Security Level: Internal

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Combining Mechanistic Modelling, Nonlinear Control, and Neuronal Learning for Road Traffic Optimization

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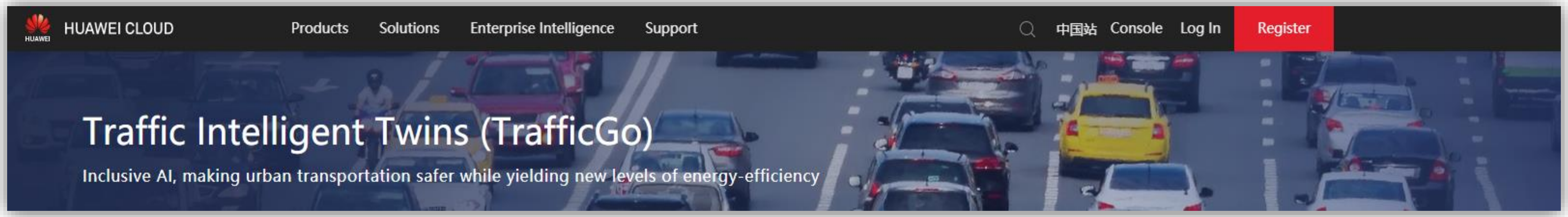
HUAWEI

Agenda

- TrafficGO Solution
- Real Time Traffic Control at District Level
- System design: modelling, control, and learning
- Evaluation
- Conclusions

TrafficGO Solution



Traffic Intelligent Twins (TrafficGO)

Inclusive AI, making urban transportation safer while yielding new levels of energy-efficiency

Lamport Lab

Real-Time Traffic Signal Scheduling

Formulates the first security communication interface standards for intelligence-infused traffic management and signal control systems.

District-wide Coordination

Maximizes traffic volume and minimizes vehicle wait time. Coordinates travel requirements of vehicles and pedestrians for smooth traffic.

Deep Data Mining

Integrates the Internet with big data for traffic control to deepen data mining efforts.

