

# Design and Management of GREEN networks with low power consumption

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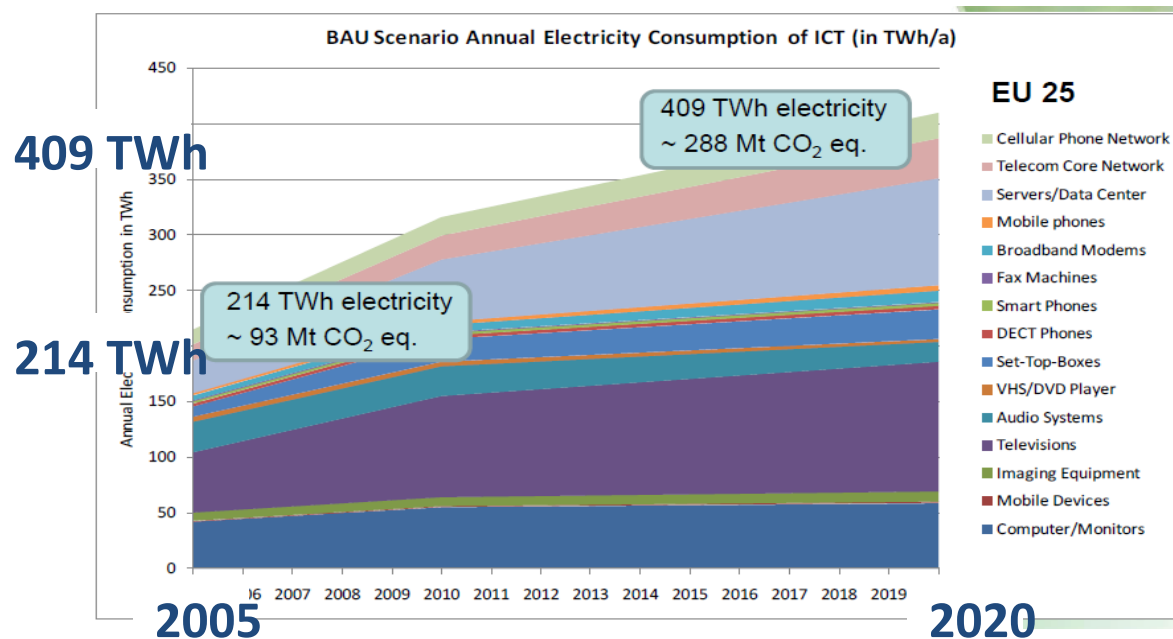
MASCOTTE



# Context and Motivations

- Power Consumption of ICT (*Information and communication technologies*) around **10%** of the global consumption\*

~ 4 billion \$



The power consumption due to ICT in Europe could double between 2005 and 2020

\*[Chiaraviglio et al., GreenComm'09]

# Network Power Consumption

## Several ways to reduce this consumption:

- Hardware
- Virtualisation, Cloud Computing
- Resources utilization policies – Network design

## With theoretical tools :

- Algorithmic
- Linear Programming
- Graph Theory
- Modelling and Combinatorial Optimization

# Mascotte related projects

## 1. 3ROAM (2007-)

*Wireless Microwave Backhaul Networks*

## 2. ANR ECOSCELLS (2009-2012)

*Small Cells Networks*

## 3. ANR-JCJC DIMAGREEN (2009-2012)

*Backbone Networks*

## 4. FP7 NoE TREND (2012-)

*Toward Real Energy Efficient Network Design*

## Mascotte members involved:

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# ANR DIMAGREEN, 09/2009 – 09/ 2012

## 1. Experimentation Campaigns - Measures

- Design parameters that influence power consumption of network equipments
- Design realistic cost function

## 2. Network Design

- Use the cost function previously defined to design an energy-efficient network
- Where to place the servers in the network? Study of CDN Networks

## 3. Network Management

- Energy-Aware Routing
- Dynamic Traffic

<http://www-sop.inria.fr/teams/mascotte/Contrats/DIMAGREEN/wiki>

# Backbone Networks

- Measurement campaigns on routers show:
  - **small influence** of the traffic load\*
- Important parameter : Number of switched-on interfaces
  - **turn off** some interfaces under utilized (Sleep Mode)
- Find energy efficient routing
  - on a **simplified network** architecture : if the two interfaces are turned-off then the link is turned-off.
  - using a **simplified cost function**: number of links



\* [Chabarek et al., INFOCOM 08; Mahadevan et al. Networking 09]

