

A practical approach to network planning using both operational and optimization tools

Orange Labs

N. Perrot, V. Chandrakumar, L. Burity and S. Nicaisse

Research & Development
October, 1st, Networks 2008



France Telecom Group



contents

section 1 multi layer optimization

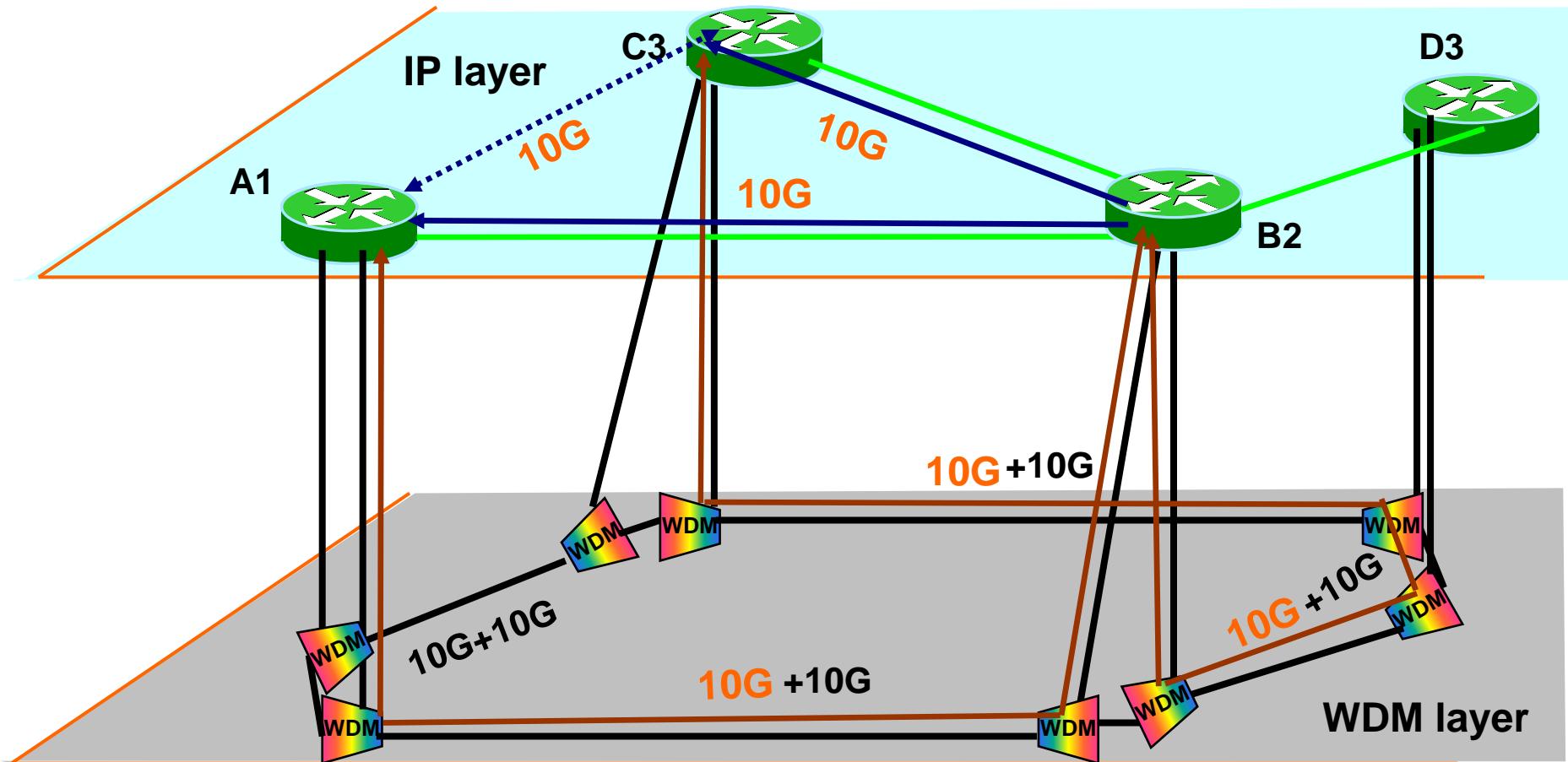
section 2 an operational tool

