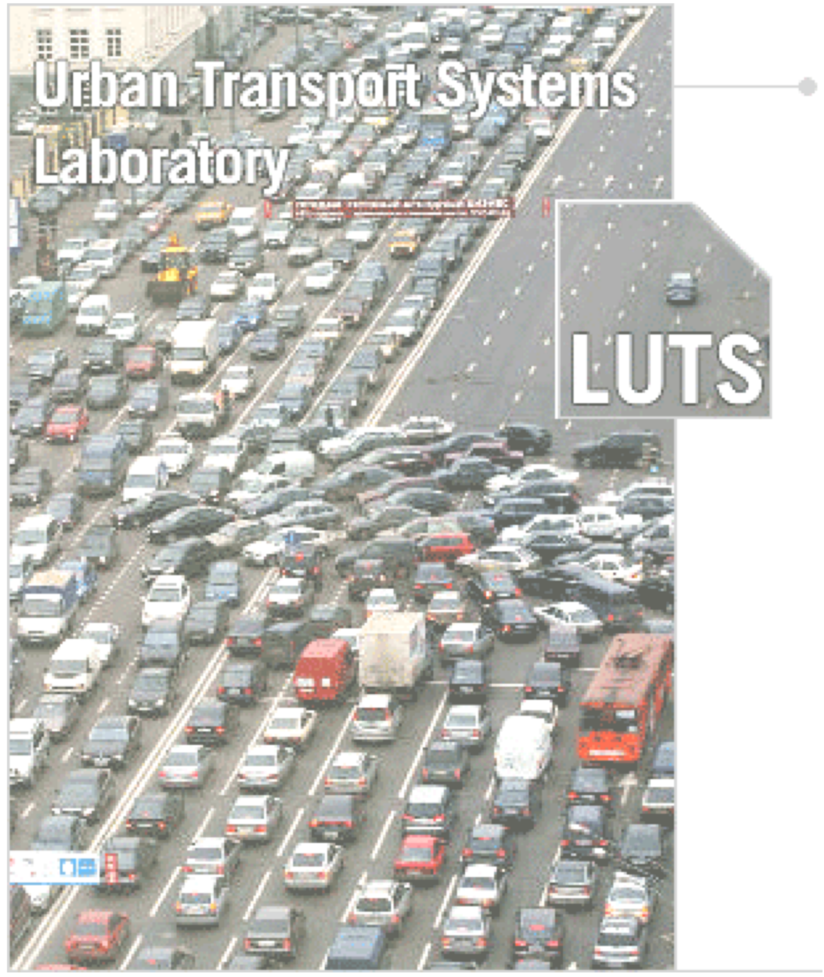
EPFL

Network-level traffic management and control with MFDs

Intro to traffic flow modeling and ITS

Prof. Nikolas Geroliminis



Welcome

Week Outline

- Week 5.1
  - Control Logic
  - Single-region perimeter control
  - Multi-region perimeter linear control
- Week 5.2
  - Model Predictive Control with MFDs