# With simplified Network Architecture: NP-Hard

**INPUT:** Network  $G=(V,E)$  with capacities on links, traffic matrix

**OUTPUT:** Find a sub-network  $G'=(V,E'\subseteq E)$  and a routing of the demands in  $G'$

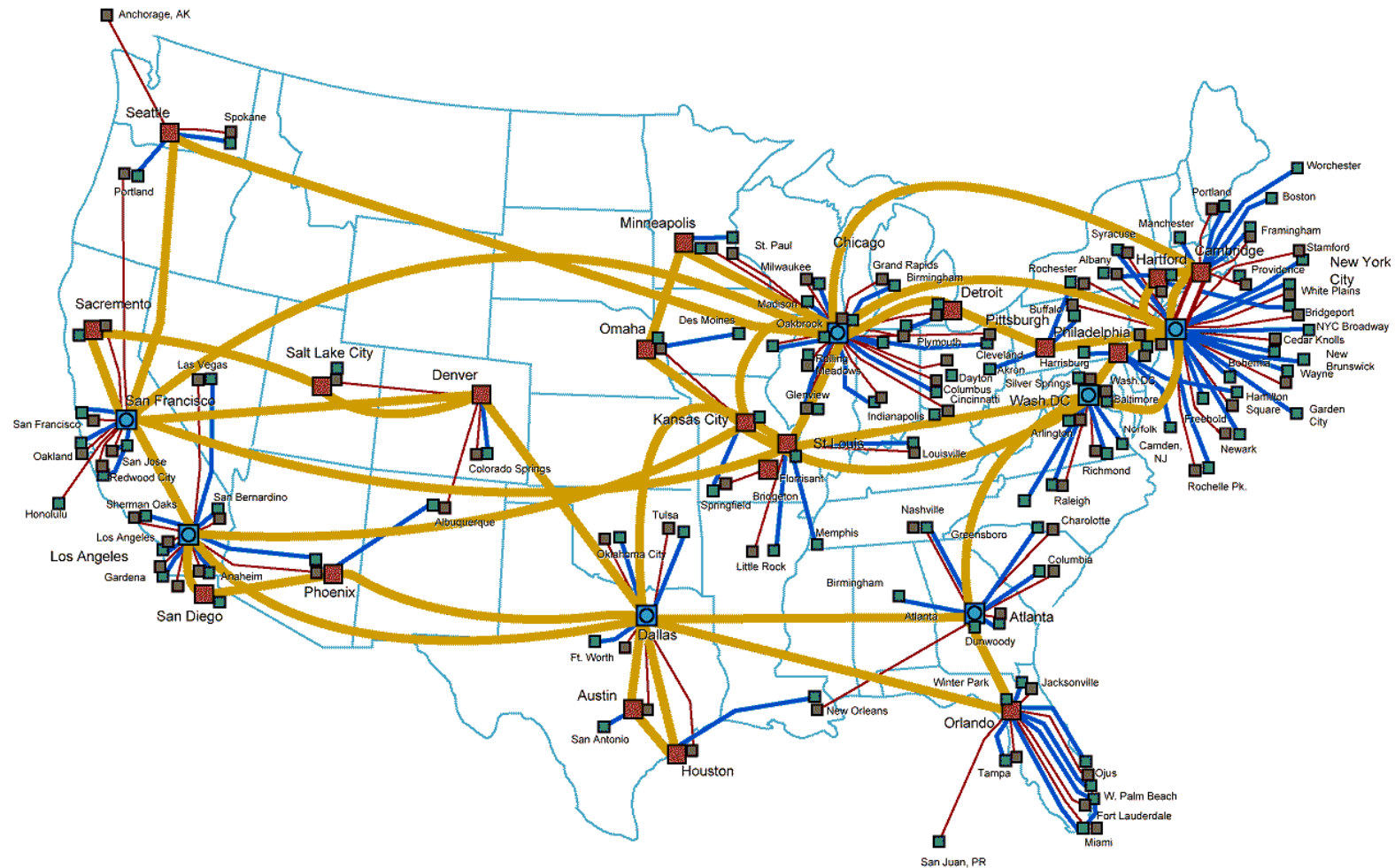
