Traffic congestion avoidance through a cross simulation between ns-3 and SUMO

Authors:

Castelletto Riccardo

Masiero Davide

DIPARTIMENTO
DI INGEGNERIA
DELL'INFORMAZIONE

Index

The presentation follow this order:

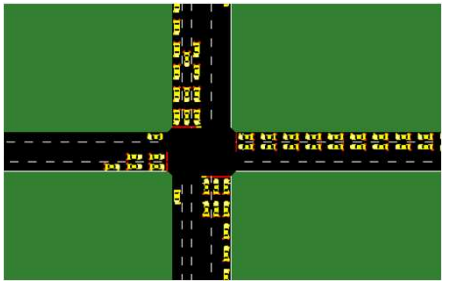
- **Introdaction**
- **Simulators:**
  - Ns-3
  - SUMO
  - Coupling
- **SW Implementation:**
  - Send
  - Receive
  - Statistics computation
- **Decision part:**
  - Rerouting
  - Chenge interval
  - Combination
- **Results**
- **Conclusion**

Introduction [1/2]

DIPARTIMENTO
DI INGEGNERIA
DELL'INFORMAZIONE

The Problem:

Network and Road congestion



Why network congestion?

Now self-driving cars, the need to have good communication between vehicles. Exchange of a lot of information and a lot of nodes in the same place.

Introduction [2/2]

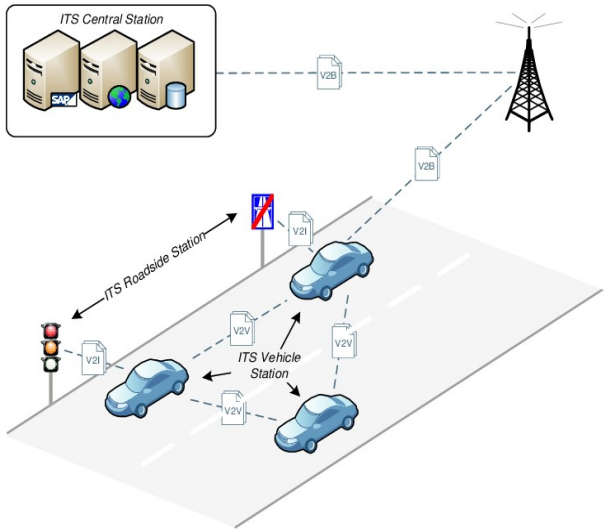
DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

Solution?

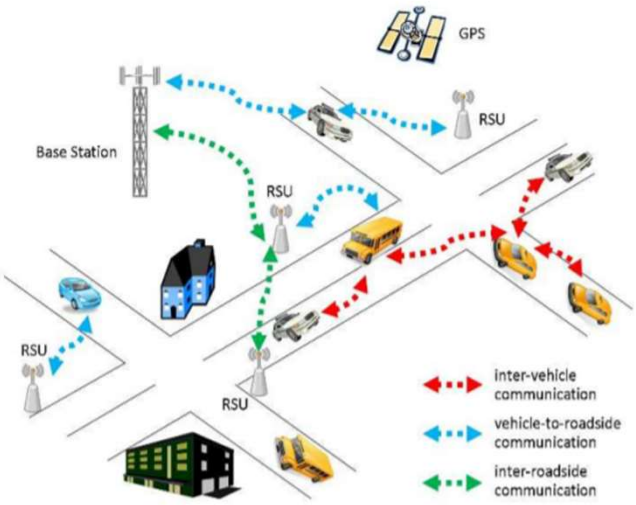
Good management of the channel to maintain good performance

How?

By simulation, because it's too expansive to recreate a complete scenario like that.



VANET Simulator



Simulators

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

How simulate a VANET environmnent?

Using more existing simulators:

- **NS-3**

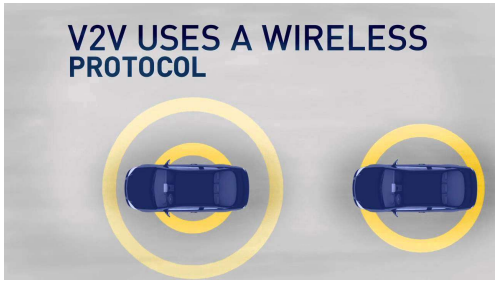
- **SUMO**

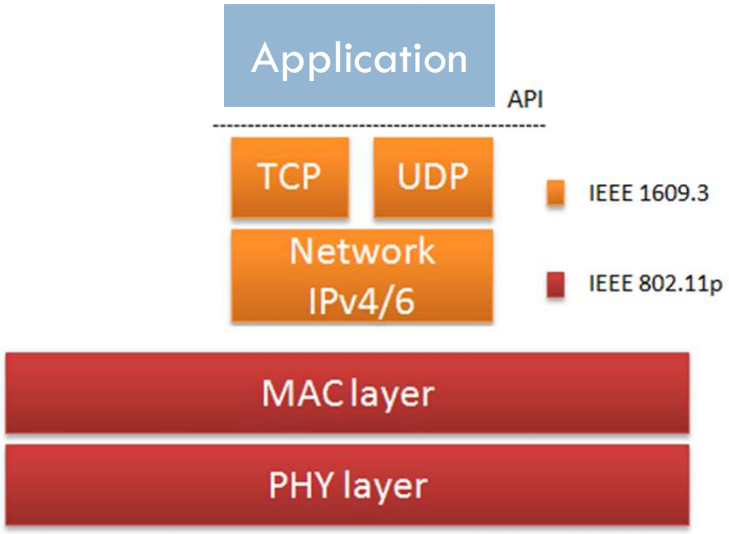
NS-3

NS-3: Network simulator

- Implementation of the communication stack:
  - Log-distance path loss model
  - Nakagami-m fading
  - Random loss for the shadowing

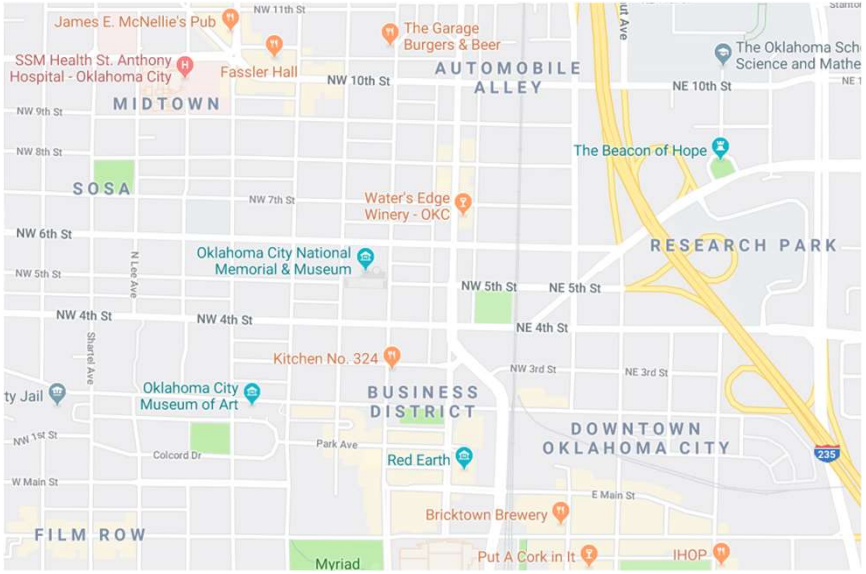
- A UDP application to implement V2V communication

