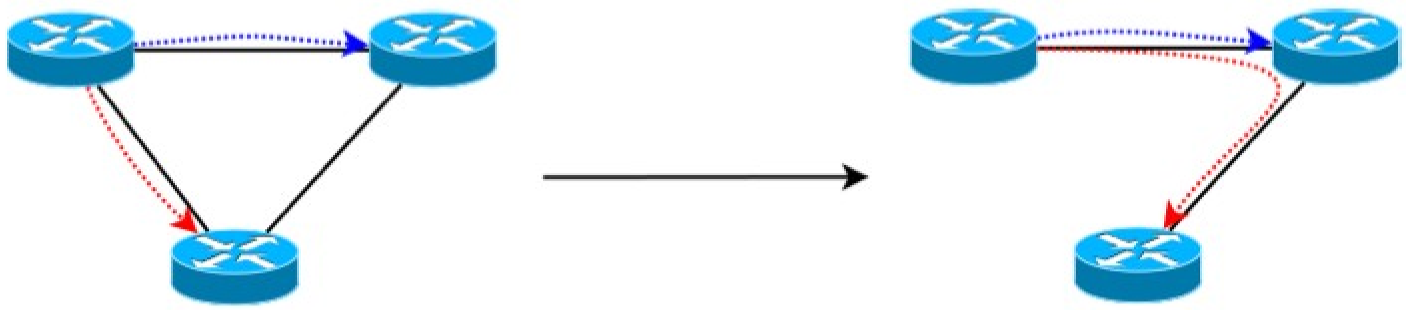
Increasing the energy efficiency

Our way: increase the utilization ...

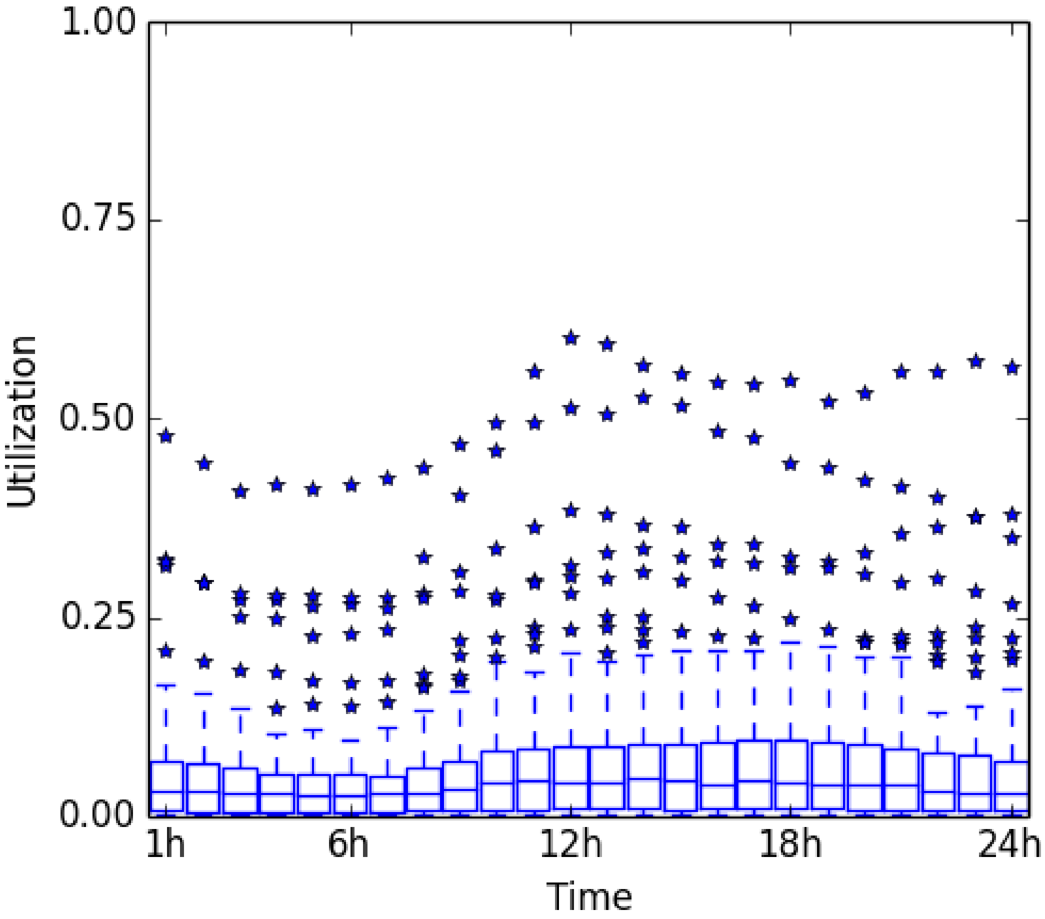
... of some links

Completely unload other links and switch them off

- lesser trafic in the network = more savings possible



Overprovisioning



Distribution of link utilization in the Geant network

On-demand ON/OFF

During the off-peak hours, choose the best links to be **switched off**

- May be easy (inefficient), up to NP-hard
- Using link utilization (actual solution), or flow matrices:
  - In most cases are difficult to obtain
  - Can be estimated, but error-prone and expensive