**OBJECTIVE:** Minimize  $|E'|$

Related to fundamental problems of combinatorial optimization

## We need:

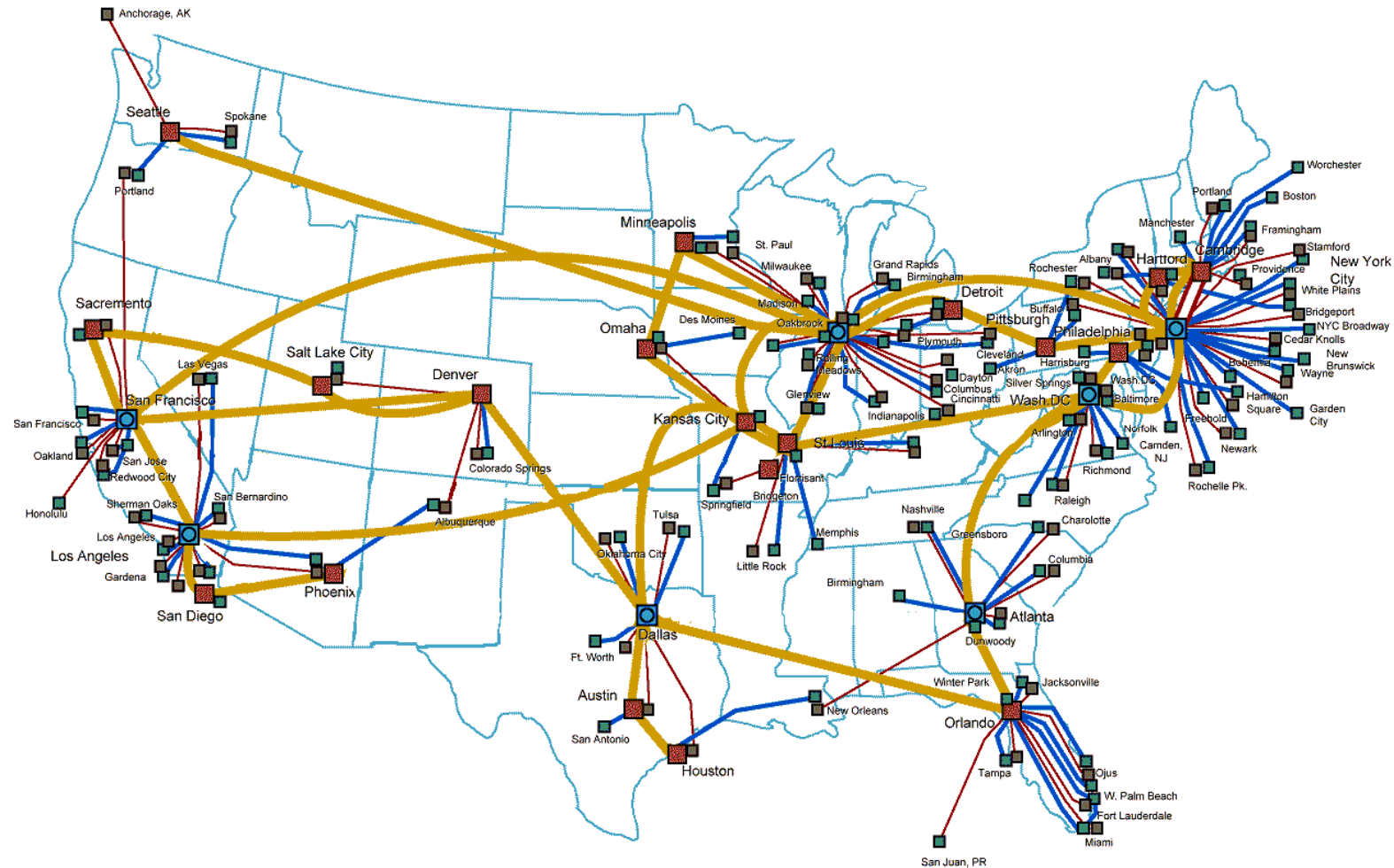
- **Energy-efficient** heuristics
- Algorithms with constant approximation factor
- Theoretical bounds on specific topologies