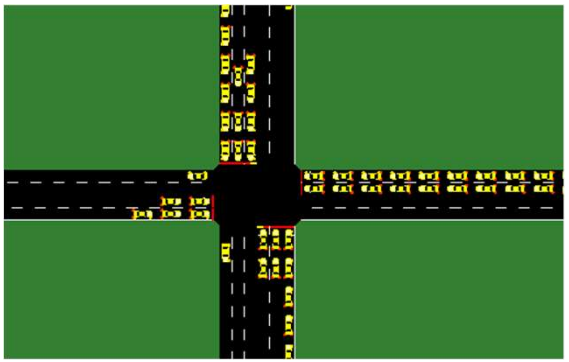




SUMO: Simulation of Urban MObility

- Realistic environment
- Correct mobility pattern





NS3-SUMO-COUPLING

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

Coupling:

TECHNISCHE UNIVERSITÄT DRESDEN

TU Dresden module that implements a TCP client for the communication

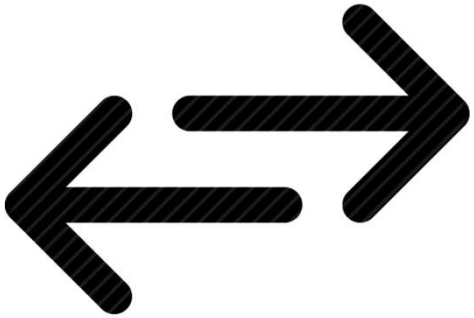
NS-3  **SUMO**

A TCP server that answers to the requests of the client

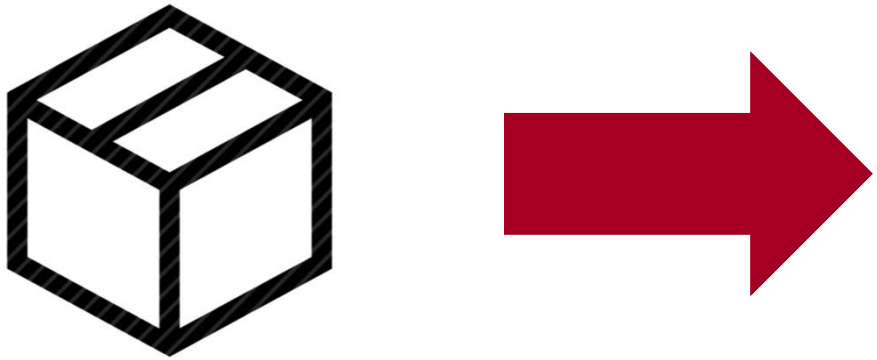
SW Implementation

After the creation of the environment, we start to speak about our UDP application, that can be seen as the conjunction of three main methods:

- Send
- Receive
- Stats computation and decision



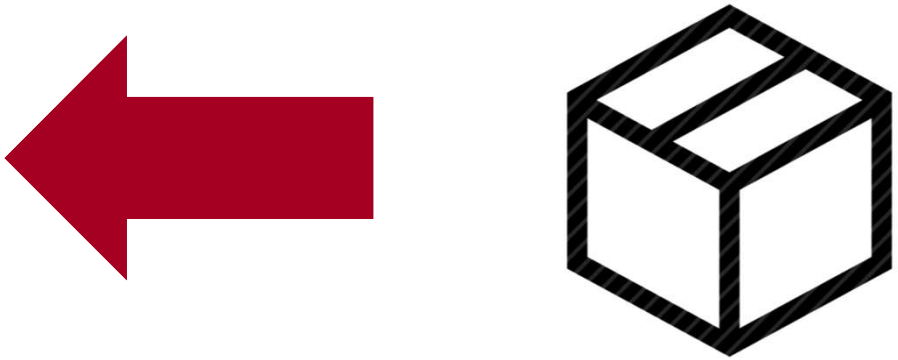
Send



The UDP packet contains the following information:

- ID
- Road ID
- Timestamp
- Number of packets/s
- If is congested or not

Receive



When a UDP packet arrives at a node the process is the following:

- Extraction of the information
- Gather some metrics
- Data organization

Stats calculation

DIPARTIMENTO
DI INGEGNERIA
DELL'INFORMAZIONE

Computation and aggregation of some statistics that will be then used to make a decision:

- Throughput
- Delay
- Packet loss

Decision part

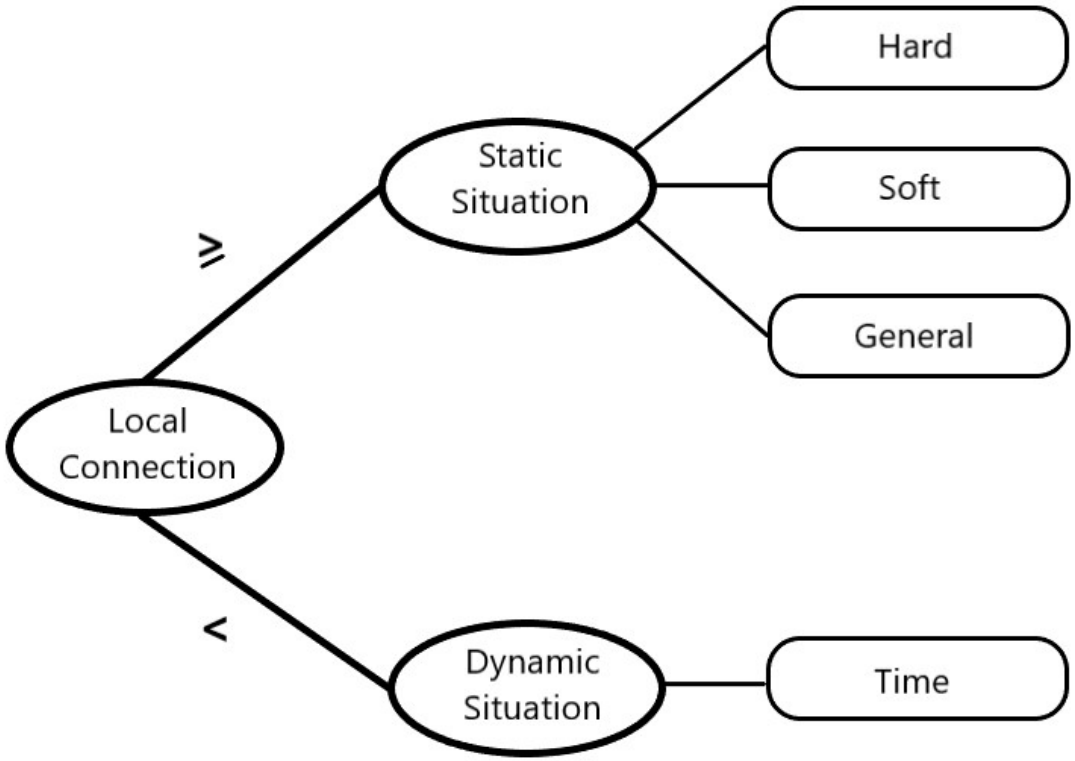
Now that we have all the data, we can make a decision.

