

# Traffic Grooming in Core Telecommunication Networks

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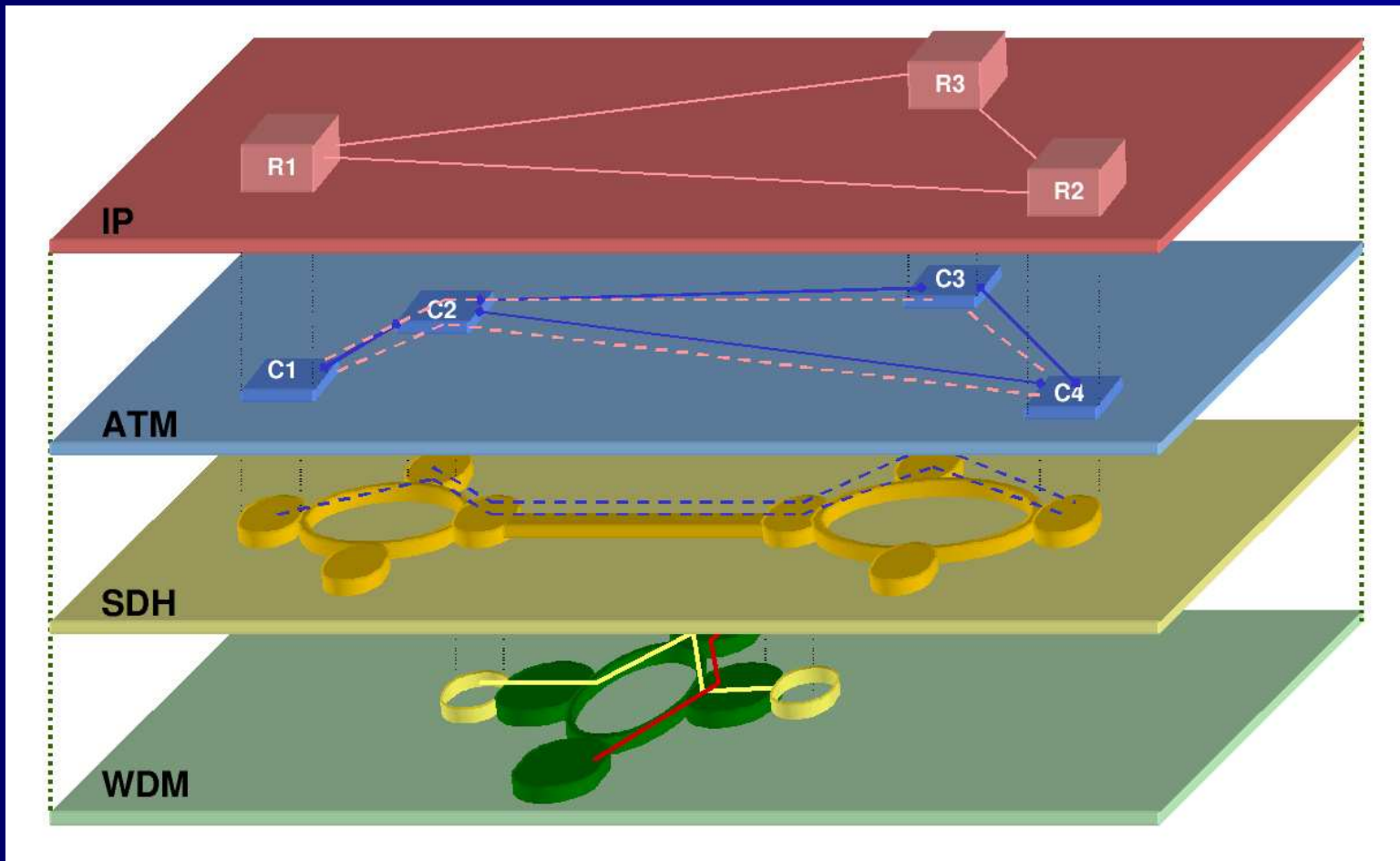
IST 2001-33135 CRESCCO

