OPTIMIZING RULE PLACEMENT IN SOFTWARE-DEFINED NETWORKS FOR ENERGY-AWARE ROUTING

FREDERIC GIROIRE, JOANNA MOULIERAC, TRUONG KHOA PHAN

GLOBECOM DEC. 2014

Nice-Sophia Antipolis, France

CNRS, University of Nice-Sophia Antipolis and INRIA

ENERGY CONSUMPTION OF TELECOM

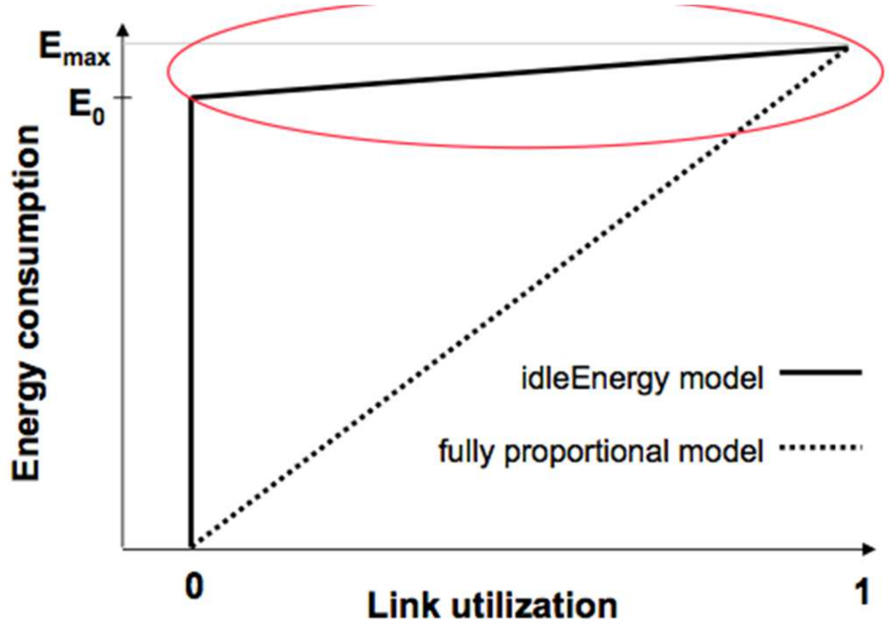
- **Energy consumption and CO_2 produced by ICT ~ 2% - 10% of the total world consumptions and man-made emissions by 2020.**

- **The challenge of the European Commission: a 20% improvement in the EU's energy efficiency by 2020.**

- **Telecom infrastructure and devices account for 25% of the ICT's energy consumption by 2020.**

ENERGY AWARE ROUTING

Measurements on energy consumption on routers [Chabarek et al. Infocom08] show:

