Institut français
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des transports, de l'aménagement
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Modélisation et gestion du trafic ferroviaire : résultats du projet SIGIFret

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IFSTTAR

Context

Railway infrastructure has a **limited physical capacity**

This capacity is often **insufficient** to smoothly accommodate traffic when unexpected events perturb operations

An **unexpected event** causing the delay of one train of one minute may imply the emergence of conflicts, mainly at junctions

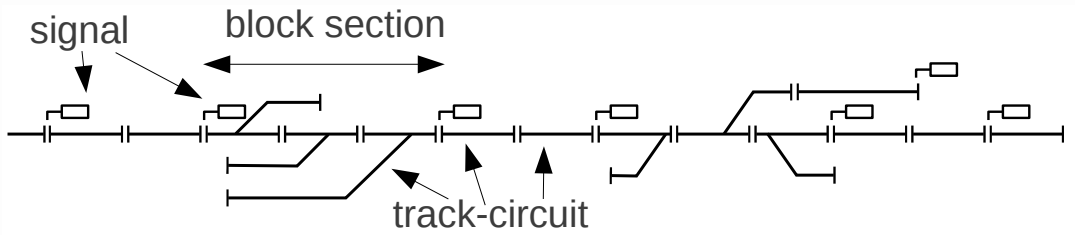
conflict : multiple trains requesting the same portion of track concurrently

junction : location where multiple lines cross

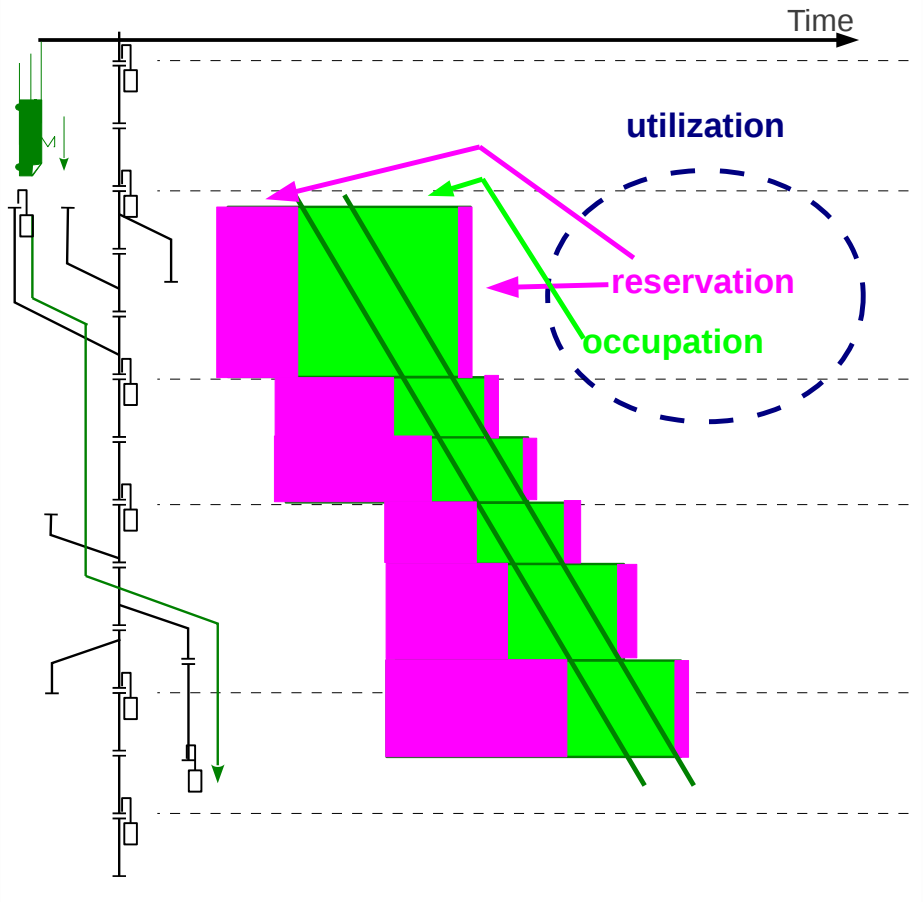
Context

conflict : multiple trains requesting the same portion of track concurrently

junction : location where multiple lines cross



Context



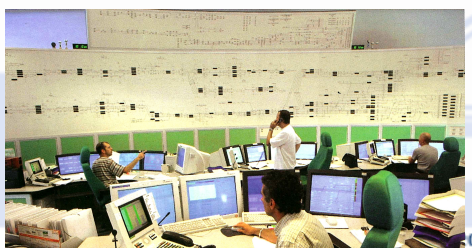
The problem

Routing and scheduling problem

What is the train routing and scheduling which minimizes delay propagation ?

