Extension of Bouygues Telecom's ADSL network

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Innovation 24 & LocalSolver

Bouygues Group

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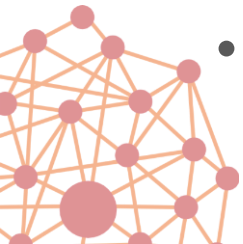
Business Analytics & Optimization subsidiary of Bouygues

PhD-engineers in computer science and applied maths

20 years of experience in operations research

- Optimization
- Planning
- Forecasting
- Revenue Management
- Data Analysis
- Simulation
- Business Rules

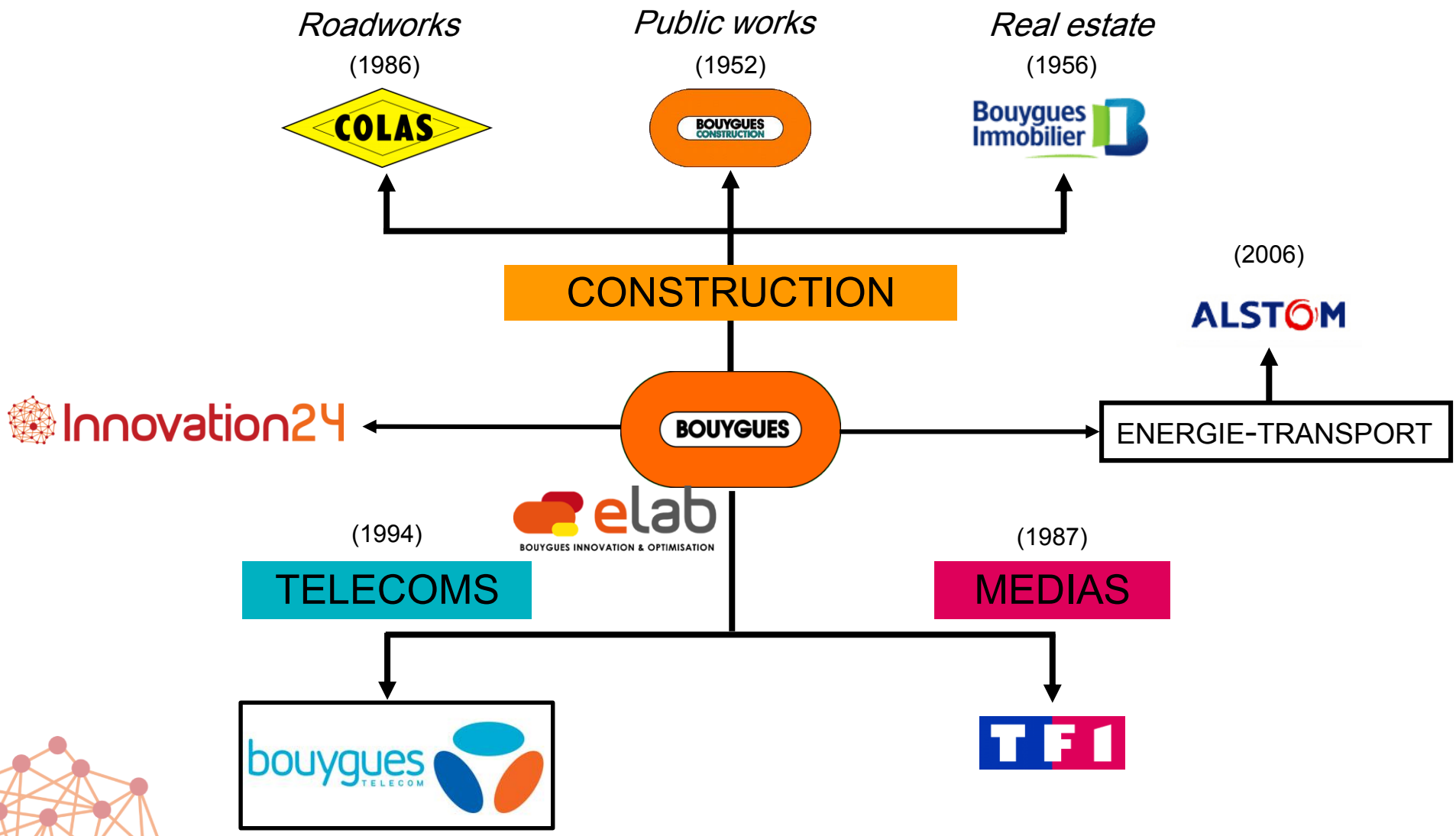


LocalSolver

www.localsolver.com

- Consulting
- Software solutions
- LocalSolver

Bouygues Group



Internet Service Providers in France

Main internet service providers

- Orange
- SFR
- Free
- Bouygues Telecom

Most of the customers are connected using ADSL

Average prices: 30 - 40 € / month

Bouygues Telecom strategy

- New offer 20€ / month (Feb. 2014)
- Unbundle 1,500 local loops (June 2014)