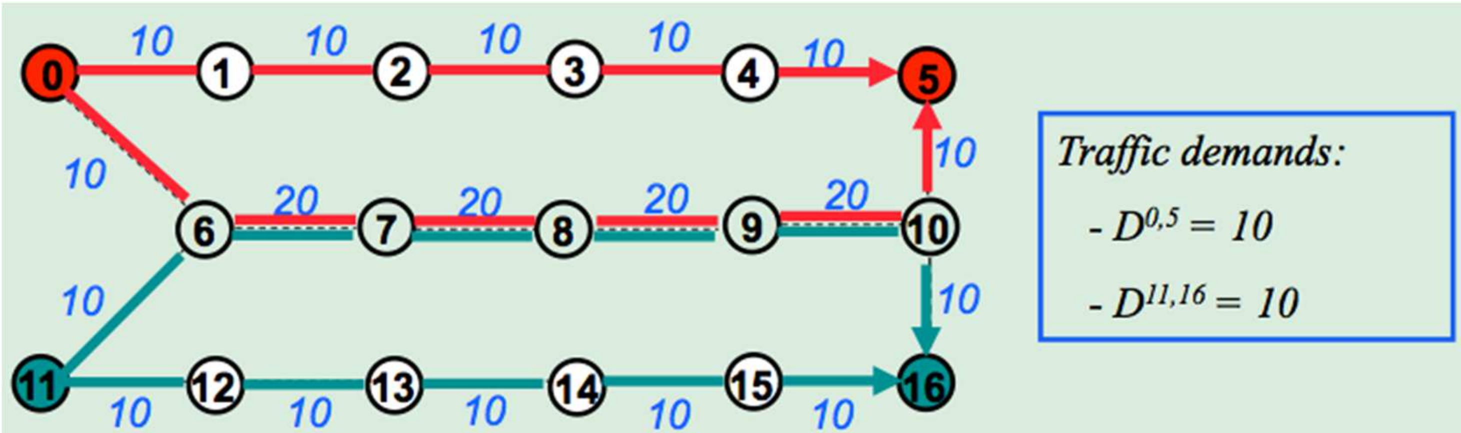


Small influence of traffic load [CSBE08].
To save energy: switch-off interfaces, chassis.

ENERGY AWARE ROUTING

Routing solution minimizing the number of active links [CSBE08].

A link is turned off means two interfaces of routers are turned off.



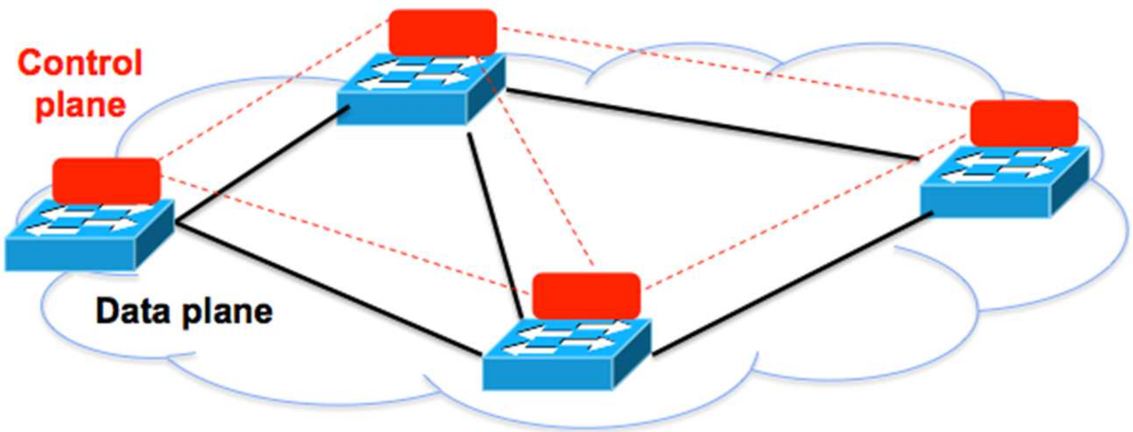
Energy-aware routing - turn off 10 links ~ 55% of energy saving

Shortest path routing – turn off 8 links ~ 44% of energy saving

ENERGY, ROUTING AND SDN

Software Defined Network: potential to bring into practice energy aware solutions.