A System-of-Systems approach

MOBILITY MANAGEMENT

Hierarchical Signal Control

Urban Space Allocation

Route Guidance

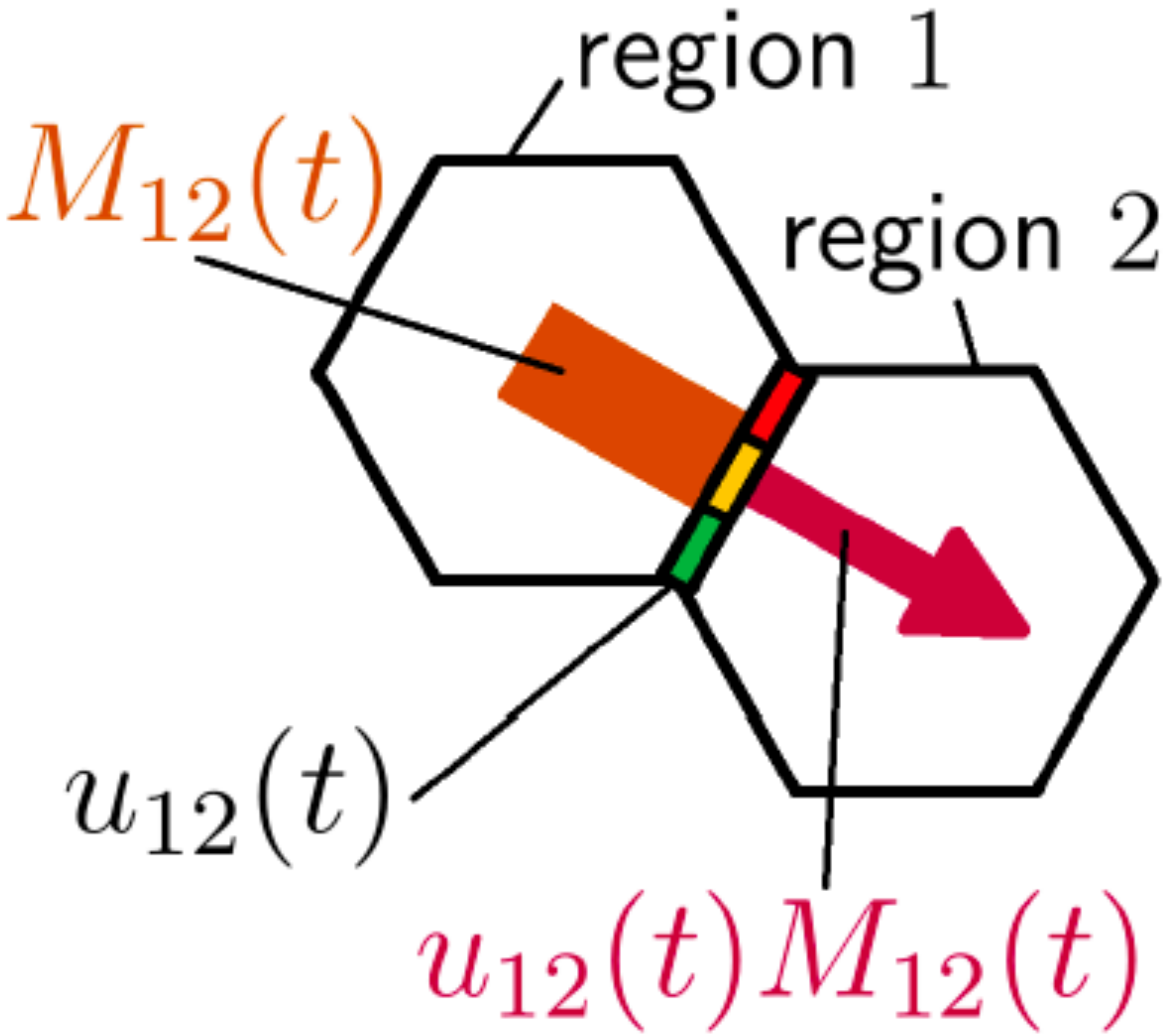
Bus Priority

On demand public transport

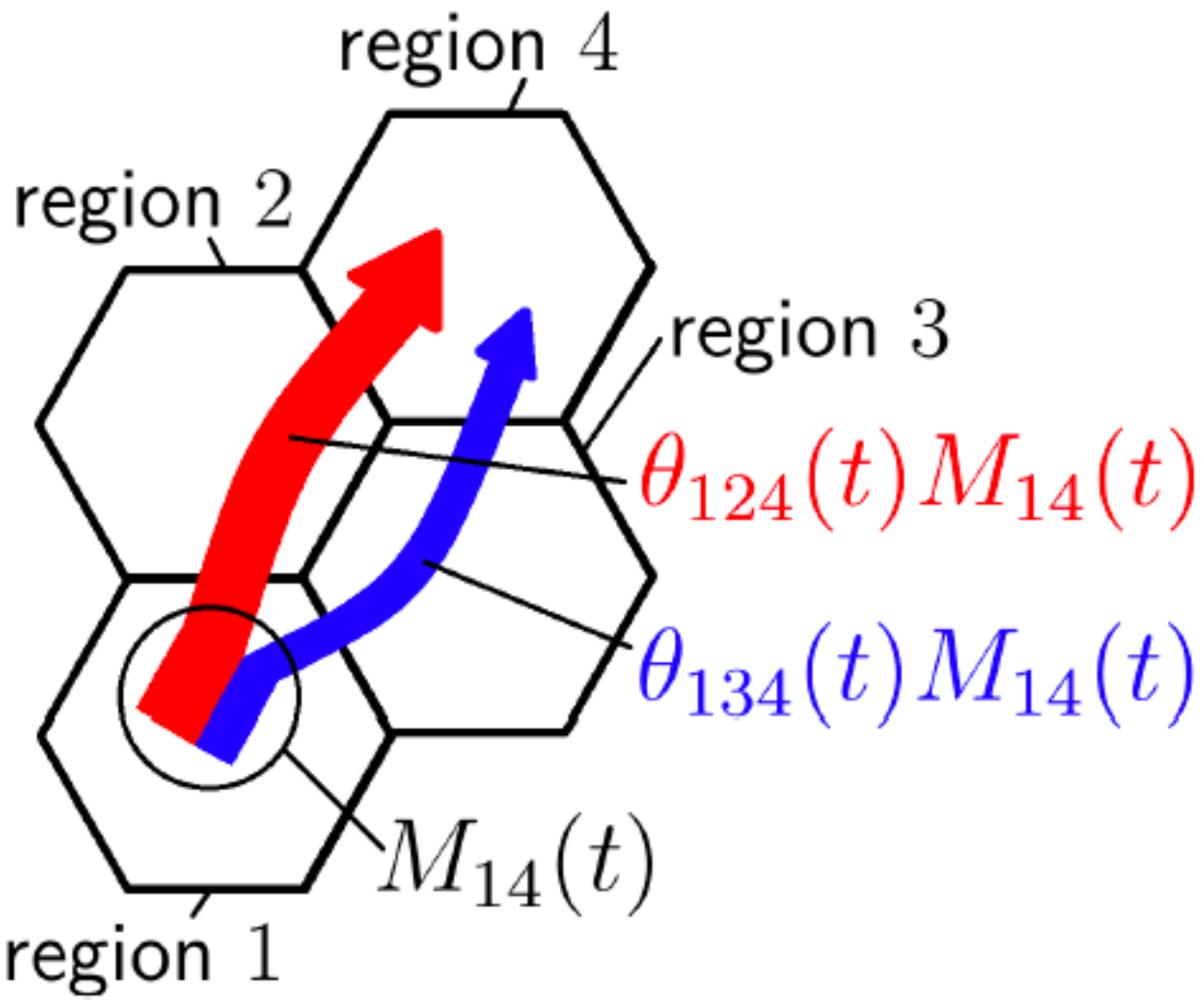
Parking

Control logic for large-scale networks

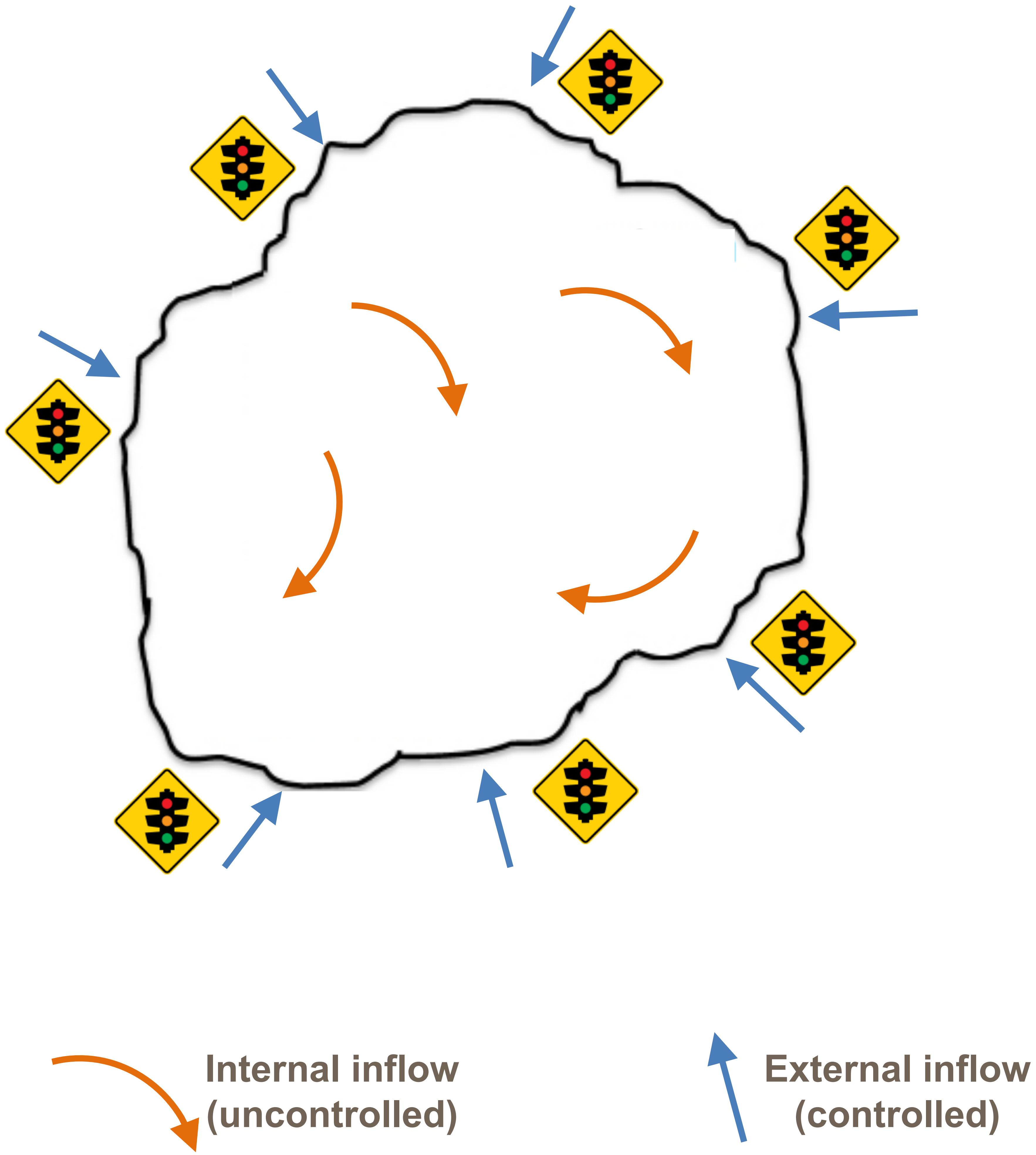
Perimeter control



Route guidance

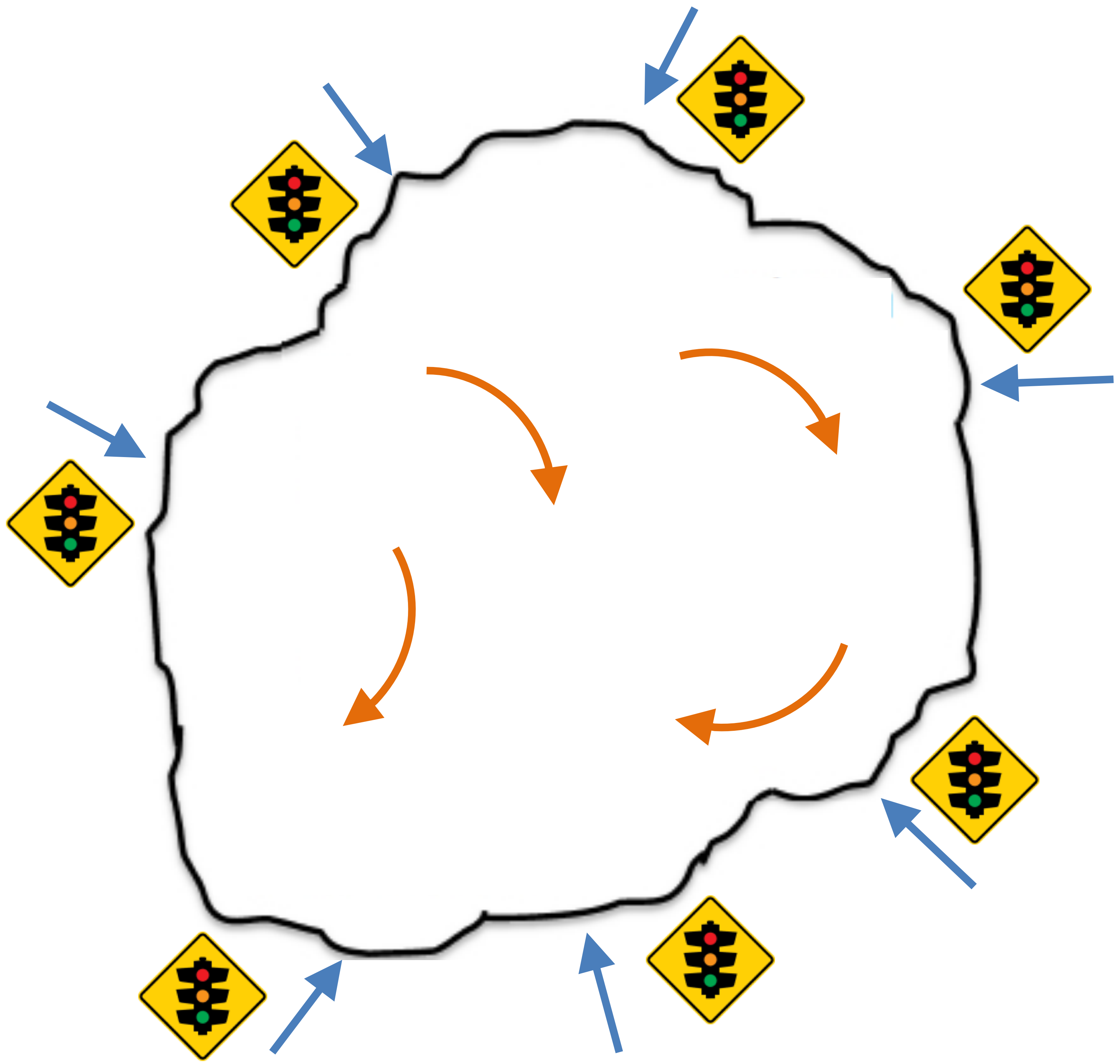


Single-region perimeter control



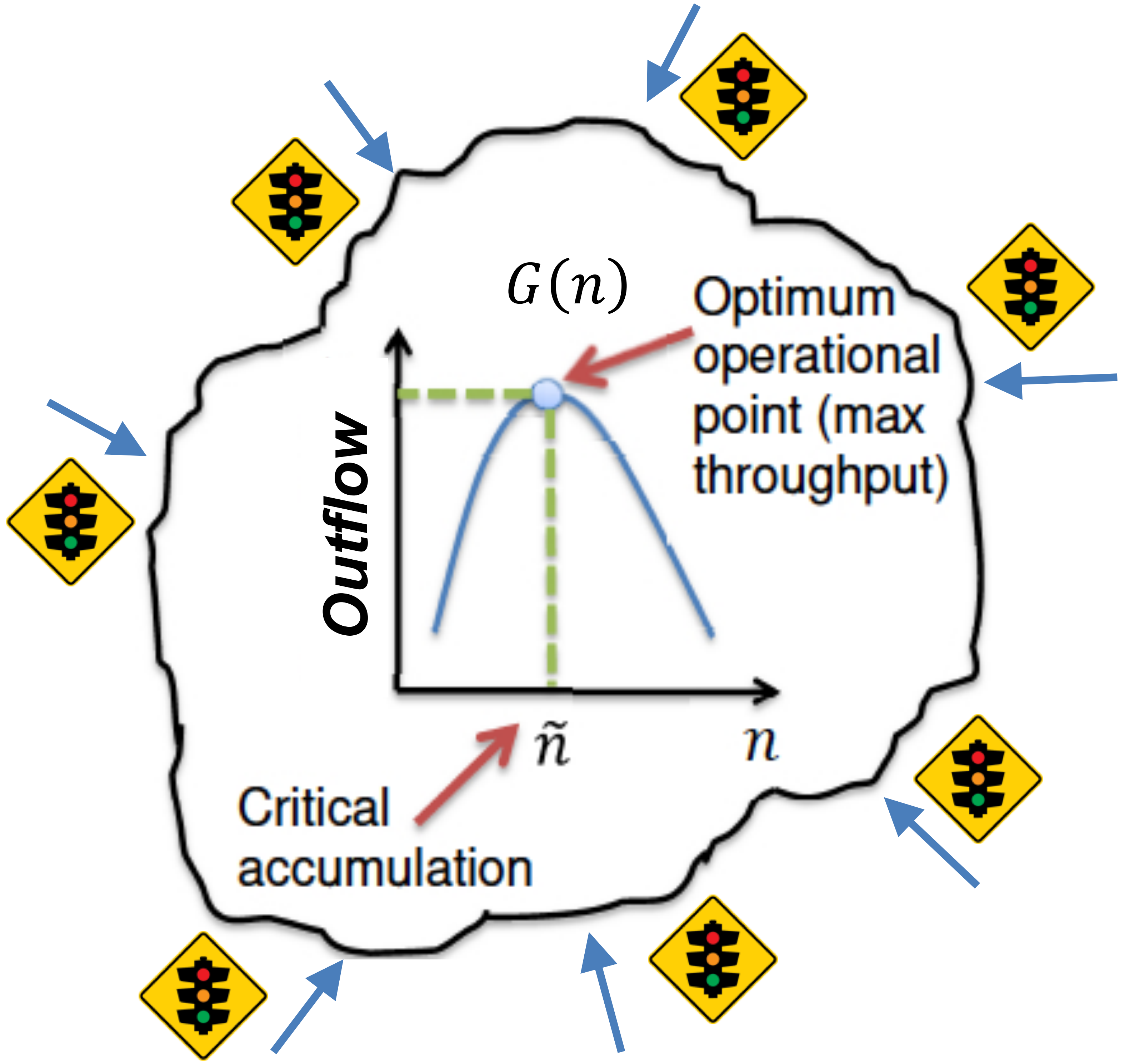
Daganzo, 2007

Single-region perimeter control



$$\frac{dn}{dt} = q(t) - G\big(n(t)\big)$$

$$q(t) = \begin{cases} q_{max} & if\ n(t) < \tilde{n} \\ q_{min} & if\ n(t) > \tilde{n} \\ G(\tilde{n}) & if\ n(t) = \tilde{n} \end{cases}$$

