Traffic Grooming in Core Telecommunication Networks

Jean-Claude Bermond, Stéphane Pérennes and Michel Syska

Mascotte, CNRS/I3S/INRIA

Sophia-Antipolis - Frankreich

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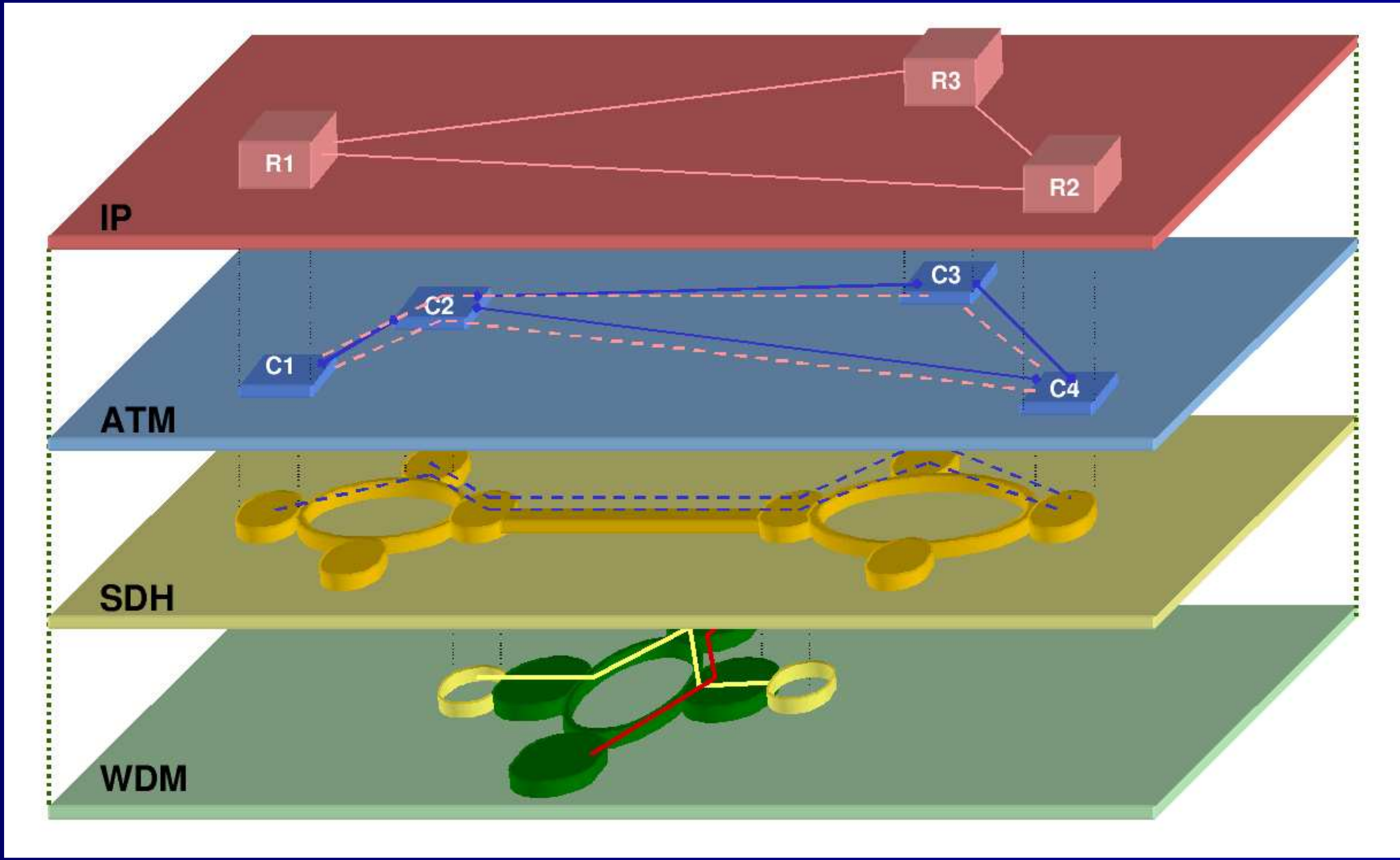
WP-4 Efficient Utilization of Optical Bandwidth