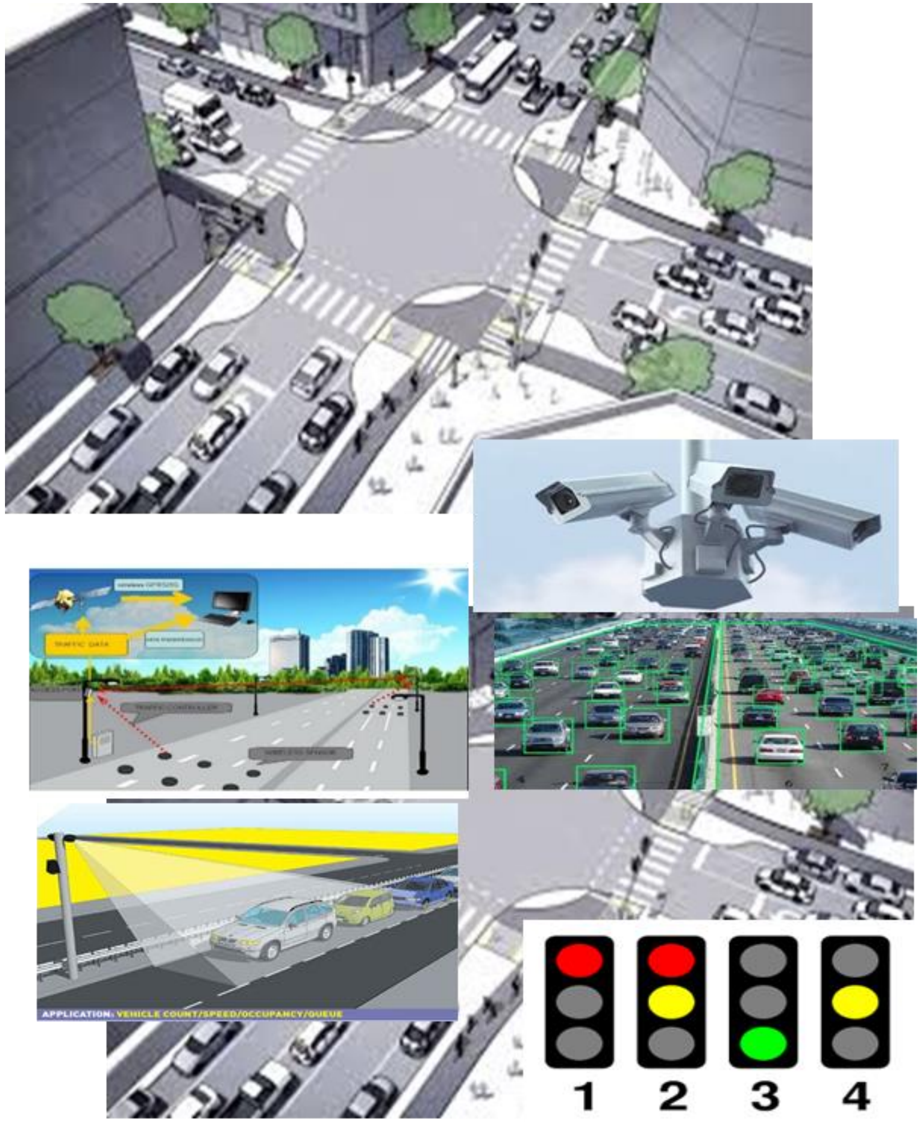
Precise Tracking and Planning

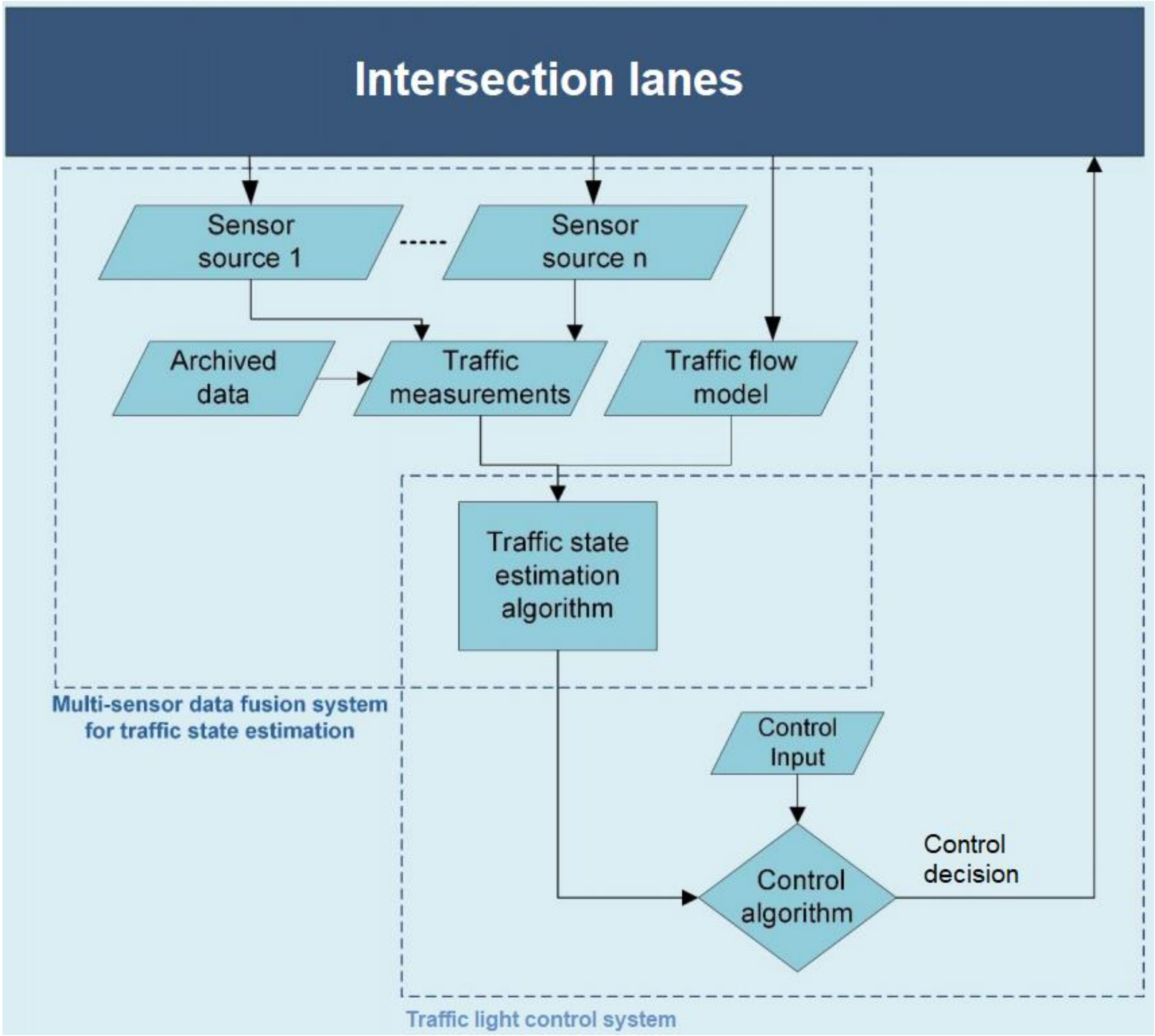
Accurately predicts trajectories and plans routes in advance.

OBELISC

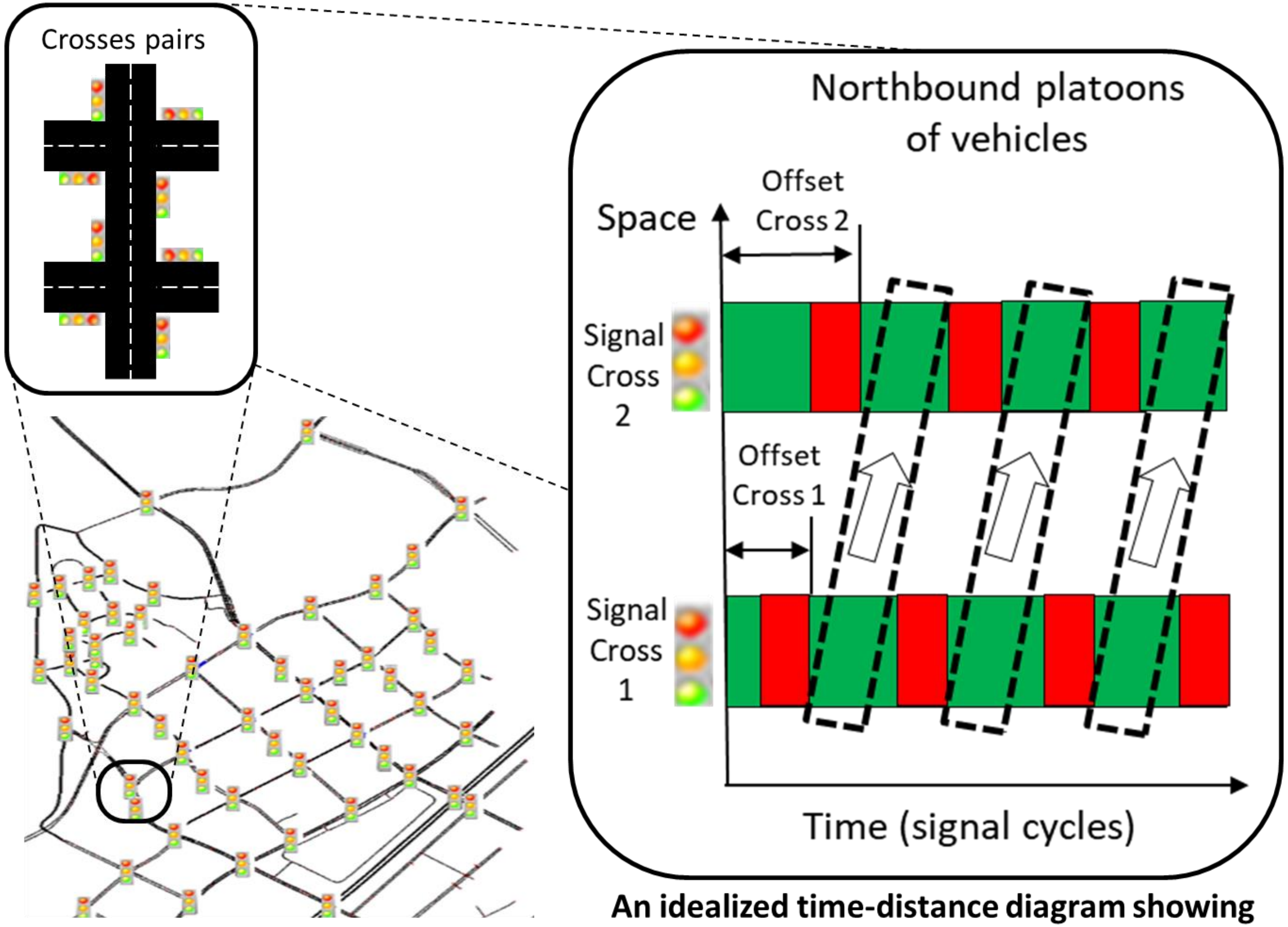
Oscillator-Based Efficient Learning In phase offset State Control