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

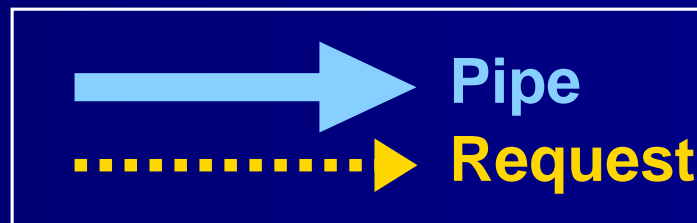
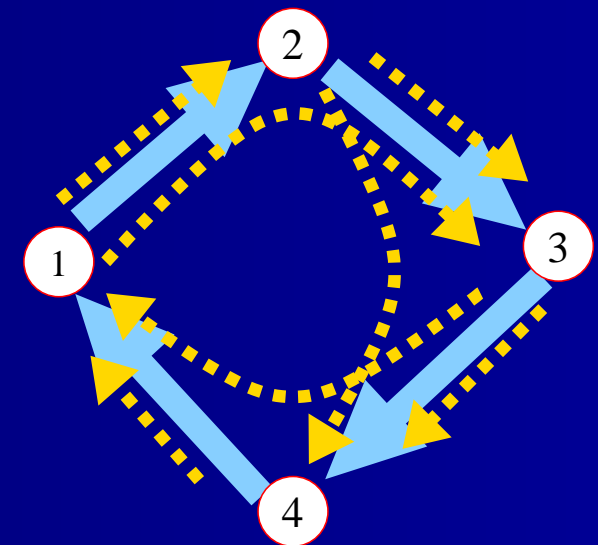
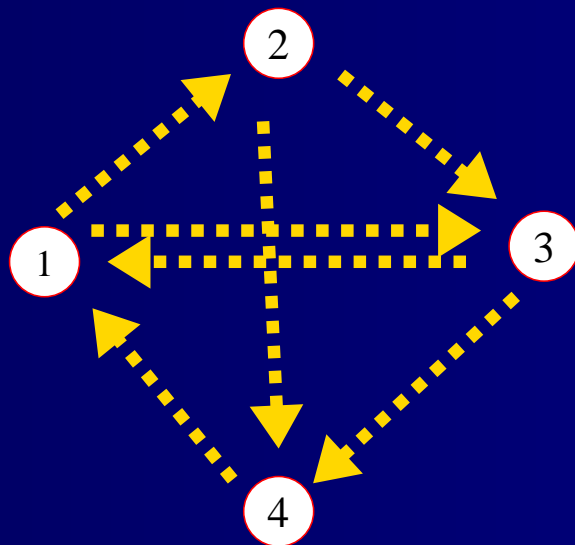
- Client/Server model : low speed connexions (*Requests*) are groomed into large speed *Pipes*
- Pipes are expensive and may be shared by a *grooming Factor* of  $C$  requests
- A request may be *routed* via a sequence of pipes
- **Objective:** Minimize the total number of pipes
- **Remarks:**
  - Different 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