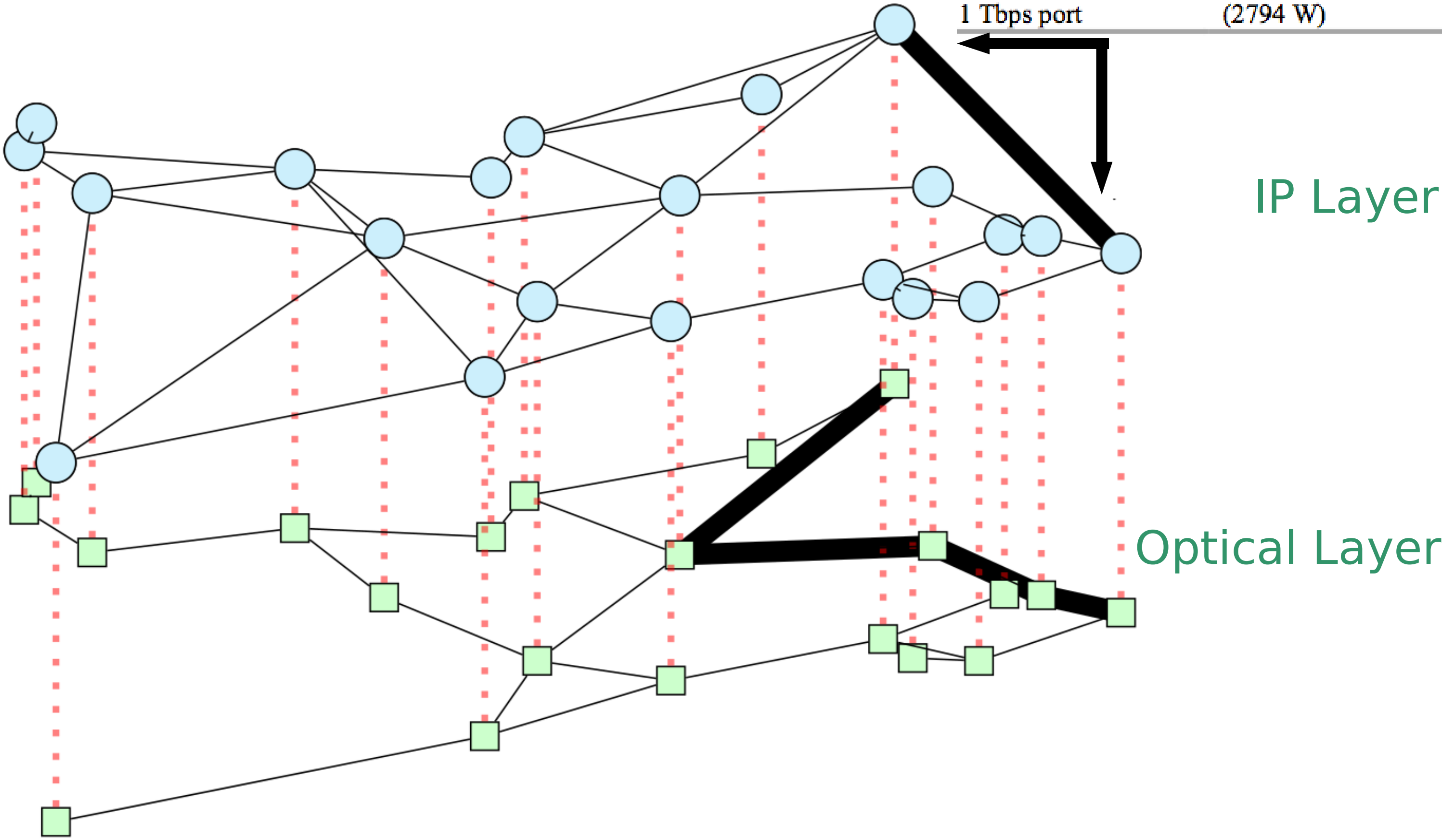
During the rush periods, find the links to be **switched on**

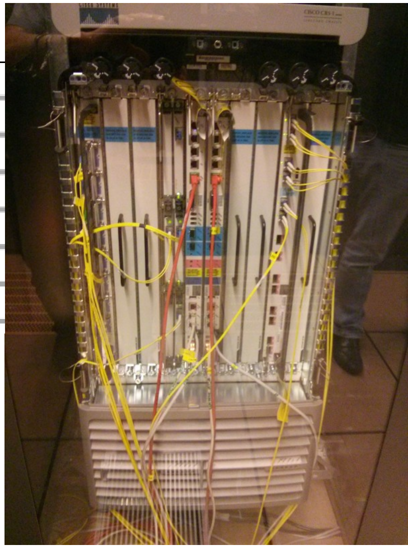
- Can be even more complex

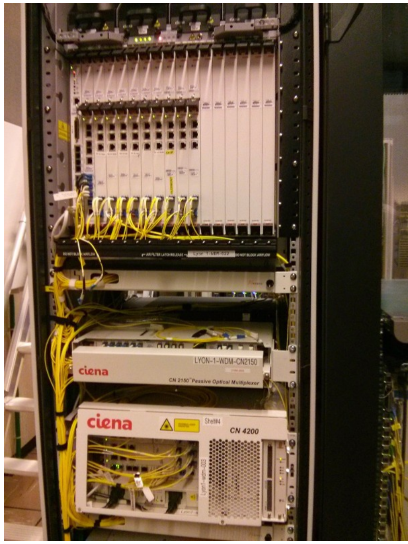
Choosing what to switch off/on
in a multi-layered network

*Van Heddeghem, Ward, Filip Idzikowski et al.. 2012. "Power Consumption Modeling in Optical Multilayer Networks." Photonic Network Communications 24 (2): 86–102

	Power consumption [Watt]
1 Gbps port	7 W
2.5 Gbps port	15 W
10 Gbps port	34 W
40 Gbps port	160 W
100 Gbps port	360 W
400 Gbps port	(1236 W)
1 Tbps port	(2794 W)





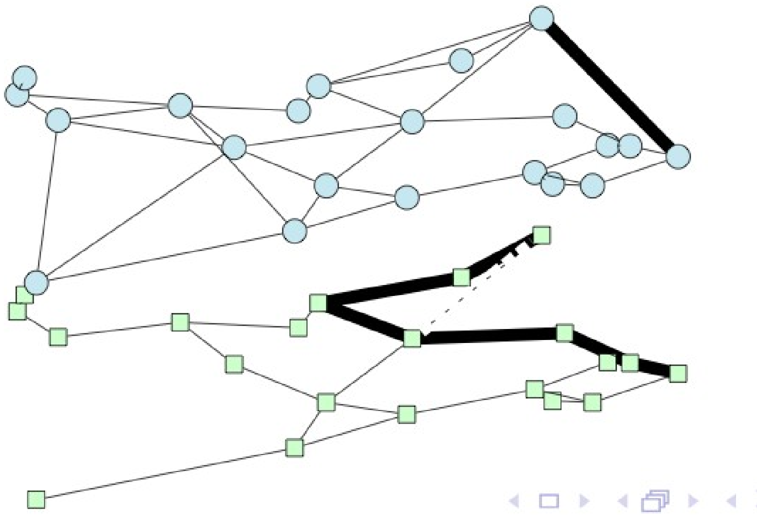


Choosing what to switch off/on

On optical layer

- Switching off optical fibers
- Allows to switch off amplifiers
- 17 -> 1870 W

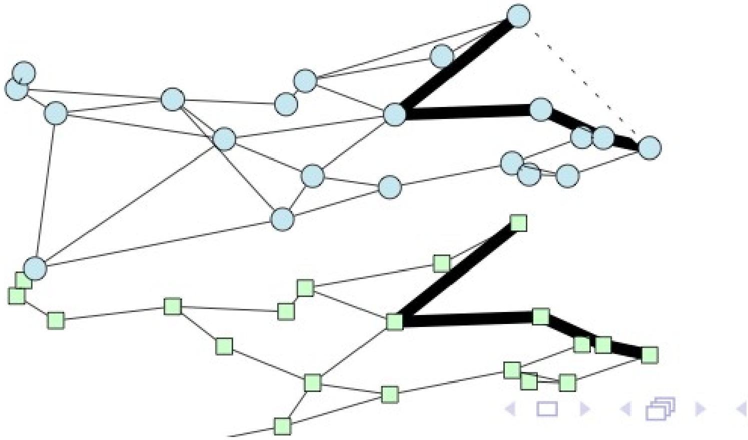
- Need to reconfigure optical paths
- Amplifiers switch ON is long