Local loop unbundling

Hub: Main Distribution Frame

Main Distribution Frame (Hub)

bouygues TELECOM

Subscriber hubs

Two options for an operator

- Install its own hardware
- Rent another operator hardware (Orange, SFR, Axione)

Operator	Unbundled subscriber hubs (06/2014)
SFR	6,714 (84.7%)
free	6,276 (83.1%)
Bouygues Telecom	4,938 (77.1%) (750 with their own hardware)
completel	4,908 (76.8 %)

Source: ariase.com & stats-degroupage.fr

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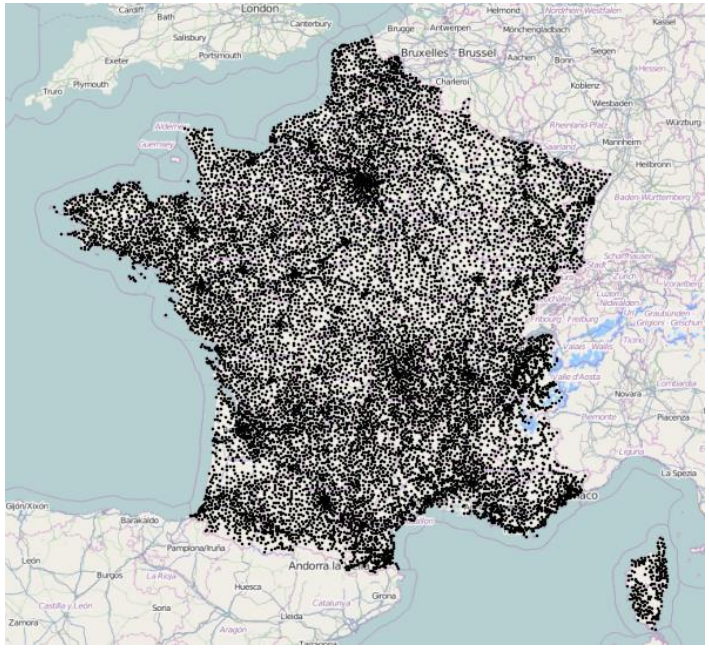
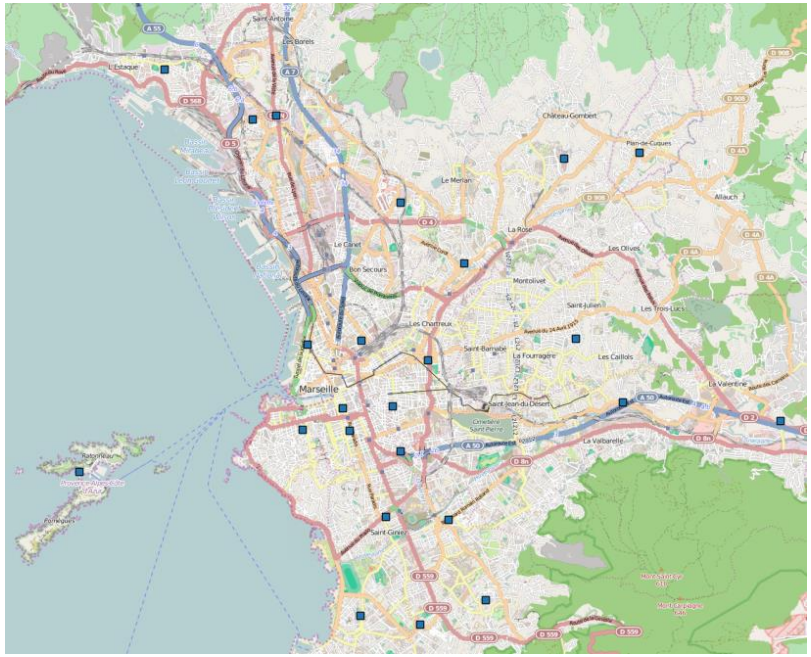
Subscriber hubs in France

Around 14,000 subscriber hubs in France





Question: how can we extend Bouygues Telecom network ?