We propose **RECIFE-MILP** :

- an algorithm based on the solution of a **mixed-integer linear programming** model
- able to find the **optimal solution** to this problem



The SIGIFret project

- Evaluation of a tool for **managing traffic** crossing a junctions
  Quantification in ***simulation*** of the potential impact of such a tool
- Design of a model for capacity analysis through the solution of the **saturation problem**

- Partners
- Labeling
- Bailleur

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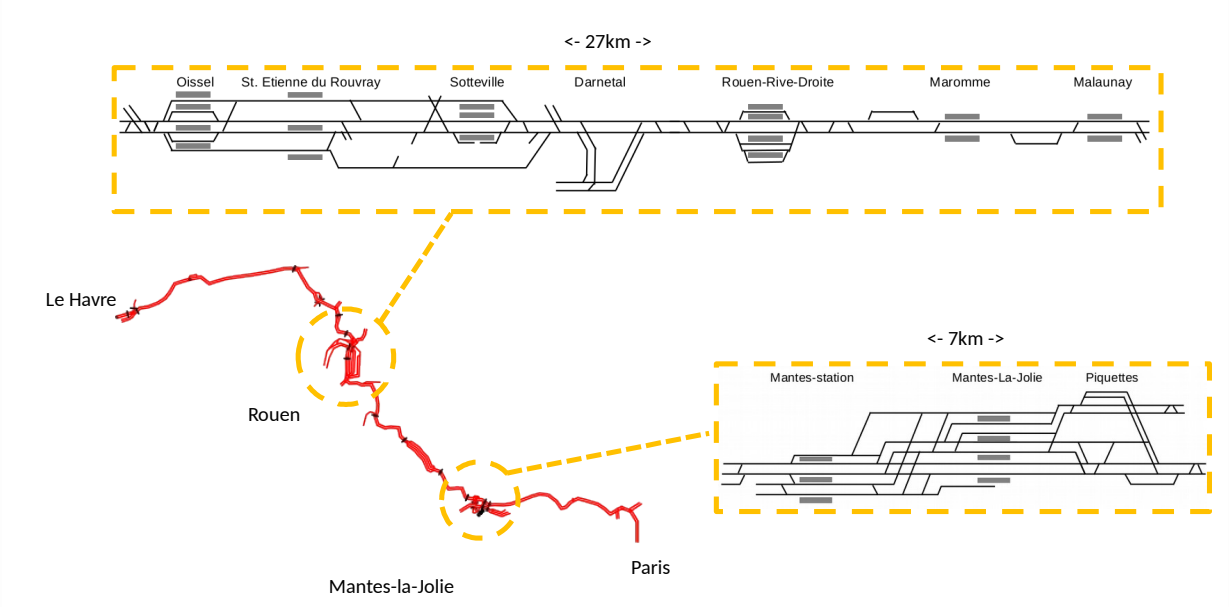
Case studies

Two control areas on the line Paris-Le Havre are considered :

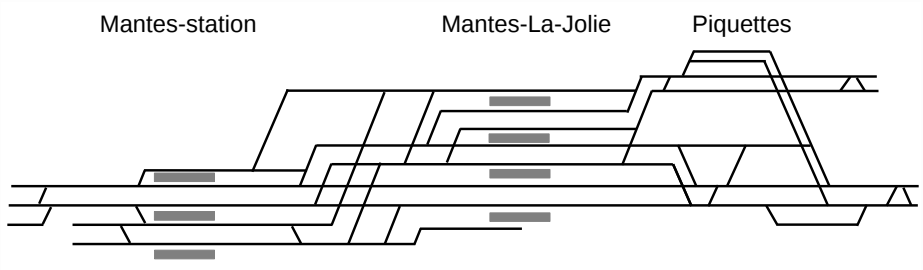
- Rouen
- Mantes-la-Jolie

This line is characterized by an intense mix traffic



Mantes-La-Jolie

- 7-km line around the Mantes-La-Jolie station
- with :
  - * 2 stations
  - * 117 track-circuits
  - * 226 block sections
  - * 282 routes

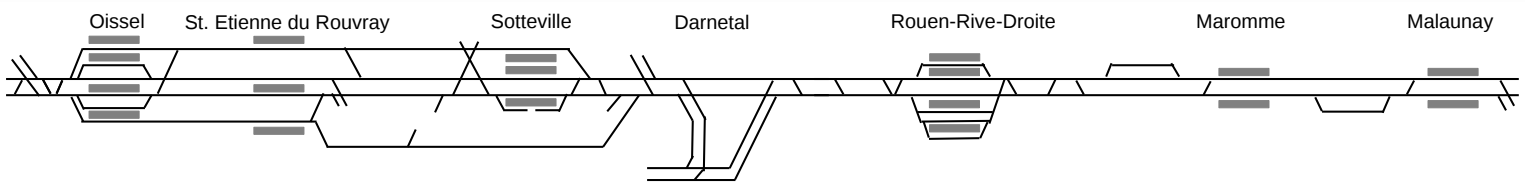


Perturbed scenarios :

- 31 perturbations of traffic at peak time (46 trains)
- 25 perturbations with dense traffic including freight trains (38 trains)
- 4 perturbations with an unscheduled freight train arriving within dense traffic (27 trains)

Rouen-Rive-Droite

- 27-km line around the Rouen-Rive-Droite station
- with : * 6 stations * 563 block sections * 188 track-circuits * 6529 routes



Perturbed scenarios :

- 14 perturbations of traffic at peak time (41 trains)

Types of perturbation

- Entrance **delay** in the infrastructure
- Additional **dwell time** at stations
- Temporary **speed limit**
- **Neglect of instructions** on the entrance time in the infrastructure by some trains
- **Absence of equipment** for speed recommendation on some trains
- **Unexpected performance** of some trains
- Unavailability of a part of the infrastructure due to **maintenance works**