The decision process is subdivided in this way:

- Status identification and Rerouting
- Interval change
- Combination of the two

Status Identification [1/2]

The status (as congested) is identified by a decision tree:



HARD: high "local" throughput AND high "local" delay both compared to a minimum value.

SOFT: high "local" throughput OR high "local" delay AND the speed of the car.

General: we have a very high general throughput OR a very high general delay

Time: we consider the evolution of the "local" delay and "local" throughput by using two sub-windows if the values in the newest window are bigger than the old one it means that the vehicle is congested.

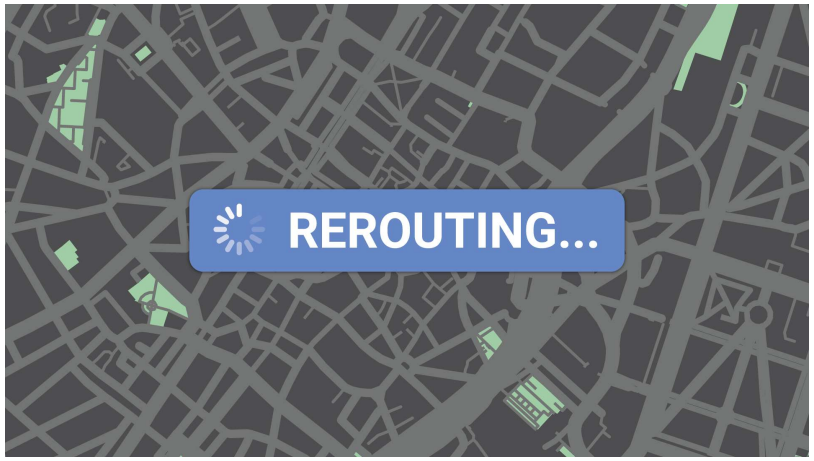
Status Identification [2/2]

Another way to decide the status of the vehicle is a voting system that works in this way:

- If the half + 1 (including myself) of the vehicles in the road tell that the road is congested, then we are congested.

Rerouting

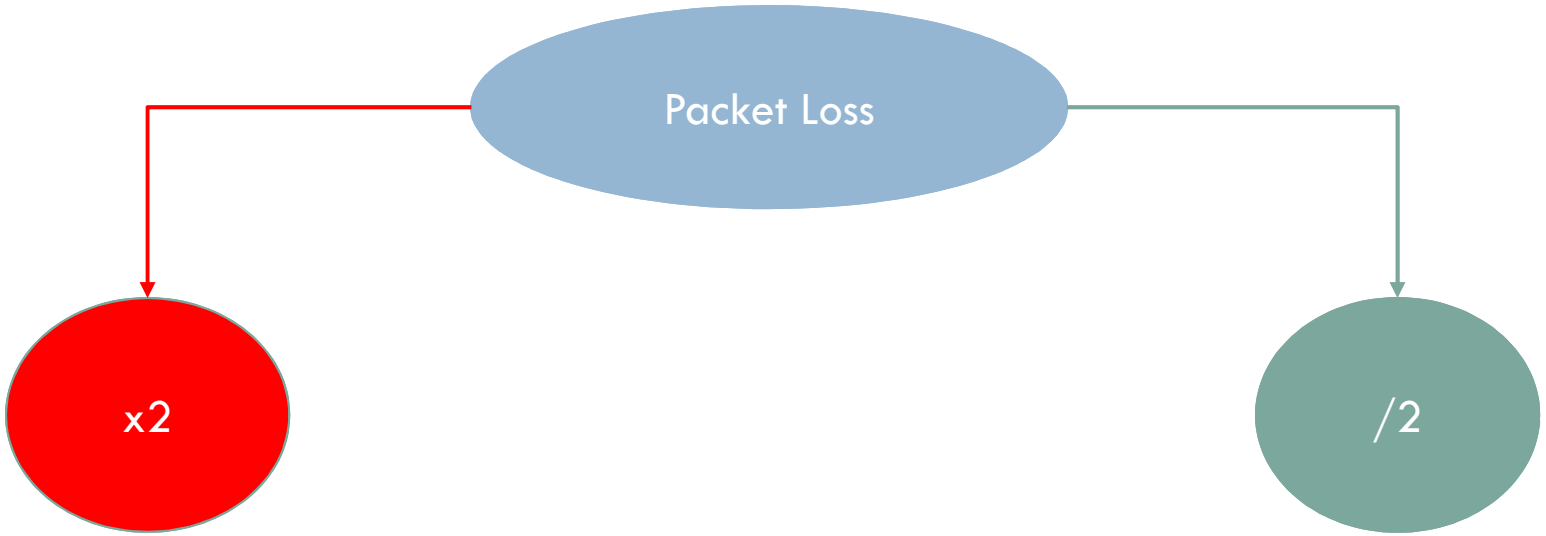
The rerouting phases are:



- Identification of the congested road
- Setting a new cost for the congested road
- Rerouting callback of TraCI (SUMO)
- Reset the cost of the roads

Change Interval

Another approach that we used to reduce the network congestion is to reduce the interval on which the packet is sent from a node.



Combination

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

Rerouting  **Change Interval**

The rerouting procedure affects the change of the interval because we have set that, if the vehicle is stacked the interval must decrease.

Rerouting  **Change Interval**

The change interval procedure affects the rerouting because in this way we obtain a different number of packets, and this changes the overall state.

Results

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

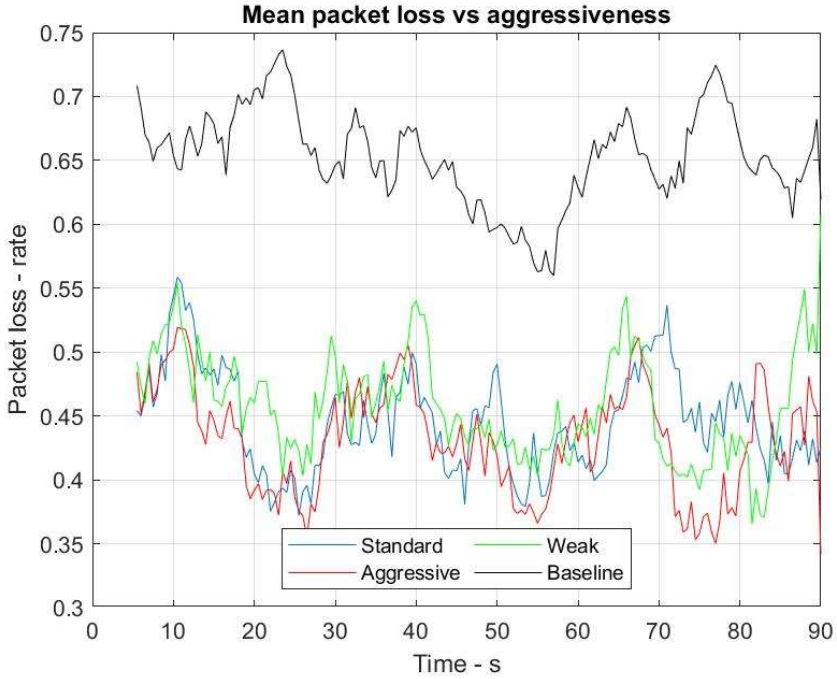
Variables considered:

- The aggressiveness of the thresholds → standard, weak, aggressive
- Size of the dynamic window → 1, 2, 3, 4, 8 instants
- Number of vehicles in the scene → 50, 75, 100, 125, 150, 175, 200
- Type of strategy adopted
  - Rerouting → yes/no
  - Interval change → yes/no

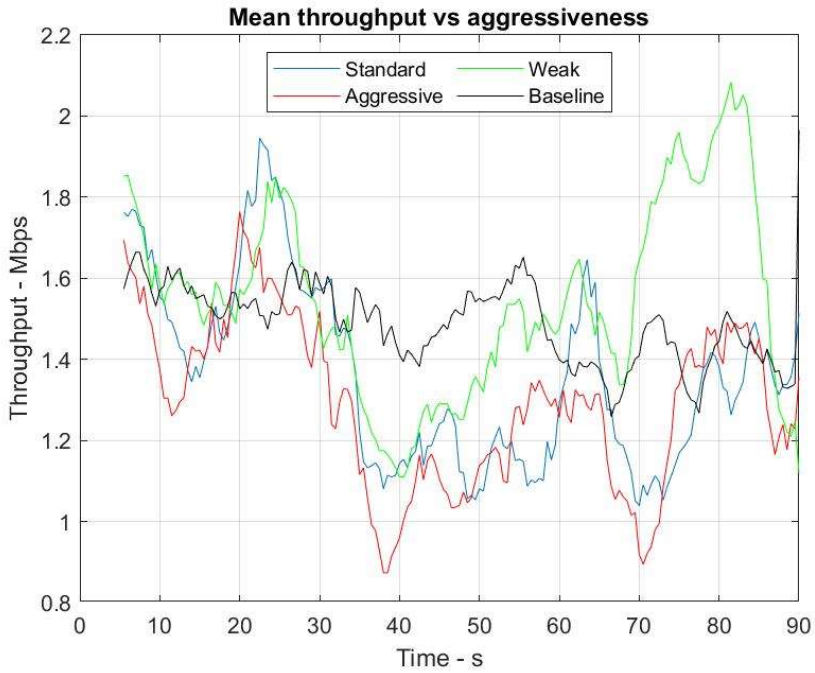
90 seconds of simulation

Threshold aggressiveness

DIPARTIMENTO
DI INGEGNERIA
DELL'INFORMAZIONE



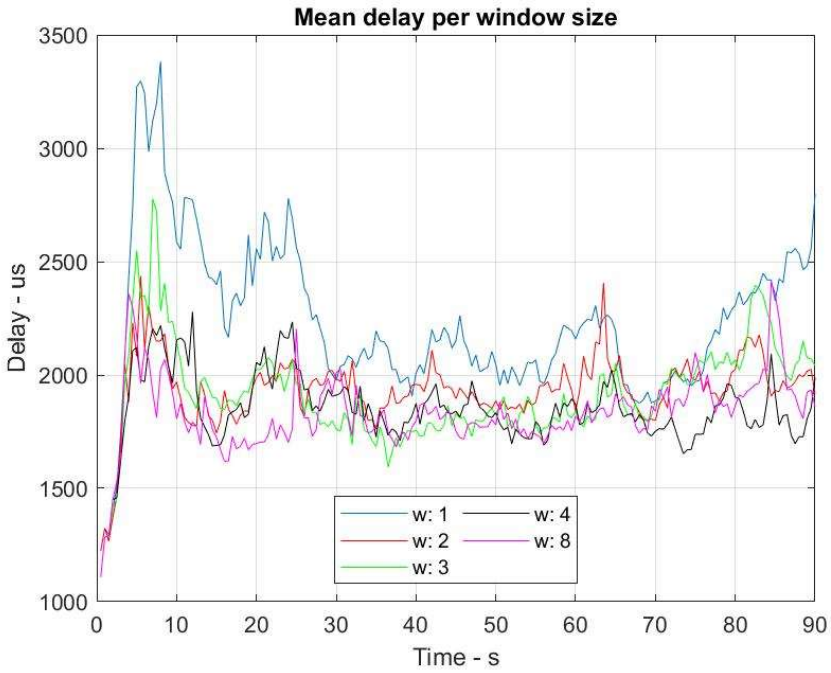
Packet loss: baseline way higher than any threshold choice on the project

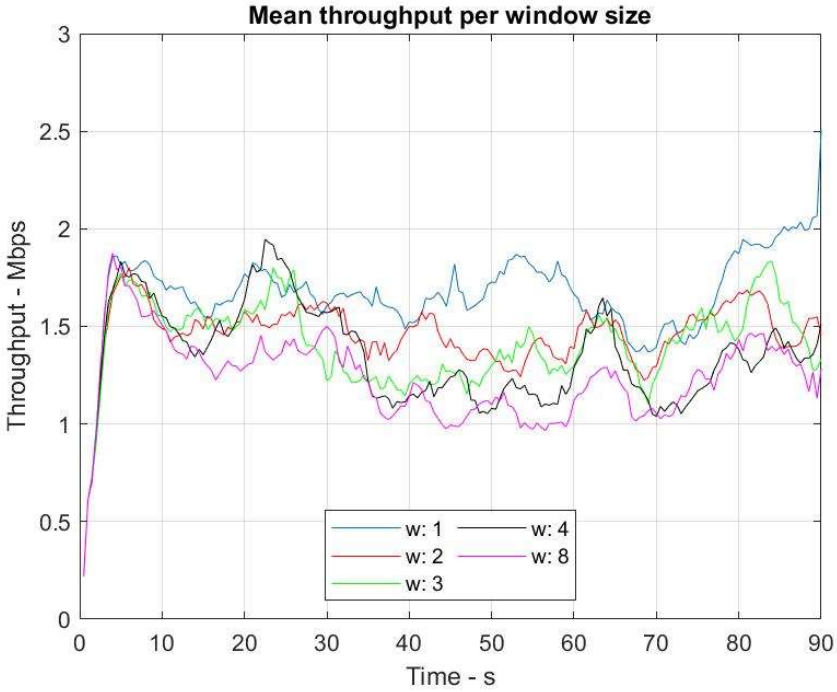


Throughput: baseline more stable, situations where weak thresholds give better results

Dynamic window size

Higher delay with the static case. In general, bigger window size means lower delay.





Throughput very similar, but lower as the window gets bigger.