Network Design and Planning

- Given an predicted traffic matrix, compute the allocation of resources
- Constrained by technological and quality of services issues:
  - Wavelength routing : connexions are routed along color-disjoint paths
  - Fault-tolerance : protection or restoration of 1 node/link failure
- Minimize the cost of the network: node equipments

Core Network = Overlay Network



Packet and Transport Layers

The Grooming Problem

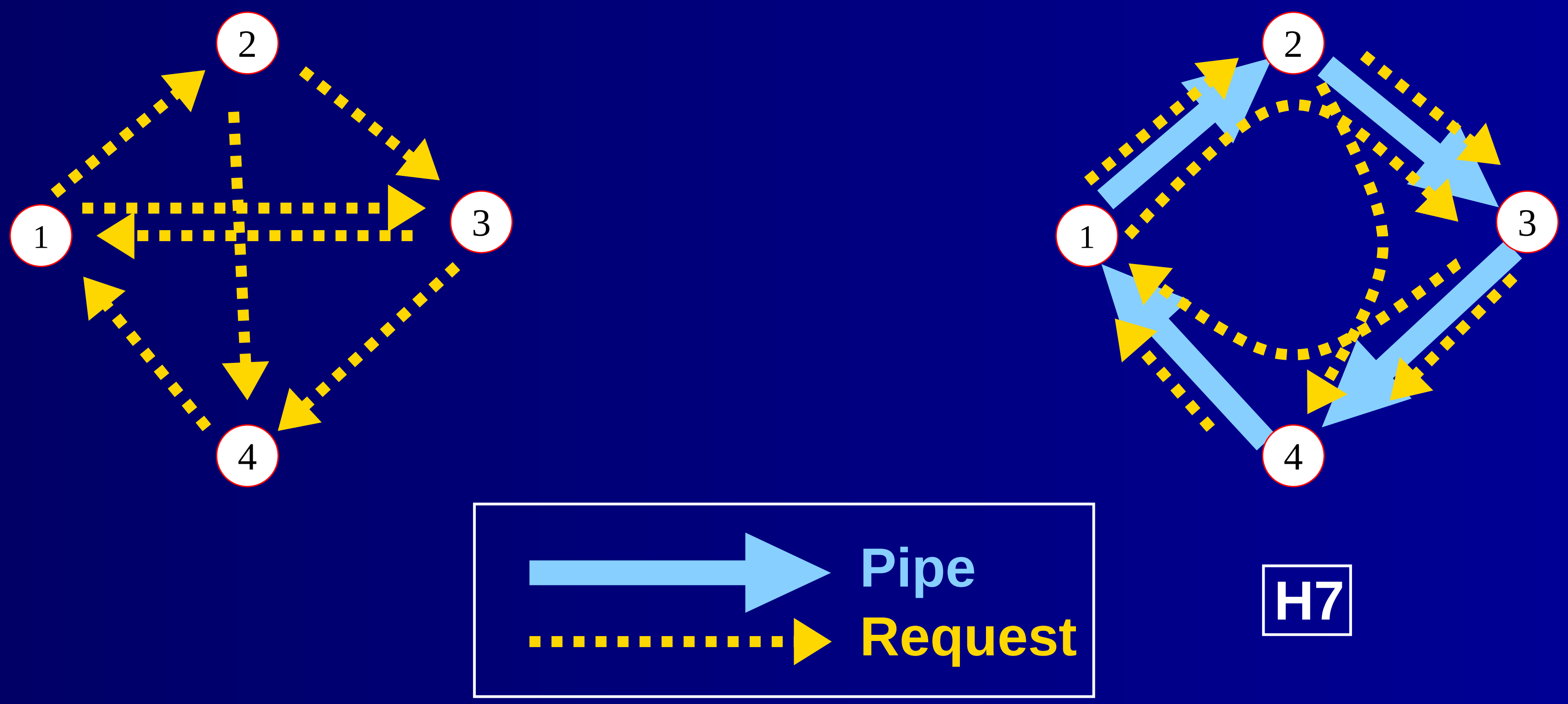
- Client/Server model : low speed connexions (*Requests*) are groomed into large speed *Pipes*
- Pipes are expensive and may be shared by a *grooming Factor* of C requests
- A request may be *routed* via a sequence of pipes
- Objective: Minimize the total number of pipes
- Remarks:
  - Different from Virtual Path Layout problem: pipe capacity
  - Ignore routing of pipes and capacity of the physical links