section 3 network planning

Introduction

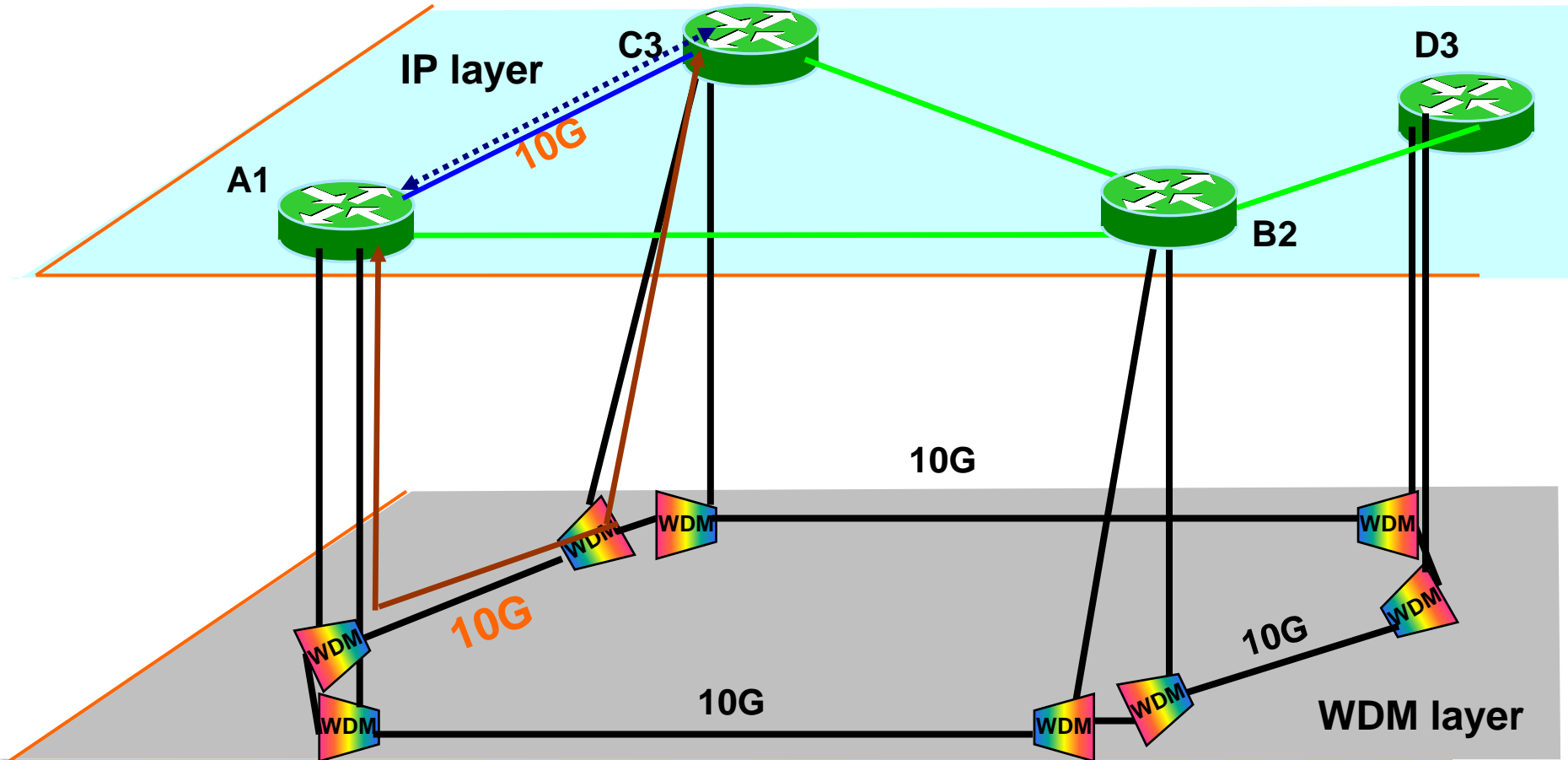
- Why ***multilayer optimization tools*** ?
 - Multilayer optimization allows to optimally use the resources of lower/underlying layers (example)
 - SRLG (Shared Risk Link Group)
 - Compare different levels of protection at each layer, ...

