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Road Side Units location optimization for traffic control application: an Integer Linear Program approach

Eleonore Fauchet, Matthieu Guillot, Pierre-Antoine Laharotte, Maxime Guériaux, Nour-Eddin El Faouzi

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Introduction

CONTEXT

The development of Cooperative-Intelligent Transport Systems (C-ITS) requires the costly installation and maintenance of telecommunication infrastructures such as Road Side Units (RSUs). RSUs might be used as a road sensor when it collects messages emitted by Connected Vehicles (CVs), or as a traffic controller when messages are broadcast to end-users.

POSITIONNING

Accordingly, the problem of locating RSUs in the network is part of the Traffic Sensor Location Problem (TSLP) already widely explored in the literature. However, in this study, we explore the controller dimension of RSUs by locating them to ensure the efficient application of traffic control strategies.

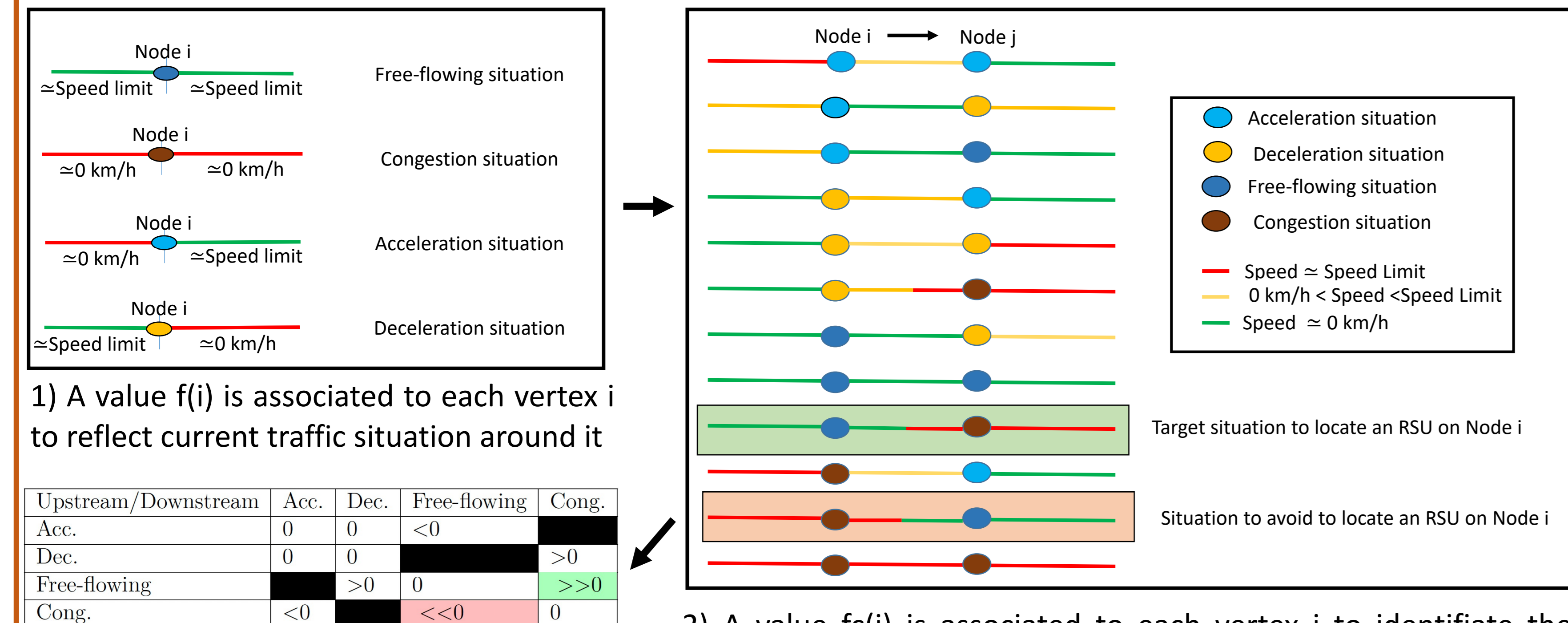
OBJECTIVE

Based on an Integer Linear Program (ILP), we propose a formulation to locate the RSUs in areas that transition from smooth traffic to congested ones. Then, RSUs should be able to react to congestion by sending instructions to CVs. To validate our approach and achieve a Proof of Concept (PoC), we test it on the M50 network of Dublin with a straightforward test case and a simplified Variable Speed Limit (VSL) strategy.