RECIFE-MILP : The MILP formulation

Variables

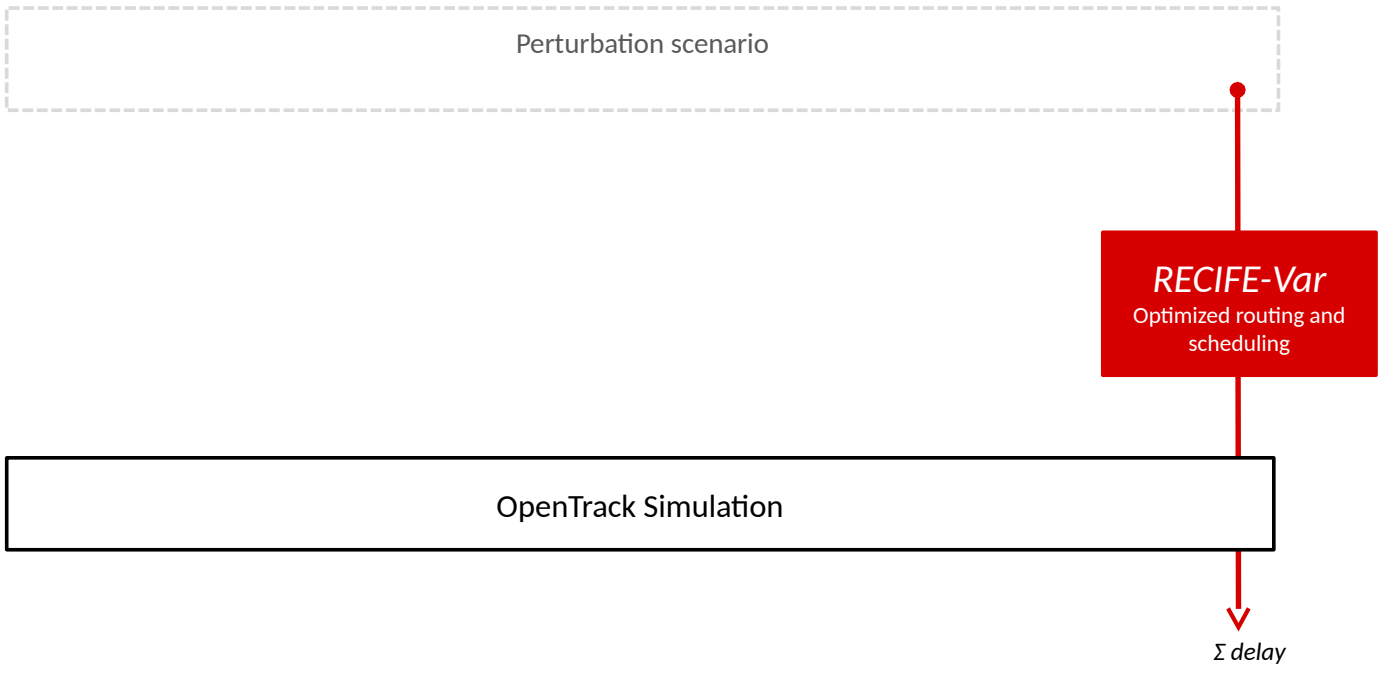
Continuous variables

- ***start time of detection*** of a train on a track-circuit along a route
- ***delay*** suffered by a train on a track-circuit along a route
- ***start time of utilization*** of a track-circuit by a train
- ***end time of utilization*** of a track-circuit by a train