Grooming problem

- Input : traffic matrix = set of directed requests = instance digraph I
- Output : a virtual multidigraph H allowing the routing of the requests with at most C requests using one given pipe
- Objective : Minimize the total number of pipes

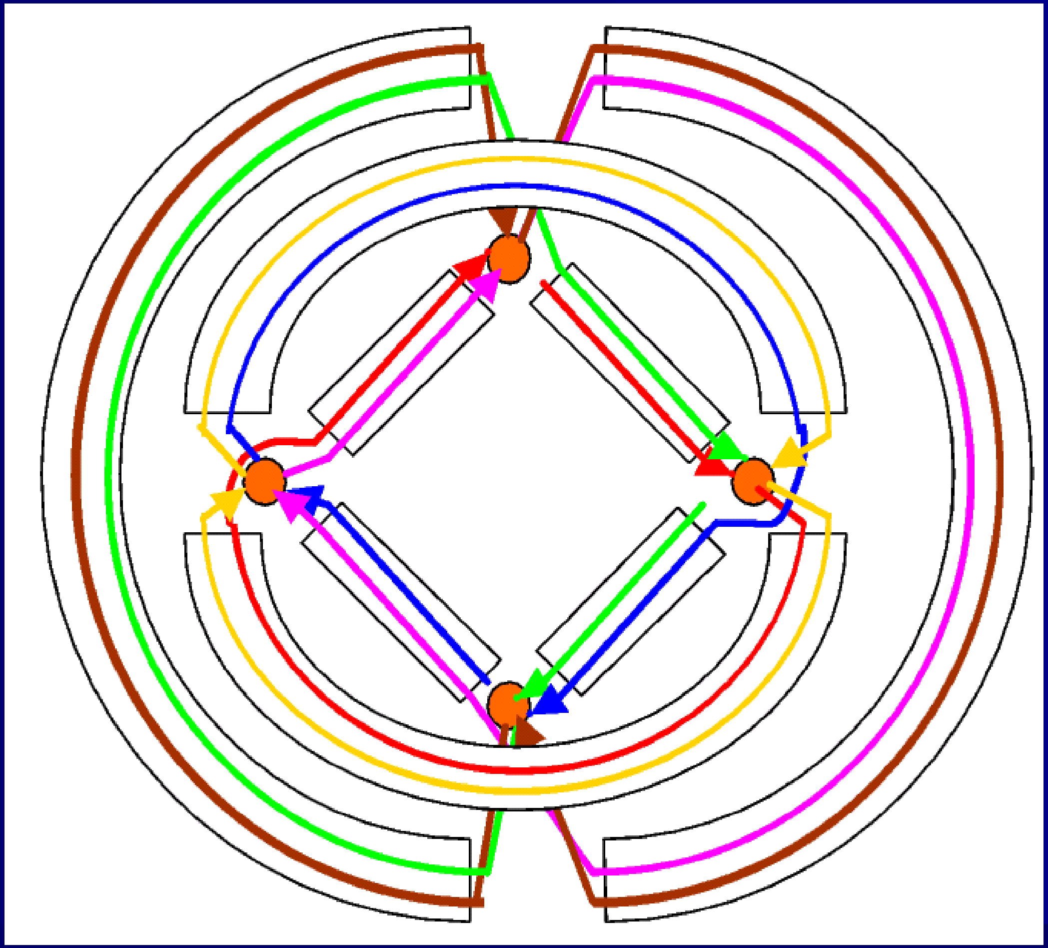
Grooming Example I

7 requests groomed with 4 pipes ($C = 3$)