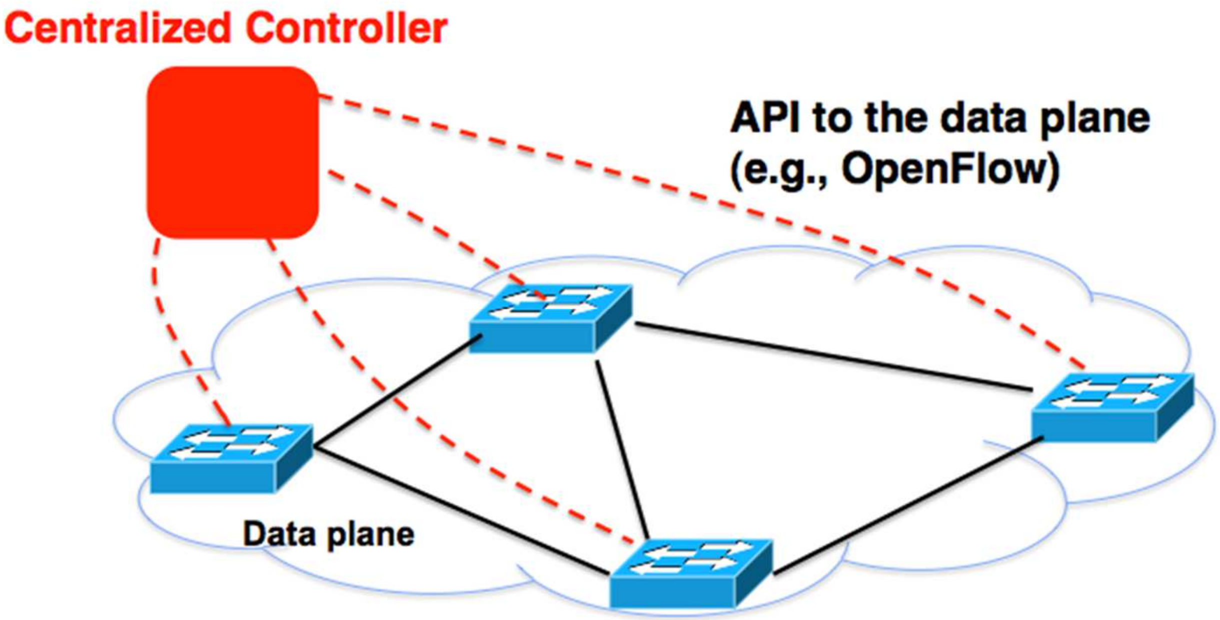
Traditional network:



Routers and switches are “closed systems” → difficult to deploy new network protocols.

ENERGY, ROUTING AND SDN

Software Defined Network: potential to bring into practice energy aware solutions.

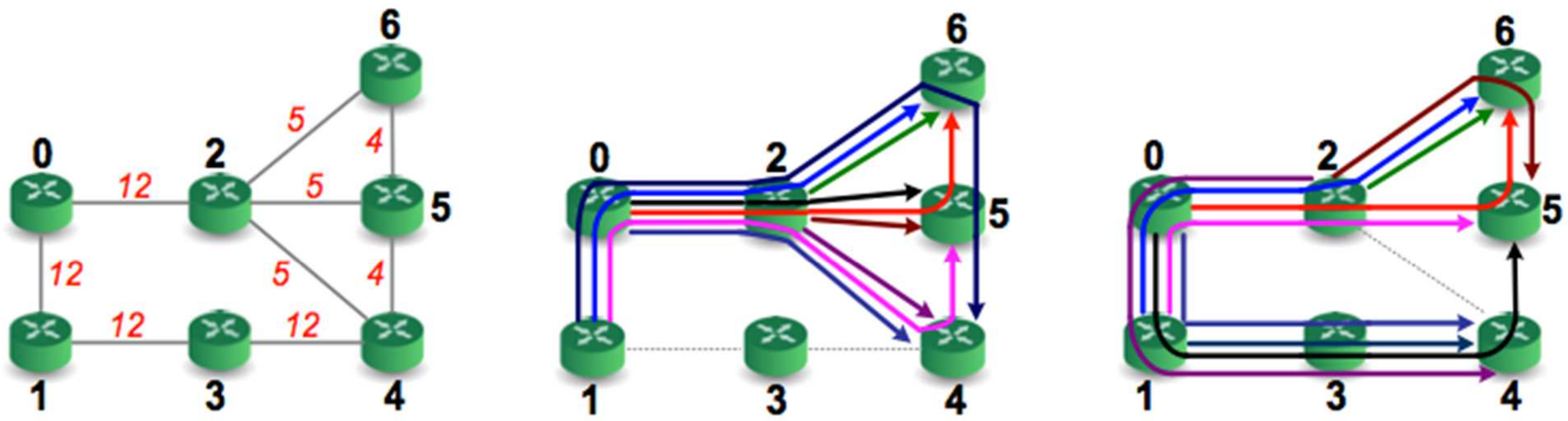


Centralized controller with computational capacity

-> can dynamically adapt to traffic load.