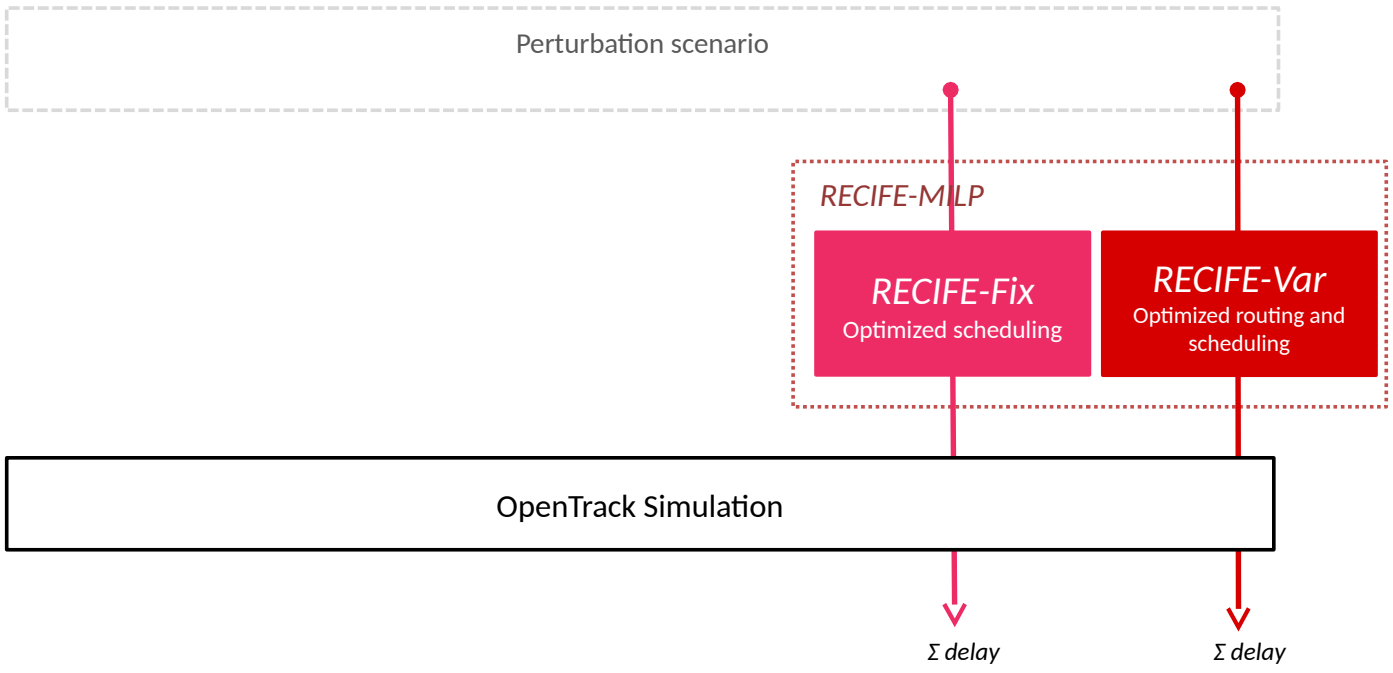
Binary variables

- ***use*** of a route by a train
- ***precedence*** on track-circuit utilization for pairs of trains

Traffic management strategies



Traffic management strategies



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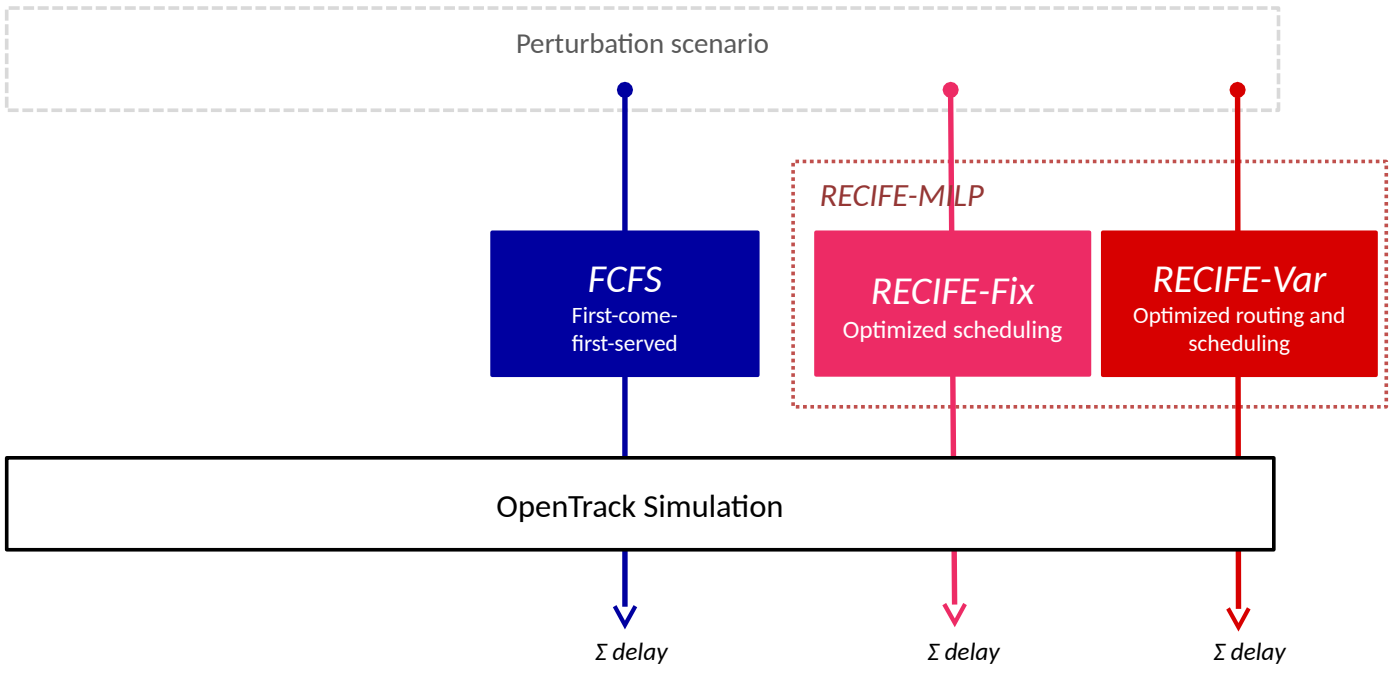