Real Time Traffic Control at District Level





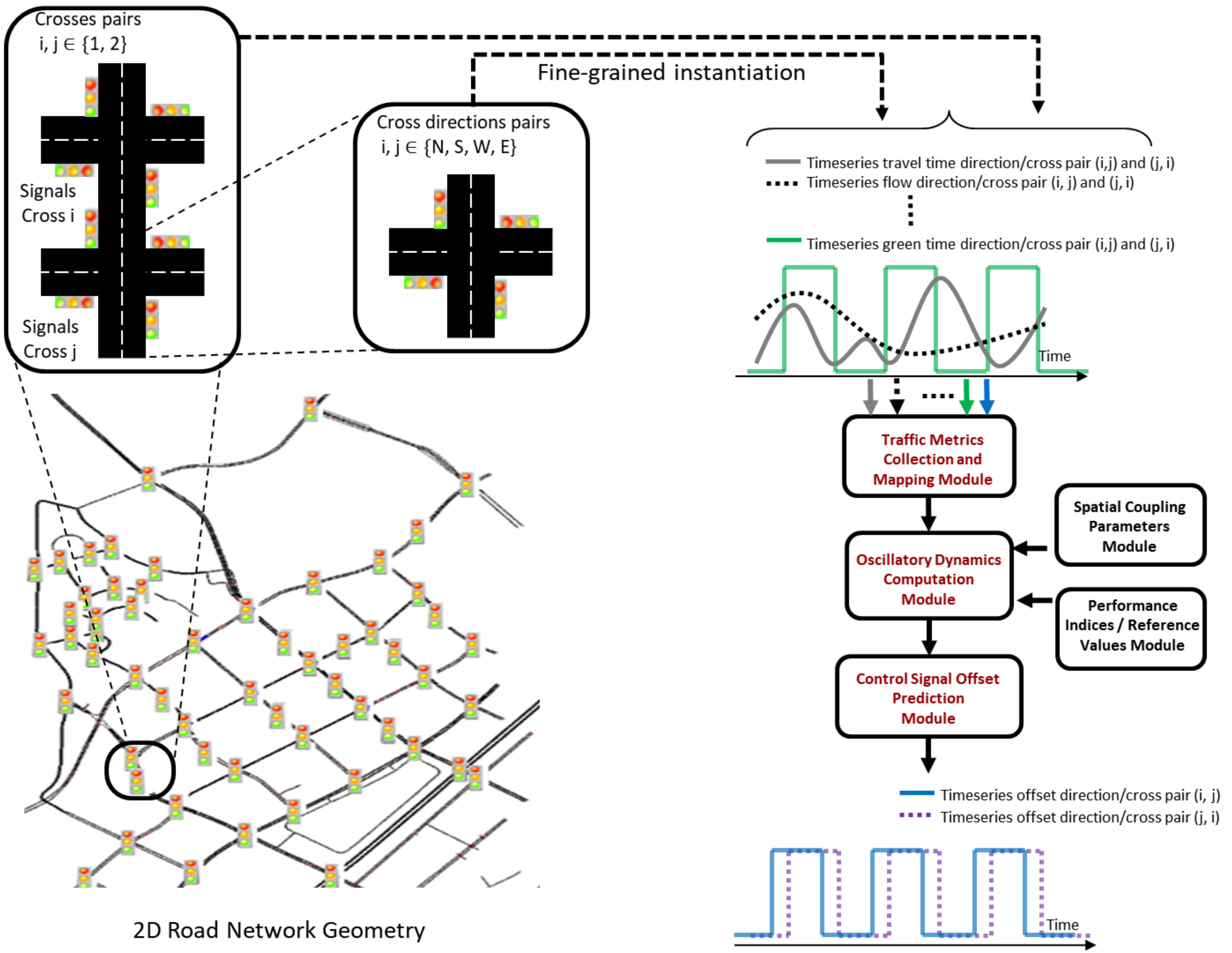
Real Time Traffic Control at District Level