On IP layer

- Switching off IP links
- Allows to switch off router ports
- 2 -> 5588 W

- Need to re-route in IP layer
- Ports switch ON is faster than amplifiers switch ON



Coordinating the switch off/on process

Usualy used In optical transport networks : GMPLS distributed management.

Industry moving towards centralized network management: SDN

Good news for energy efficiency !

- SDN controller can coordinate the switch-off/on optimaly
  - Use trafic matrices for optimal rerouting
  - Without disconnecting the network
  - Fast reaction to increase in network load

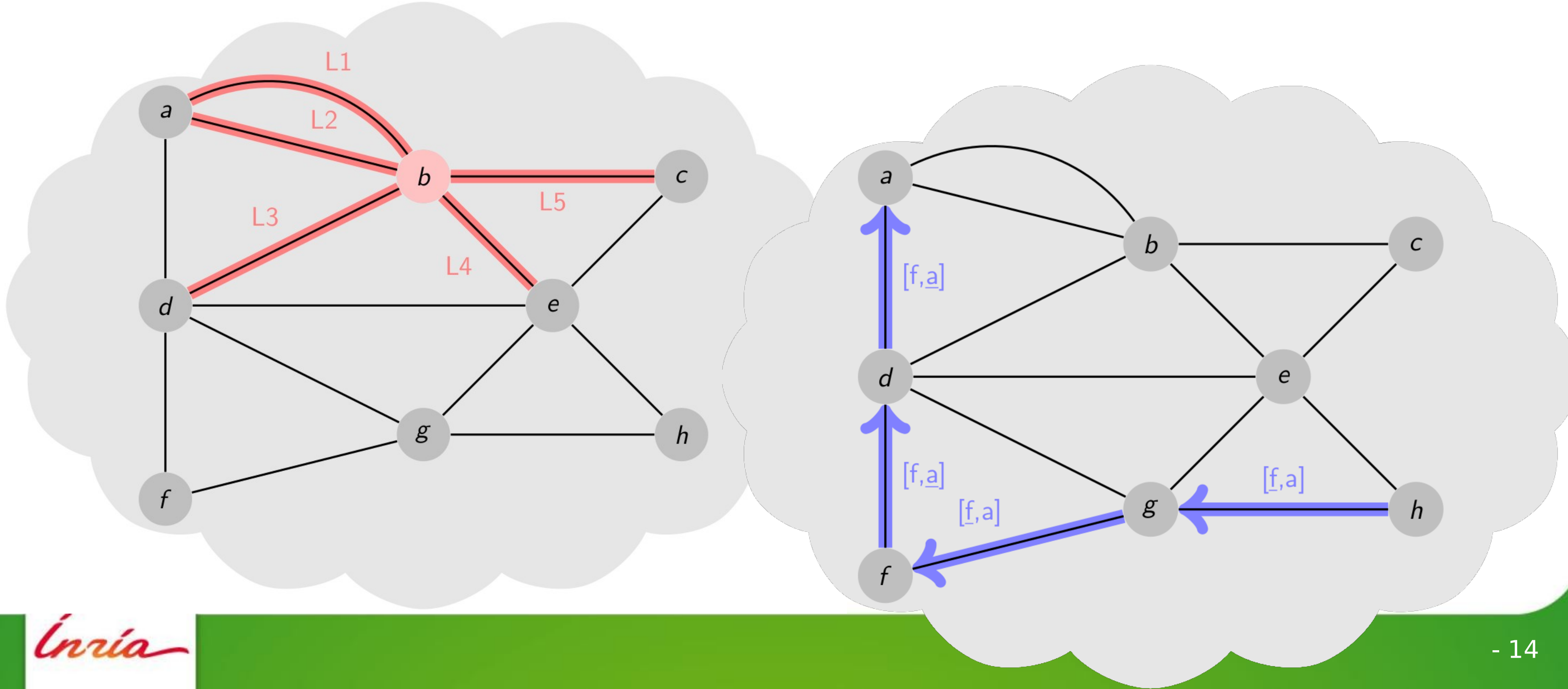
Rerouting: SPRING/Segment Routing

Source Packet Routing In NetworkinG

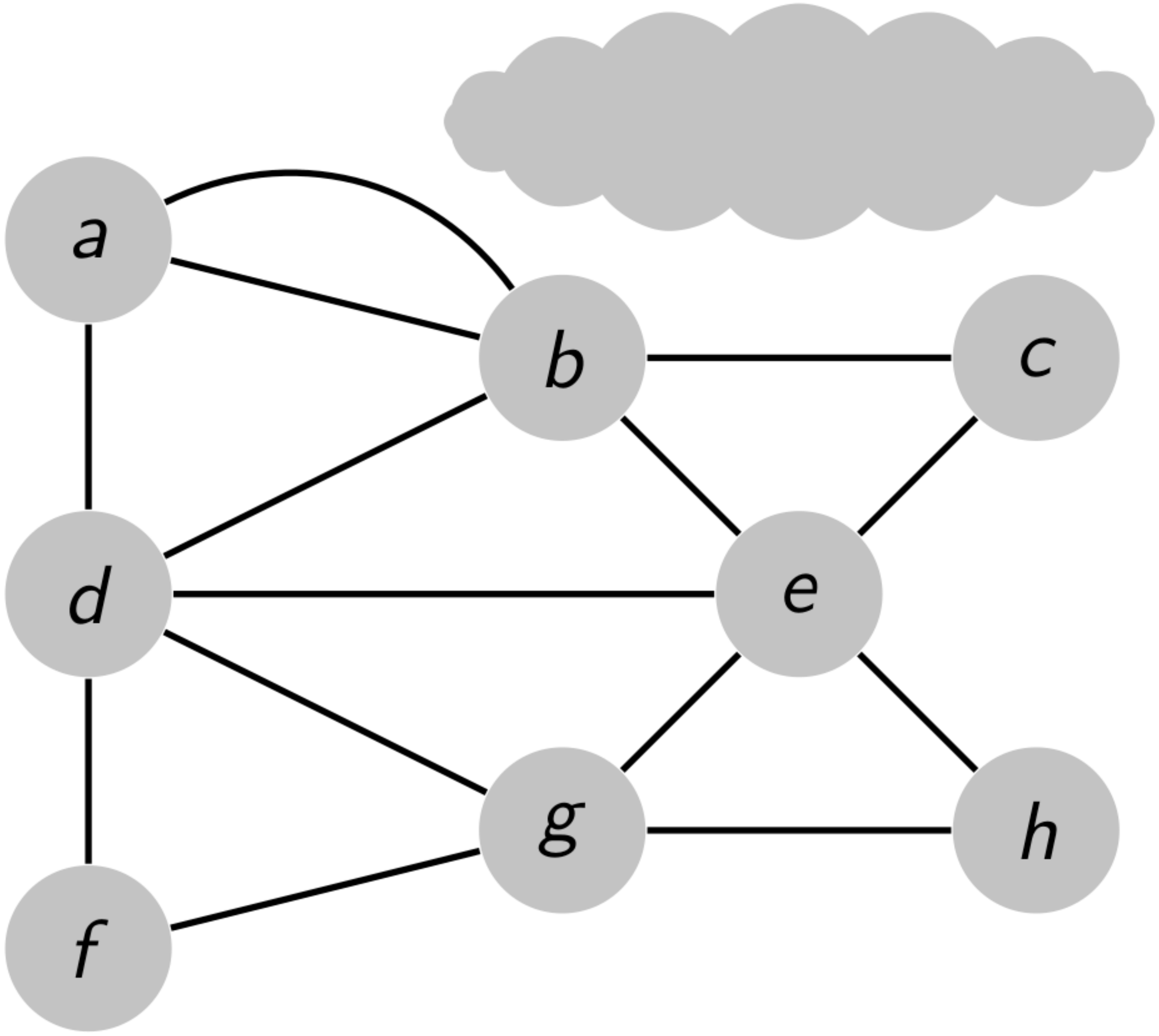
Current IETF draft (last update on march 3, 2015)

