TE dans les réseaux IP/MPLS

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Traffic Engineering for IP/MPLS networks

- **Traffic Engineering:** define the way traffic is « *efficiently* » routed throughout the network

- **what is « *efficiently* » ?**
  - ✓ <u>for the network</u>: reasonable use of resources (capacities)
  - ✓ <u>for the services</u>: satisfy SLAs, ensure reasonable QoS

- **which often translates into contradictory objectives:**
  - ✓ minimize path length
  - ✓ minimize load (avoid congestion)

- **difficult problems:**
  - ✓ indirect control on the traffic
  - ✓ need to cope with routing protocols

“Real-life” behavior of IP/MPLS networks

IGP routing

1. the network admin configures link weigths
2. each router computes shortest-paths towards all reachable destinations
3. the traffic is forwarded allong these shortest-paths

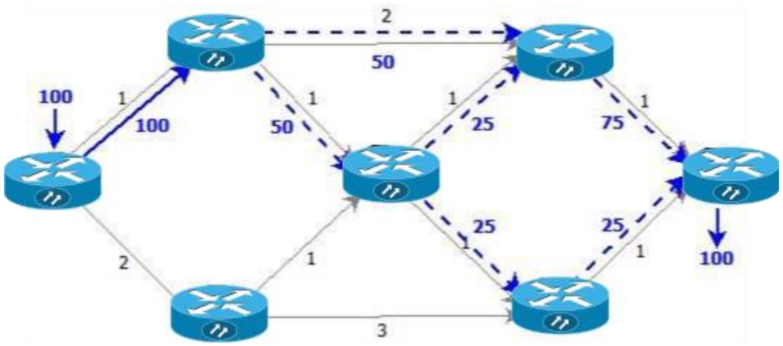
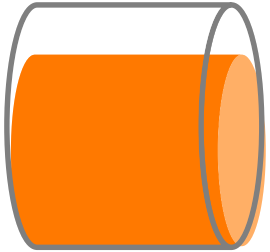


Illustration of ECMP = Equal Cost Multi-Path



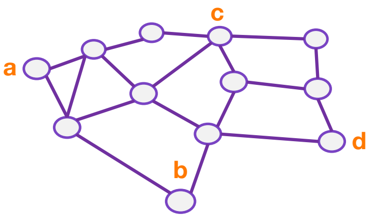
Resulting link loads

First optimization problem:

Find link weights so that max load is minimized !!!

Need to build a “model” (static)

network = capacitated graph



$G = (V,A)$
V: set of nodes
A: set of arcs
C_a: capacity of arc a

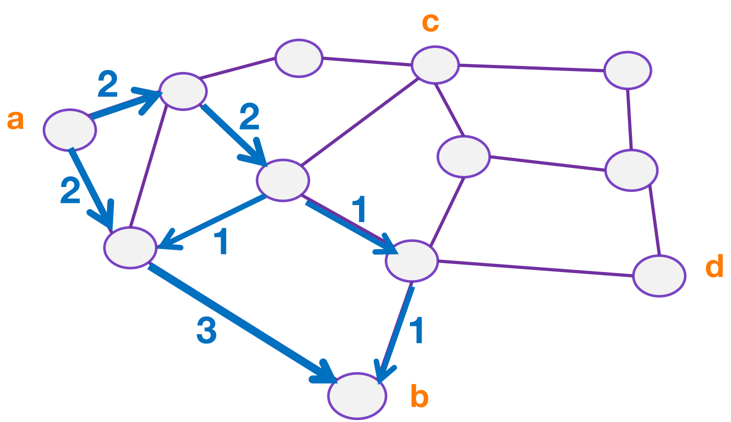
set of commodities = traffic matrix

	a	b	c	d
a		4	2	7
b	5		1	2
c	5	3		3
d	2	1	6	

K
s^k: source of commodity k
t^k: sink of commodity k
d^k: volume of commodity k

Flow model can be used…

a flow = a way to send traffic from source to sink



compact model

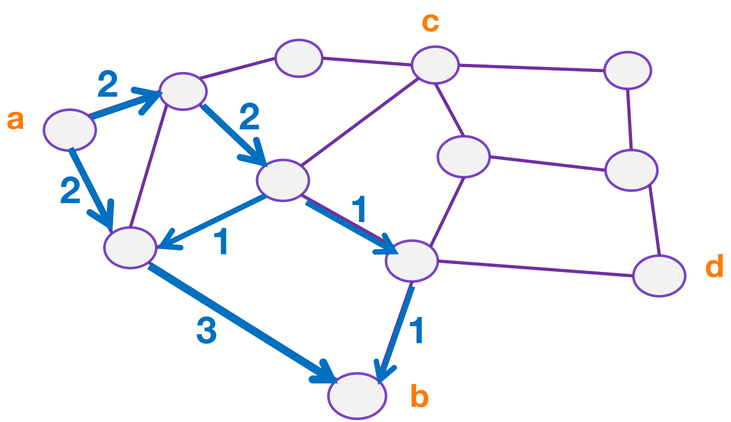
$$
\begin{array}{lll}
\min / \max & \text{objective} & \\
\text{s.t.} & \boxed{\displaystyle\sum_{a\in\delta^-(v)} f_a^k = \sum_{a\in\delta^+(v)} f_a^k} & k\in K, v\in V\setminus\{s^k,t^k\} \\
& \displaystyle\sum_{a\in\delta^-(t^k)} f_a^k = d^k & k\in K \\
& \displaystyle\sum_{a\in\delta^+(s^k)} f_a^k = d^k & k\in K \\
& \boxed{\displaystyle\sum_{k\in K} f_a^k \le C_a} & a\in A \\
& f_a^k \ge 0 &
\end{array}
$$

flow conservation constraints

capacity constraints

...but very difficult to capture all the complexity

a **flow** = a way to send traffic from source to sink



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IGP weights ?

Shortest-paths ?

ECMP ?

Modal work

- **Investigate some of those difficult problem**
  - ✓ Understand the background (routing protocols)
  - ✓ Understand the problems, formalize…
  - ✓ Propose methods, algorithms,…
  - ✓ Test on some instance (python code)

- **Many (potential) variants**
  - ✓ Different routing protocols (IS-IS, OSPF, ECMP, Segment Routing,…)
  - ✓ Uncertain traffic matrix (robustness, oblivious routing,…)
  - ✓ Failures in the network (survivable routing,…)
  - ✓ Congestion avoidance, QoS,…

Article à étudier

- Hao, Fang, Kodialam, Murali and Lakshman, T.V., “Optimizing Restoration with Segment Routing”, IEEE Infocom 2016

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3. Azar, Yossi et al. (2004). “Optimal oblivious routing in polynomial time”. In: Journal of Computer and System Sciences 69.3, pp. 383–394.
4. Applegate, David and Edith Cohen (2003). “Making intra-domain routing robust to changing and uncertain traffic demands: Understanding fundamental tradeoffs”. In: Proceedings of the 2003 conference on Applications, technolo-gies, architectures, and protocols for computer communications. ACM, pp. 313–324.
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Thank you!

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