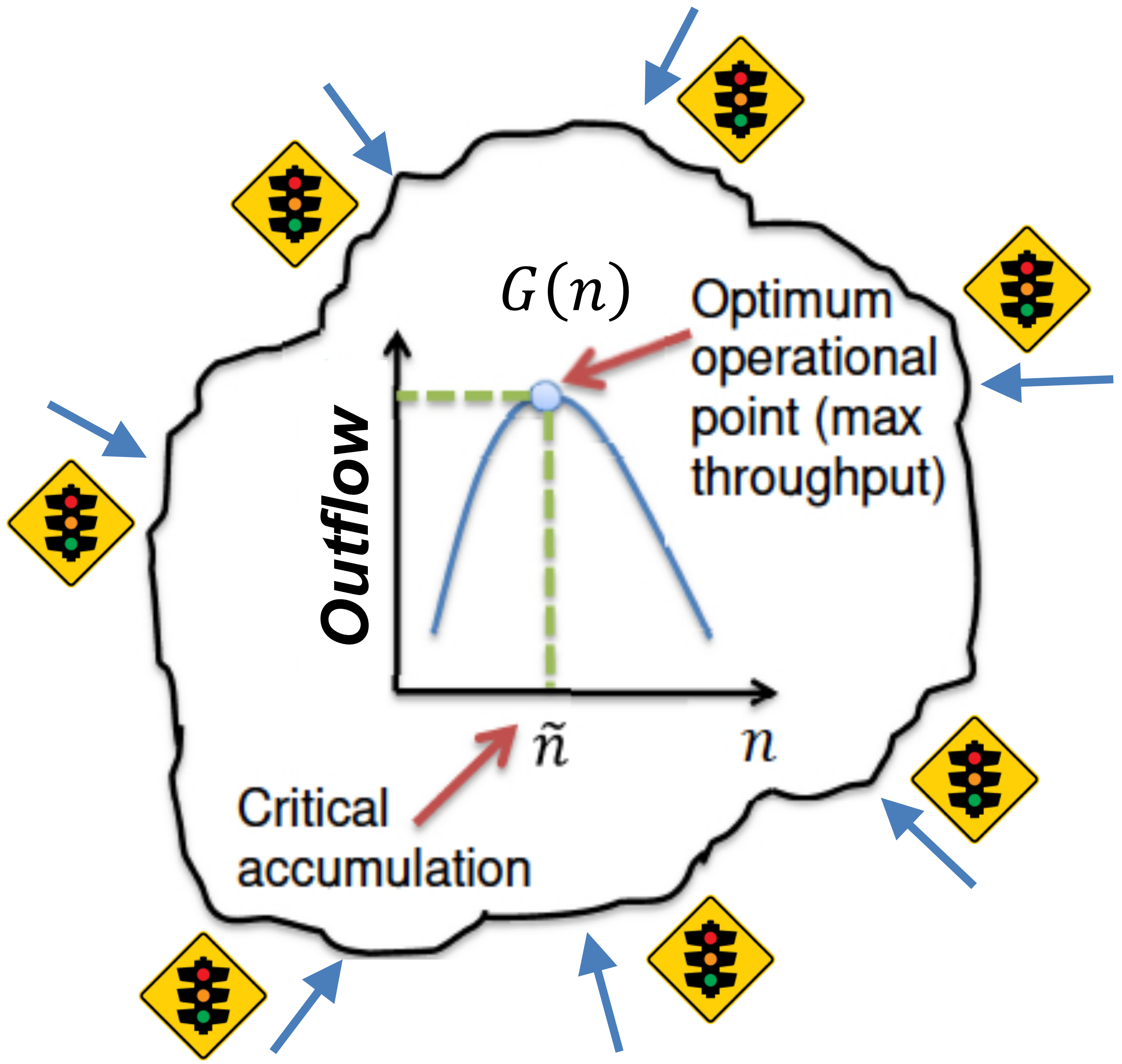


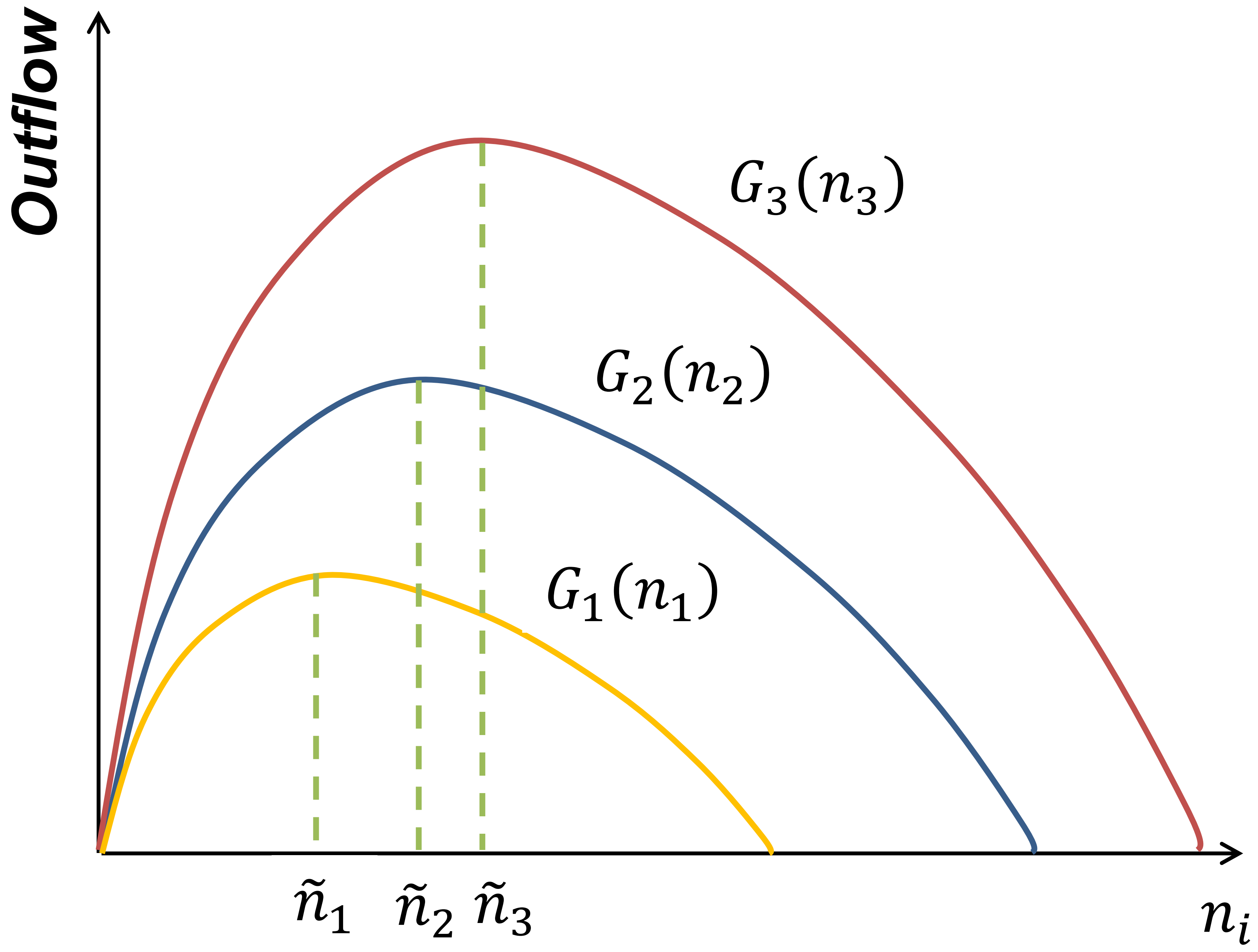
Internal inflow (uncontrolled)

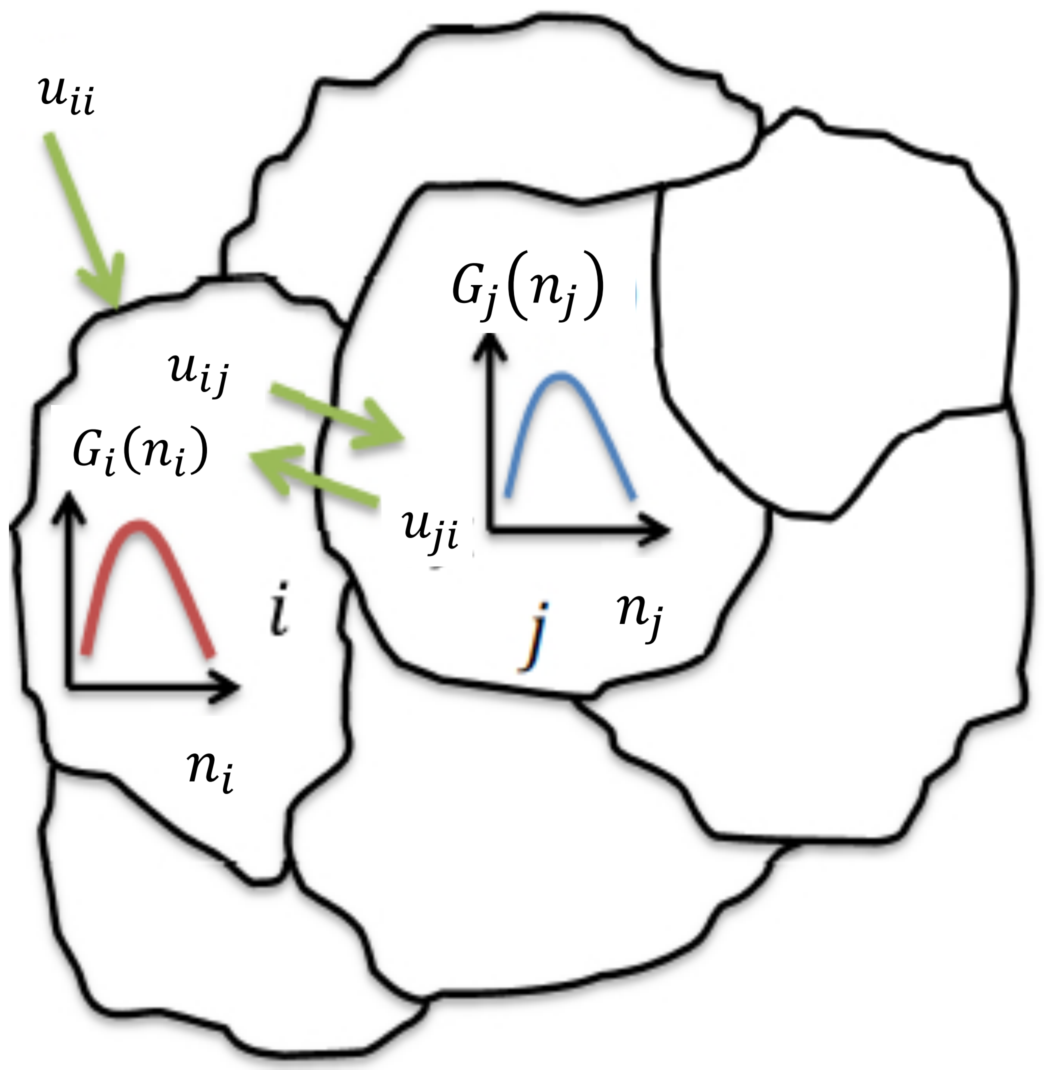
External inflow (controlled)