2D Road Network Geometry

An idealized time-distance diagram showing signal coordination with a fixed time plan and the corresponding offset calculation

System design

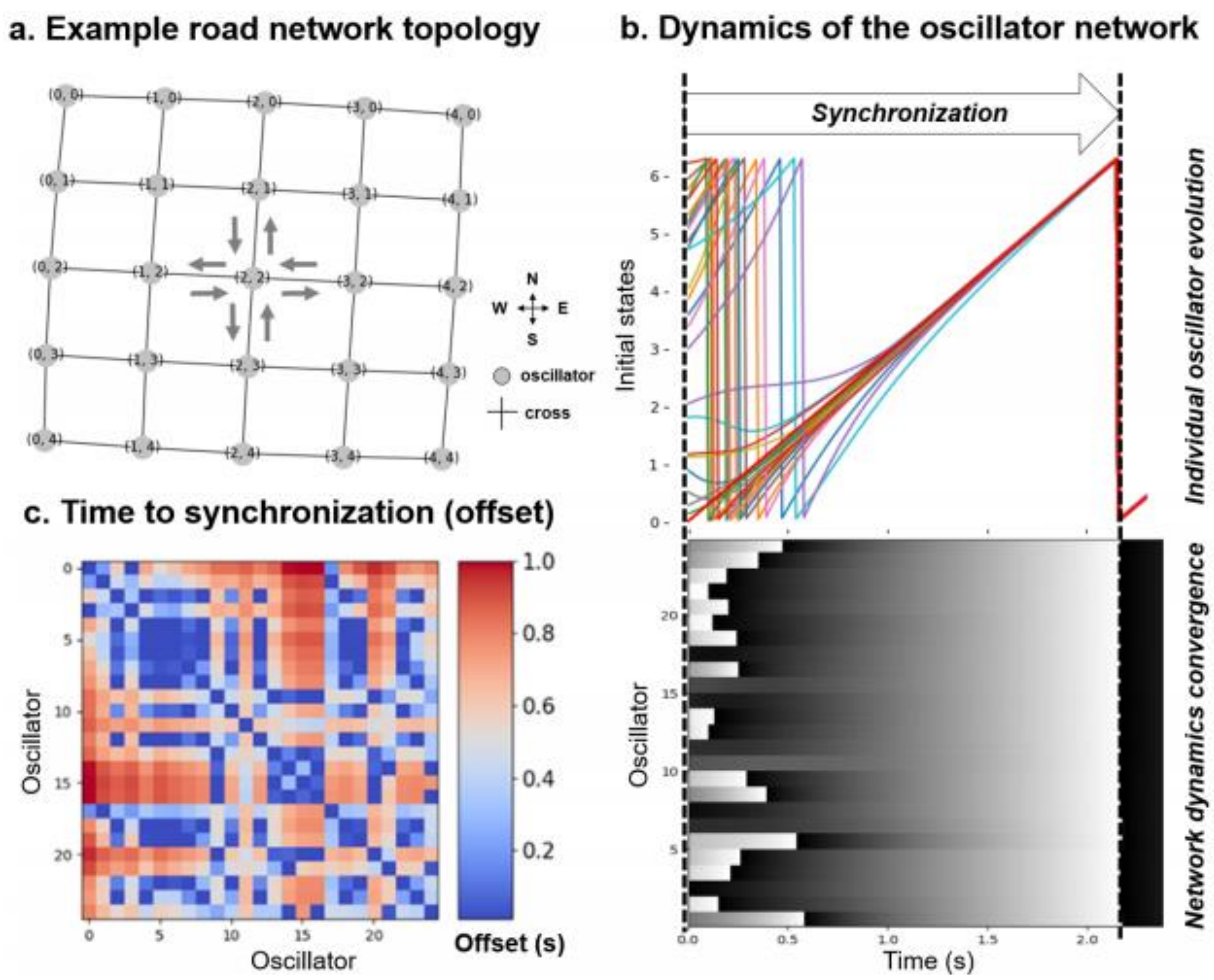


System design: modelling

$$\frac{d\theta_i(t)}{dt} = \overset{\text{Angular speed}}{\boxed{\omega_i(t)}} + \overset{\text{Coupling strength}}{\boxed{k_i(t)\sum_{j=1}^{N} A_{ij} sin(\theta_j(t) - \theta_i(t))}} + \overset{\text{Variability}}{\boxed{F_i sin(\theta^*(t) - \theta_i(t))}}$$

where:
θ_i - the amount of green time of traffic light i
ω_i - the frequency of traffic light i oscillator
k_i - the flow of cars passing through the direction controlled by traffic light i oscillator
A_{ij} - the static spatial adjacency coupling between oscillator i and oscillator j
F_i - the coupling of external perturbations (e.g. maximum cycle time per phase imposed by law)
θ^* - the external perturbation (e.g. the upper limit of green time)

System design: modelling



System design: control

Oscillator dynamics

Regularizing control law

$$\frac{d\theta_i(t)}{dt} = \boxed{\omega_i(t) + k_i(t)\sum_{j=1}^{N} A_{ij} sin(\theta_j(t) - \theta_i(t)) + F_i sin(\theta^*(t) - \theta_i(t))} + \boxed{u_i(t)}$$