Schema : hierarchy



Consider a traffic demand between C and A
 Traffic routing at IP layer
 Physical routing through Optical layer
 Capacity with protection

Schema: Direct



Capacity with protection

Introduction

- Why ***multilayer optimization tools*** ?
 - Multilayer optimization allows to optimally use the resources of lower/underlying layers (example)
 - SRLG (Shared Risk Link Group)
 - Compare different levels of protection at each layer, ...

- Why ***operational tool*** in addition to network planning tools ?
 - Simulation on the real network topology
 - Operational constraints (equipage, capacity occupation, ...)

contents

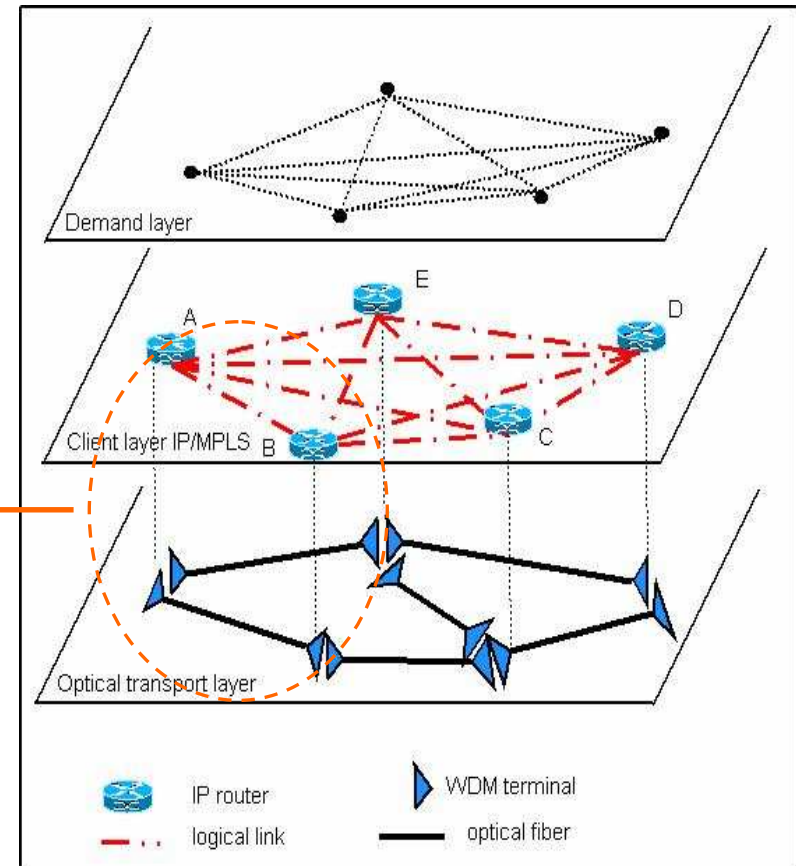
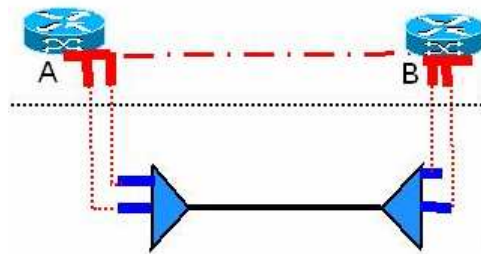
section 1 multi layer optimization