Daganzo, 2007

Control logic: from single- to multi-region







WHY MULTI-region?

- heterogeneously congested cities with multiple pockets of congestion (partitioning)
- High internal inflows (controllability)
- Avoid long queues at boundaries (equity)

LUTS publications, 2012-2018

Multi-region perimeter control (LQI control)

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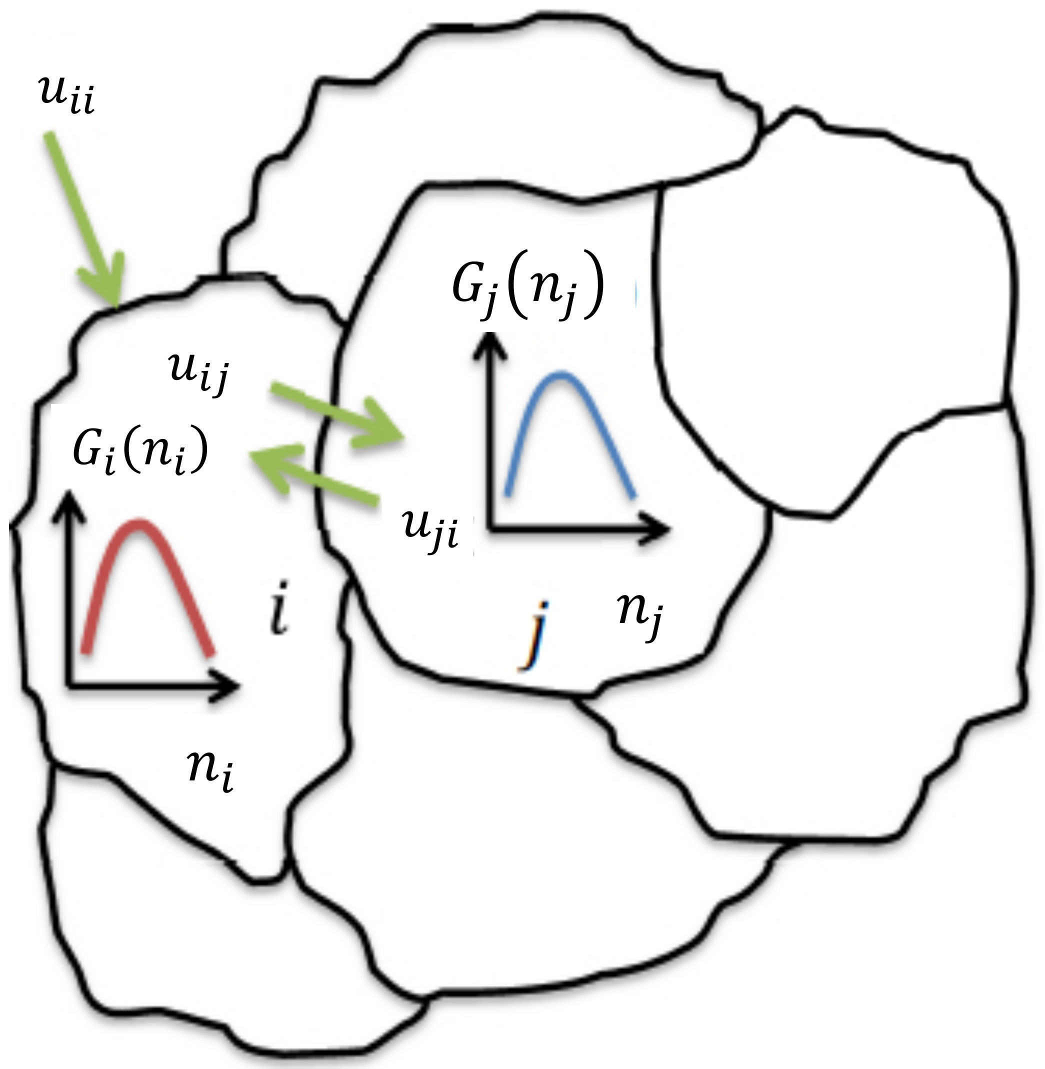
- **Given:** MFDs for each reservoir $G(n)$
- **Observe:** Accumulation $n_j(t)$
- **Control:** Boundary flows and external inflows
- **Maintain** Throughput Optimal Operational Point

- **Linear-Quadratic-Integral control** (multivariable PI-regulator)

$$\mathbf{u}(k) = \mathbf{u}(k-1) - \boxed{\mathbf{K}_\mathrm{P}}\,[\mathbf{n}(k) - \mathbf{n}(k-1)] - \boxed{\mathbf{K}_\mathrm{I}}\left[\mathbf{n}(k) - \boxed{\hat{\mathbf{n}}}\right]$$

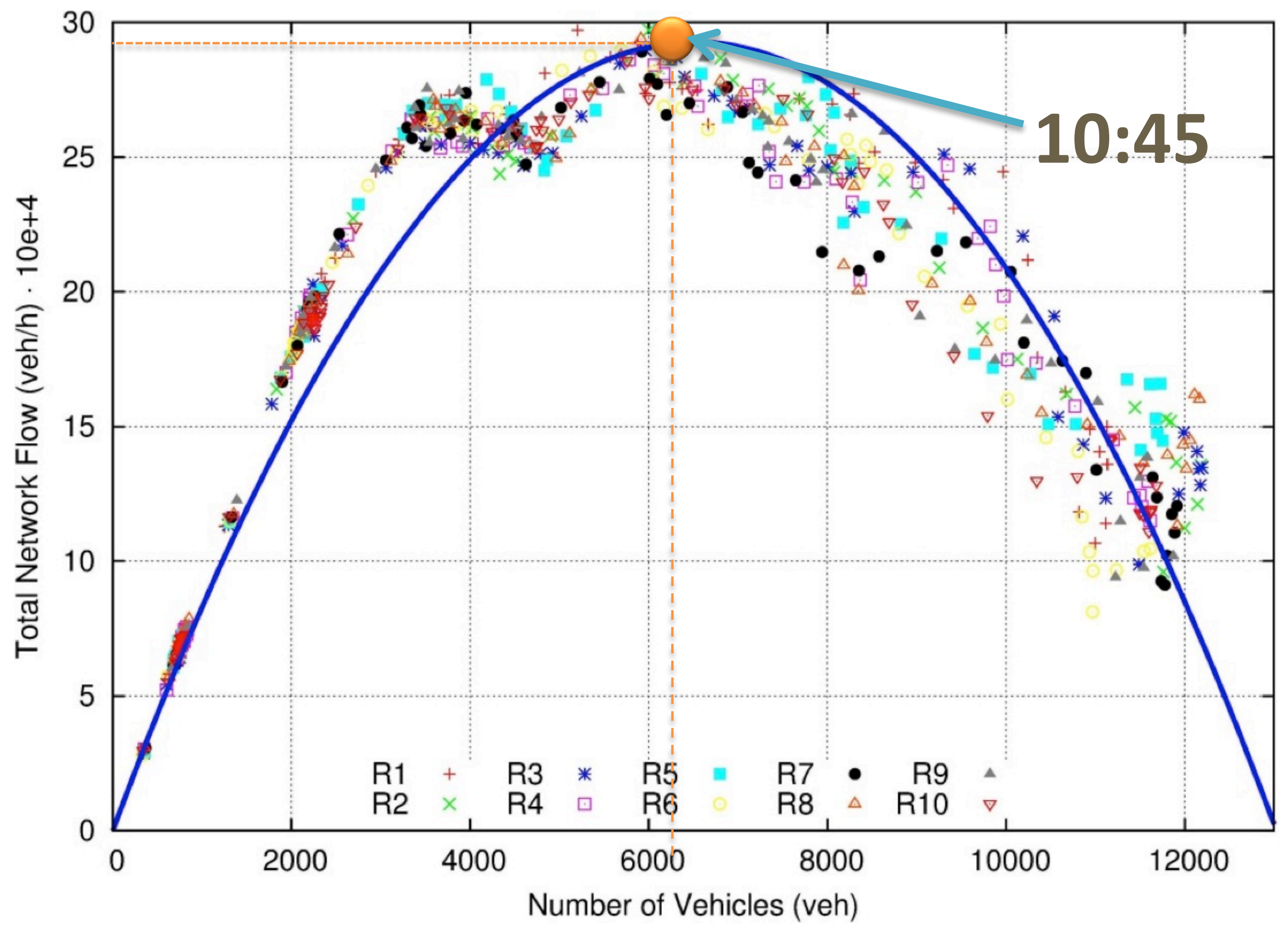
- $\mathbf{u}(k)$: control vector of $u_{ij}(k), \forall i \in \mathcal{N}, j \in \mathcal{N}_i$
- $\mathbf{n}(k) \in \mathbb{R}^N$: state vector of region accumulations $n_i(k), \forall i \in \mathcal{N}$
- $\hat{\mathbf{n}} \in \mathbb{R}^N$: vector of the set points $\hat{n}_i$ for each region i
- $\mathbf{K}_\mathrm{P}, \mathbf{K}_\mathrm{I}$: proportional and integral gains.