with

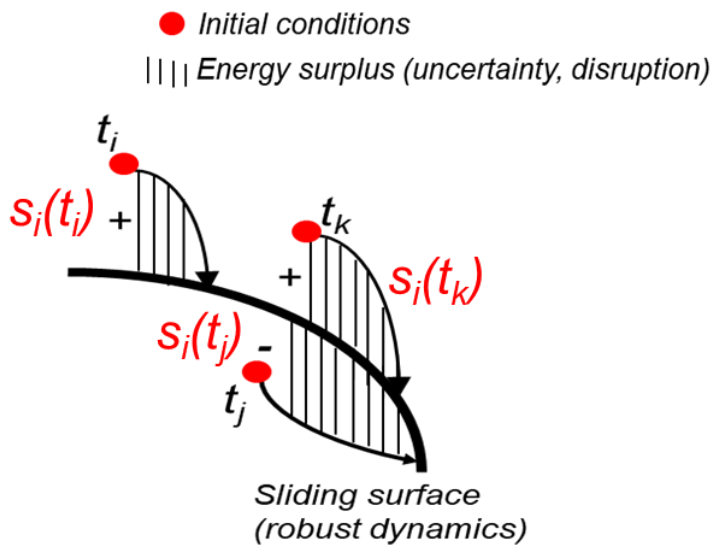
Sliding Mode Control

$$u_i(t) = \epsilon_1 \int_0^t \hat{s}_i(\tau) d\tau$$

$$\frac{\hat{s}_i(t)}{dt} = \epsilon_2 (\sum_{i,j} (\hat{s}_j(t) - \hat{s}_i(t)) + s_i(t))$$

$$\frac{s_i(t)}{dt} = \epsilon_3 \sum_j (s_j(t) - \frac{\hat{s}_i(t)}{dt}) - sign(\hat{s}_i(t)) \frac{d^2\theta_i(t)}{dt^2}$$

$$0 < \epsilon_1 < \epsilon_2 < \epsilon_3 < 1$$

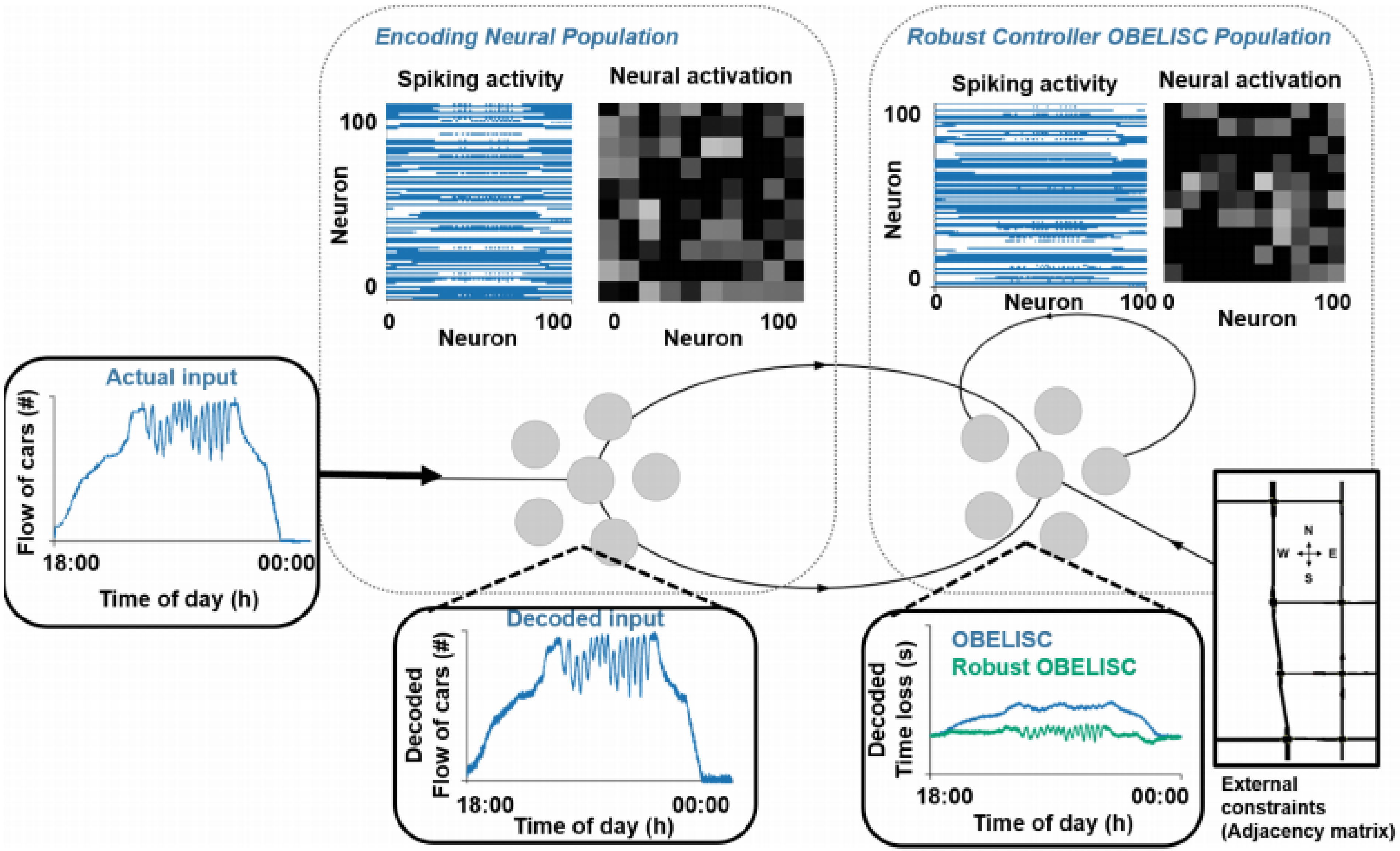


where:

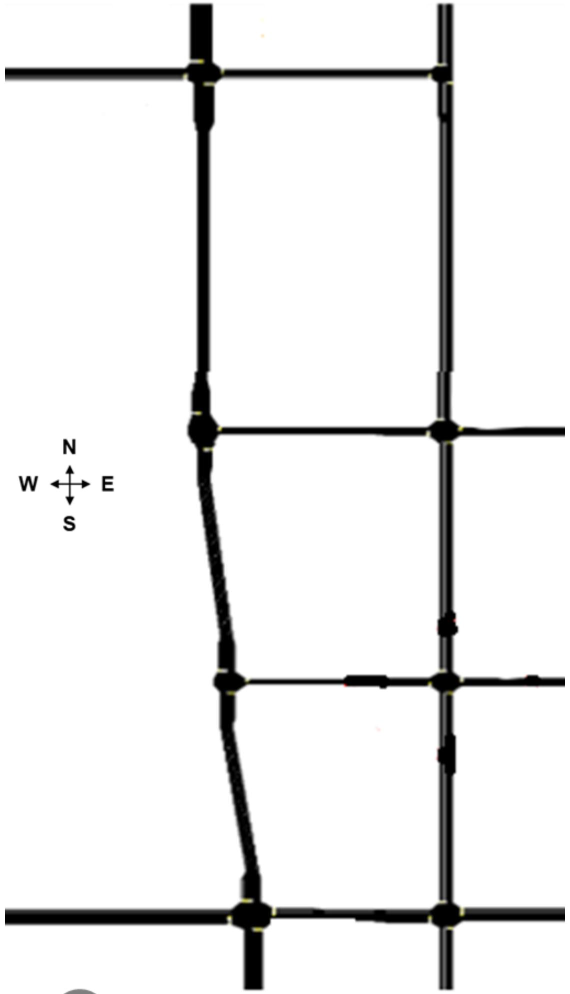
$s_i(t)$ - the surplus energy of traffic light i oscillator