Costs model

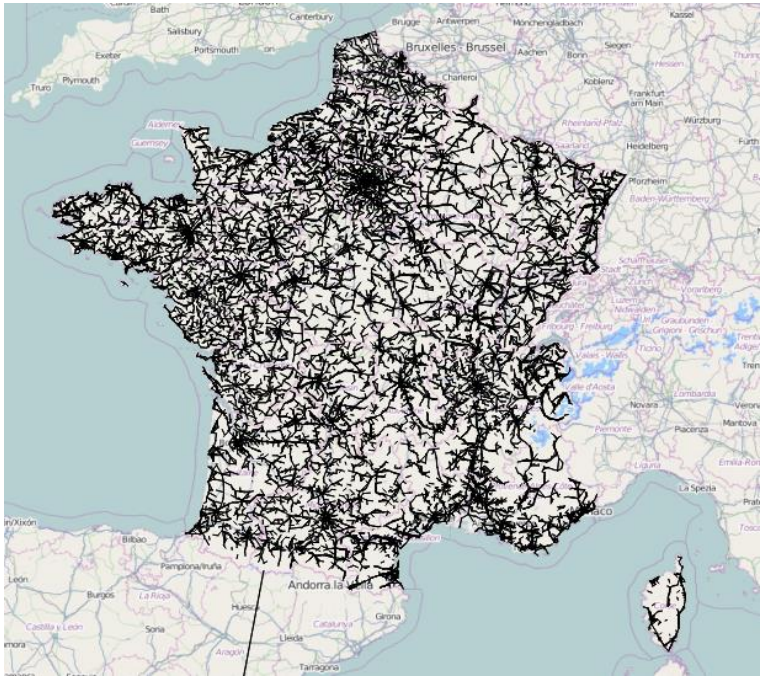
Economic hypothesis

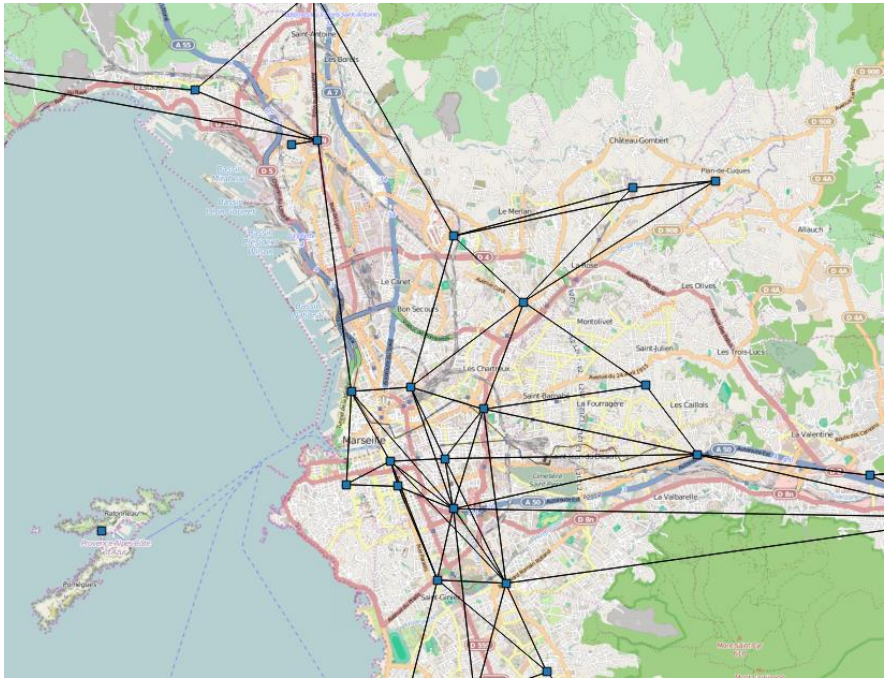
- Gain from each customer (periodic)
- Number of customers per hubs
- Two options
  - Rent a hub to another operator (periodic)
  - Install Bouygues Telecom's own hardware: unbundle (fix + periodic)

Question: how can we connect an unbundled hub to Bouygues Telecom network ?