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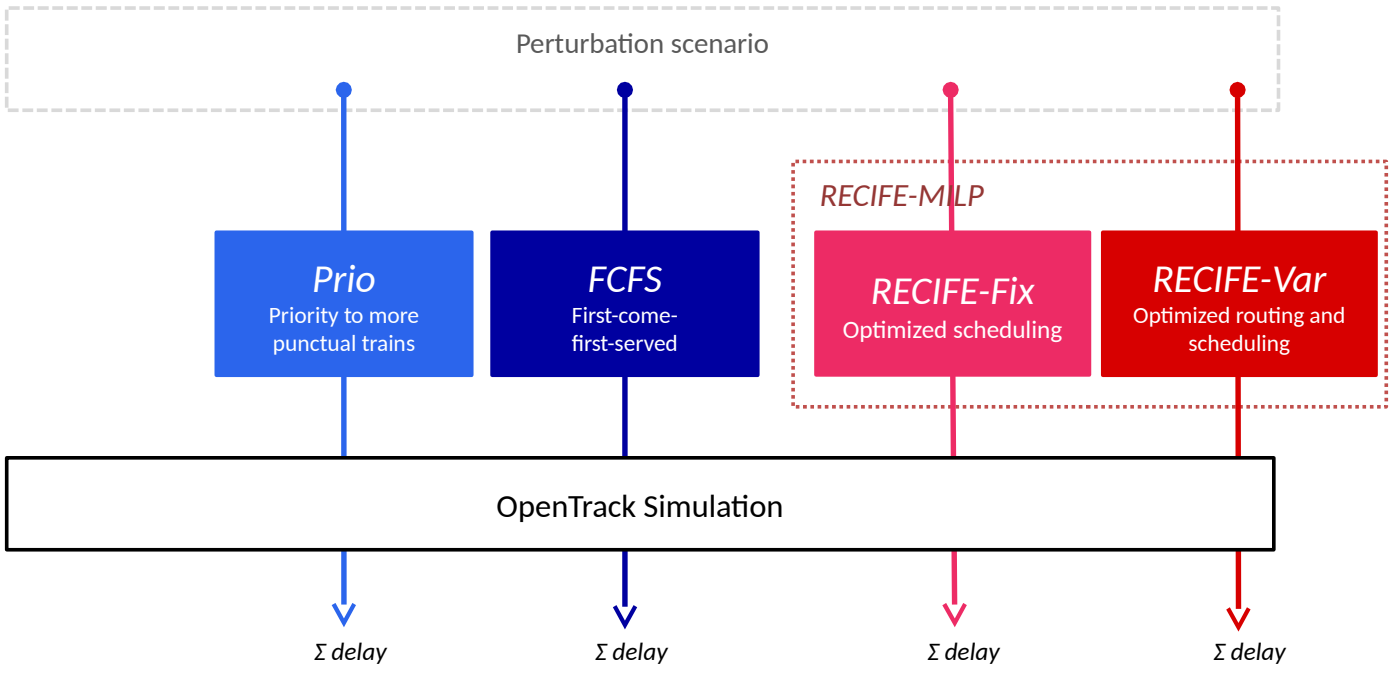

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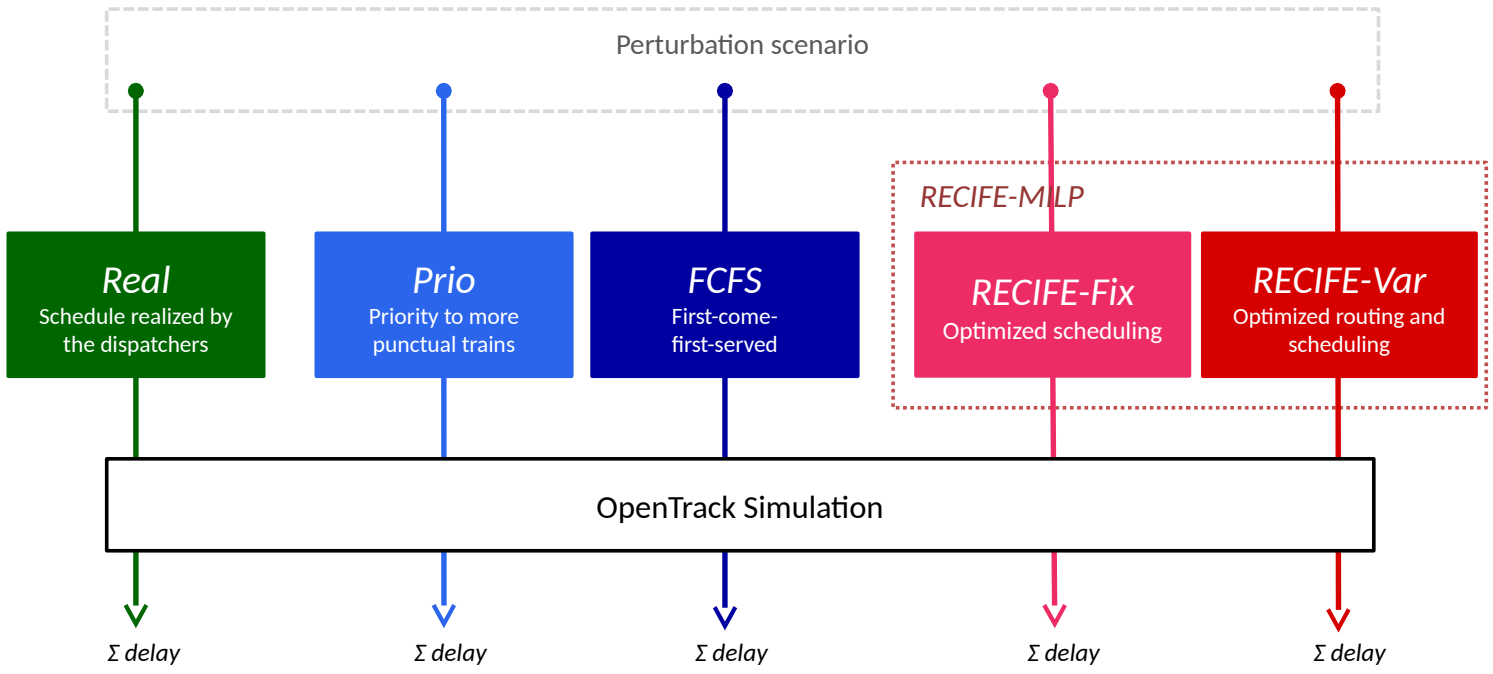