# Examples on real topology

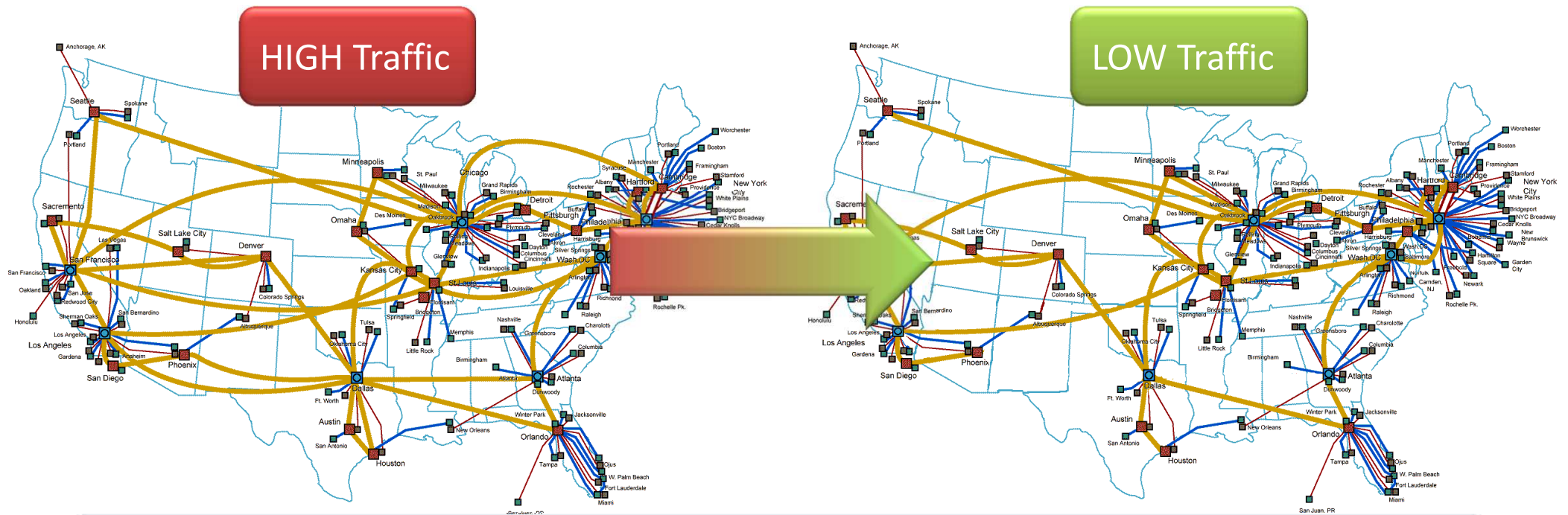




# Examples on real topology



# Examples on real topology



30% of turned-off interfaces, but with impact on

- route length
- fault tolerance (number of disjoint paths)

Evaluation of the load of the network in function of the traffic

# Results

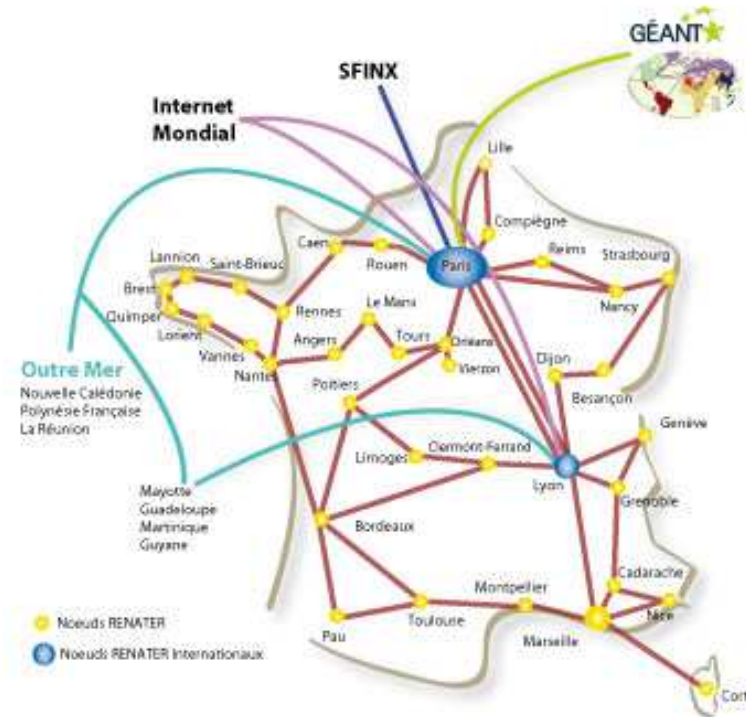
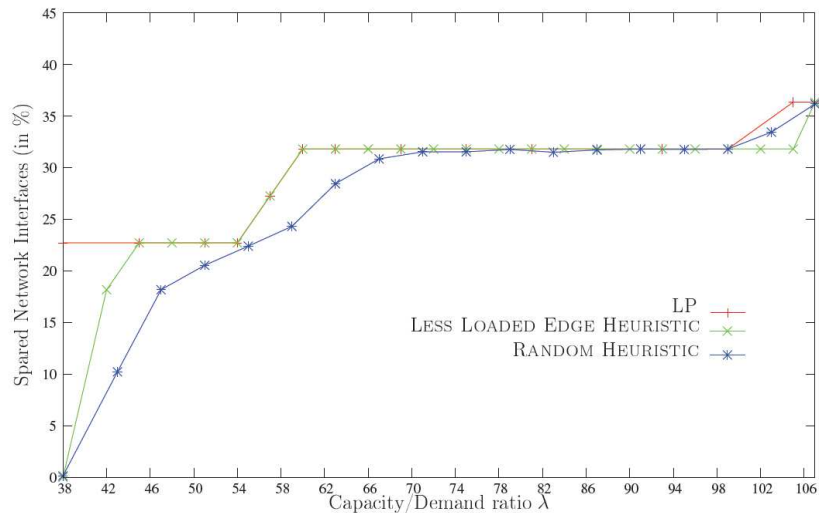
- **Theoretical bounds** for specific topologies (grids, rings, trees, etc...) and all-to-all
- **Hardness** results (No-APX)
- **Energy-efficient** heuristics
- **Simulations:**
  - Comparison gains obtained by heuristics with **optimal solution** (linear program)
  - Analysis of the impact of the solution on **length of routes**, and **fault tolerance**