$\hat{s}_i(t)$ - the estimated surplus energy of traffic light i oscillator

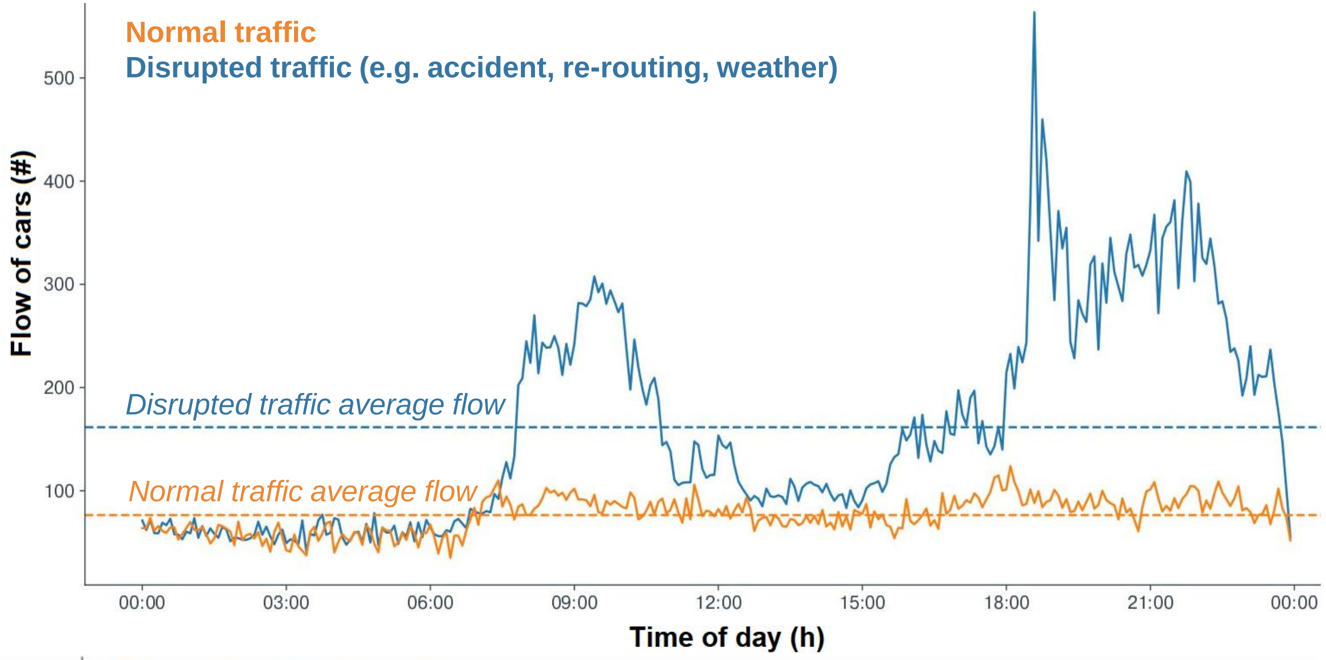
System design: learning

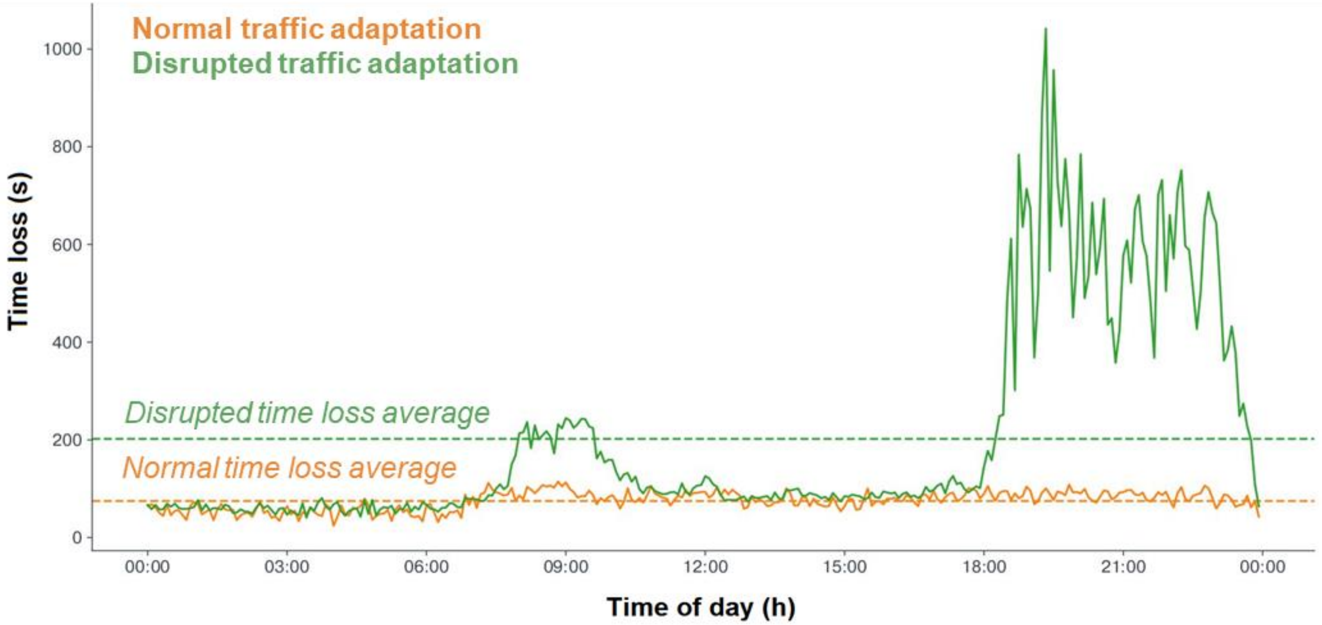


Evaluation



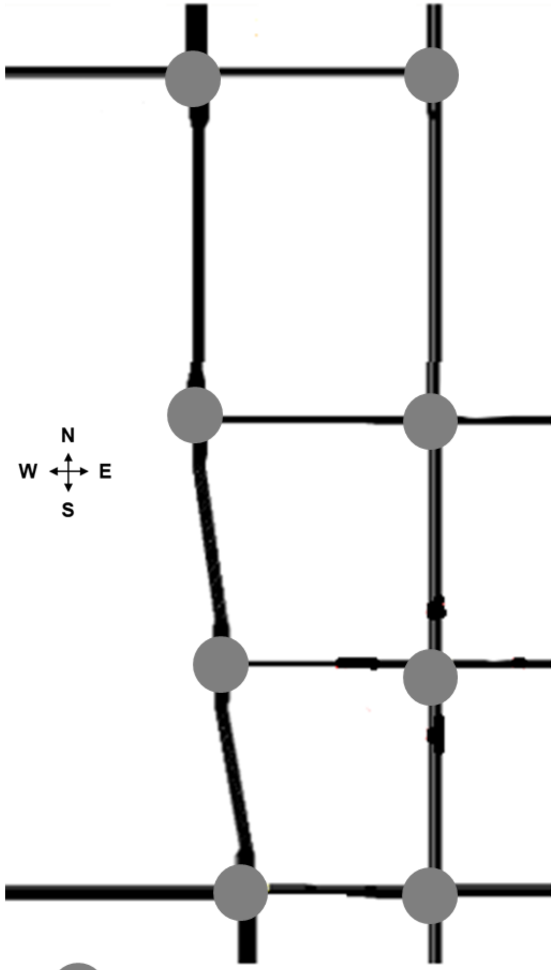
Crosses
1 oscillator per direction
5 crosses with 4 directions
3 crosses with 3 directions