Computational details

We set a **maximum computational** time of 5 minutes for each optimization

If RECIFE-MILP proves the **optimality** of a solution earlier, the computation stops

The mean computational time [1] has been :

- Mantes-la-Jolie :
  - RECIFE-Fix : 1 second
    (3K real and 4K binary variables, 17K constraints)
  - RECIFE-Var : 11 seconds
    (16K real and 9K binary variables, 72K constraints)
- Rouen-Rive-Droite :
  - RECIFE-Fix : 21 second
    (6K real and 6K binary variables, 28K constraints)
  - RECIFE-Var : 273 seconds
    (900K real and 22K binary variables, 3187K constraints)

1. On an Intel Xeon 2.67GHz, 12 cores, 24 GB RAM

Results : Mantes-La-Jolie

mean % impr. in total secondary delay

- 31 scenarios : traffic at peak time

	RECIFE-Fix	RECIFE-Var
Prio	73%	94%
FCFS	26%	82%

- 25 scenarios : dense traffic including freight trains

	RECIFE-Fix	RECIFE-Var
Prio	70%	93%
FCFS	8%	80%

- 4 scenarios : freight train within dense traffic

	RECIFE-Fix	RECIFE-Var
Prio	79%	95%
FCFS	17%	80%

Results : Rouen-Rive-Droite

mean % impr. in total secondary delay

- 14 scenarios : traffic at peak time

	RECIFE-Fix	RECIFE-Var
Prio	67%	69%
FCFS	46%	60%

Results : Rouen-Rive-Droite

mean % impr. in total secondary delay

- 14 scenarios : traffic at peak time

	RECIFE-Fix	RECIFE-Var
Prio	67%	69%
FCFS	46%	60%

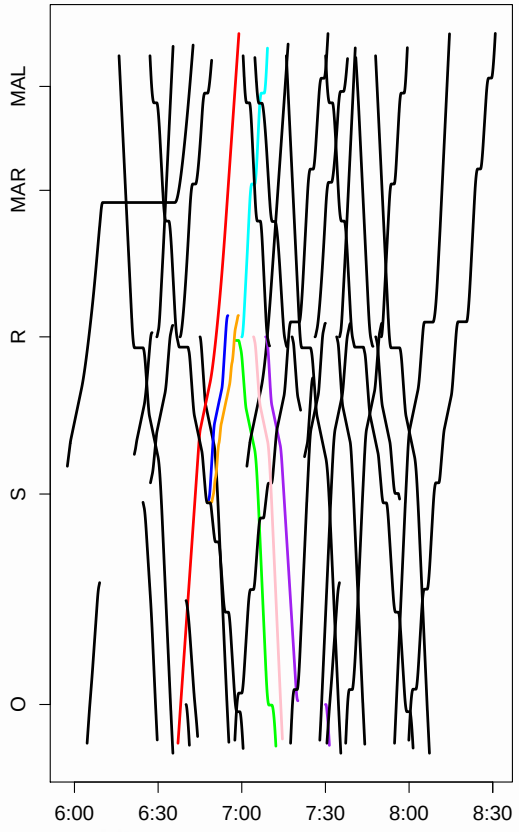
total secondary delay (sec)

- 3 scenarios : perturbations actually occurred and managed by dispatchers

Real	Prio	FCFS	RECIFE-Fix	RECIFE-Var
325	317	317	220	**207**
1328	887	86	66	**0**
664	1021	**480**	**480**	**480**

A real scenario at Rouen-Rive-Droite

Freight train : 6 minutes late at entrance



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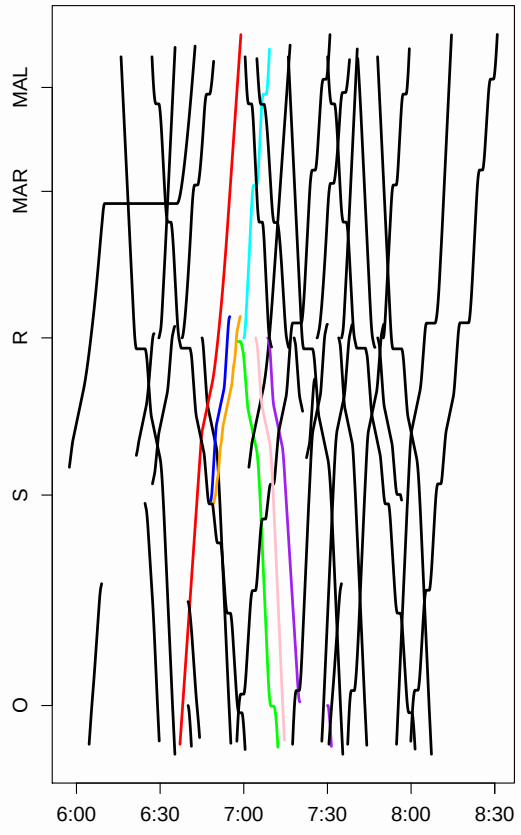