section 2 an operational tool

section 3 network planning

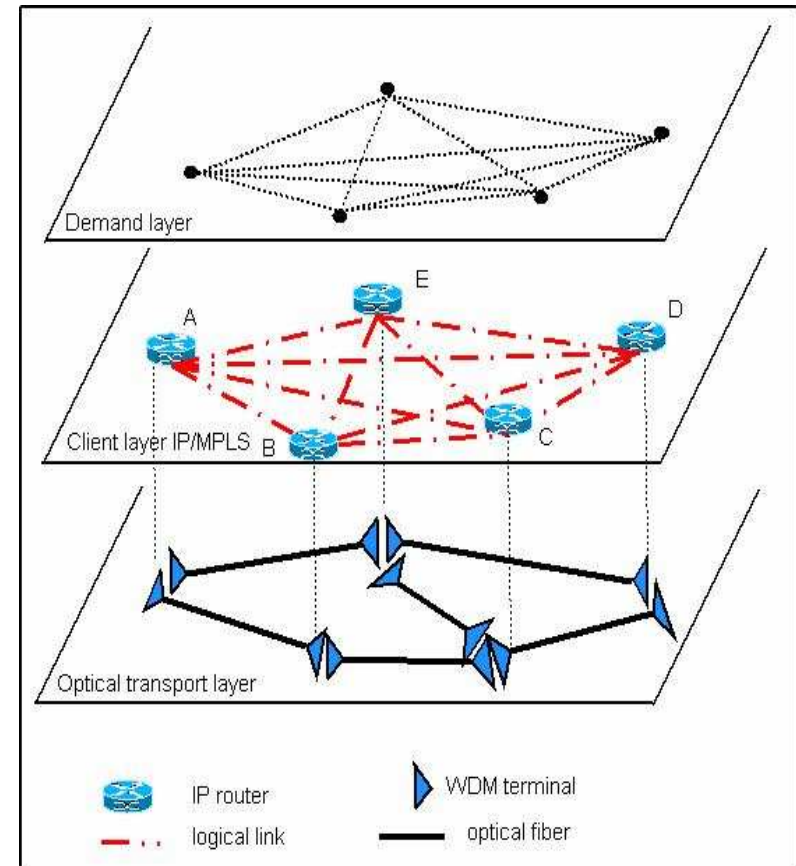
Bi layer planning process

- Design of IP/MPLS over WDM networks



Bi layer planning process

- Design of IP/MPLS over WDM networks
- Objectives:
 - Optimize the resources to deploy on each network layer
 - Take into account existing traffic
 - Consider the interactions between the layers