LFO Offer from Orange

Orange rents a network of optical fibers between hubs (32,000 links*)





Costs model

Economic hypothesis

- Gain for each subscriber
- Numbers of customers per hubs
- Renting cost of a hub
- Unbundling cost
- Renting cost of LFO links

Constraints

- All unbundled hubs must be connected to a Bouygues Telecom Point of Presence (POP)

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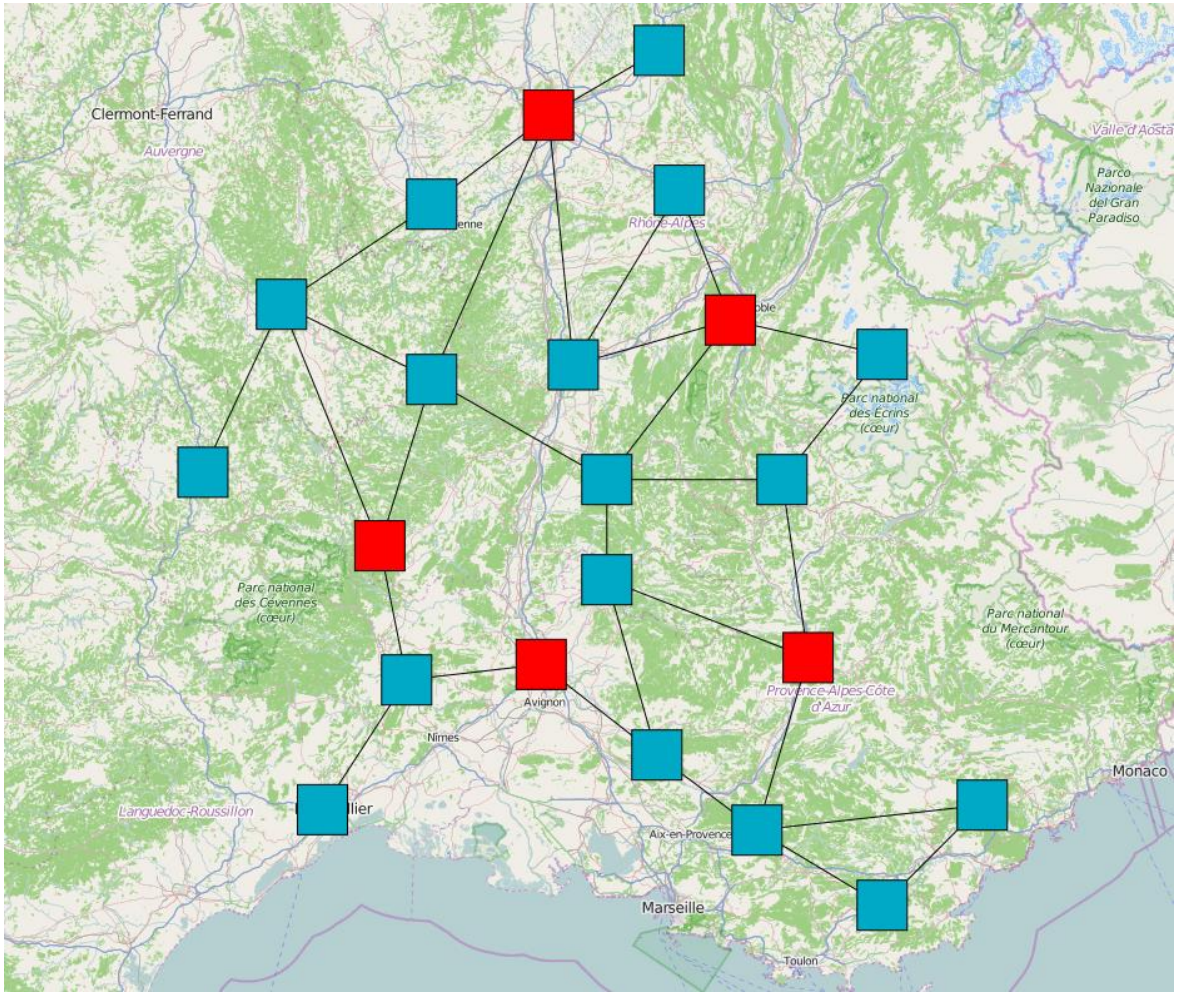
Toward a graph problem



Prize collecting Steiner Forest

Input: Graph $G = (V, E, c, p)$

- V : Nodes
- E : Edges
- $p(v)$: Profit per selected node v
- $c(e)$: Cost per edge e