Grooming Example II

All-to-All requests groomed with 8 pipes ($C = 2$)



Lower bound

Theorem: The number of pipes T for grooming a simple instance (at most one request from s to d) with R requests and grooming factor C is at least $\frac{2R}{C+1}$

Proof: Let R_i be the number of requests using i pipes

$R = \sum_i R_i$ and $T \geq R_1$

$$\begin{aligned} C \cdot T &\geq \sum_i iR_i = 2R - R_1 + \sum_{i \geq 3}(i-2)R_i \\ &\geq 2R - T + \sum_{i \geq 3}(i-2)R_i \\ T &\geq \frac{2R + \sum_{i \geq 3}(i-2)R_i}{C+1} \geq \frac{2R}{C+1} \end{aligned}$$

Lower bound

Lower bound achieved iff:

- Every pipe contains exactly C requests
- A request uses at most 2 pipes
- Any pipe contains the request between its end nodes

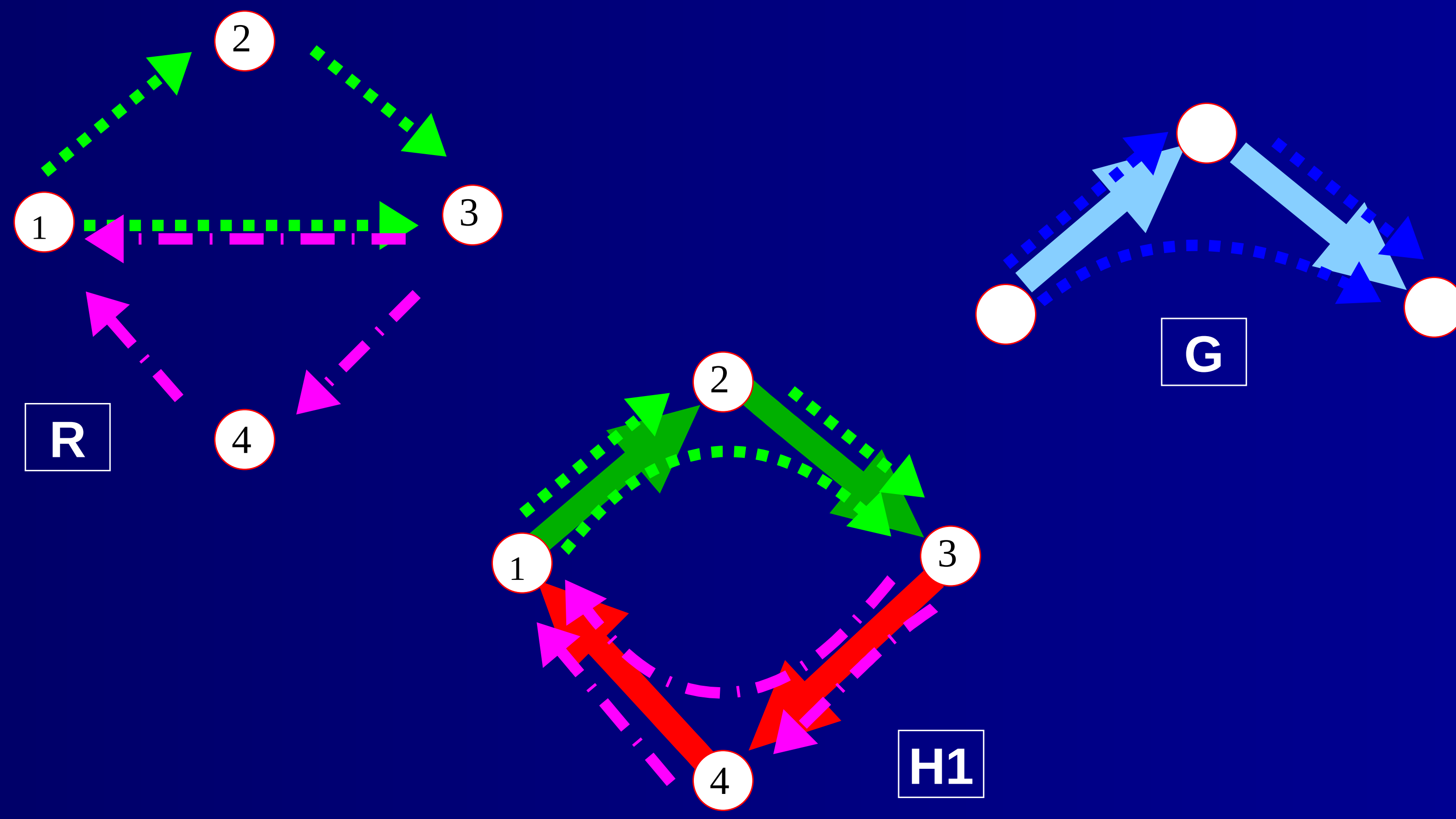
Block Covering / Upper Bounds

- Idea : Cover the set of requests I (arcs of I) with *blocks*
- Block I_j allows to groom R_j requests with a minimum number of pipes $T_j = \frac{2R_j}{C+1}$

If we get a partition of I, H is optimal for the corresponding number of pipes (but *Set Cover*, MAX SNP-complete even for triangles)

Block Covering / Upper Bounds

Example for $C = 2$ using as blocks transitive triple tournaments $TT3$ (simplest block with $3/2$ requests per pipe)



Results

When $C = 2$ the grooming problem is in MAX SNP

- partitioning of I in $\frac{R}{3}$ $TT3$ or $(1+\epsilon)\frac{R}{3}$ $TT3$ is NP-complete (reduction to the partitioning of a graph into triangles)
- Routing with $\sim \frac{2|R|}{3}$ only for $\sim \frac{2}{3}$ $TT3$ partioning