Towards an efficient algorithm for multi layer design

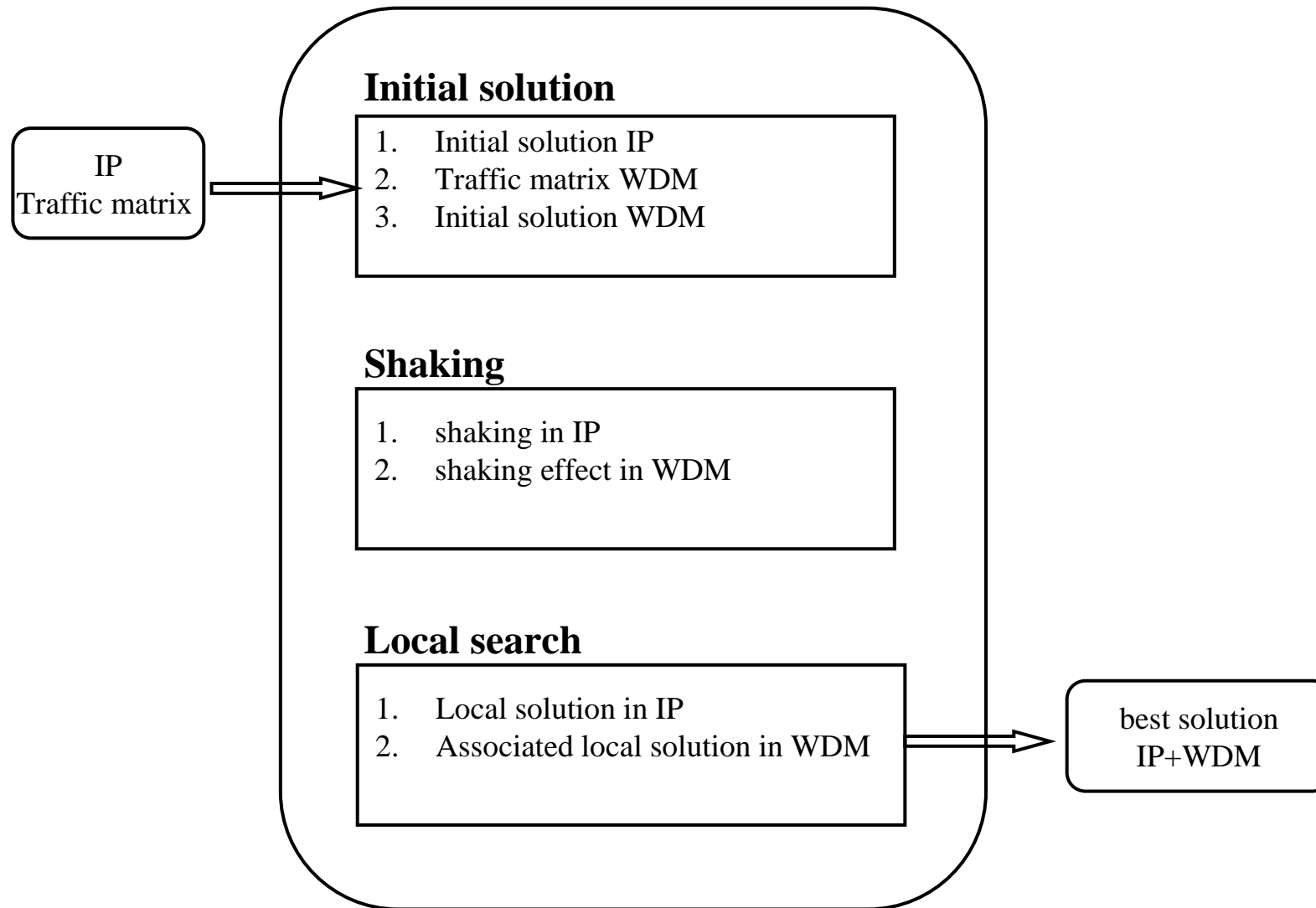
- Difficulty in managing an exact formulation
 - too many engineering constraints
hard to model, big formulation, no efficient method,
no flexibility, ...
 - computation time explodes for real instances
(several days for 9 nodes per layer and 50 demands)
- Heuristic based on a variable neighborhood search
 - effective for a single layer network design problem
 - flexible enough to be extended and adapted

Variable Neighborhood Search

- Initialization:
 - elementary routings of each demand (initial solution x):
 - estimation of links cost
 - shortest path with new costs
 - determination of some neighborhood structures $Nk(x)$

- Repeat:
 - shaking: generate a new random solution in $Nk(x)$
 - local search: variable neighborhood descent methods
 - if the solution is better than x , then move to the last solution otherwise, enlarge the neighborhood

Towards an efficient algorithm: simultaneous approach



Multi layer optimization

Comparison of our algorithm with an exact formulation

$ V^1 $	$ V^2 $	$ K $	CostIP	CostWDM	Cost	Gap	Theur(s)	Texact(s)
5	5	5	2320	1500	3820	0.08	3	60
5	5	10	4750	1950	6700	0.02	1	600
6	6	5	2320	1500	3820	0.08	1	60
6	6	10	4750	1950	6700	0.02	2	1080
<i>6</i>	<i>6</i>	<i>15</i>	<i>6750</i>	<i>2550</i>	<i>9300</i>	<i>0</i>	<i>2</i>	<i>2340</i>
8	8	5	2320	1500	3820	0.08	1	240
8	8	10	4750	1950	6700	0.02	2	14220
<i>8</i>	<i>8</i>	<i>15</i>	<i>6750</i>	<i>2550</i>	<i>9300</i>	<i>0</i>	<i>2</i>	<i>27000</i>
8	10	20	8500	3300	11800	-	2	-
9	9	5	2320	1500	3820	0.08	2	360
9	9	10	4750	1950	6700	0.02	2	20220
<i>9</i>	<i>9</i>	<i>15</i>	<i>6750</i>	<i>2550</i>	<i>9300</i>	<i>0</i>	<i>5</i>	<i>5 jours</i>
9	9	20	8500	3300	11800	-	3	-