Output: a forest $F = (V', E')$ maximizing $p(V') - c(E')$

- V' : selected nodes
- E' : selected edges to ensure connectivity

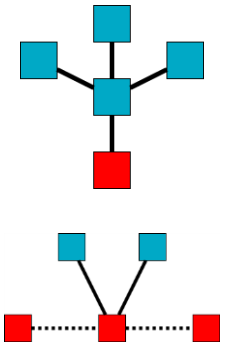
NP-Hard ☹

Instance: 15,000 nodes & 180,000 edges

Additional constraints

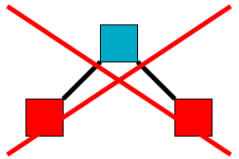
Node degrees

- 4 links can leave a hub
- 2 links can leave a POP



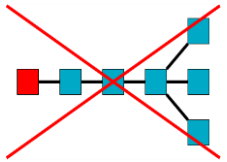
No cycle

- A cycle can occur between two POP



No subtrees with to much subscribers

- To minimize the impact of a line default



Number of hubs to unbundle is fixed

- In practice, around 1,500 hubs should be unbundled

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Problem resolution

Manual processing at Bouygues Telecom

- Up to 400 hubs
- Several weeks of work
- Creation of a benchmark

Client needs

- Solve the global problem (15,000 Hubs, 1,500 to select)
- Reasonable response time (few minutes)
- Dynamic specifications

Heuristic

- Based on our solver: LocalSolver
- Main difficulty: To ensure the connectivity of the solution

LocalSolver

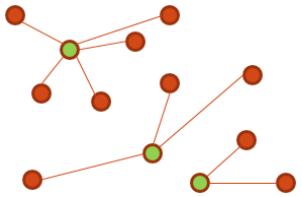
Model & run

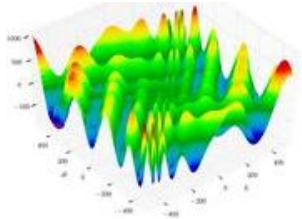
Combinatorial optimization,
continuous & mixed variable

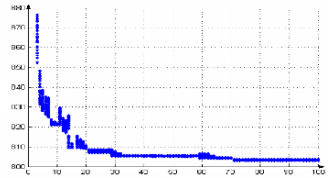
Large scale problem,
non convex optimization

Good solutions in short
running time

LocalSolver 5.5
=
LS + CP/SAT + LP/MIP + NLP







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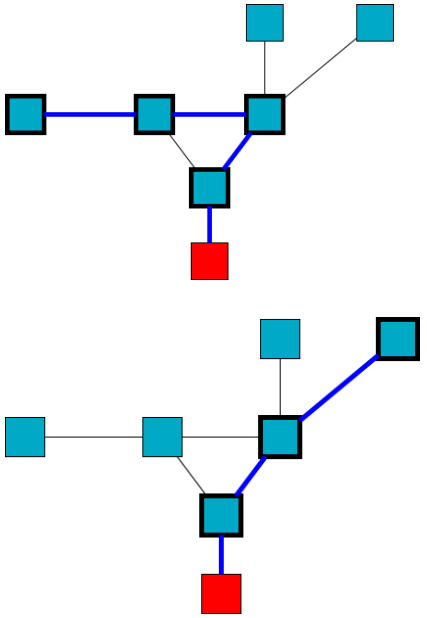
Path formulation



Path generation

- Start from the POP
- Exhaustive enumeration of « short » paths
- Greedy enumeration of « profitable » paths
- Avoid loops