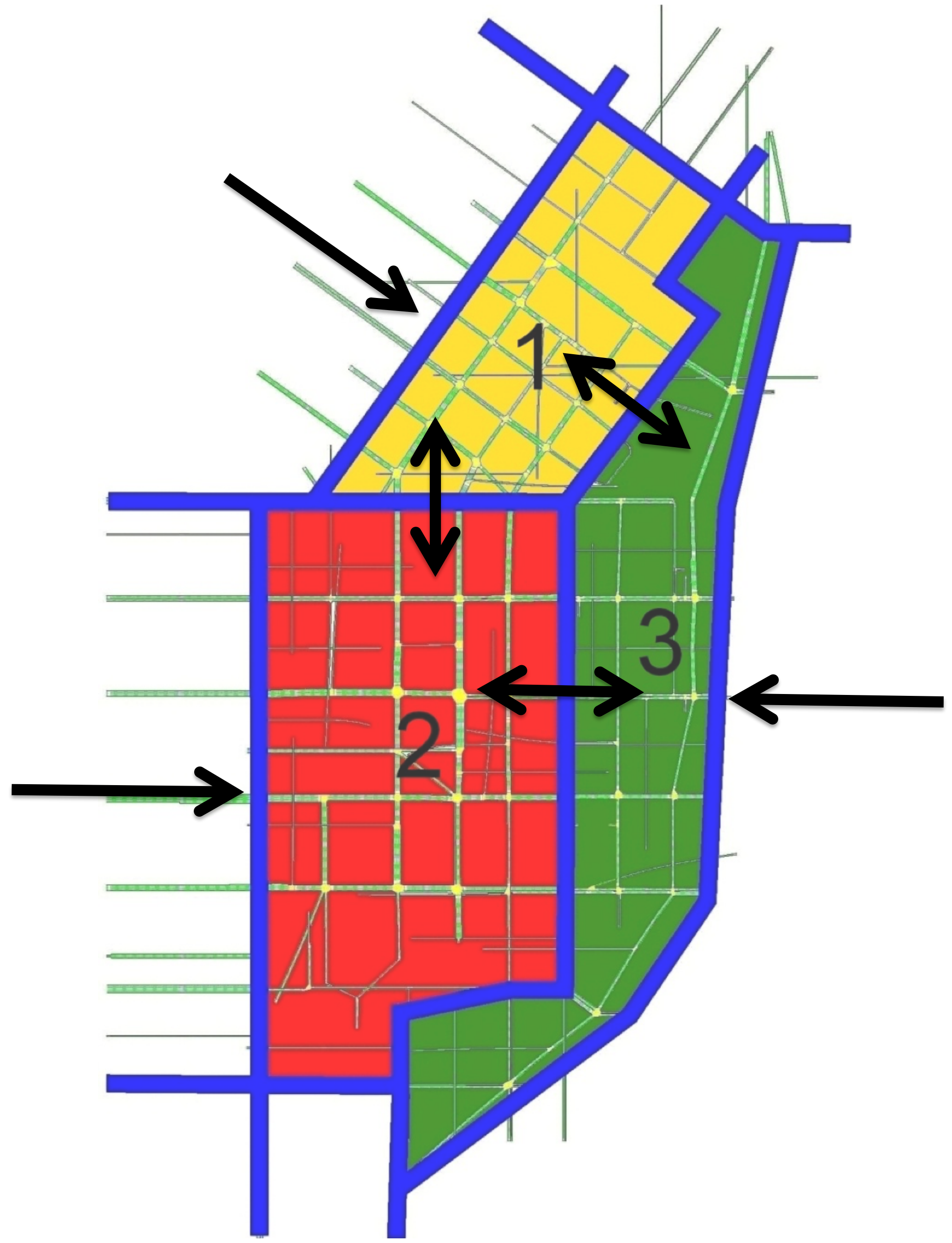


Aboudolas & Geroliminis, 2013

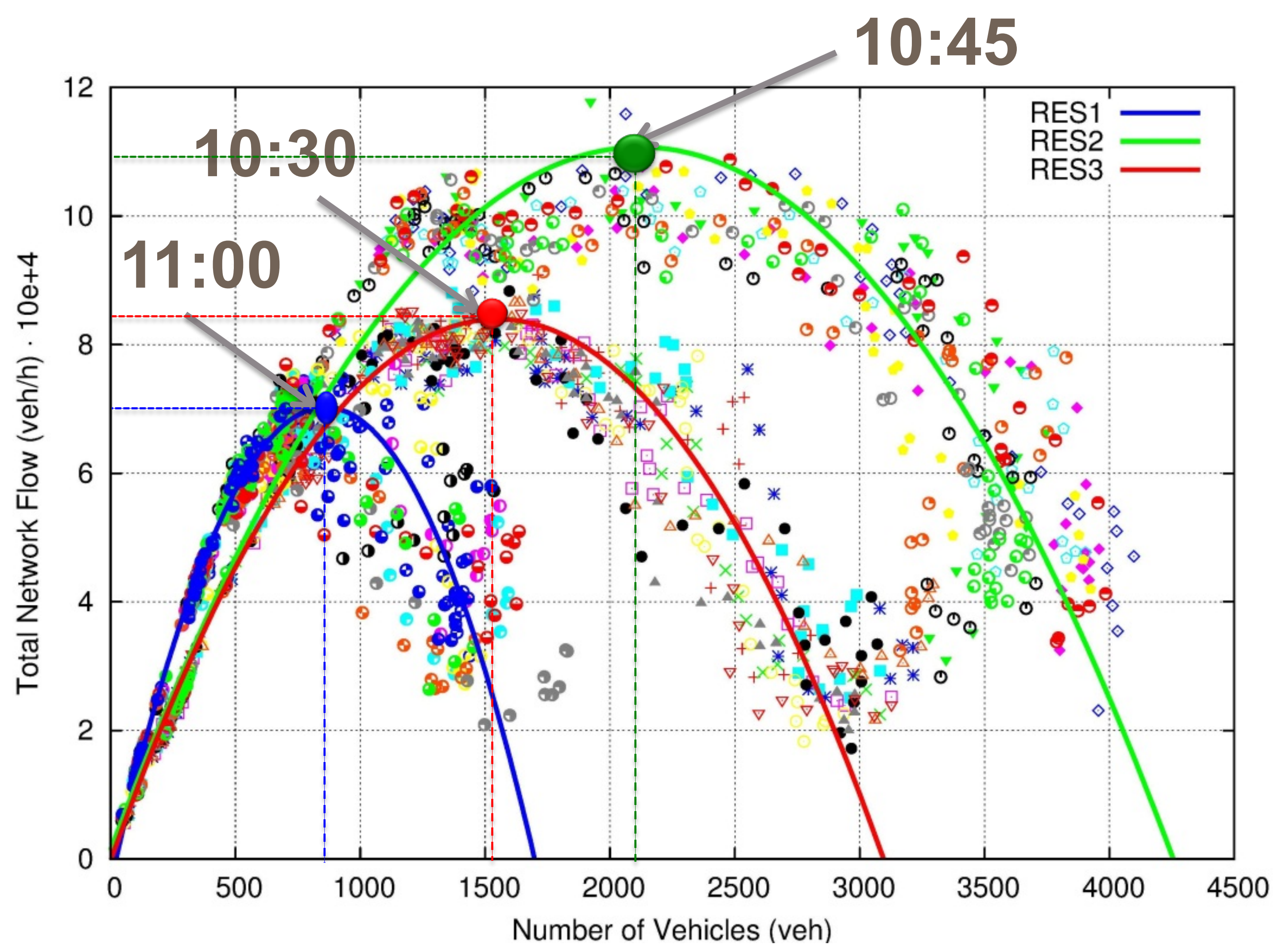
A multi-region case study

MFD for the original network





MFDs for each reservoir



Observations:

- MFD: regions exhibit MFDs with quite moderate scatter
- Heterogeneity: regions reach the congested regime at different times