Source routing protocol designed for trafic engineering

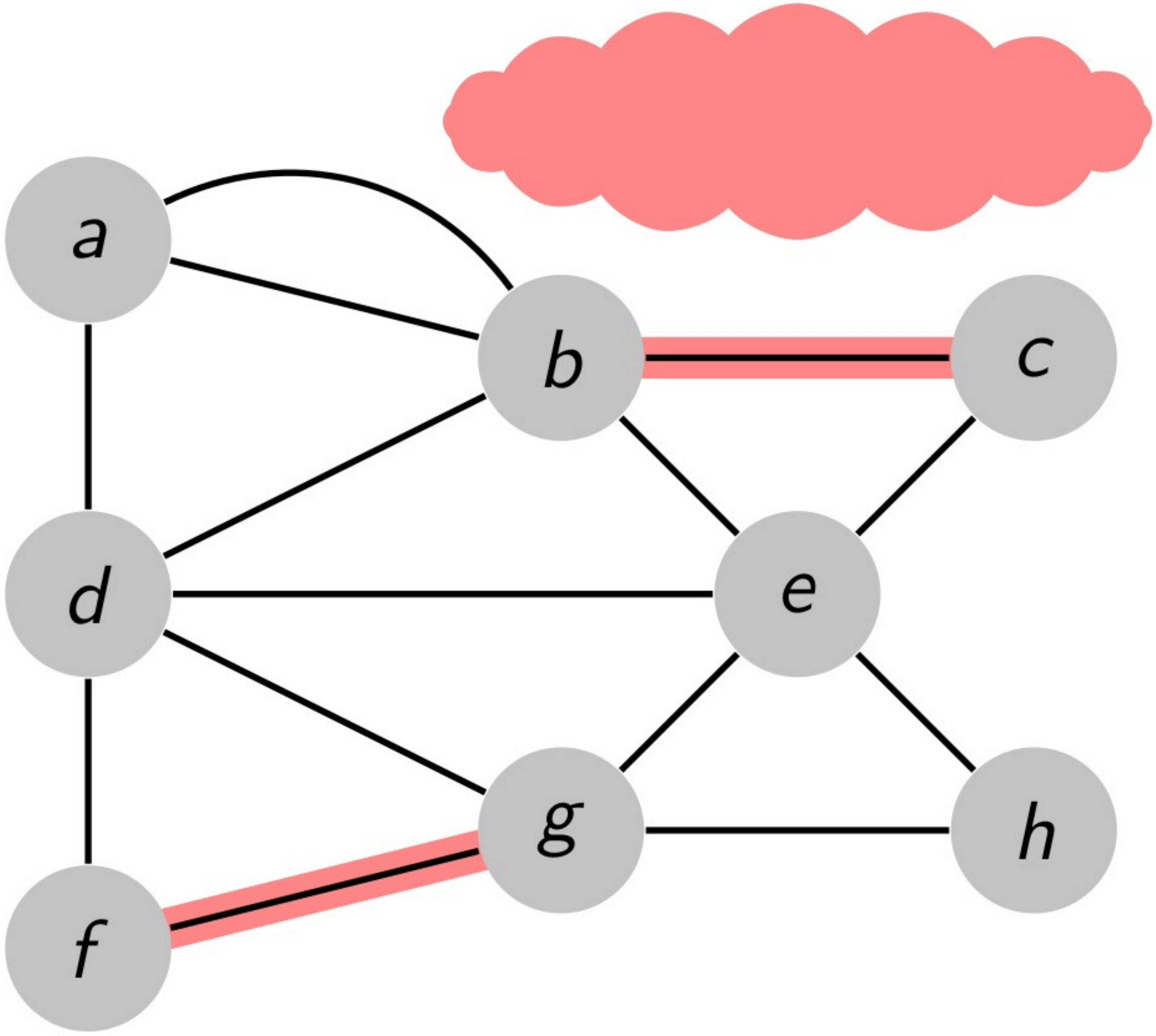
Robust and scalable



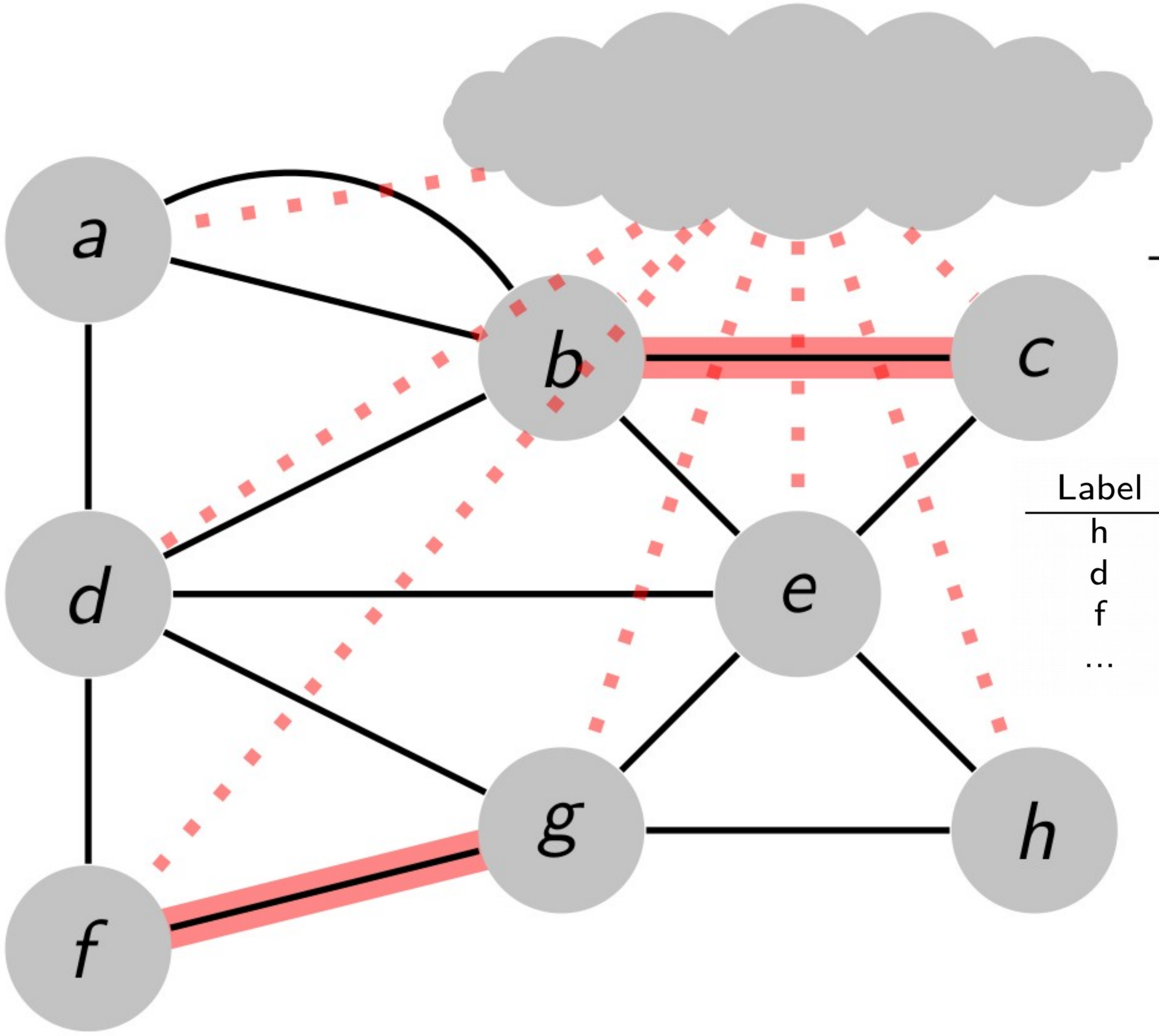
Example