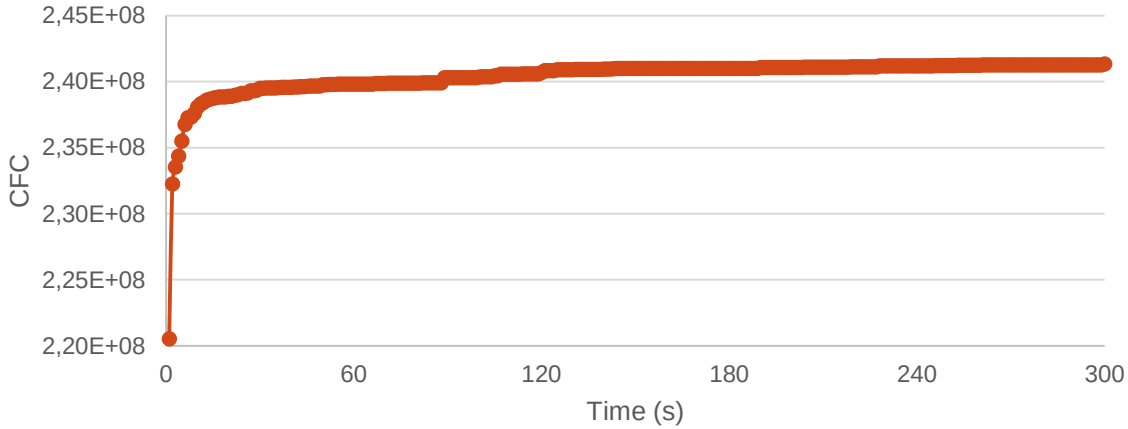
LocalSolver model

- $z_P = 1$, if path P is selected (decision)
- $x_v = 1$, if a path P containing v is selected (expression)
- $y_e = 1$, if a path P containing edge e is selected (expression)
- All the previous constraints can be expressed with z, x, y (400 000 decisions and 1 400 000 expressions)

Results

Fast convergence

- Hubs that are selected after 600s are already selected in less than 60s
- Improve the edge costs



GAP < 10% (computed with a MIP Solver)

- Oriented node / edge model x_v et y_e
- No subtour elimination constraints
- Poor relaxation

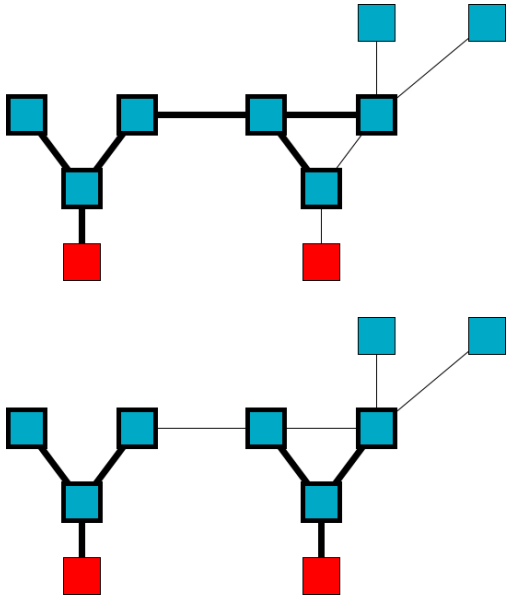
Find the optimal solution ?

Practical difficulties

- Economic hypothesis
- Orange can refuse part of the solution

Ill posed problem

- Forecast future needs
- Increase robustness with security loops



Tool to help the network team

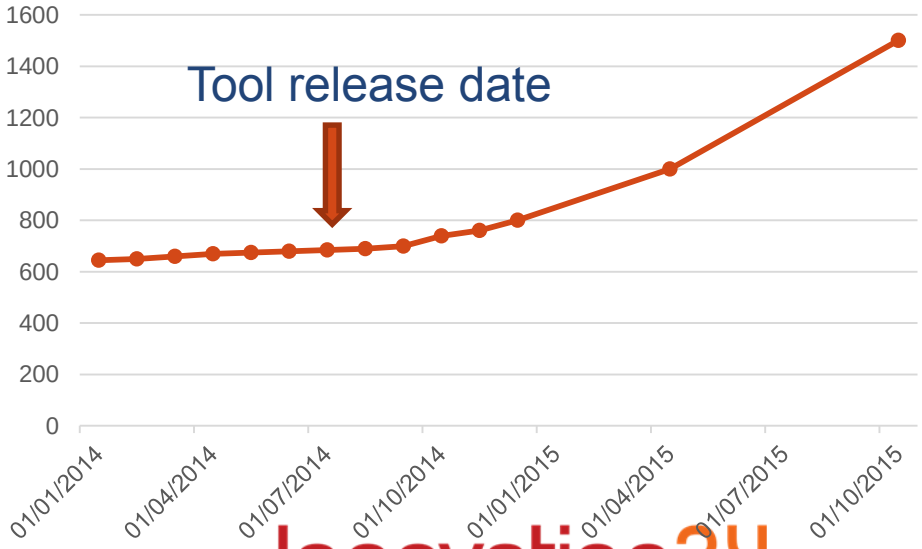
Conclusion

Scientific interest

- Large problem 14,000 nodes & 180,000 edges => 1.4M expressions
- Good solutions in 1 minute and stability in 10 minutes

Practical interest

- Bouygues Telecom +100,000 new subscriber / quarter on the last 4 quarters
- 1500 unbundled hubs in October 2015 (bbox-actus.com)



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