ENERGY, ROUTING AND SDN

Challenge : **OpenFlow Switch can hold a limited number of rules.**



(a) Network and capacity on links (b) EAR - unlimited rule space (c) EAR - limited rule space

Fig. 1: Example of EAR with and without rule space constraints

ENERGY, ROUTING AND SDN

Challenge : OpenFlow Switch can hold a limited number of rules.

Routing tables:

Rule	Action
(0, 2)	**Port-2**
(0, 3)	**Port-2**
(0, 4)	**Port-1**
(1, 4)	**Port-1**
(0, 5)	**Port-2**

Simple routing table

Rule	Action
(0, 4)	**Port-1**
(1, 4)	**Port-1**
Default	**Port-2**

Routing table with default rule

Rule	Action
(*, 4)	**Port-1**
Default	**Port-2**

Routing table with default rule and wild card

OUR CONTRIBUTIONS

Limited rule space important to put Energy Aware Routing (EAR) into practice.

However, no work in literature addressing this problem for EAR.

Our contributions:

- **Exact formulation and heuristic algorithm in case of routing tables with default rule.**
- **Using real-life traffic traces, we quantify energy saving achieved by our approaches.**

EXACT SOLUTION

We succeeded in modeling the problem using linear programming.

Goal: minimizing the number of active links while respecting capacity and rule space constraints

Defaut port of router u ➔ v : $k_{uv} = 1$

$$\min \sum_{(u,v)\in E} x_{uv}$$

$$\sum_{v\in N(u)} \left(f_{vu}^{st} + d_{vu}^{st} - f_{uv}^{st} - d_{uv}^{st}\right) = \begin{cases} -1 & if\ u = s \\ 1 & if\ u = t \\ 0 & else \end{cases} \qquad \forall (s,t)\in D, \forall u \in V;$$

$$\sum_{(s,t)\in D} D^{st}\left(f_e^{st} + d_e^{st}\right) \le \mu C_e x_e \qquad \forall e\in E;$$

$$f_{uv}^{st} + f_{vu}^{st} + d_{uv}^{st} + d_{vu}^{st} \le 1 \qquad \forall (u,v)\in E, (s,t)\in D;$$

$$\sum_{(s,t)\in D} \sum_{v\in N(u)} f_{uv}^{st} \le C_u - 1 \qquad \forall u\in V;$$

$$\sum_{v\in N(u)} k_{uv} \le 1 \qquad \forall u\in V;$$

$$d_{uv}^{st} \le k_{uv} \qquad \forall (u,v)\in E, (s,t)\in D;$$

$$x_{uv}, f_{uv}^{st}, d_{uv}^{st}, k_{uv} \in \{0,1\} \qquad \forall (u,v)\in E, (s,t)\in D;$$