Example

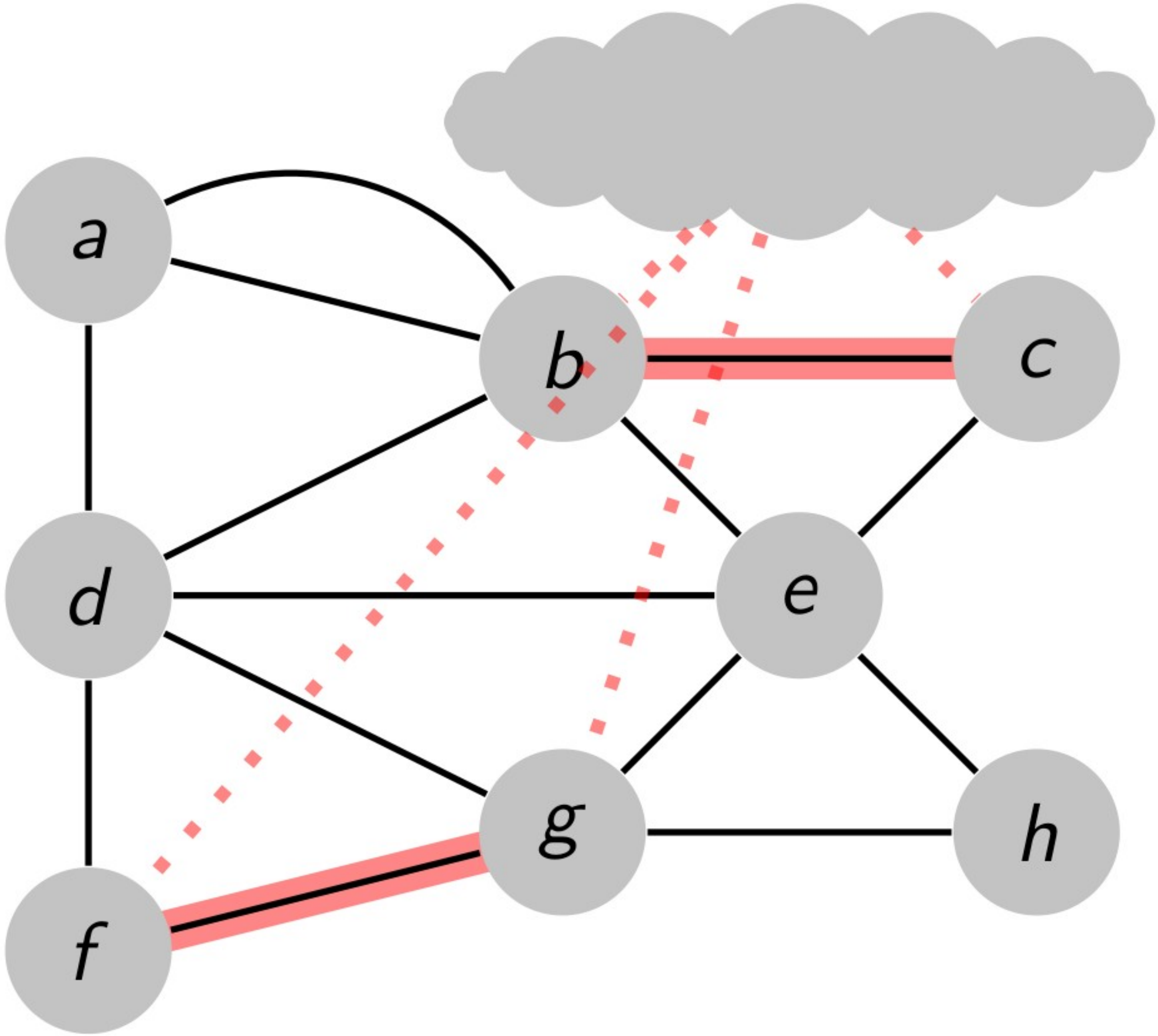


Example

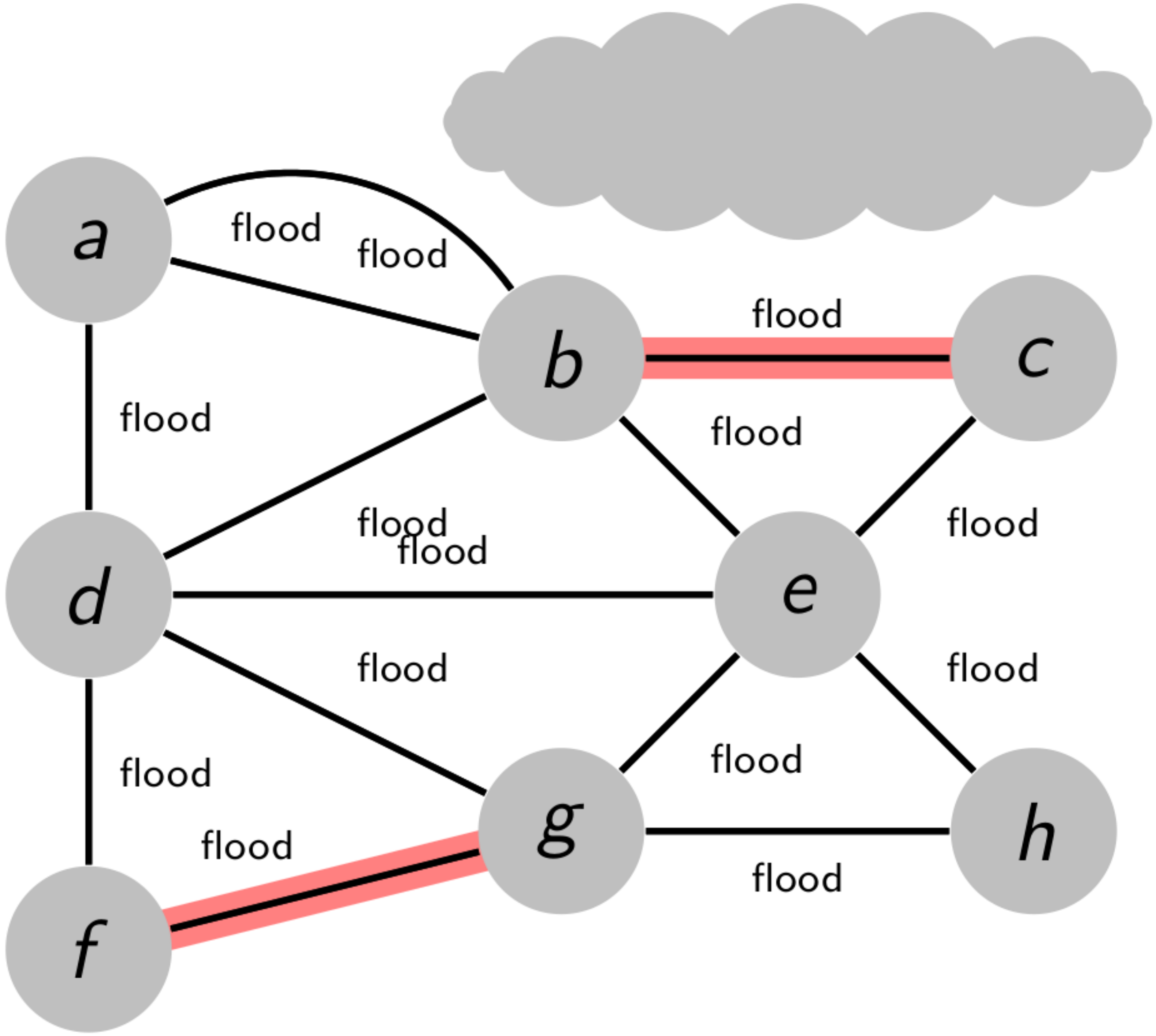


Label	Oper.	NH
h	next	e
d	push(g)	e
f	push(g,d)	e
...	...	...