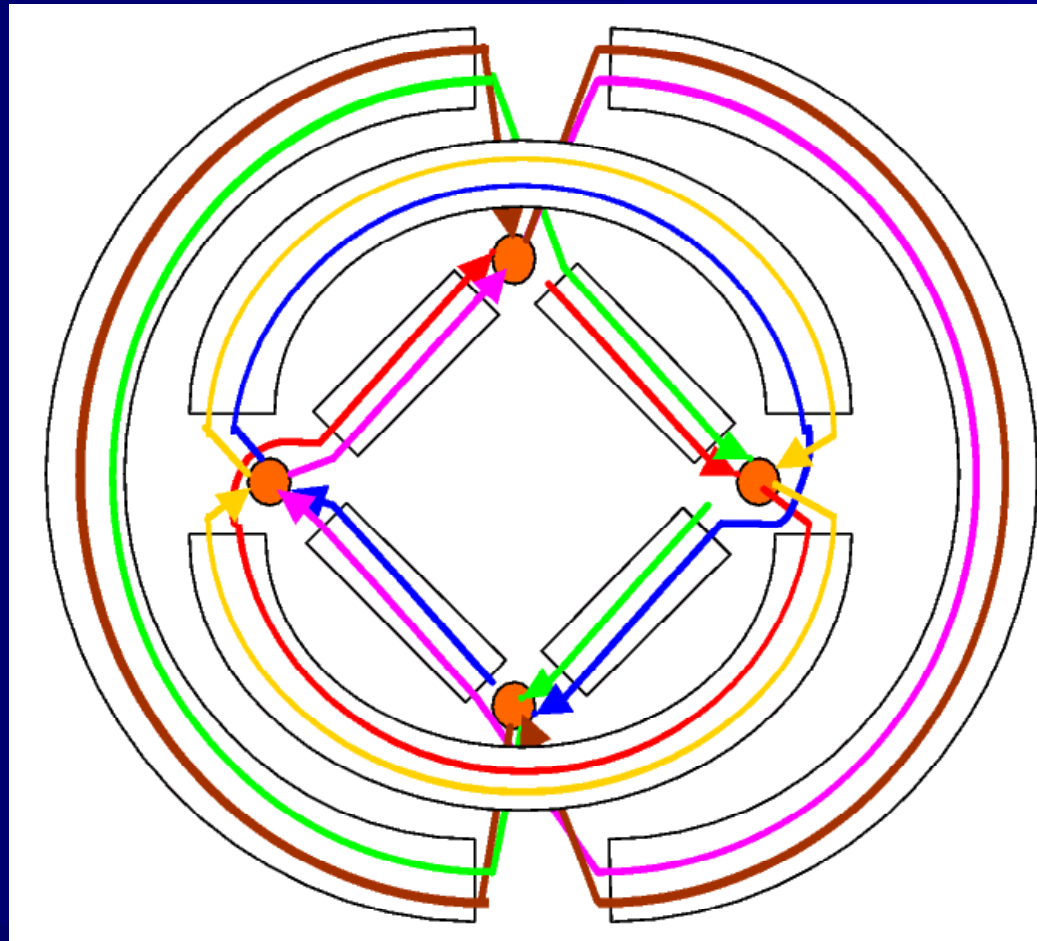
7 requests groomed with 4 pipes ( $C = 3$ )