Methodology

Step 1: Problem definition

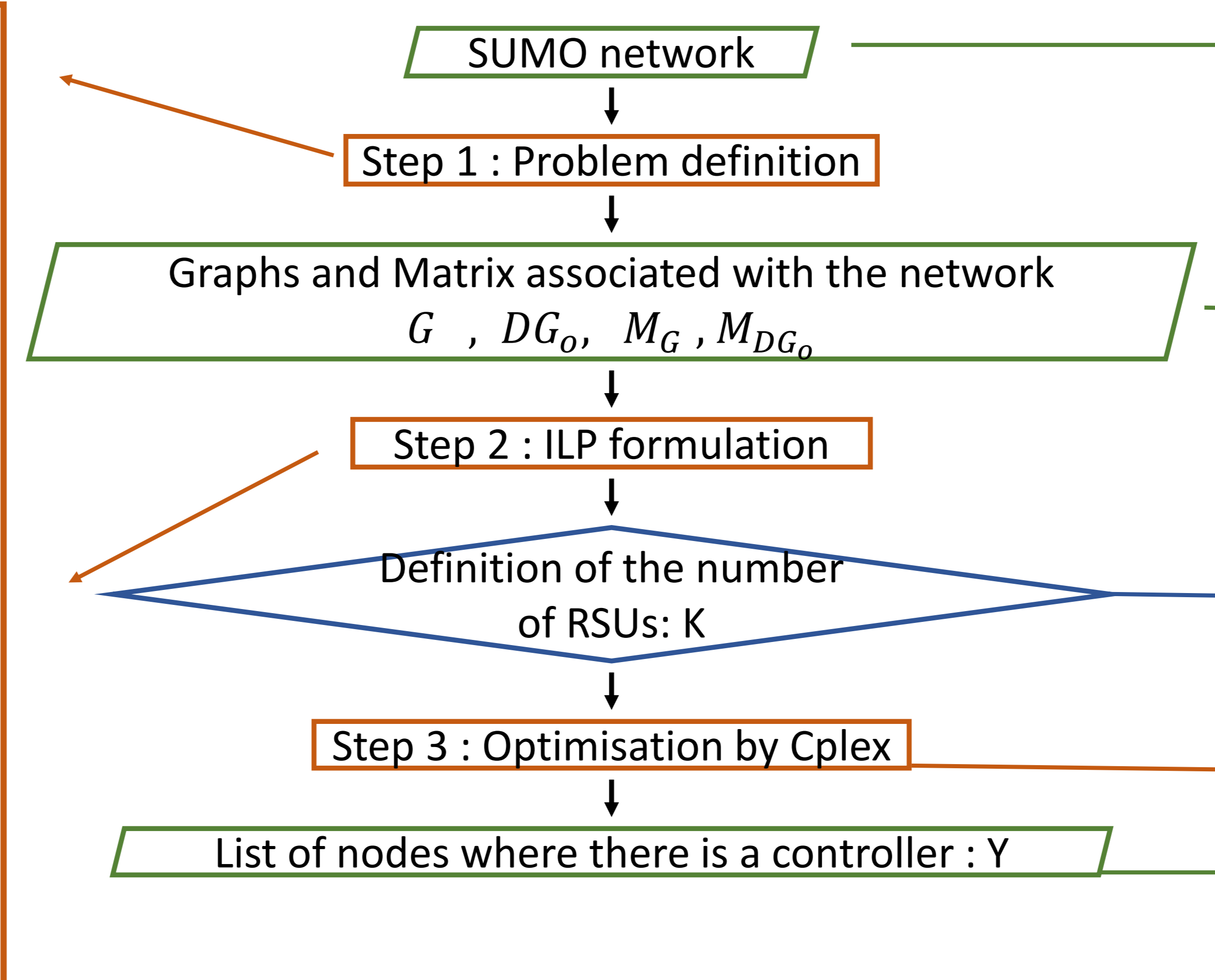
The aim is to identify the targeted situation i.e. a node in a free flowing situation upstream a congestion one