Half way recap

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

Best choice

Threshold aggressiveness:

The packet loss is always better than the baseline, where the mean value is almost doubled. Throughput similar, but more stable in the baseline; weak thresholds give best values

WEAK

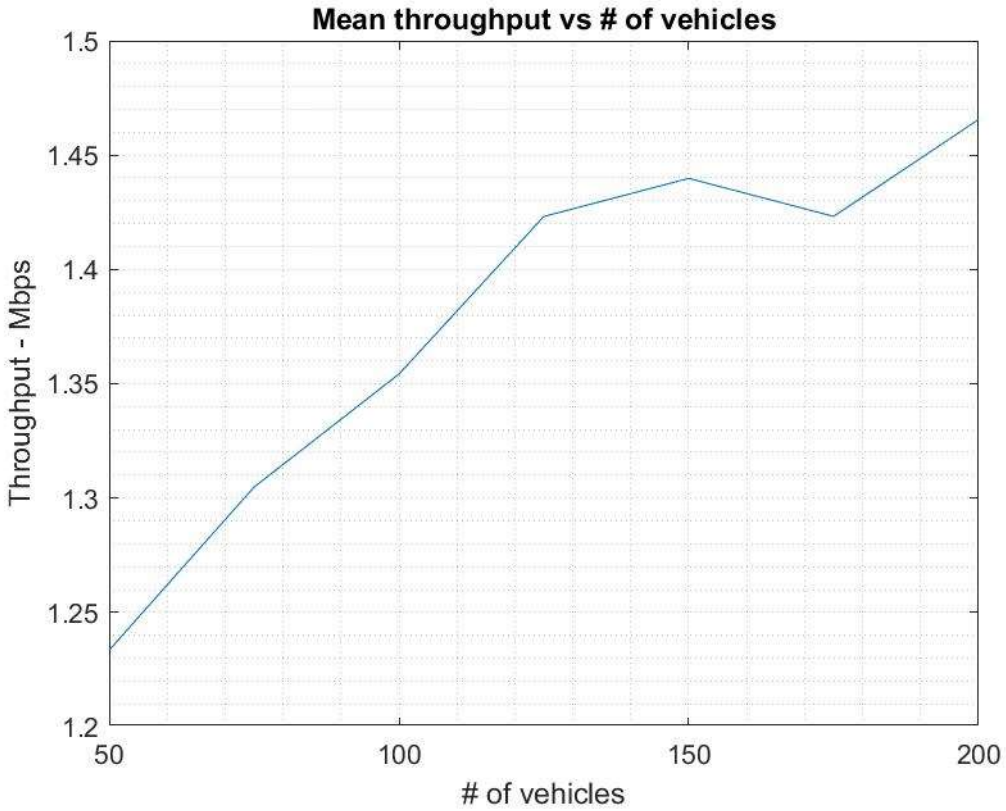
Dynamic window size:

A mid-small value has a better packet loss and doesn't penalize the throughput too much

2-3

Number of vehicles [1/2]

DIPARTIMENTO
DI INGEGNERIA
DELL'INFORMAZIONE

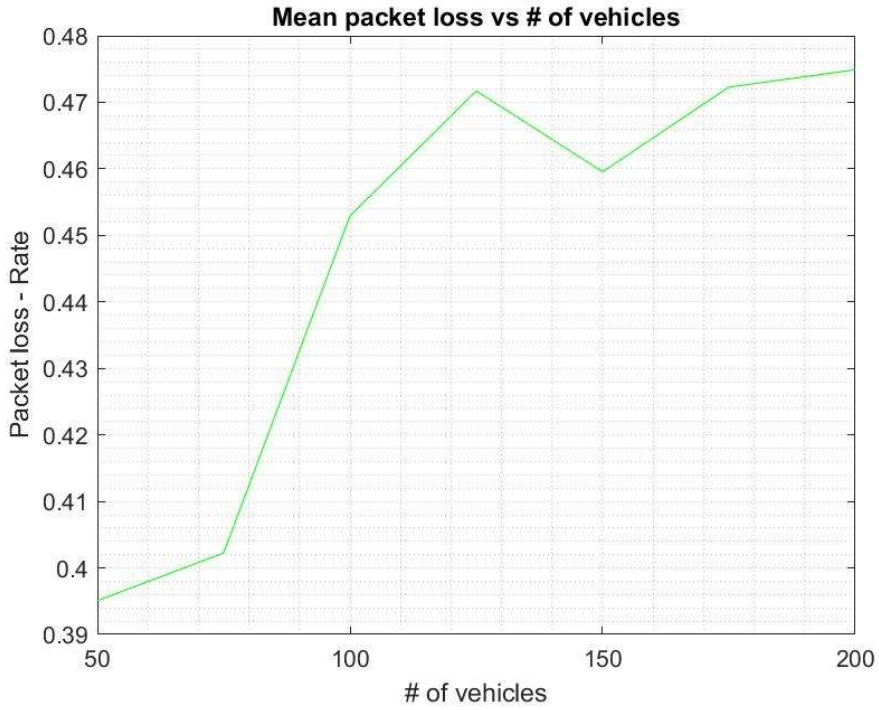


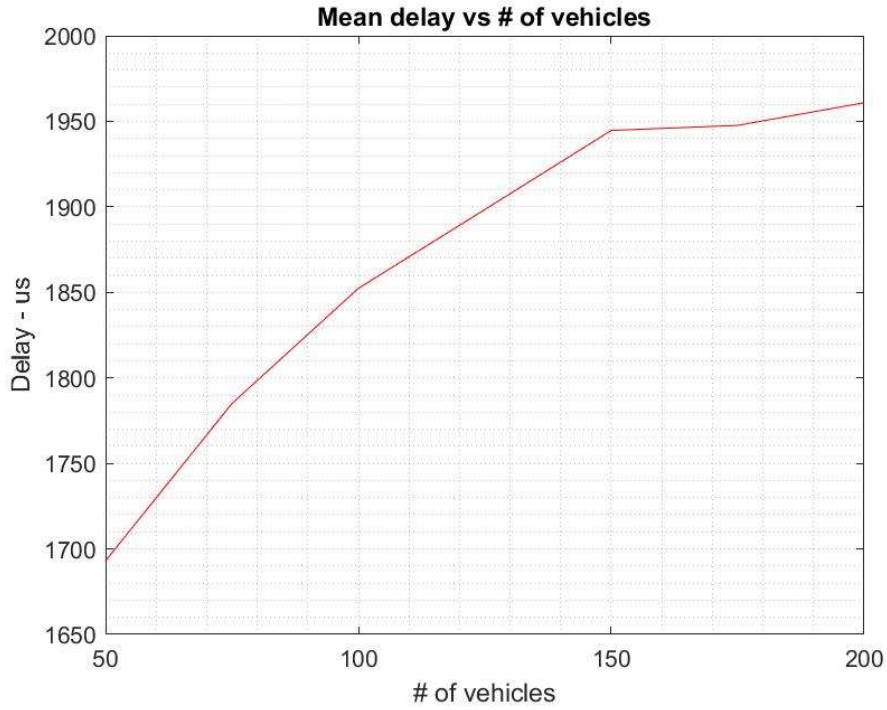
In general, as expected, if the number of vehicles rises in the scene, the throughput goes up