Greedy partioning leeds to a $\frac{4}{3}$-approximation

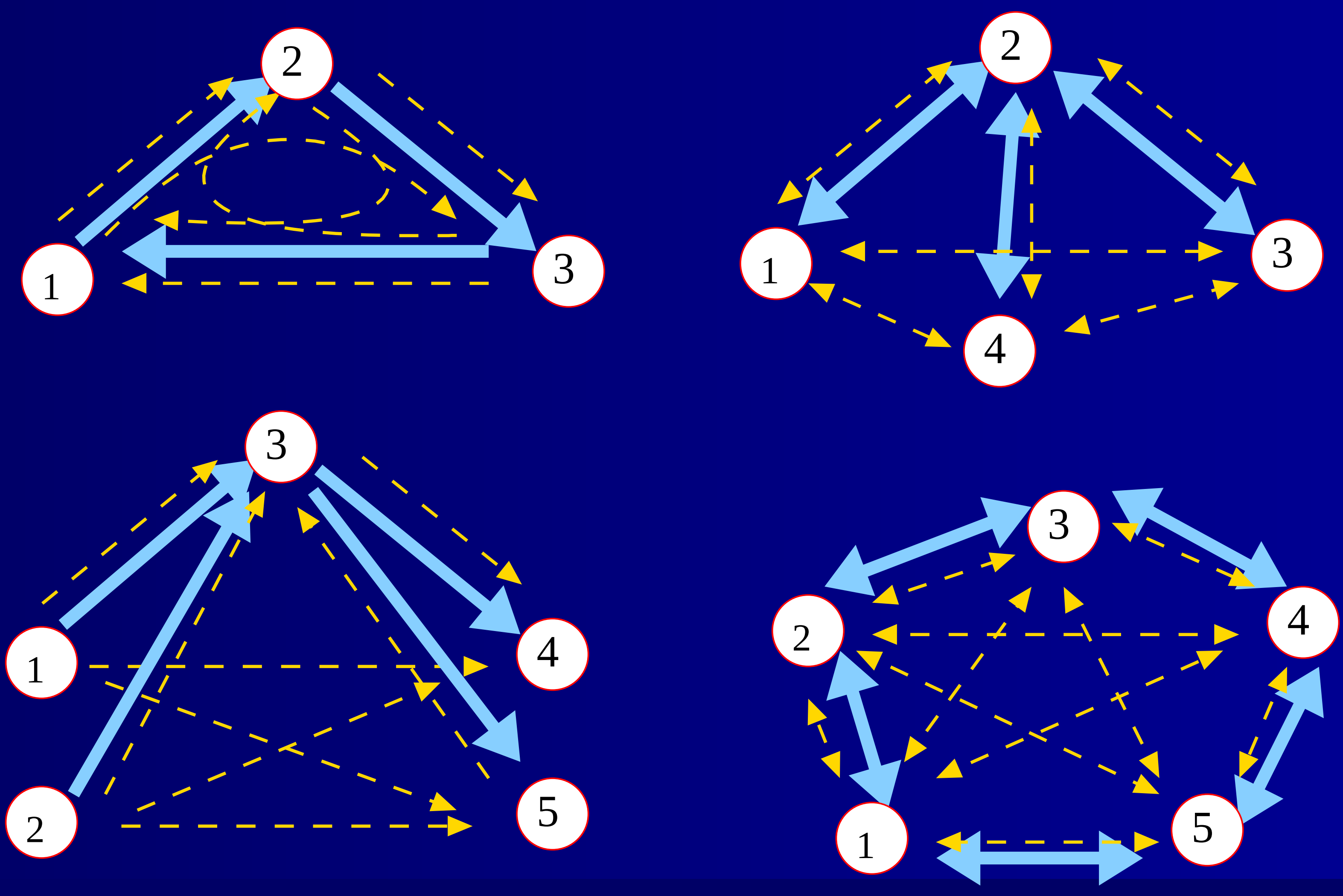
Results

- When $C = 2$ and I = *All-to-All* there exists an optimal grooming with $T = \frac{2}{3}n(n-1)$

  Using old results on the partitioning of K_n^*

- When $C = 3$ and I = *All-to-All*, there exists a grooming with the minimum number of pipes $T = \frac{1}{2}n(n-1)$) for $n \notin \{6, 8\}$
- For any C and I= *All-to-All* grooming with roughly $\frac{2R}{C}$ pipes

Blocks for C=3



Perspectives

- Upper bounds for General instance I ?
  - Approximation algorithms for $C = 2$?
- Influence of the physical network
  - What is the minimum number of pipes with a fixed load parameter
  - Case of the path, the unidirectional ring , etc ...
- Previous work (ILP, OADMs, ...)

Previous work

- minimization of the number of OADM for ring networks (see examples)
- ILP model (routing of requests and capacities of pipes are fixed)

Work in progress with Hu Zhang and Jean-Francois Lalande: use of Lagrangian Relaxation (pipes with unbounded capacities)

References

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- Bermond & Céroi, *Minimizing SONET ADMs in Unidirectional WDM Rings with Grooming Ratio 3*, Networks, 41(2):83-86, 2003
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Conclusion