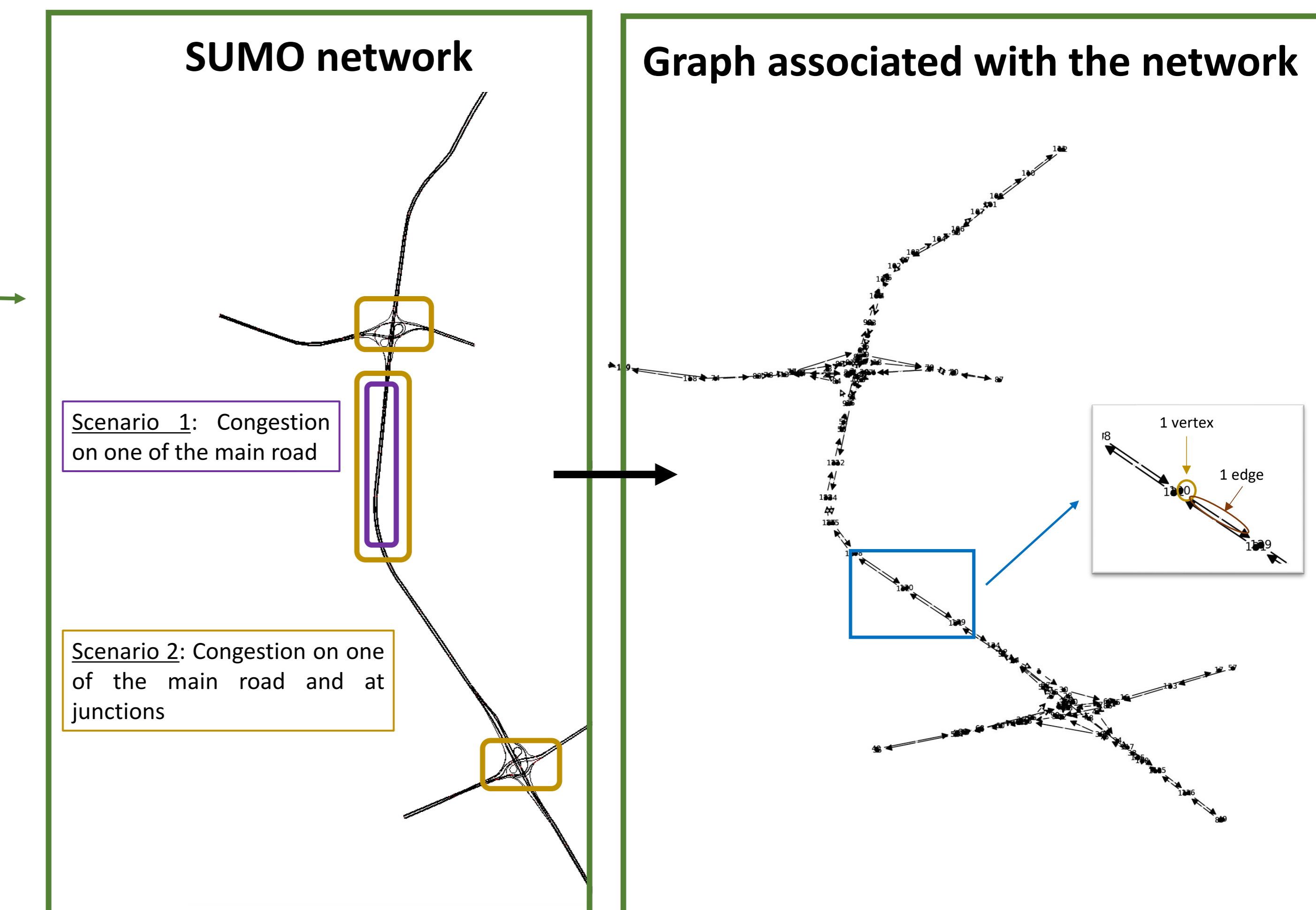
1) A value $f(i)$ is associated to each vertex i to reflect current traffic situation around it

2) A value $fc(i)$ is associated to each vertex i to identify the targeted situation (for each vertex i $fc(i) = f(i) - f(j)$)