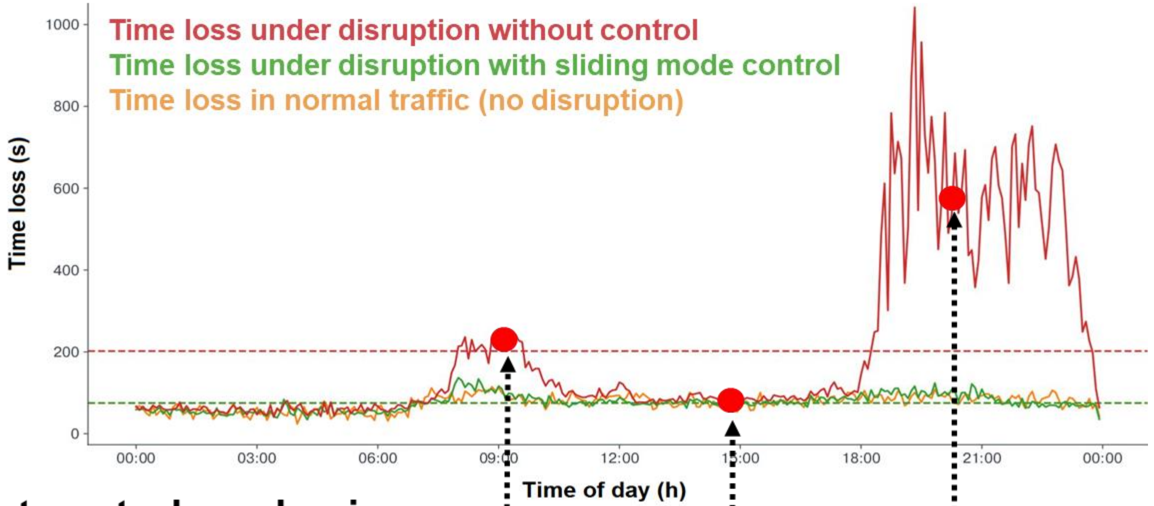
Evaluation

Real road network layout

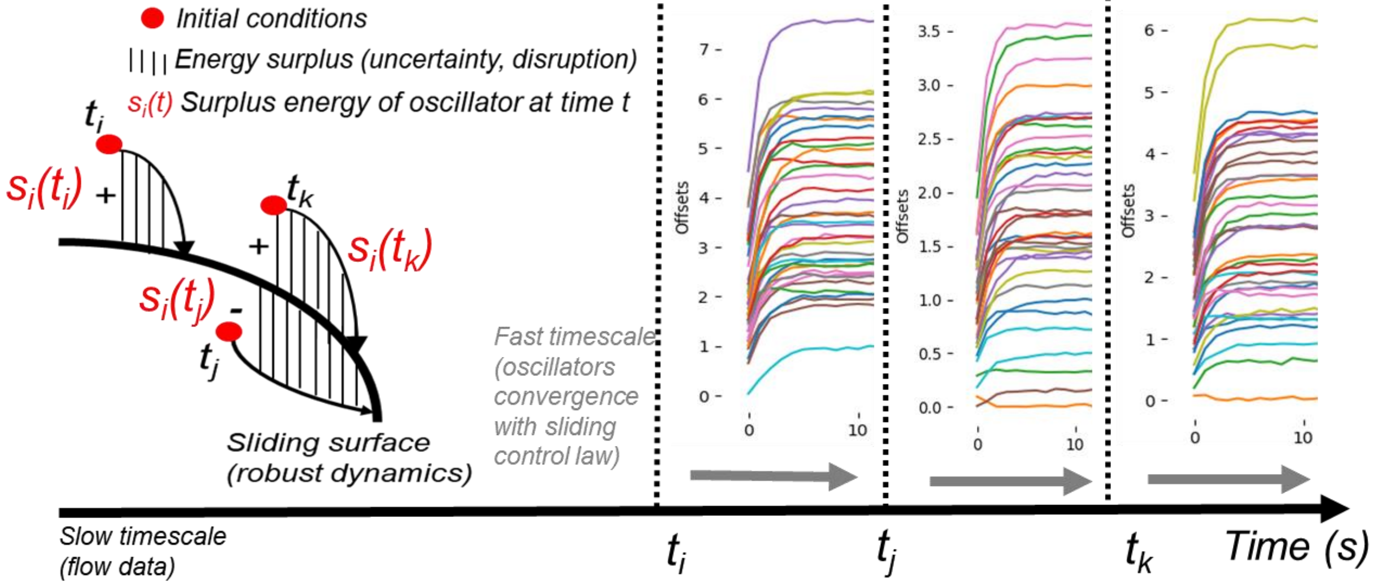


Crosses
1 oscillator per direction
5 crosses with 4 directions
3 crosses with 3 directions

Traffic profile in the road network

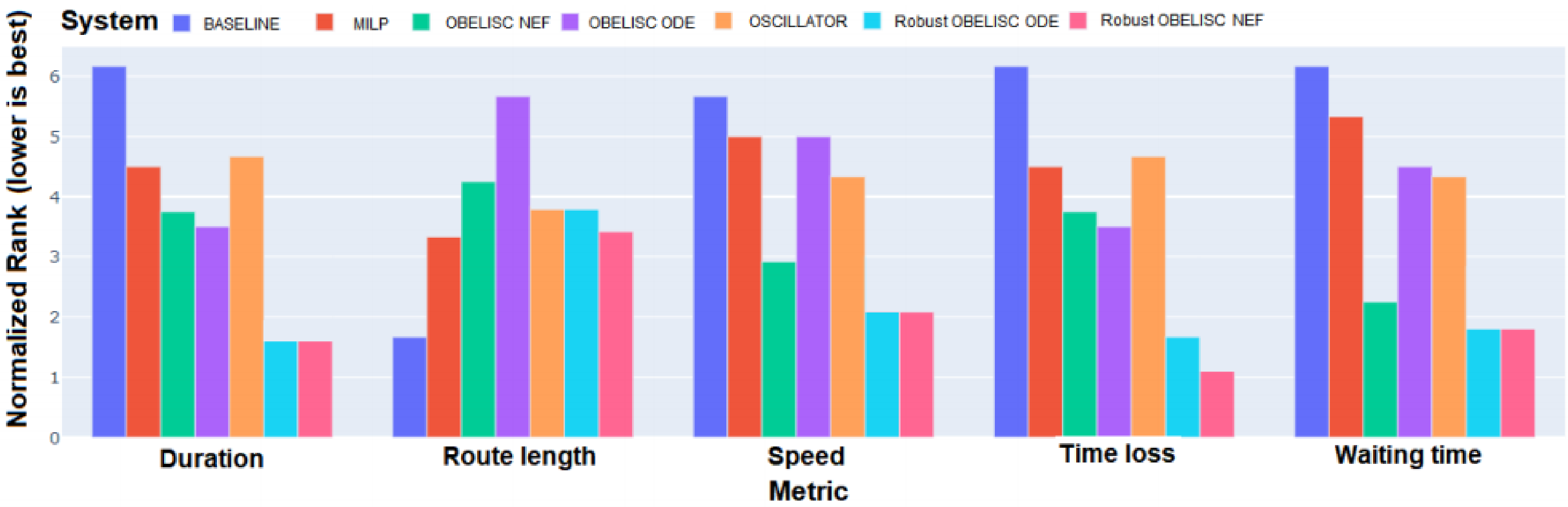


Robust control mechanism



Evaluation

Performance



Run-time

Model	Single cross	Region (8 crosses)
MILP	0.0510	0.3930
OSCILLATOR	0.0568	0.4544
OBELISC ODE	0.0489	0.4534
OBELISC NEF	**0.0071**	**0.0426**

Conclusions

- **modelling** is a fundamental dimension for **control**
- **network of oscillators** capturing the **spatial** and **temporal interactions** among different crosses in a traffic network
- **adaptively** cope with **unexpected** traffic flow **disruptions**
- **sliding mode controller** that extends the adaptation capabilities of the model towards handling **high-magnitude high-frequency disruptions**
- lightweight **learning system** using **spiking neural networks** exploiting the **coupling** interactions among the different **controlled oscillators**
- overcoming state-of-the-art approaches

Thank You.