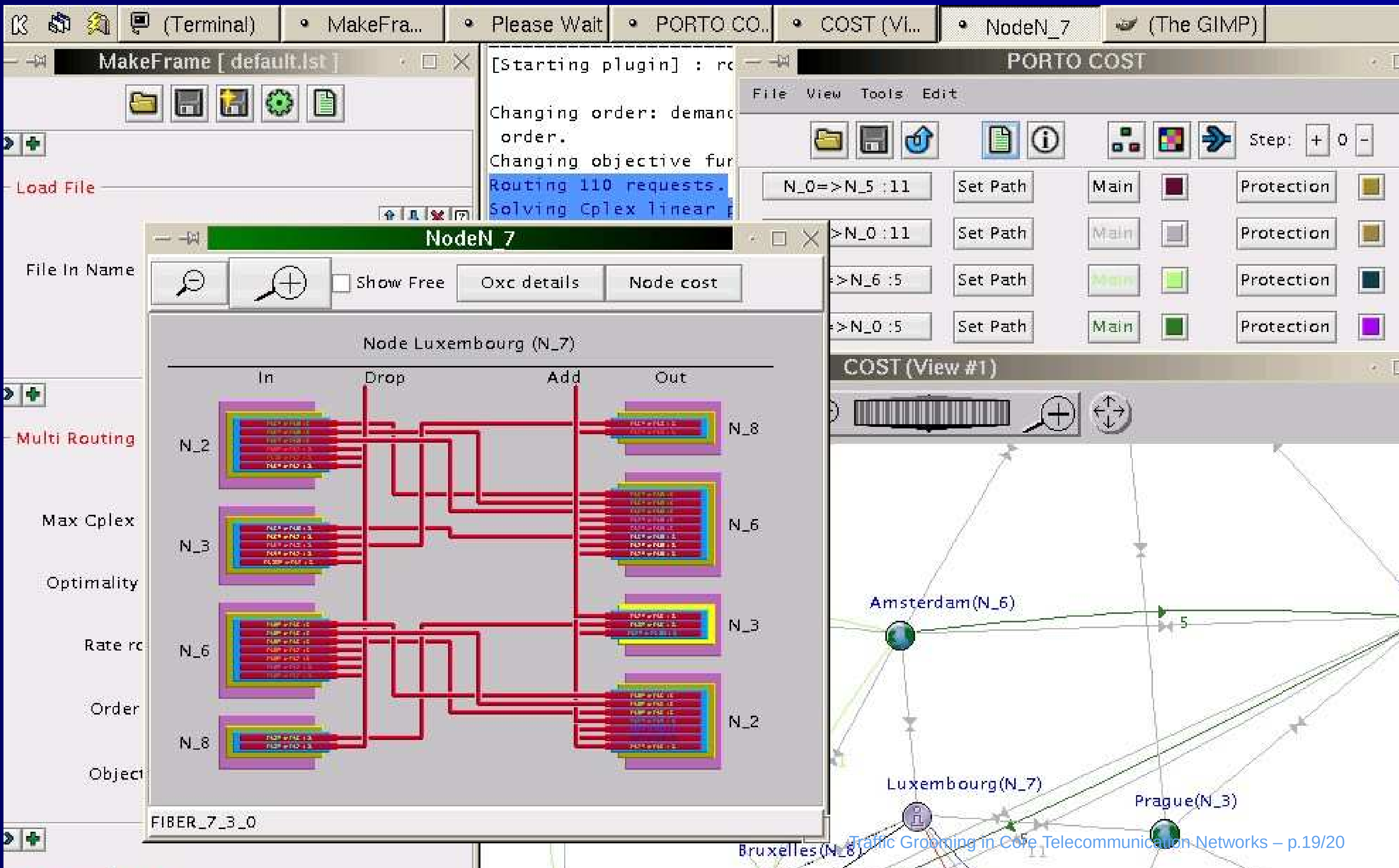
- Generic problem for telecommunication networks design motivated by a collaboration with Alcatel and France Telecom (RNRT PORTO)

  http://www.telecom.gouv.fr/rnrt/projets/pporto.htm

- Ongoing experimental work with the Mascopt library http://www-sop.inria.fr/mascotte/mascopt

Ask for demo!

PORTO planning software



Lab in Sophia