BUT

Number of vehicles [2/2]

DIPARTIMENTO
DI INGEGNERIA
DELL'INFORMAZIONE





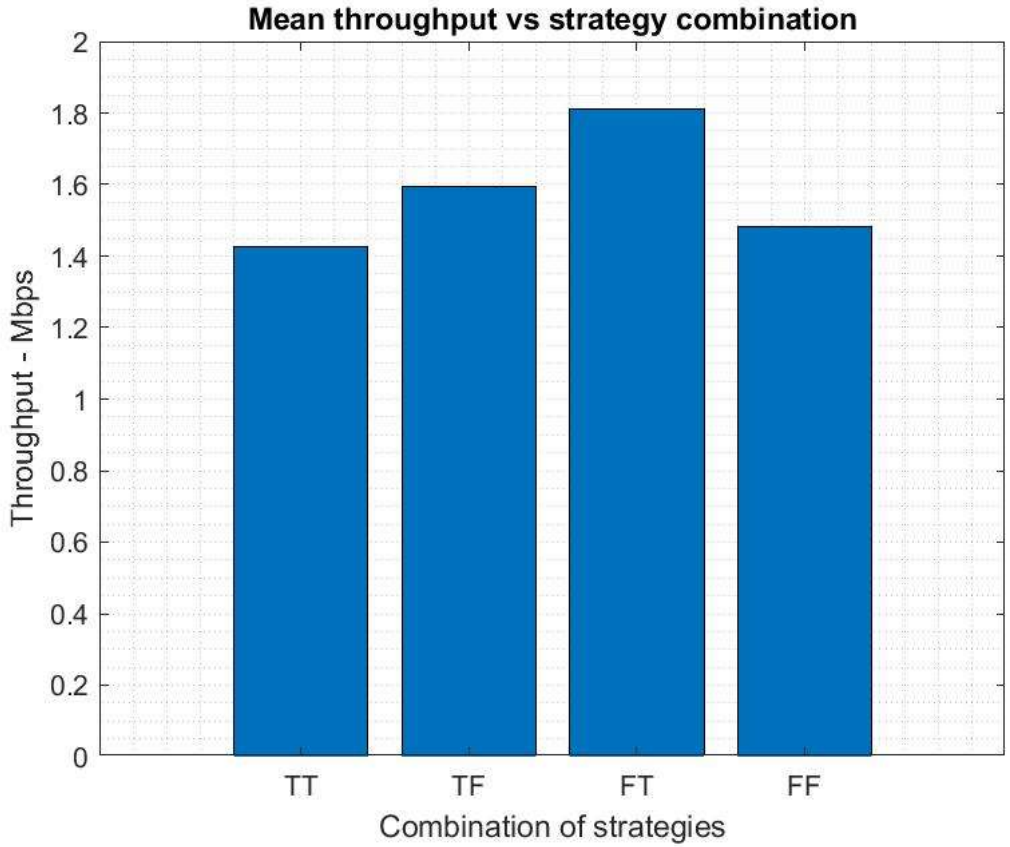
Delay and packet loss rise with the number of vehicles, so a trade-off is needed

Strategy combinations [1 /2]

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

- **TT:** both rerouting and interval change
- **TF:** only rerouting
- **FT:** only interval change
- **FF:** baseline

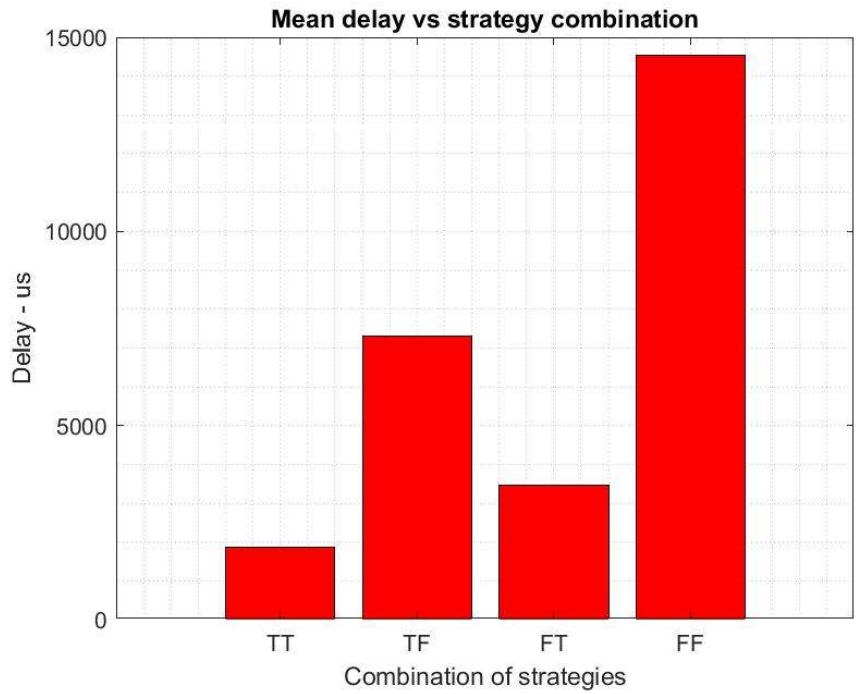
TT has a mean throughput lower than the baseline, but the other solutions are better.

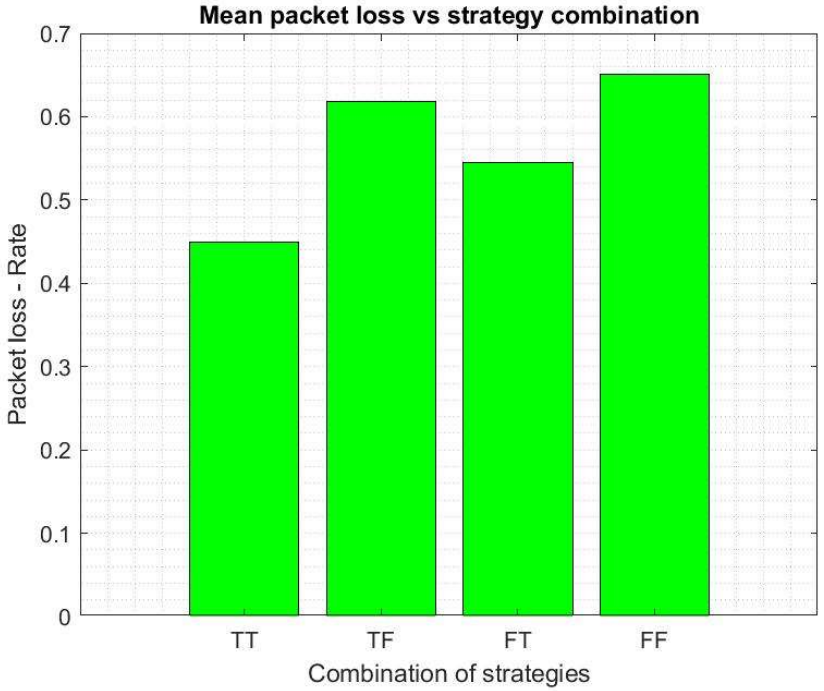


Strategy combinations [2/2]