Micro-simulation of different controllers

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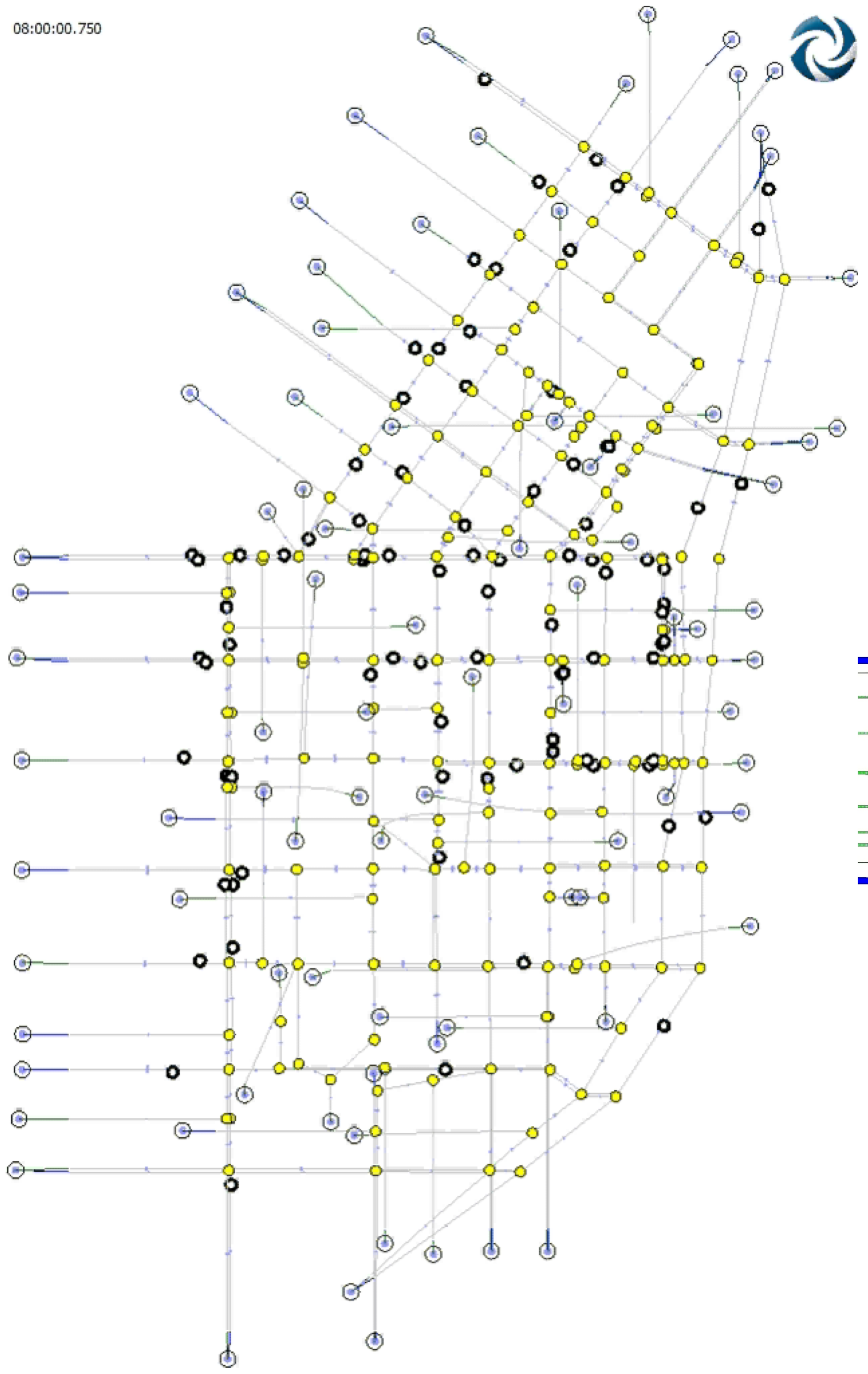
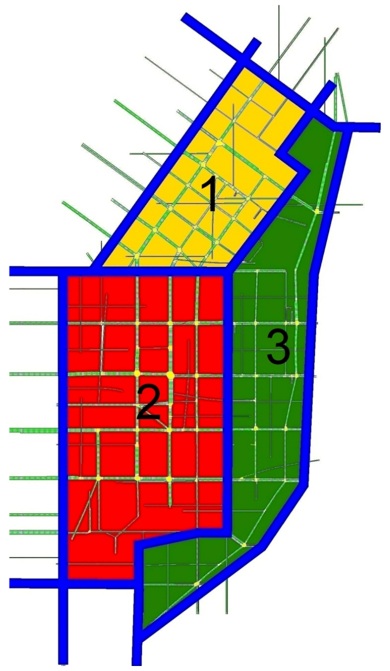
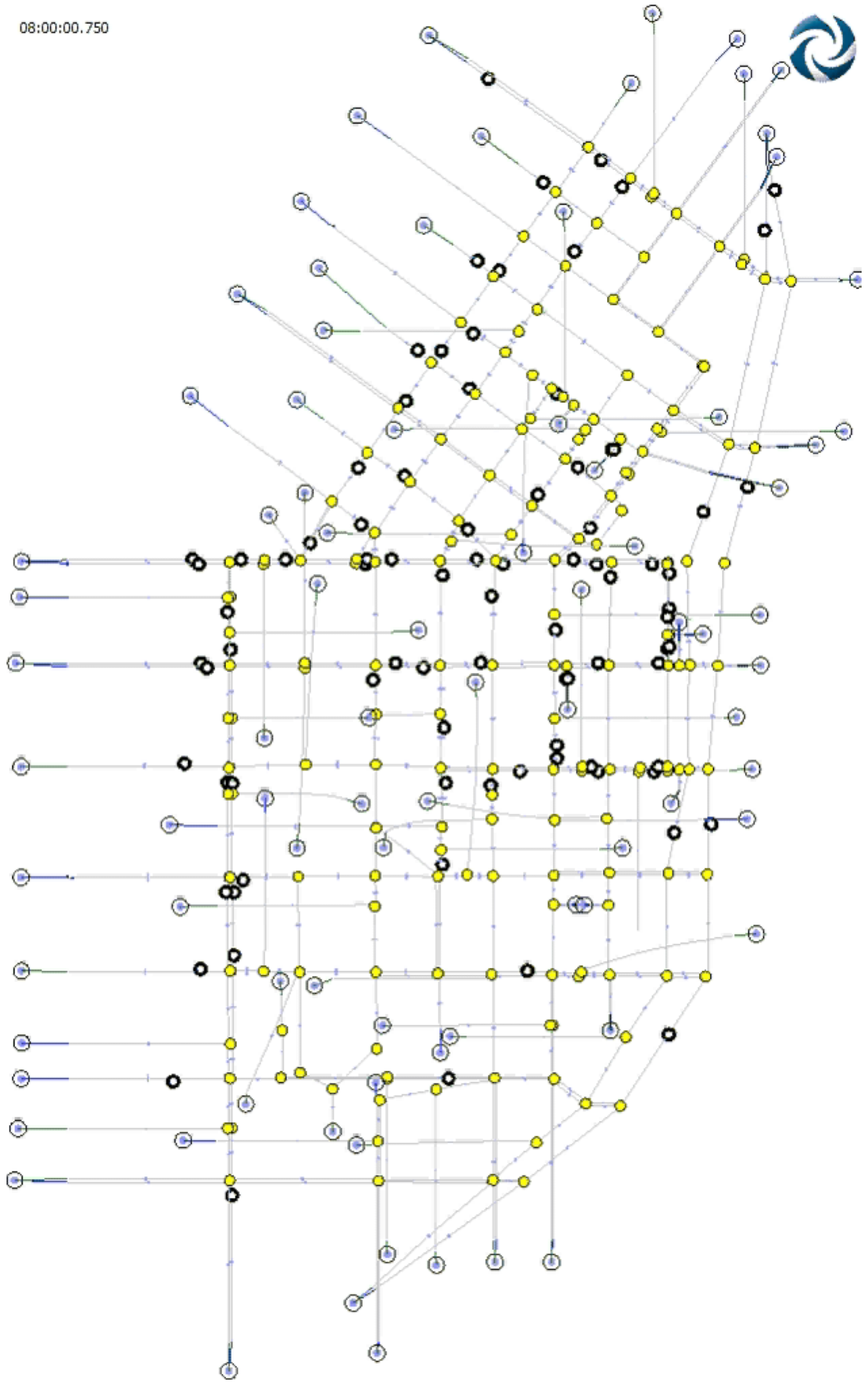
Pre-timed Traffic Control







Smart Traffic Control

Comparison of controllers

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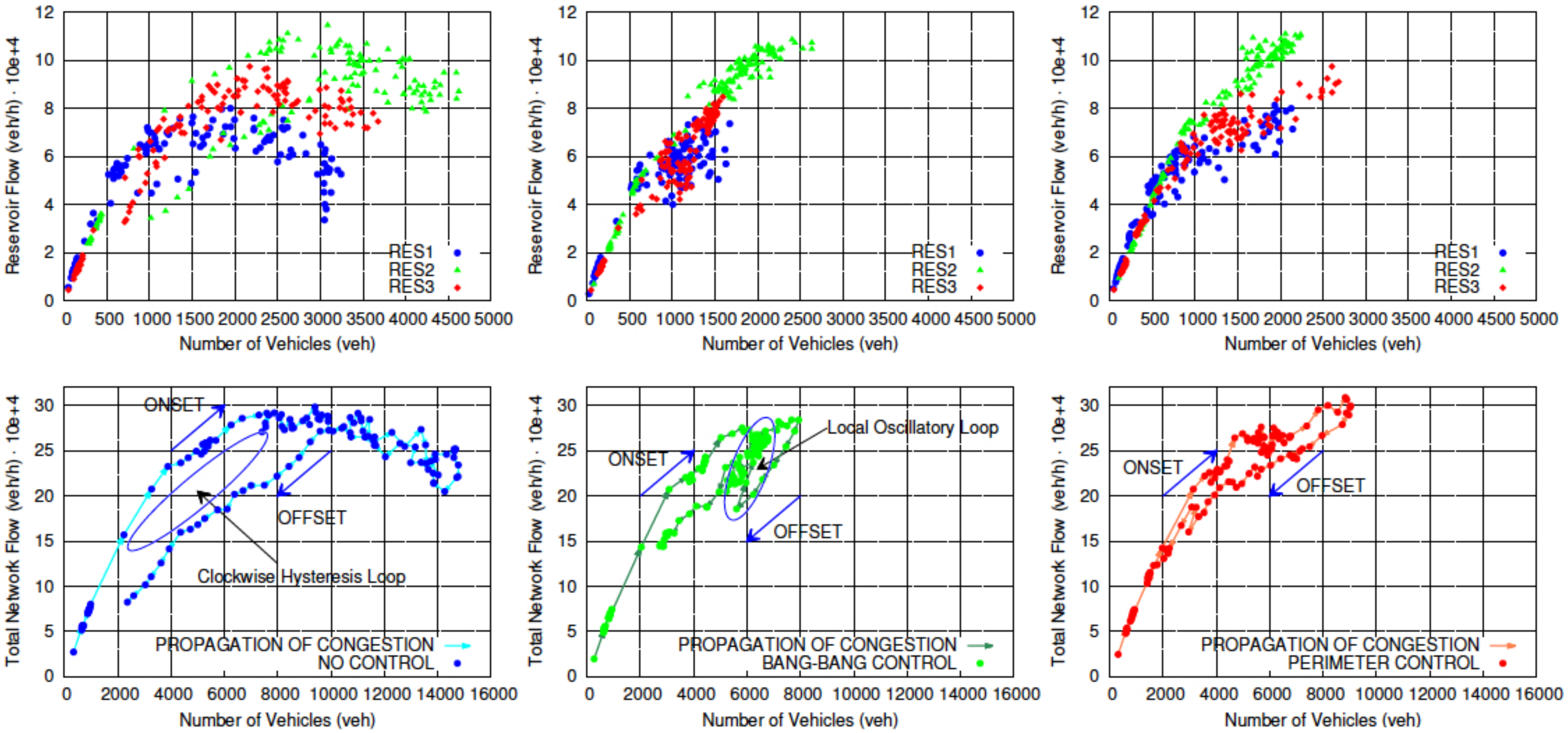
- Comparison with pre-timed fixed signals: improvement 33% for total travel time
- Comparison with Bang-bang control: Improvement 12%
- Multi-region PI: maintains throughput; respect reservoirs' homogeneity



Pre-timed fixed signals | Single-region Bang-Bang control | Multi-region PI control

A more advanced controller (PI + parameter fine tuning)