3) The metric is built



Network under consideration



Step 2: ILP formulation

$$\max \sum_{i \in N} (fc(i) * Y(i))$$

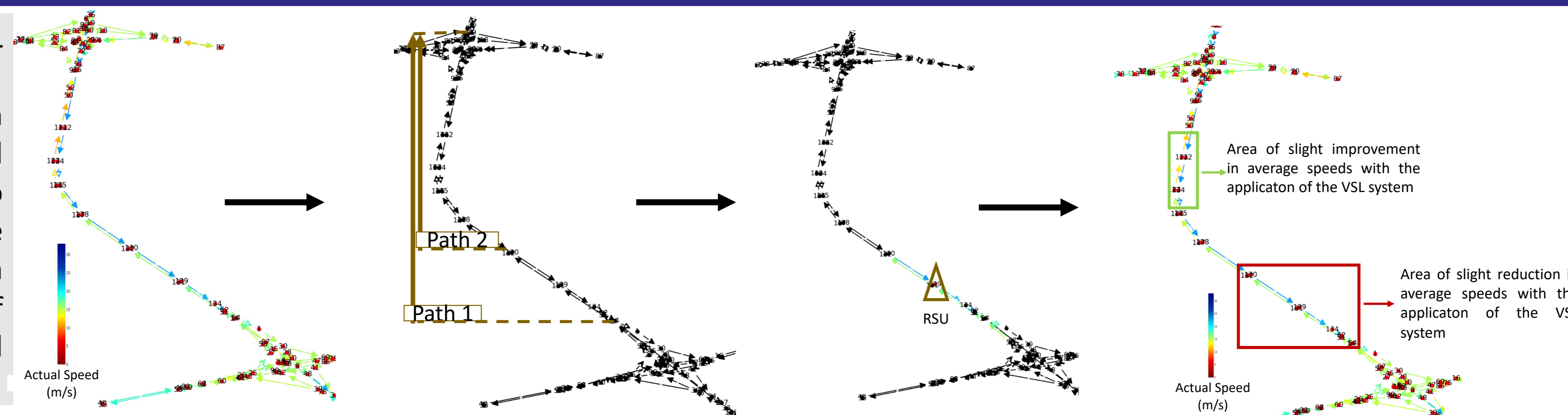
$$\text{s.t.} \sum_{i \in N} Y(i) \leq K$$

$$Y(i) \in \{0, 1\} \quad \forall i \in N$$

- ✧ K is the number of RSUs available to be located on the network
- ✧ The output of the optimization is a vector Y of length equal to the number of nodes on the network. If there is a RSU on the node i , $Y(i) = 1$

- ✧ A simplified VSL system is built
- ✧ It consists in applying a speed limit (= 15 m/s) to CVs entering the controlled area from 50s after the start of the simulation and for 7.5min

Results and Variable Speed Limit (VSL) system application with one RSU



1) Zoomed-in speed profile of the reference situation (without control)

2) Spatial extent of the congested area (Path 1) and area the VSL manager wants to control (Path 2)

3) Location of the optimized RSU and sections which can be controlled by it (coloured sections)

4) Zoomed-in speed profile of the controlled situation (with VSL system)

	No control	VSL system activation
Average Travel Time for Path 1 (s)	667	642
Number of vehicles completing Path 1	621	749
Average Travel Time for Path 2 (s)	521	489
Number of vehicles completing Path 2	4287	4724
Number of controlled (limited) vehicles	0	12

- ✧ K=1 and RSU's coverage distance = 500m
- ✧ The controlled area is on the RSU's coverage area, thus the VSL system is activated.
- ✧ There is an improvement in average travel time thanks to the VSL system compared to the no-control situation.

Conclusion

- ✧ A Proof-of-Concept to locate optimally RSUs along a motorway road network has been developed and validated.
- ✧ Results highlight that RSUs, considered as traffic controllers, are located on nodes in smooth conditions areas upstream of congested ones.
- ✧ In future work, we will refine the objective function by (i) combining the two roles of a RSU: sensor and controller, and by (ii) considering the problem of the rigid positioning of units at the same time as the dynamic problem of congestion, which evolves throughout the day.

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