# Specific topologies: Grids

## Theoretical bounds on load estimation

Edges	subgraph	load	<div>Tree with centroid of degree 4 and 4 branches of equal size</div> <div>Minimum cut in the middle of the grid</div>
$n - 1$	tree	$\frac{3}{8}n^2$	
$n + p - 2\sqrt{p}$		$\frac{1}{2} \frac{n^2}{\sqrt{p}} + \frac{3}{8} \frac{n^2}{p^2}$	
$2n - 2\sqrt{n}$	grid	$\frac{1}{2}n^{3/2}$	

# Simulation results



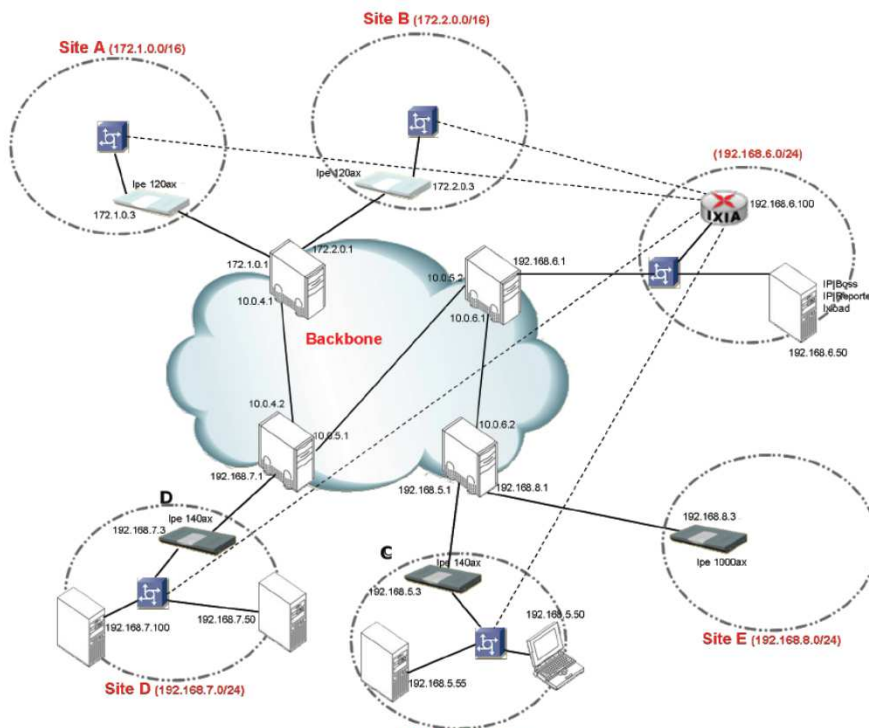
## 33 MWh of gains for medium-sized networks

→ 30% of energy reduction

→ Increase of 27% of route length

# Experimentations for WAN Optimization

- Identification of the **parameters** influencing the power consumption of WAN optimization controllers
- Definition of **realistic cost functions**