Example



Example


a
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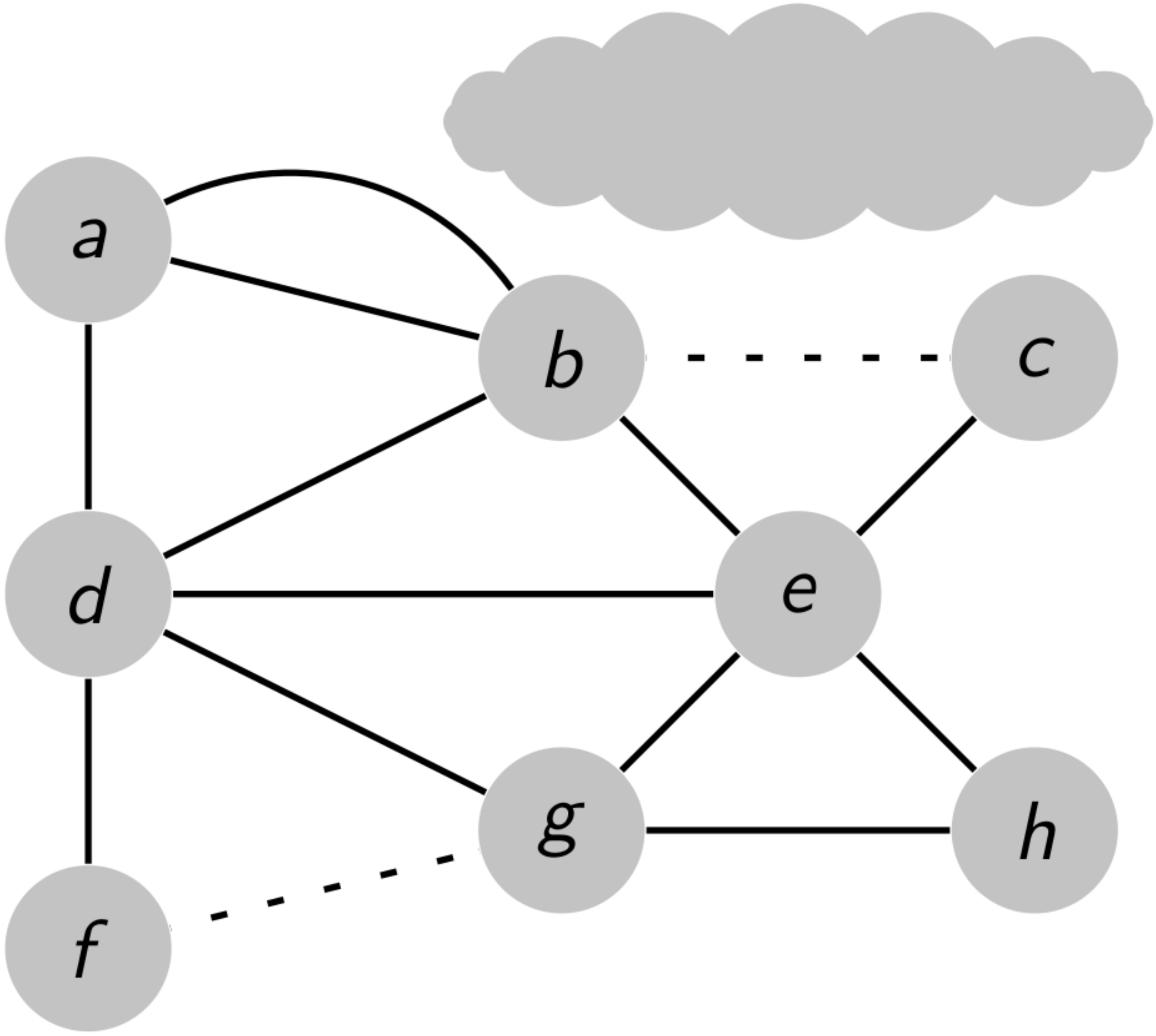
Example