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

In both delay and packet loss, if the strategy includes the interval change,



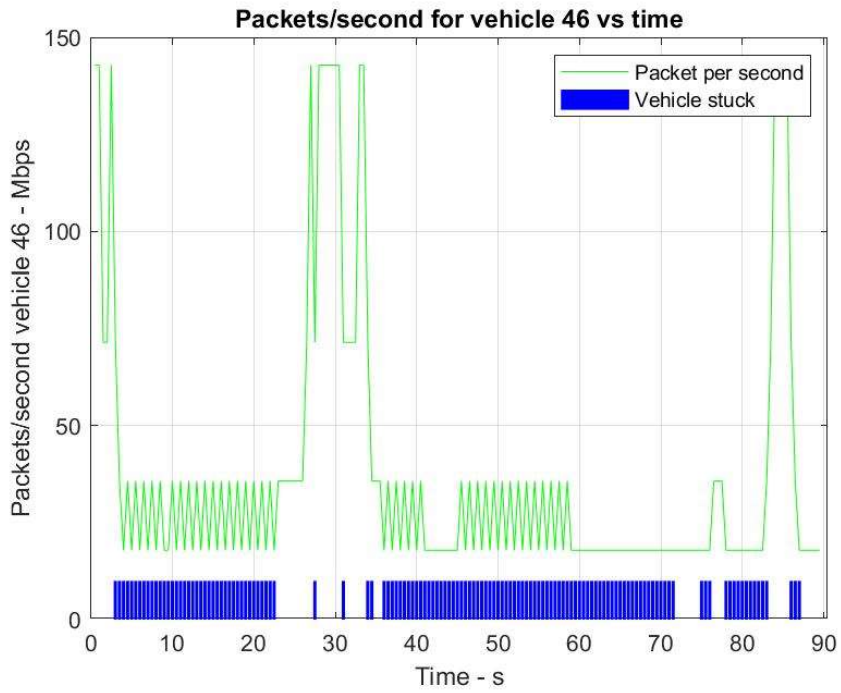


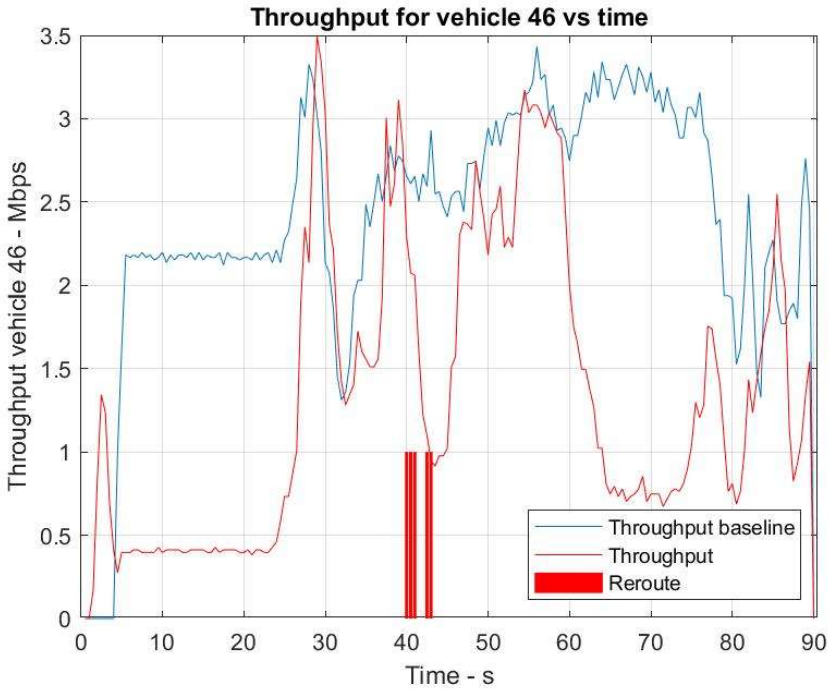
the metrics are better than the solutions with the rerouting.

Example of single vehicle

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

If the baseline throughput is high, the throughput of the project is low because the vehicle is in congestion.





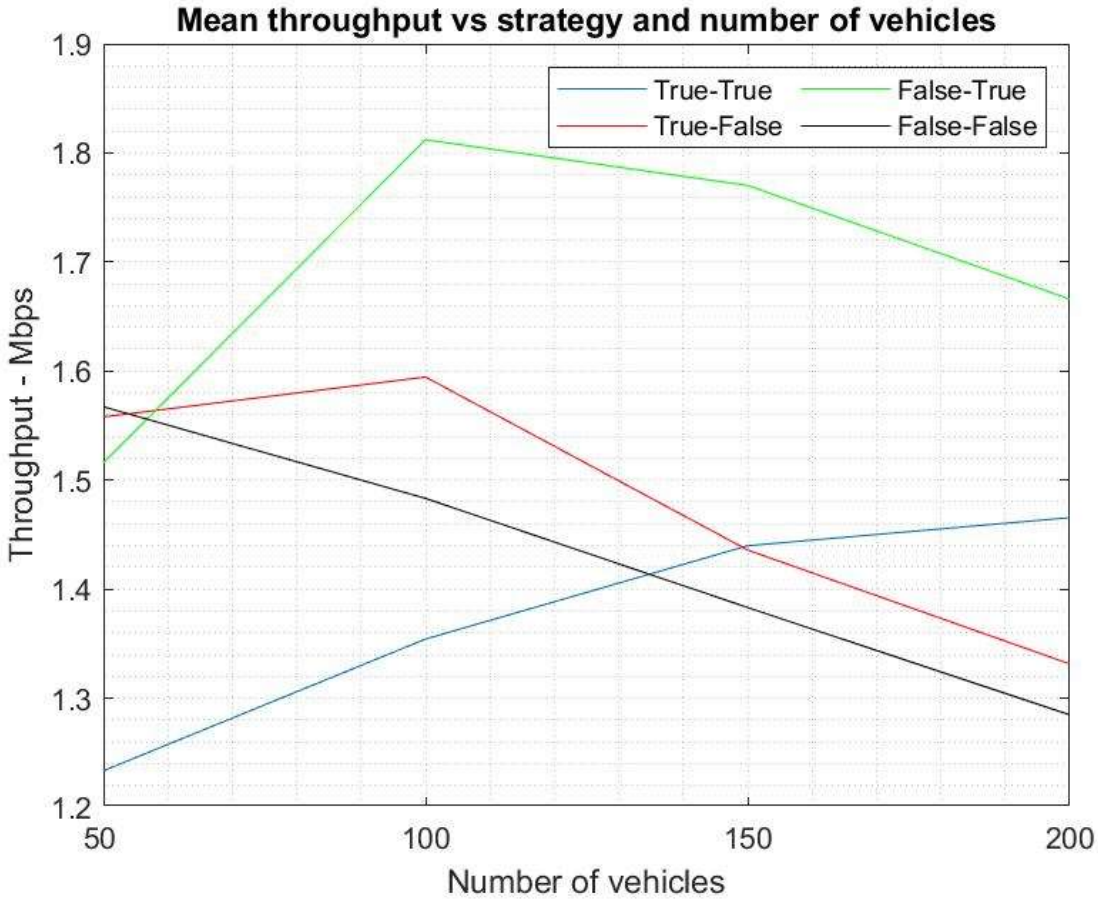
Applying rerouting strategy brings more throughput to the device.