HEURISTIC ALGORITHM

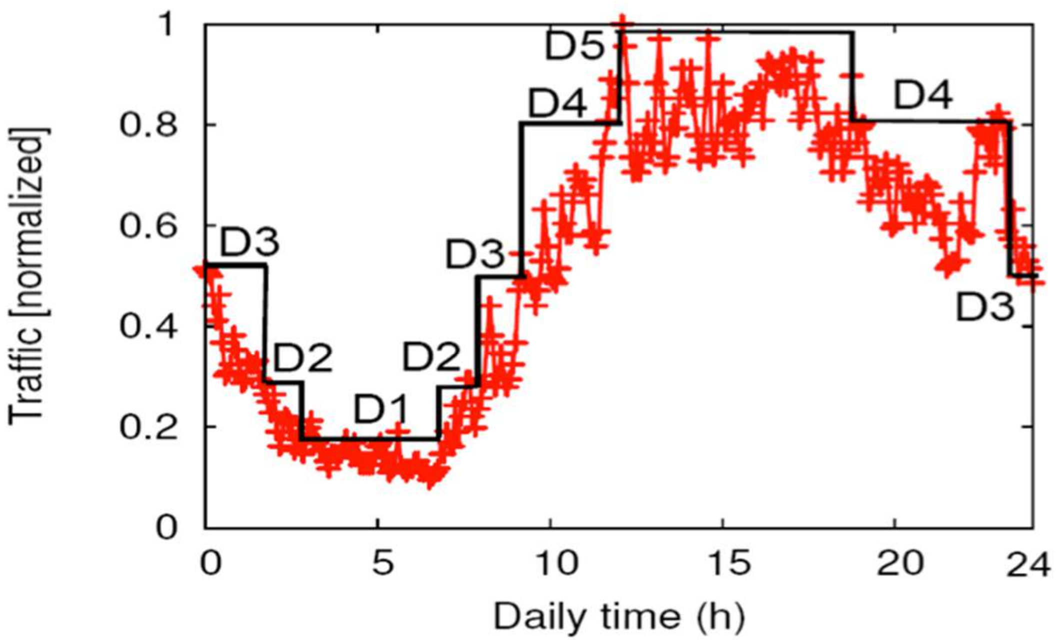
H = subset of all network links

While (Step 1 finishes with H) do:

- **<u>Step 1:</u> find feasible routing for all the demands with which respects the capacity and rule space constraints:**
  - Free to assign rules for flows until routing table is full.
  - Then shrink the routing table using default rule.
- **<u>Step 2:</u> remove the less loaded link from H.**

RESULTS

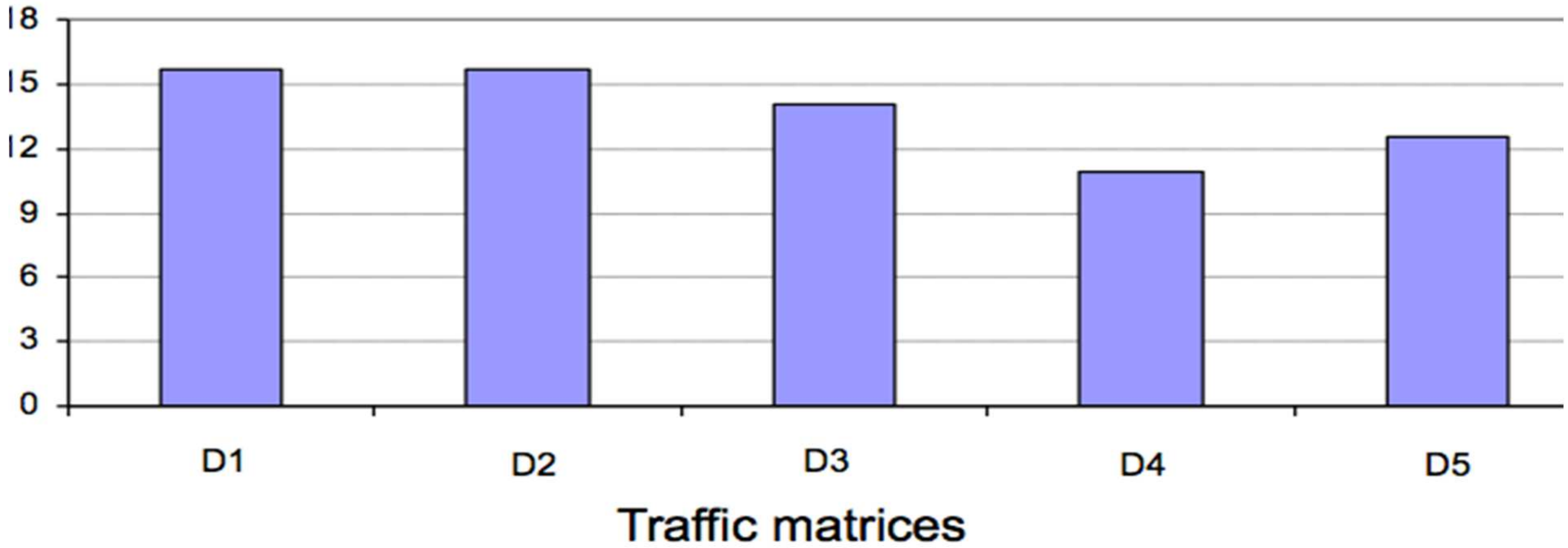
Scenarios: **Applied the Linear Program and the Heuristic Algorithms on the telecom network topologies and traffic matrices of the library SNDLib.**