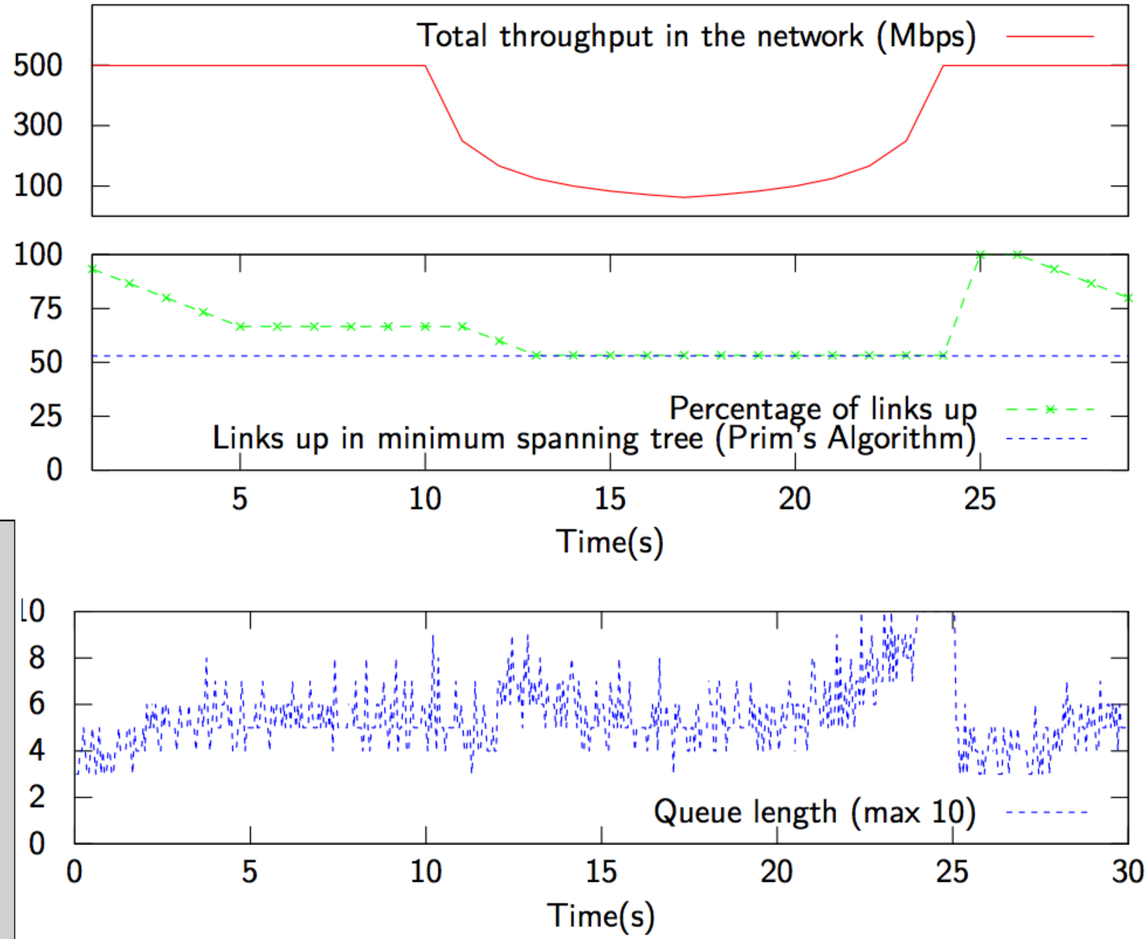
Simulation

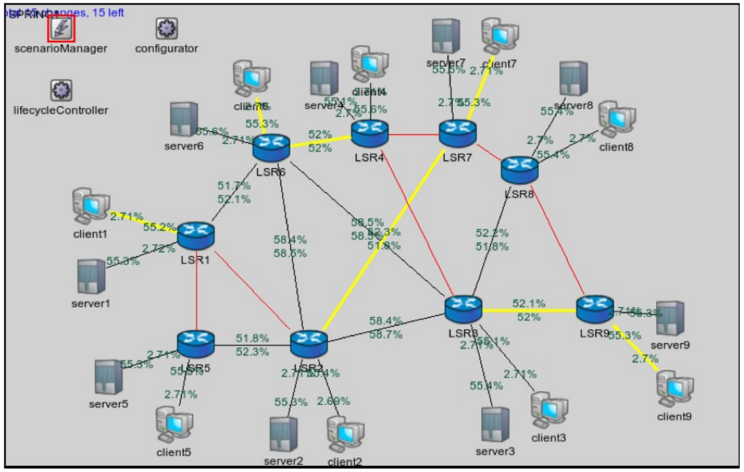
in the OMNeT++ simulator

Implementation of SPRING

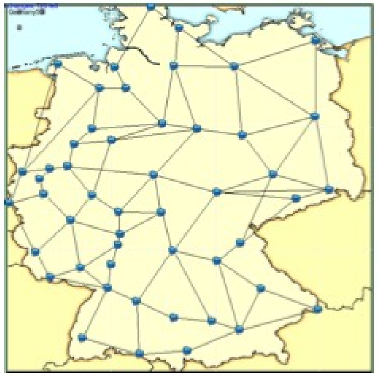
Full emulation of a network

Including management protocols



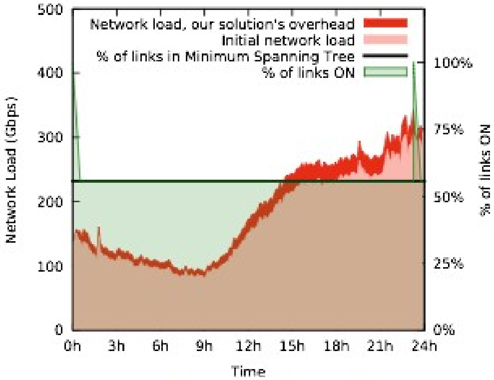


Simulation results on backbone topologies

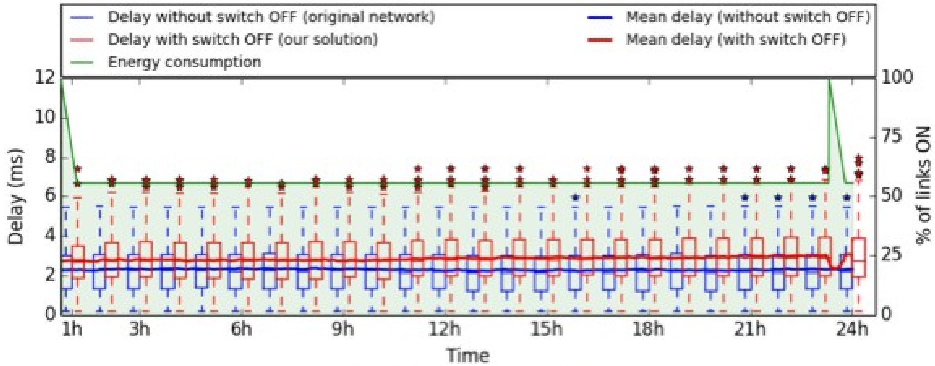


(a) Germany 50 network

(b) Géant network

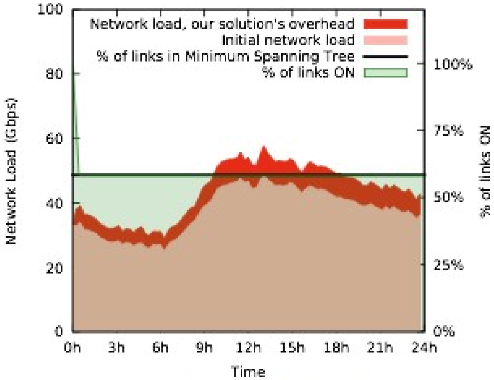


(a) Impact on link loads

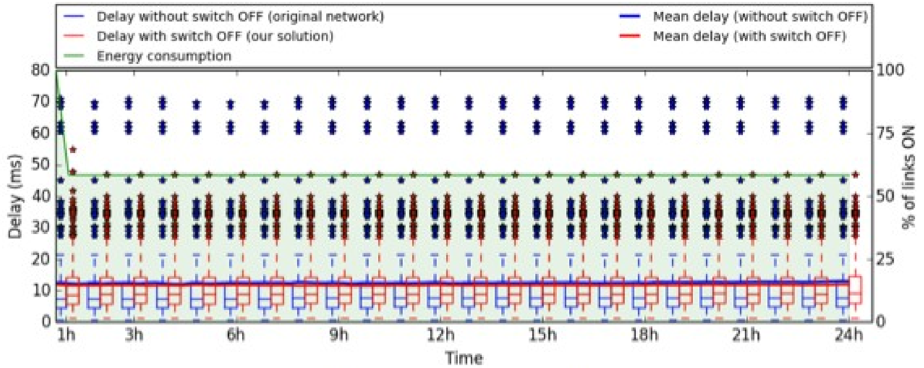


(b) Impact on end-to-end delay

Night traffic 20% delay increase



(c) Impact on link loads



(d) Impact on end-to-end delay

Impact of US nodes : switiching off links impose routing in Europe

Inria

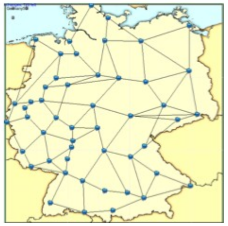
Conclusion

Solution fully implemented in OMNeT++

Proving SPRING may be the right choice for energy efficient traffic engineering

Reducing the energy consumed in ports by almost 50%:

Géant:  204 kWh/day

Germany50:  522 kWh/day

Next Steps

NetFPGA test-bed

- Implementing and testing the proposed solution on a network of NetFPGA devices

OMNeT++ : we'll try to push our changes upstream

- Opaque LSA option for OSPF
- SPRING

Thank You

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