contents

section 1 multi layer optimization

section 2 an operational tool

section 3 network planning

An operational planning tool

- Alto : a decision aid system that interfaces with the real network
- It allows to:
 - Analyze the network
 - Route on all network's layer, using real resources
 - Make a short-term planning
 - Allocate some resources
 - Detect saturations on equipments
 - Generate some statistics on the network.

contents

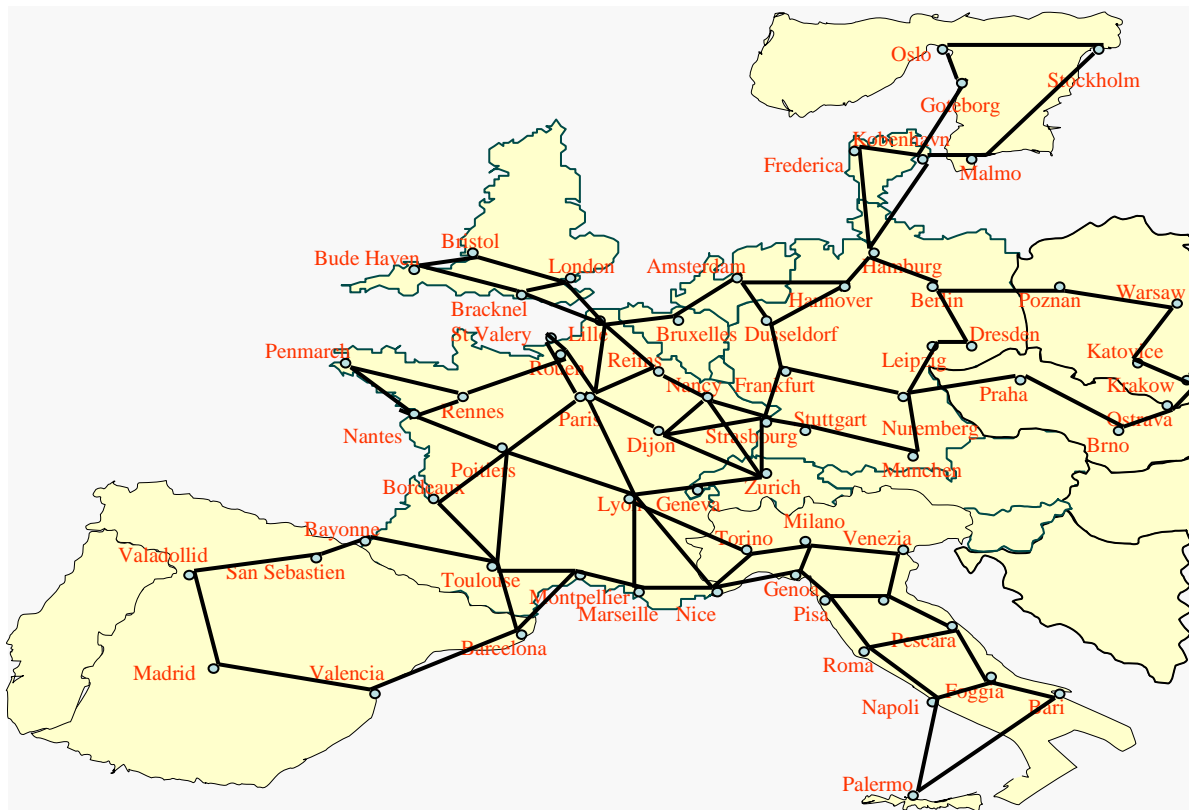
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section 2 an operational tool