# Existing challenges

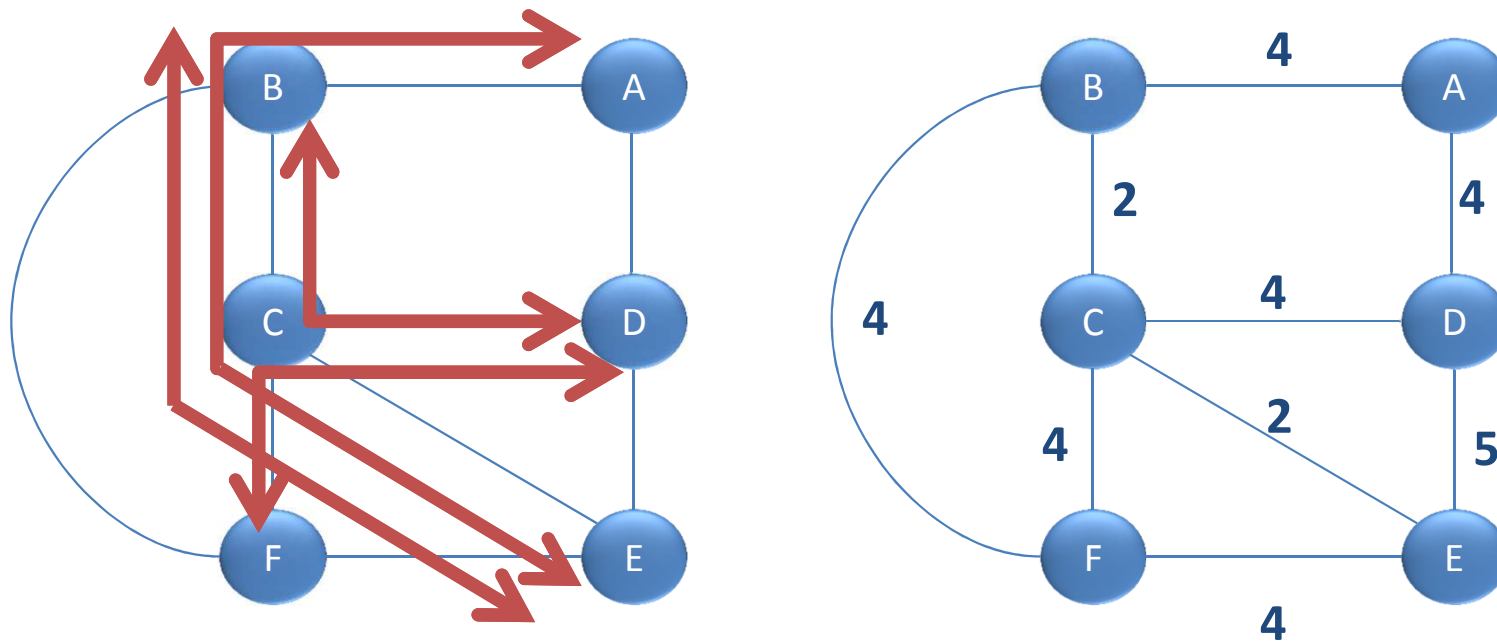
- **In practice:**
  - Realistic cost function
  - Routing protocols
  - Dynamicity of traffic and transition
- **Different types of networks:**
  - CDN
  - Backhaul microwave networks
  - Access networks
- **Placement of equipments and content management:**
  - WOC
  - Servers in CDN

# On-going work - OSPF

- How to apply such solutions within routing protocols in practice?
- Set up OSPF metrics to:
  - enable the routing without static configuration per request
- Impact of **dynamicity** of traffic matrices
- Delay for transition between two topologies (HIGH Traffic → LOW Traffic)