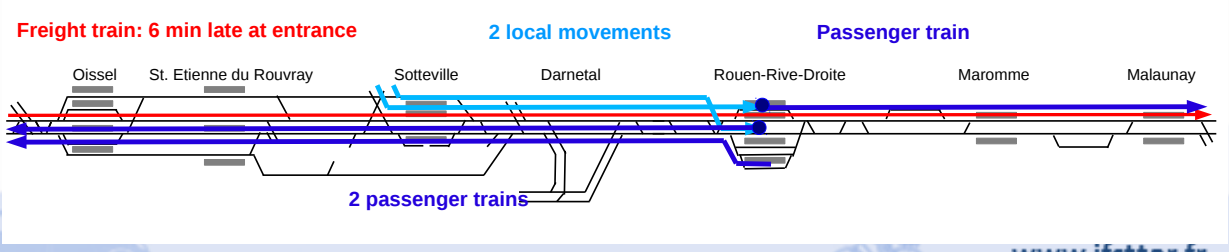

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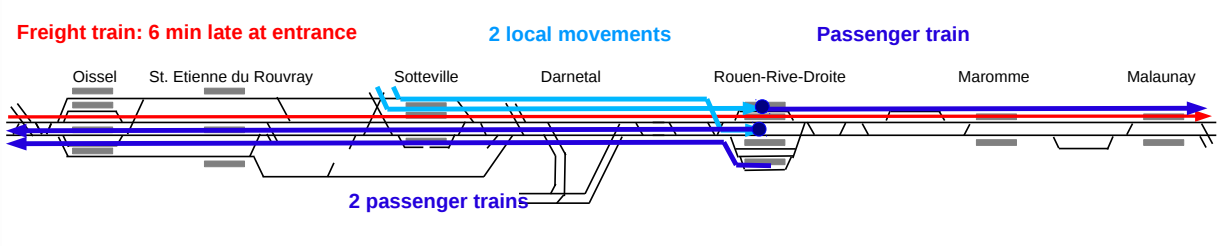
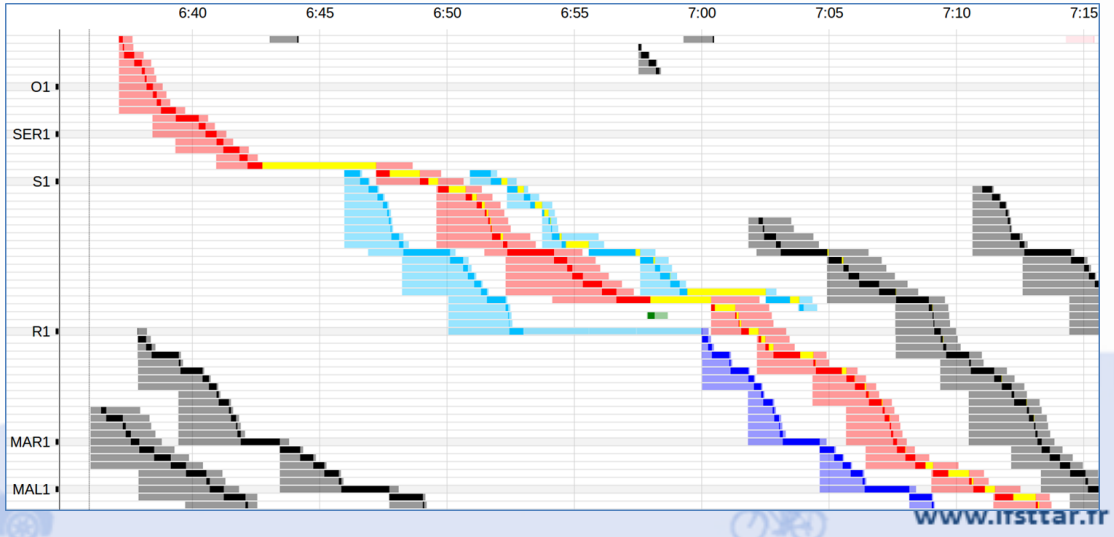


Real : total secondary delay 21'55

Freight train **between** the two local movements $\Rightarrow$

* additional freight train delay 14'45
* descending local moment delay : 2 passenger trains delay 6'20 et '50