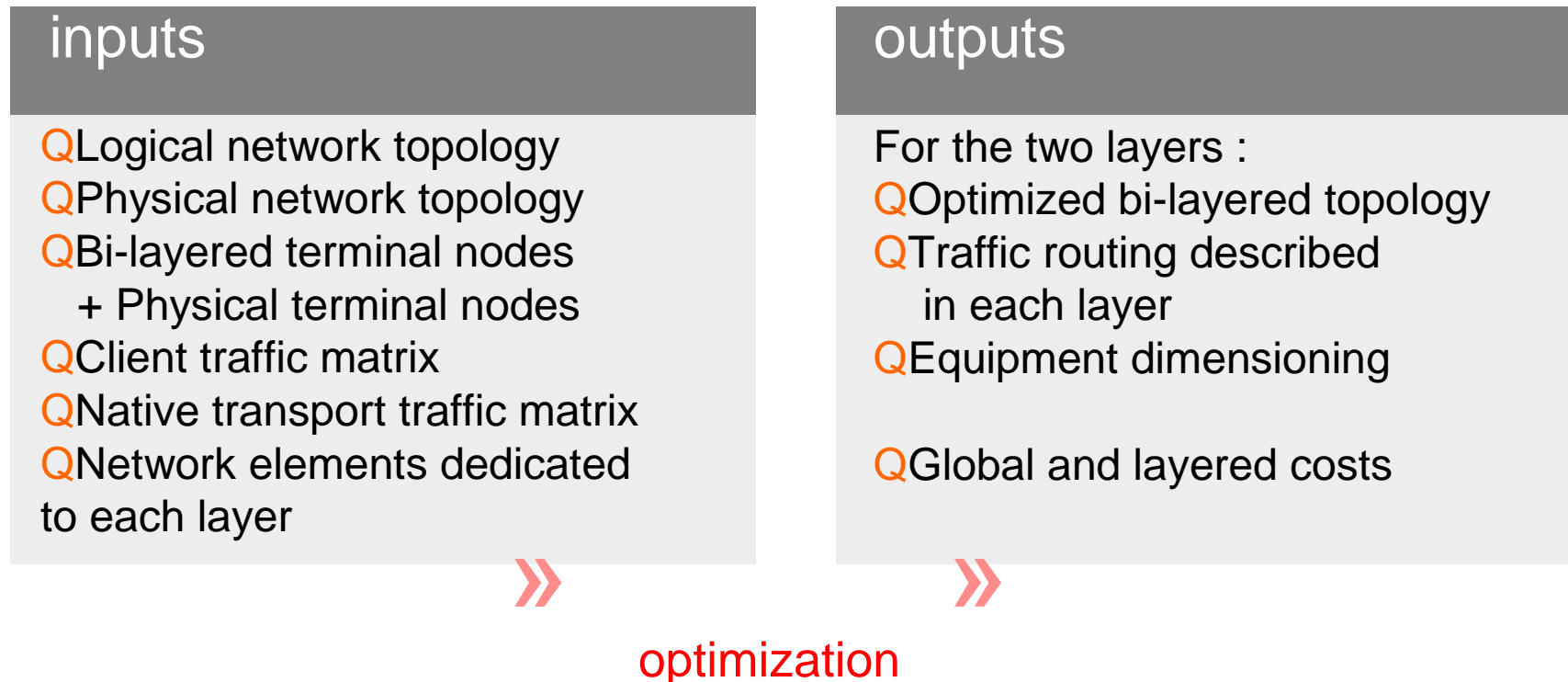
section 3 **network planning**

Network planning through an example

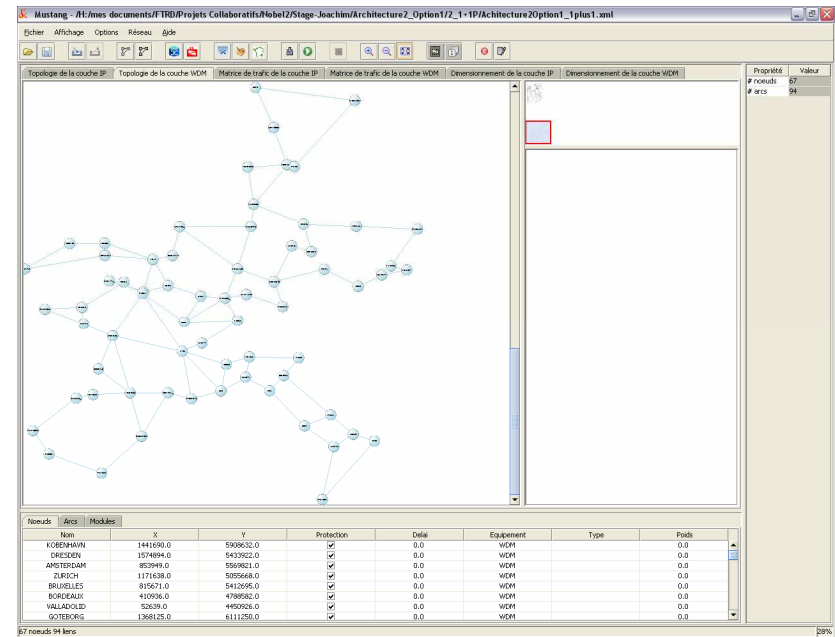
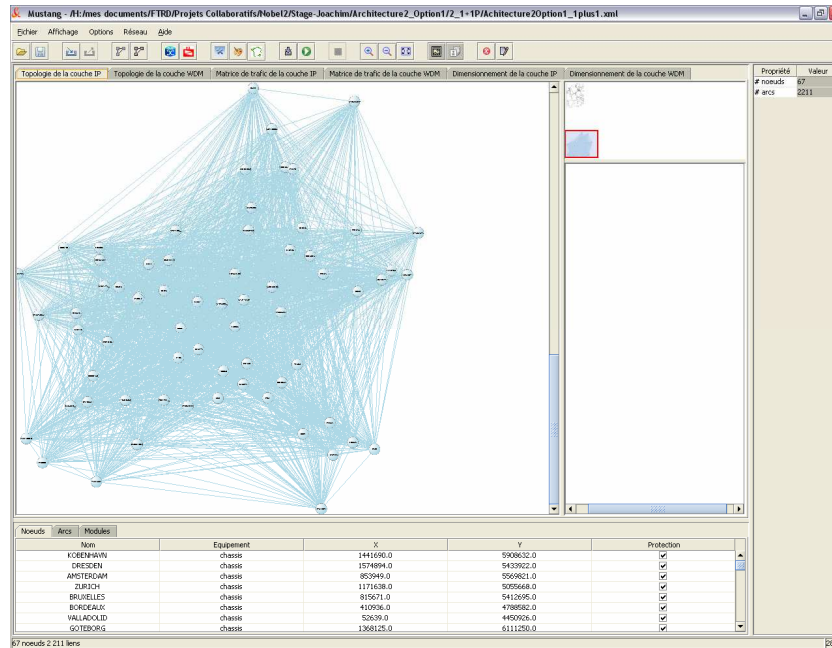
- The Nobel example European network (compare different architectures)
- Topology and traffic based on the real network



Network planning : optimization stage



Network planning : optimization stage



Network planning : operational tool

- Several scenarios are compared
 - Without considering existing network,
 - Taking into account topological constraints and some operational constraints for a given traffic matrix.
 - Network planning tool provides detailed overall network cost, links capacities and node equipage,
 - Availability tool provides network availability values.
- With the help of all these information
 - Network planner chooses two/three reliable and cost effective scenarios with lower technological risk
 - Operational tool is used to simulate these scenarios on a real network copy including all the operational constraints and company policies

Conclusions

- Need for a multilayer planning tool with a sophisticated heuristic algorithm
- Network planning tools alone not sufficient to take a decision on network evolution
- Operational tool considers hidden operational cost at network planning stage, thus allowing to take more realistic decision.