Daily traffic pattern from SNDlib

RESULTS

An example: Telecom Austria (65 routers, 106 links)



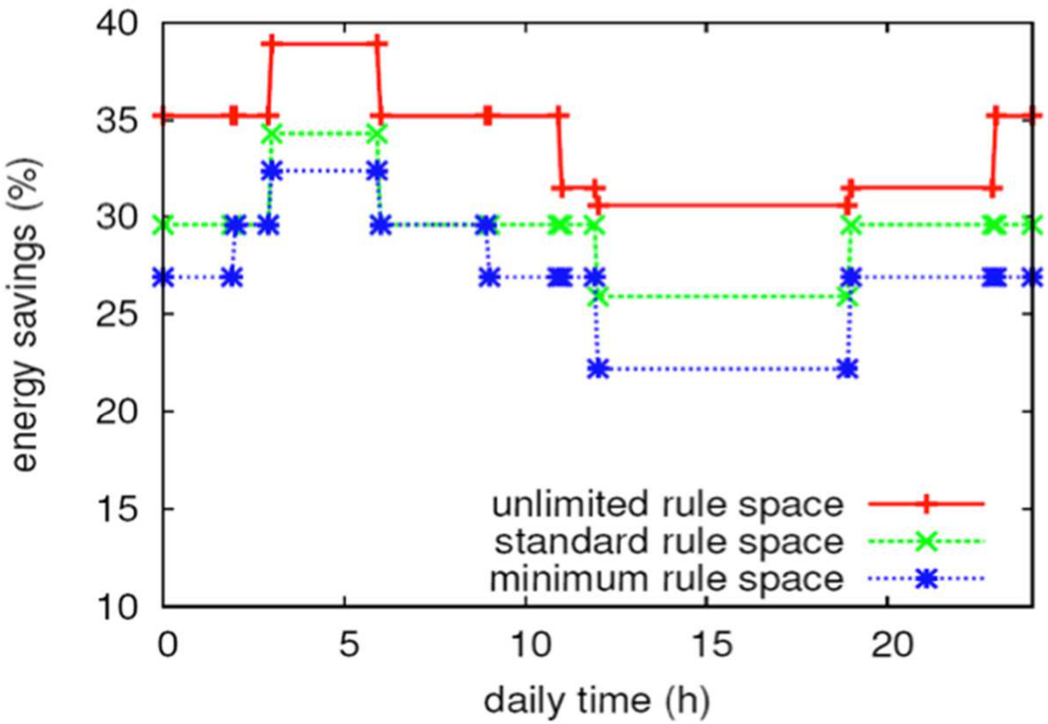
Ta2 network: routers with overloaded rule space

RESULTS

Unlimited rule space : infinite number of rules

Standard rule space : 750 rules (TCAM memory)

Minimum rule space : 695 (no solution with fewer)



Ta2 network: energy saving

CONCLUSIONS AND FUTURE WORK

One step towards putting energy-efficiency into reality using SDN:

- Solved issues in energy-aware traffic engineering about routing and software-defined networks.

Future directions:

- Considering side effects e.g. QoS when deploying EAR with SDN.
- Minimizing rule space in SDN network using wild cards.
- Study in data center networks.

CONCLUSIONS AND FUTURE WORK

One step towards putting energy-efficiency into reality using SDN:

- Solved issues in energy-aware traffic engineering about routing and software-defined networks.

Future directions:

- Considering side effects e.g. QoS when deploying EAR with SDN.
- Minimizing rule space in SDN network using wild cards.
- Study in data center networks.

Thank you ! Questions ?