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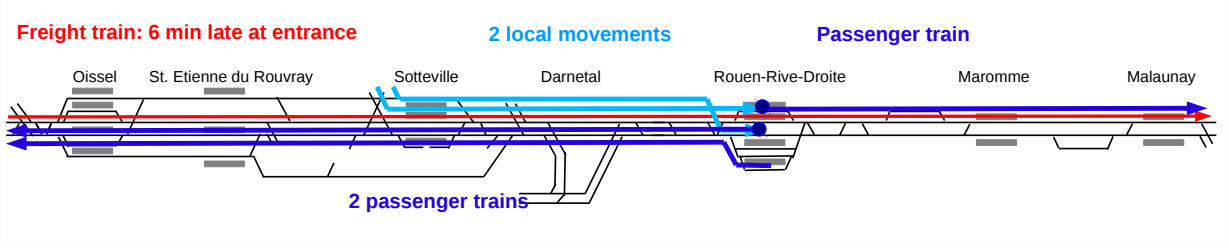
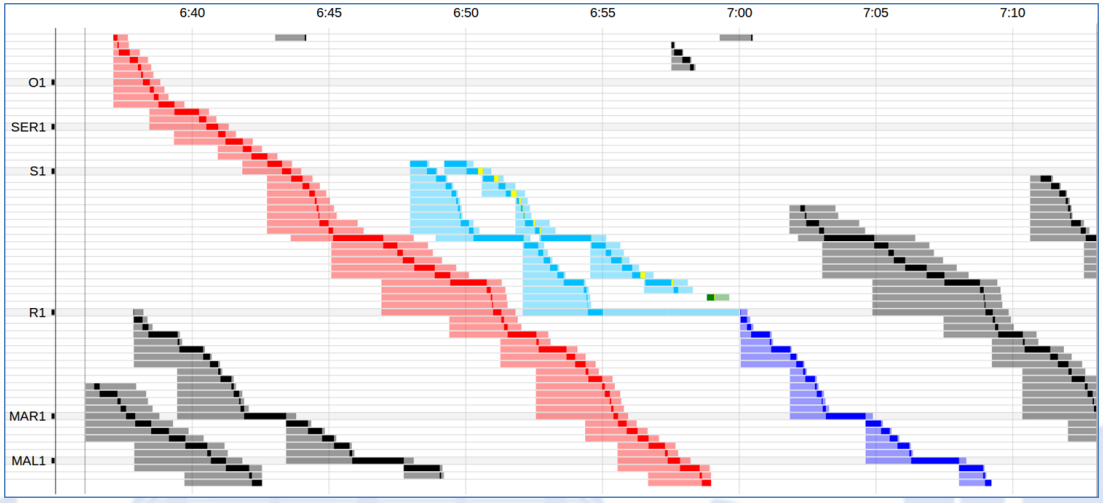


RECIFE-Fix : total secondary delay '66

Freight train **first** $\Rightarrow$ * descending local moment delay : passenger train delay '66



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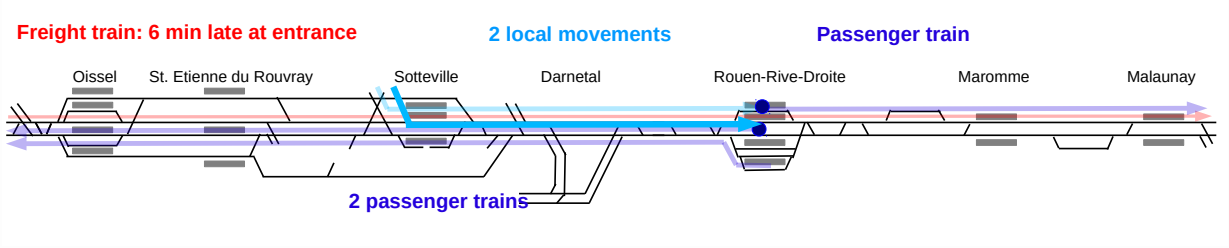
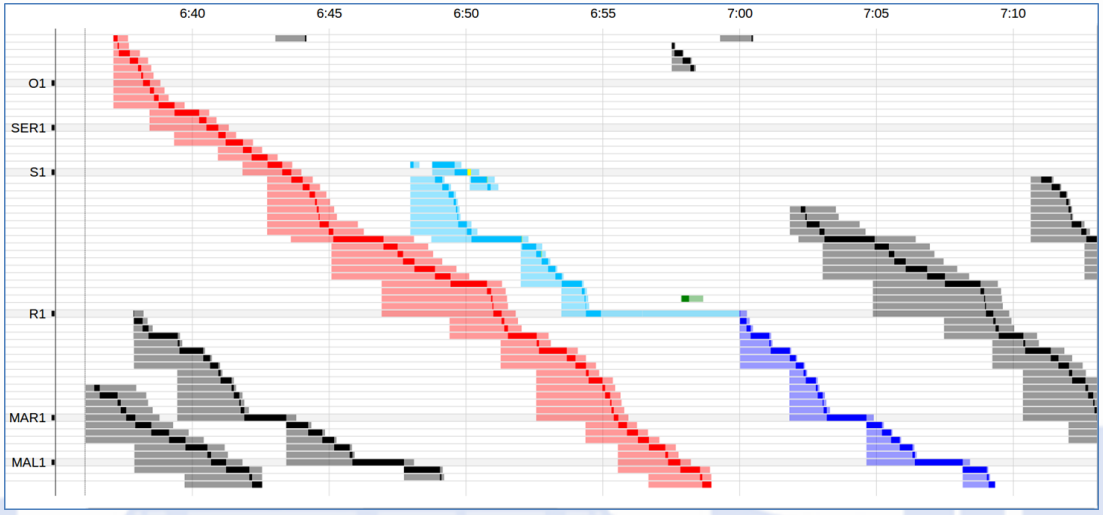


RECIFE-Var : no secondary delay

Freight train **first** & reroute of descending local moment $\Rightarrow$ no impact of the freight train primary delay



Conclusion

We have assessed the potential impact of **optimized railway traffic management** on the propagation of delay

Thanks to **microscopic simulation**, we have showed that optimization might strongly improve the current practice

Dispatchers from SNCF **supported our conclusion** after analyzing the simulation results