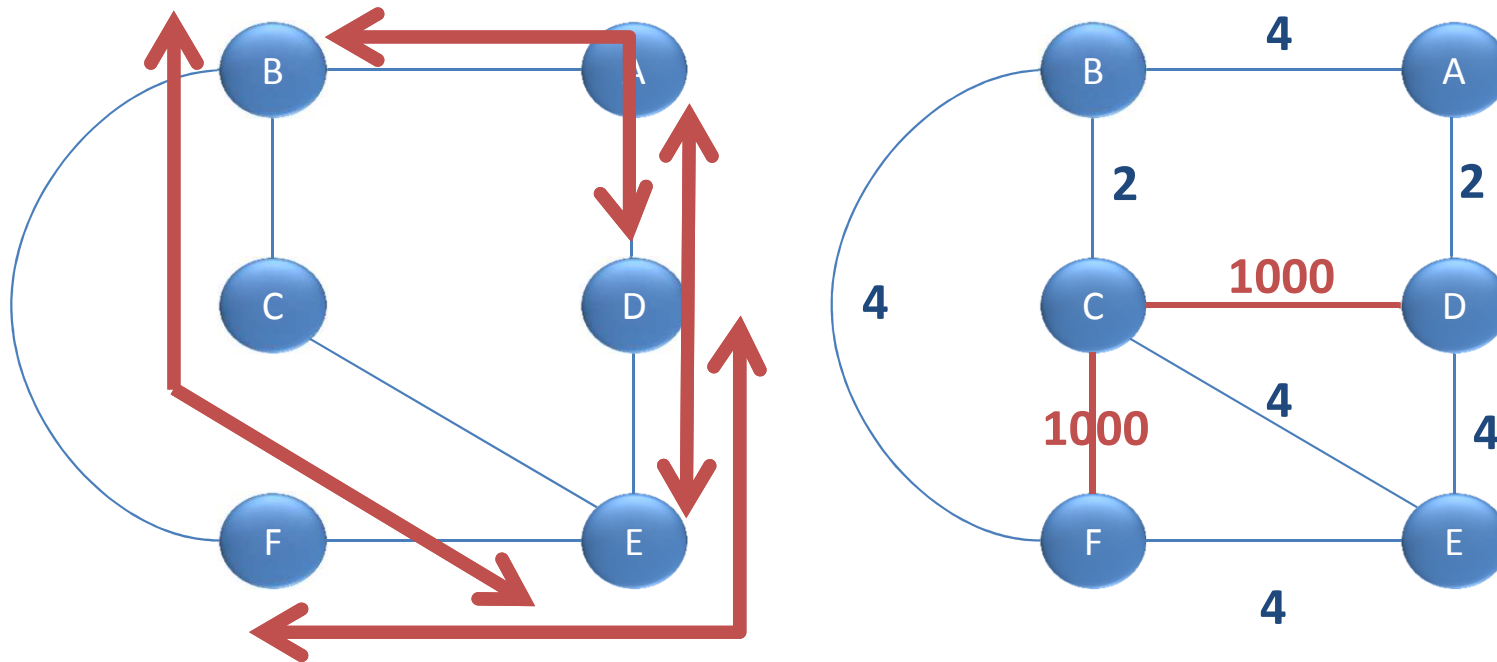


# Idea of the problem (1)



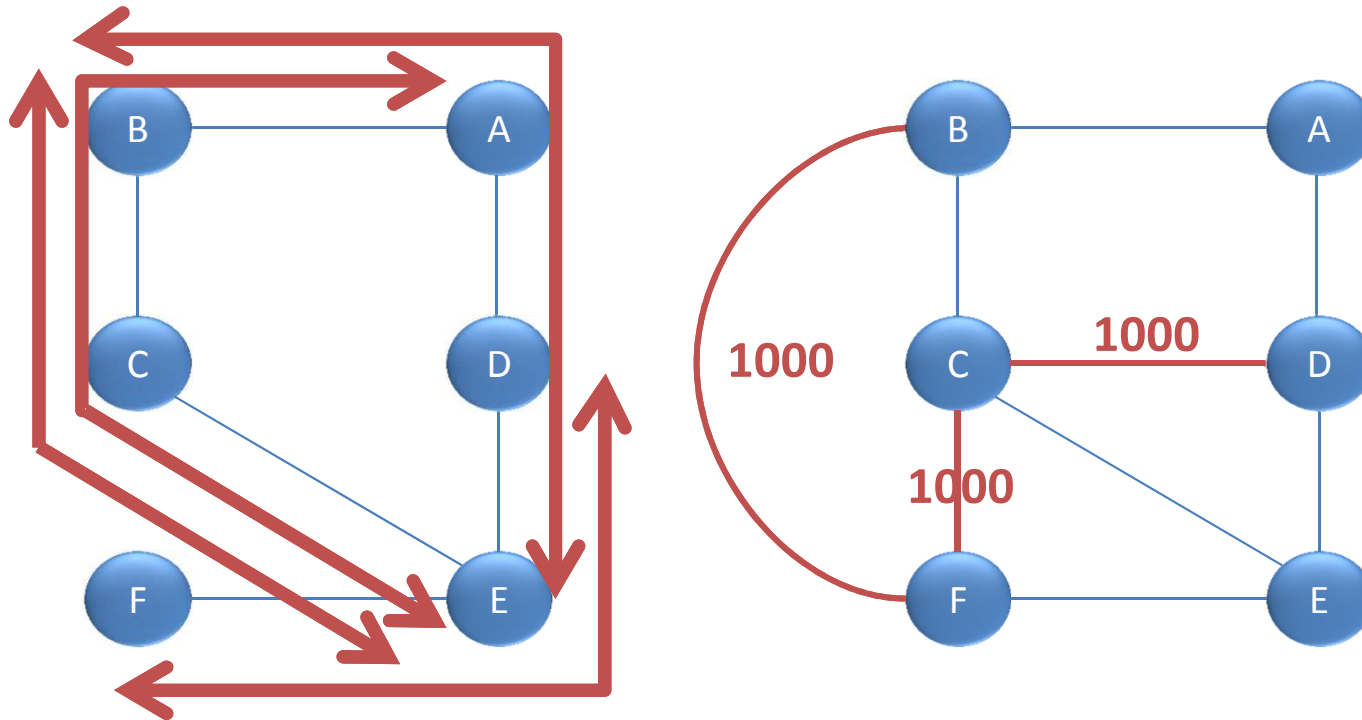
Set the OSPF link weights to enable the routing