(a) Model-based multivariable PI regulator

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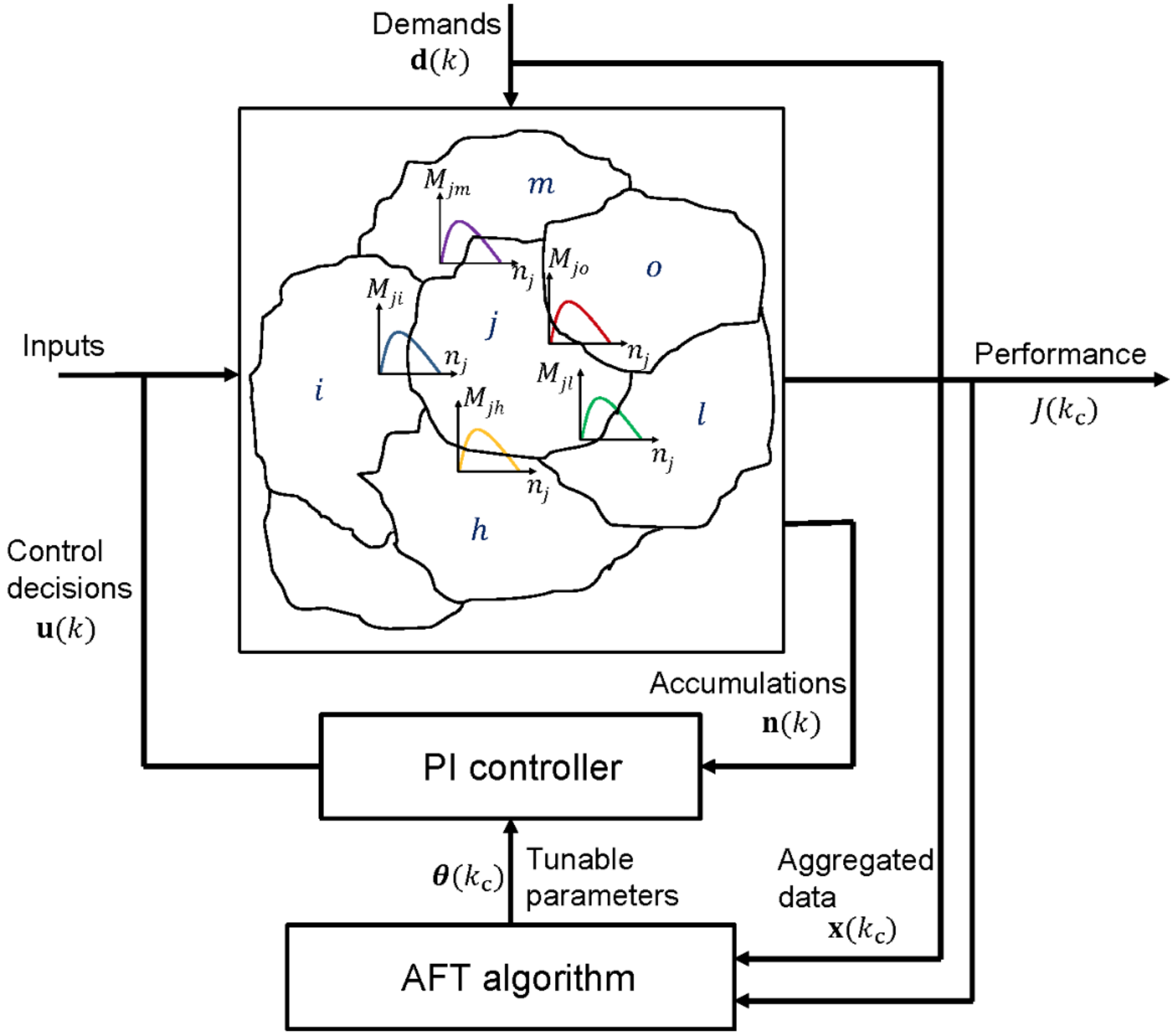
(b) Data-driven online adaptation

- At each iteration, AFT algorithm receives
  - the measured performance index J (total delay of the system)
  - the measurable external disturbances $\mathbf{x}$ (aggregated demand)
- Using the samples of the measured quantities AFT calculates new tunable parameter values to be applied at the next iteration.



AFT: automatic fine tuning

Kouvelas, Saeedmanesh & Geroliminis, 2017

A more advanced controller (PI + parameter fine tuning)

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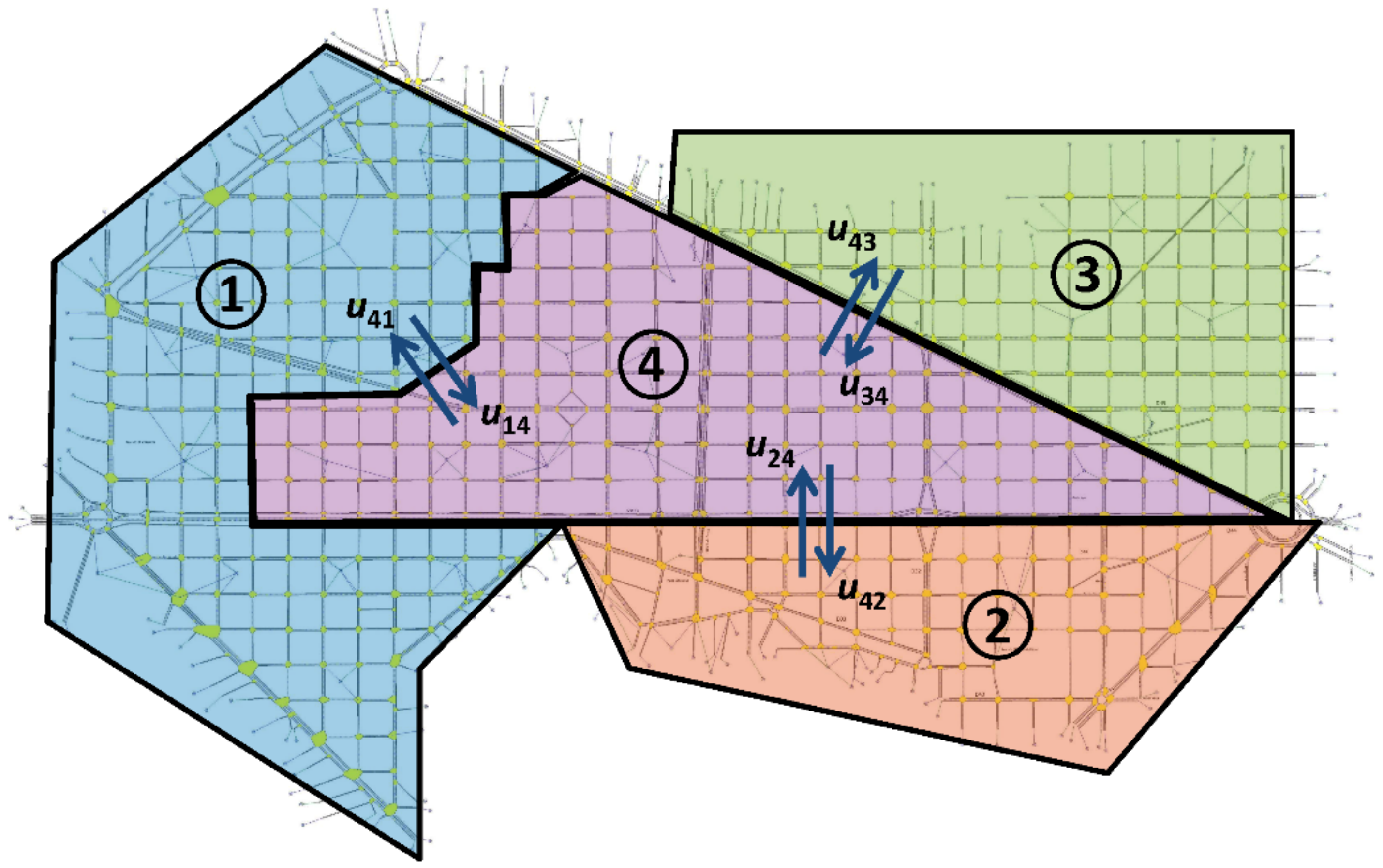

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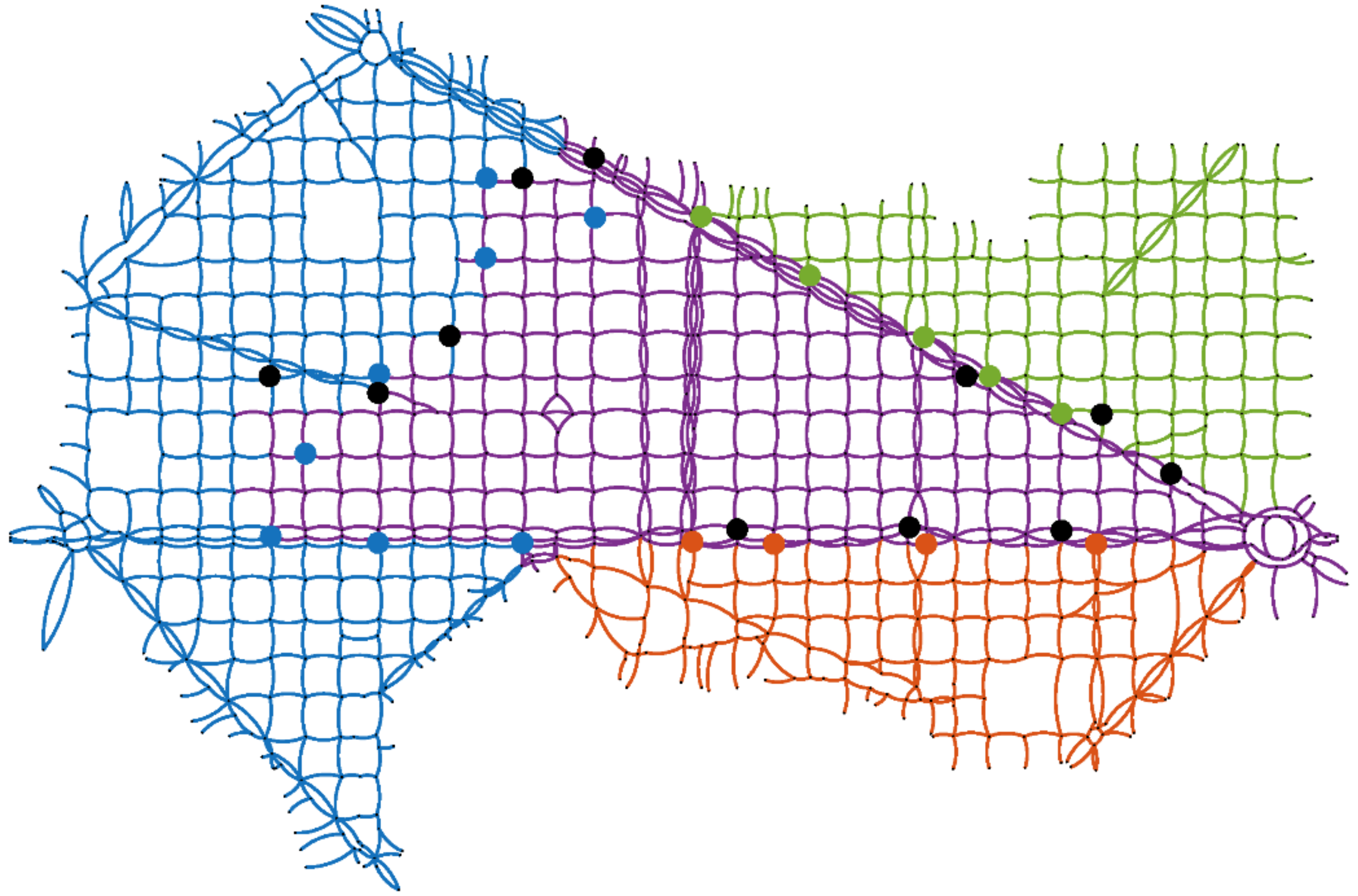
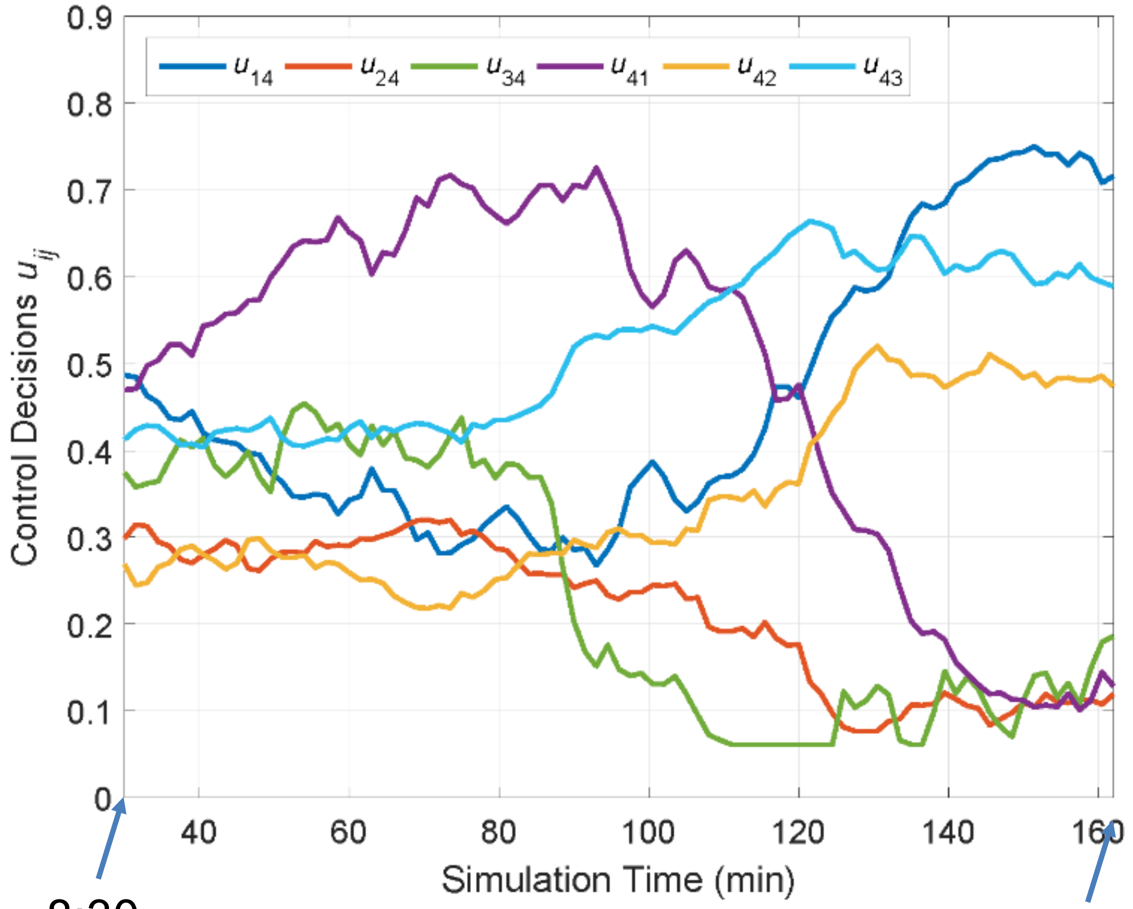