H7

# 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

$$R = \sum_i R_i \text{ and } T \geq R_1$$

$$C \cdot T \geq \sum_i i R_i = 2R - R_1 + \sum_{i \geq 3} (i - 2) R_i$$

$$\geq 2R - T + \sum_{i \geq 3} (i - 2) R_i$$

$$T \geq \frac{2R + \sum_{i \geq 3} (i - 2) R_i}{C + 1} \geq \frac{2R}{C + 1}$$



# 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

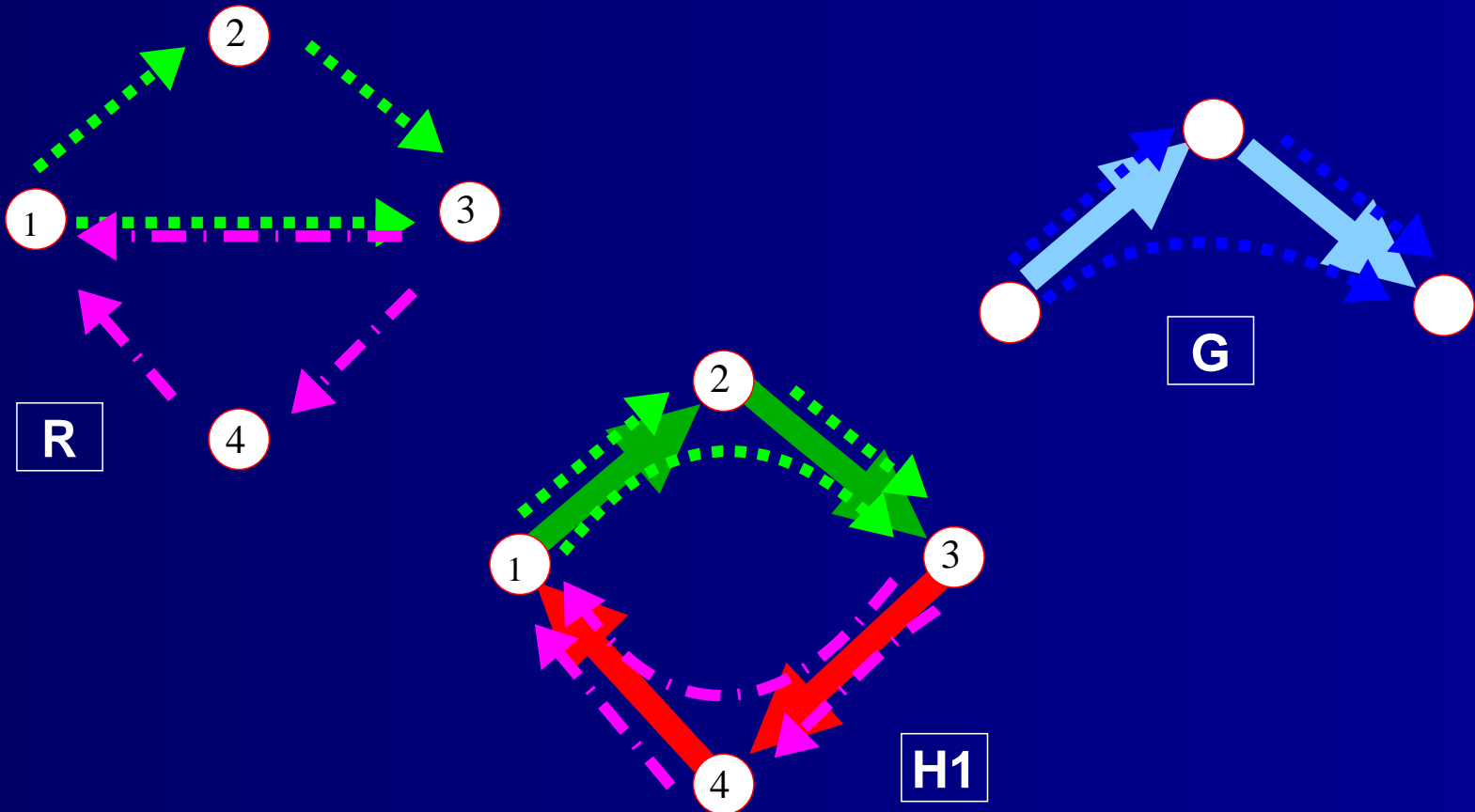
# Block Covering / Upper Bounds

- 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  $TT_3$   
(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  $\sim \frac{2}{3} TT3$  partitioning