## Idea of the problem (2)



- Find a routing with minimum number of links
- Set the OSPF link weights to enable this routing

# Idea of the problem (3)



Impossible routing: no set of link weights  
can ensure this routing

# On-going work - CDN

- Cooperation between content and internet providers
- Gain expected if energy-efficient choice of servers
- Placement of CDN servers

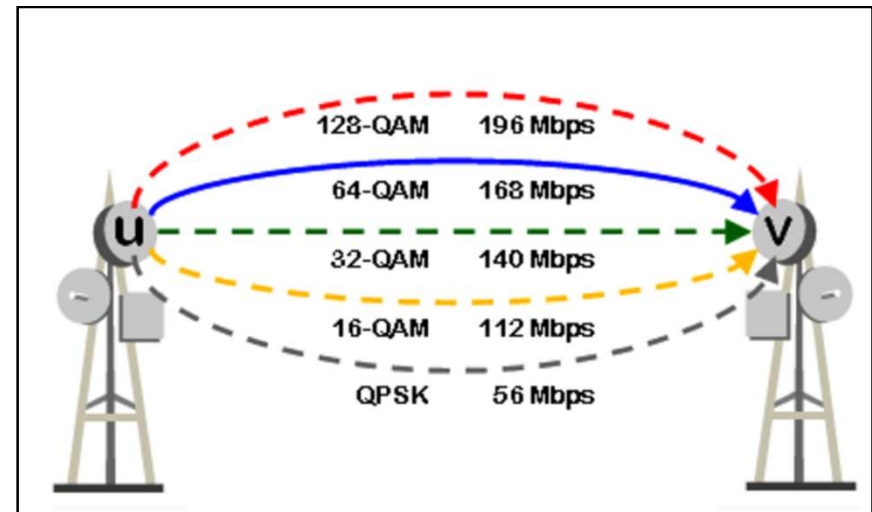
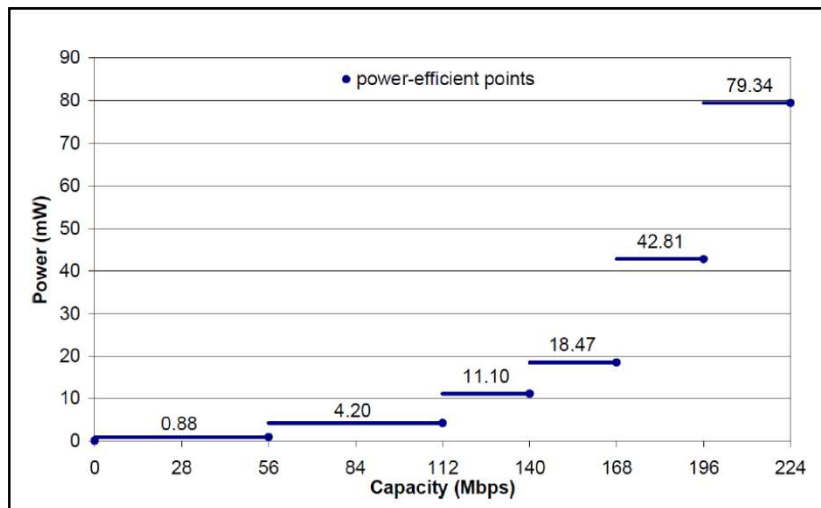


# On-going work - Microwave Backhaul Networks



## Configuration of radio links

- Devices: quality and diameter of antennas, etc.
- Transmission power, coding, modulation, bandwidth, frequency, etc.
- Required capacity
- Important to ensure the quality of transmissions



# Towards a green world\*



\*This is not a tree