AFT: automatic fine tuning

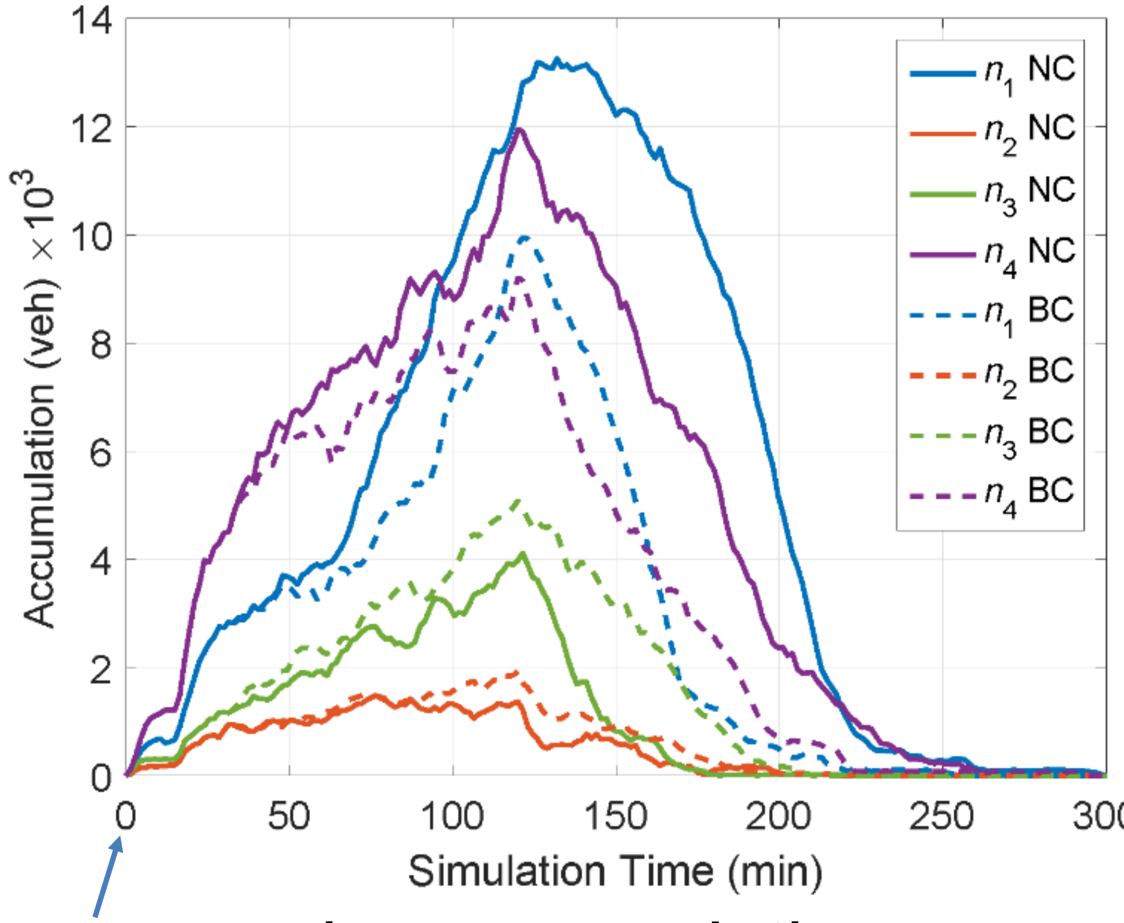
Kouvelas, Saeedmanesh & Geroliminis, 2017

Micro-simulation results



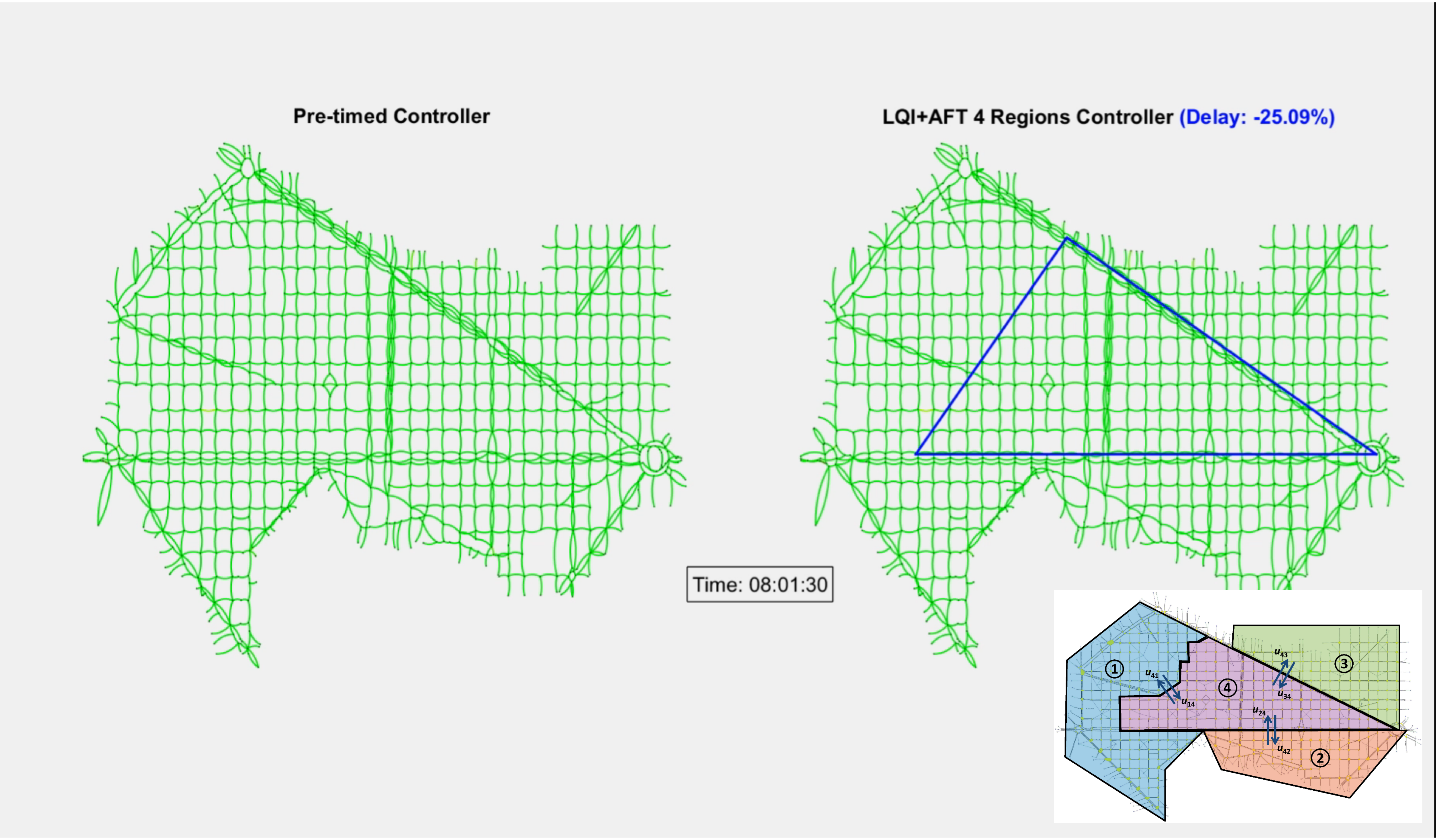
8:30 10:45

Control actions



8:00

region accumulations



MFD control - Summary