Greedy partitioning leads to a  $\frac{4}{3}$ -approximation

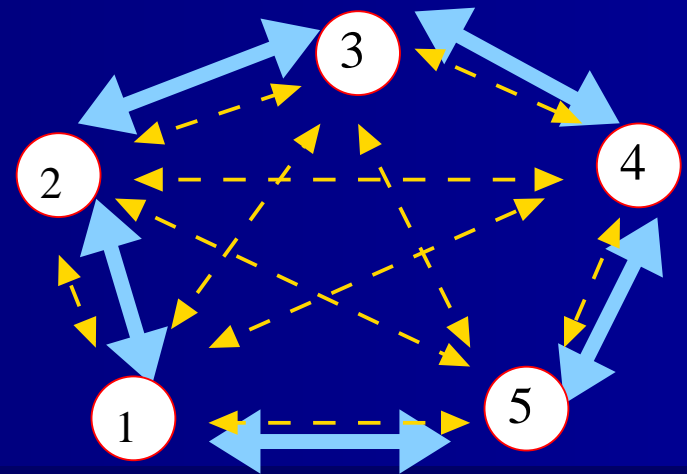
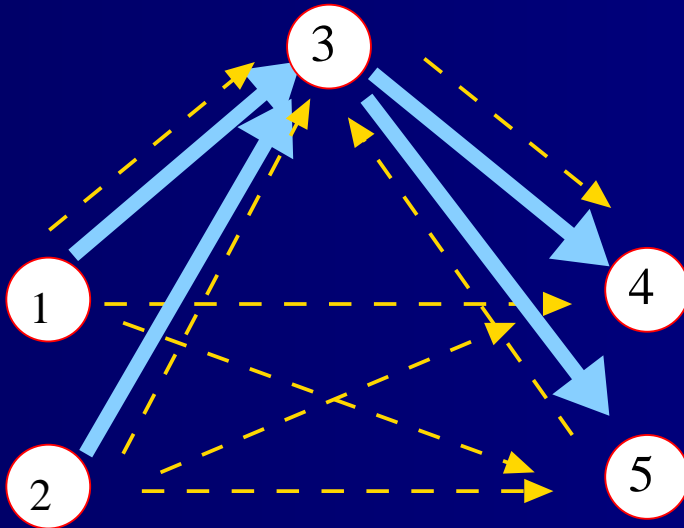
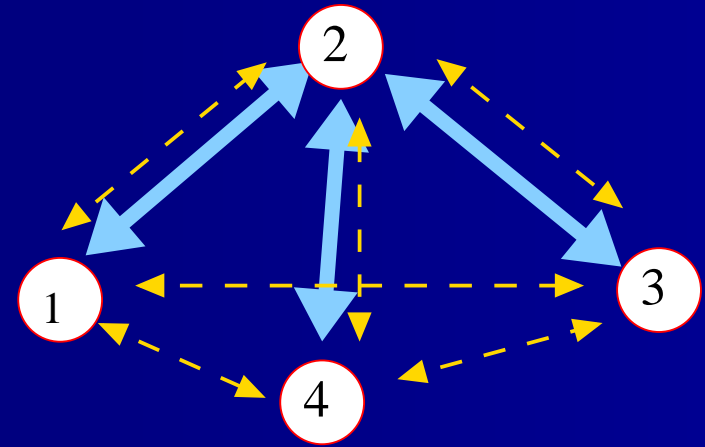
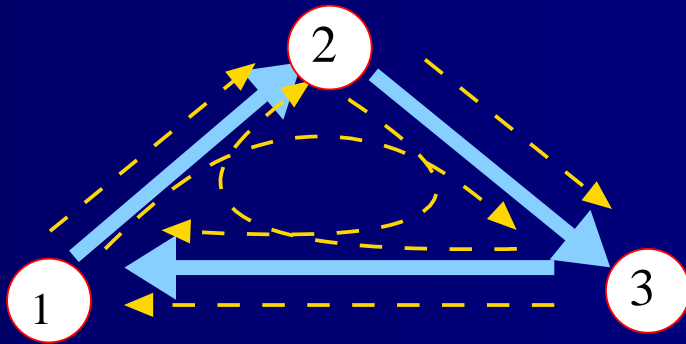
# Results

- When  $C = 2$  and  $I = \text{All-to-All}$  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  $I = \text{All-to-All}$ , 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  $I = \text{All-to-All}$  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, OADM's, ...)

# 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, Coudert & Muñoz, *Traffic Grooming in Unidirectional WDM Ring Networks: The All-to-All Unitary Case*, *ONDM*, Feb 2003
- Bermond, Colbourn, Ling, & M.-L. Yu., *Grooming in Unidirectional Rings :  $K_4 - e$  Designs*, *Discrete Mathematics*, Lindner's Volume, 2003
- 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 Mascot library <http://www-sop.inria.fr/mascotte/mascot>

Ask for demo!

# PORTO planning software

The screenshot displays the PORTO COST software interface, which is used for network planning. The main window, titled "PORTO COST", shows a network diagram with nodes and connections. A terminal window in the background displays the following text:

```
[Starting plugin] : re
Changing order: demanc
order.
Changing objective fur
Routing 110 requests.
Solving Cplex linear p
```

The "NodeN 7" window is open, showing a detailed view of "Node Luxembourg (N\_7)". This window is divided into four columns: "In", "Drop", "Add", and "Out". Each column contains a stack of fiber ports, with red lines indicating the connections between them. The "In" column has ports labeled N\_2, N\_3, N\_6, and N\_8. The "Drop" column has ports labeled N\_2, N\_3, N\_6, and N\_8. The "Add" column has ports labeled N\_2, N\_3, N\_6, and N\_8. The "Out" column has ports labeled N\_8, N\_6, N\_3, and N\_2. The "FIBER\_7\_3\_0" label is visible at the bottom of this window.

The "COST (View #1)" window shows a network diagram with nodes labeled "Amsterdam(N\_6)", "Luxembourg(N\_7)", and "Prague(N\_3)". The diagram includes a scale bar and a zoom control.

The "NodeN 7" window also includes a "File In Name" field, a "Show Free" checkbox, and buttons for "Oxc details" and "Node cost". The "Multi Routing" section is visible on the left side of the interface.

# Lab in Sophia