Complete analysis [1/4]

DIPARTIMENTO
DI INGEGNERIA
DELL'INFORMAZIONE

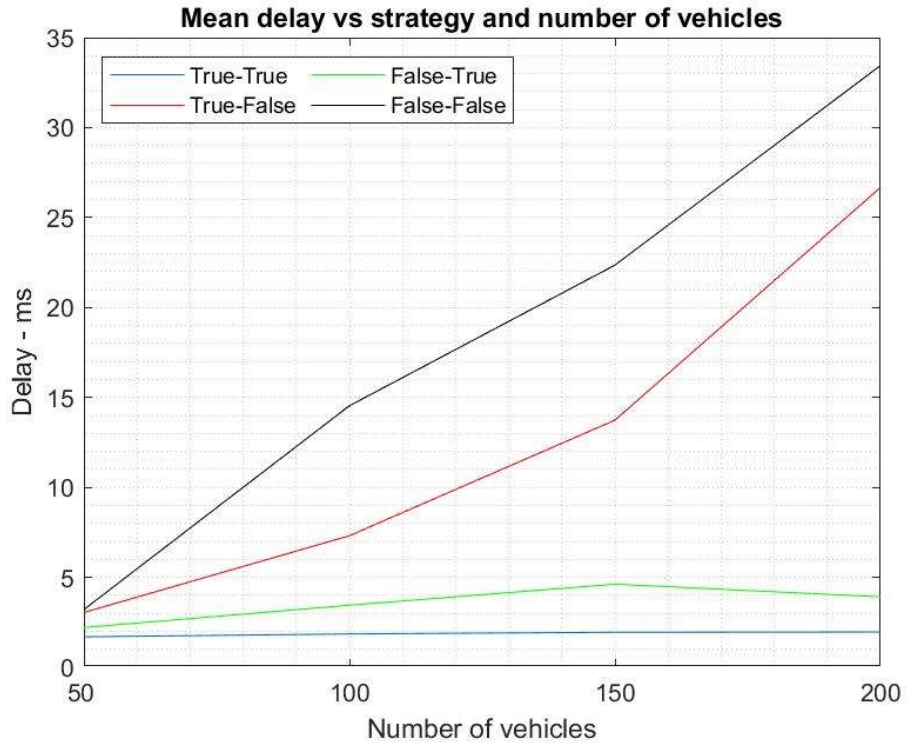
Combination of number of vehicles and strategy adopted:

The throughput is the best in the solution with only the interval change, but the complete strategy rises with the number of vehicles



Complete analysis [2/4]

DIPARTIMENTO
DI INGEGNERIA
DELL'INFORMAZIONE



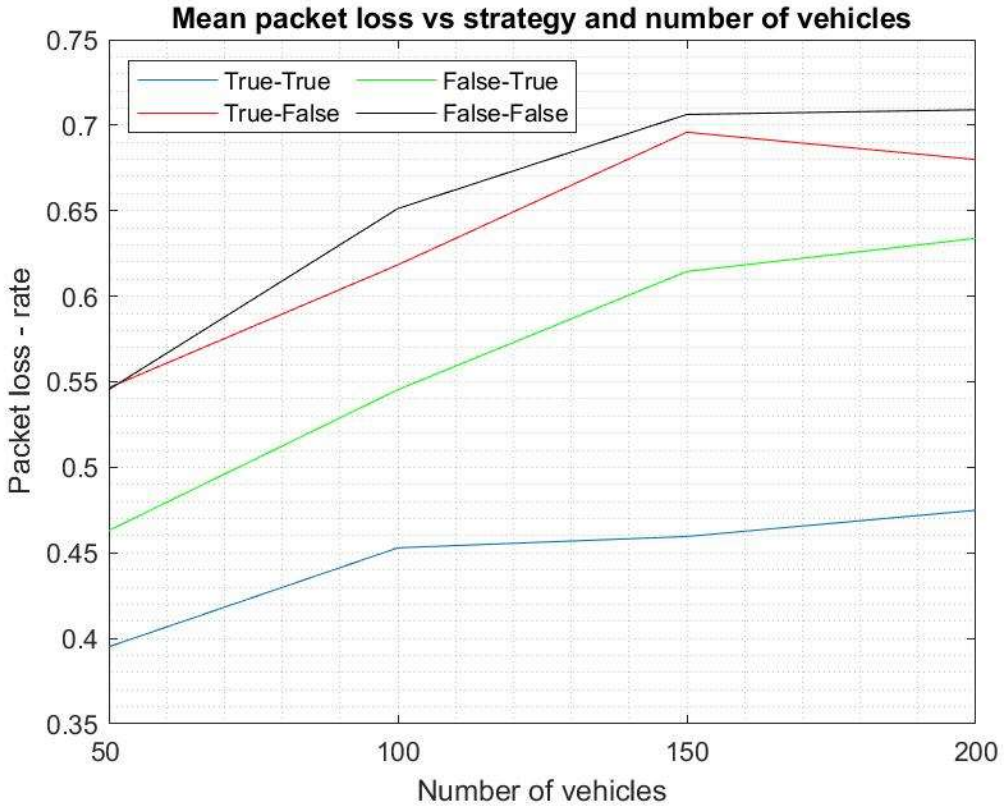
Strategies *without* interval change: very bad increasing delay

Strategies *with* interval change: low and stable delay

Complete analysis [3/4]

DIPARTIMENTO
DI INGEGNERIA
DELL'INFORMAZIONE

The complete strategy (TT), has the lowest packet loss; on average it's 20% better than the other strategies.



Between the other strategies, the best is the one with interval change only.

Complete analysis [4/4]

DIPARTIMENTO
DI INGEGNERIA
DELL'INFORMAZIONE

- The interval change strategy is a **MUST**
- Rerouting is an **ok** solution but lowers the throughput

RESULTS

- If the throughput is important, the best is the *interval change-only* strategy
- If the throughput can be sacrificed, the best choice is the *complete* strategy

Conclusions

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

- The number of vehicles affects every considered metric
- Changing the interval is a good strategy to improve the traffic and the reliability in the network
- This same strategy, when coupled with the rerouting, has the potential to improve the traffic in an urban scenario

For the future:

- Considering more variables and their combinations
- Considering different maps
- Gather more data with many runs

Credits

DIPARTIMENTO
DI INGEGNERIA
DELL'INFORMAZIONE

Thanks for your attention

Special thanks to:

- Drago Matteo
- Giordani Marco
- Polese Michele
- Zugno Tommaso