Model predictive control of large-scale urban networks via perimeter control and route guidance actuation

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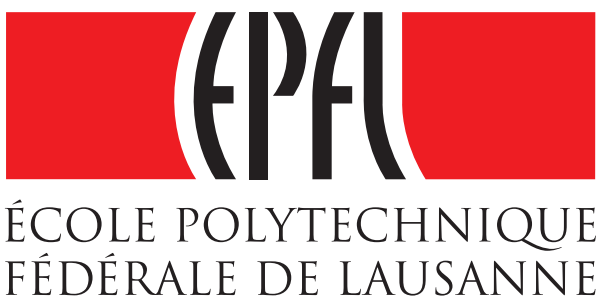
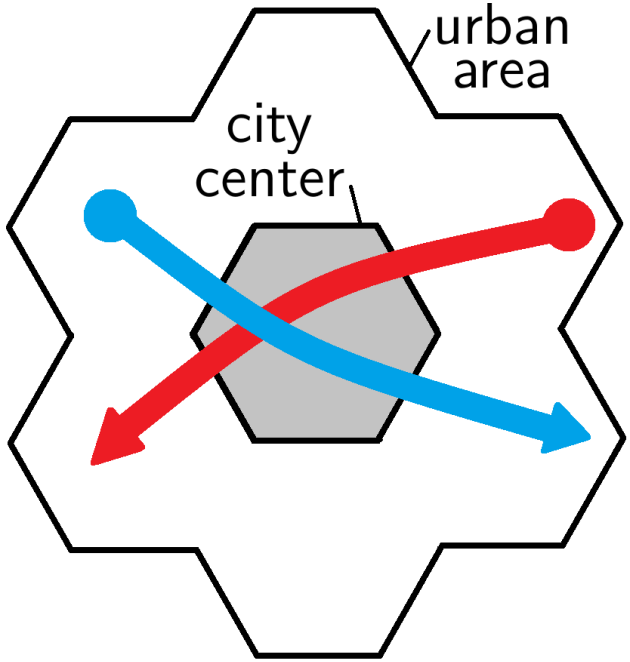


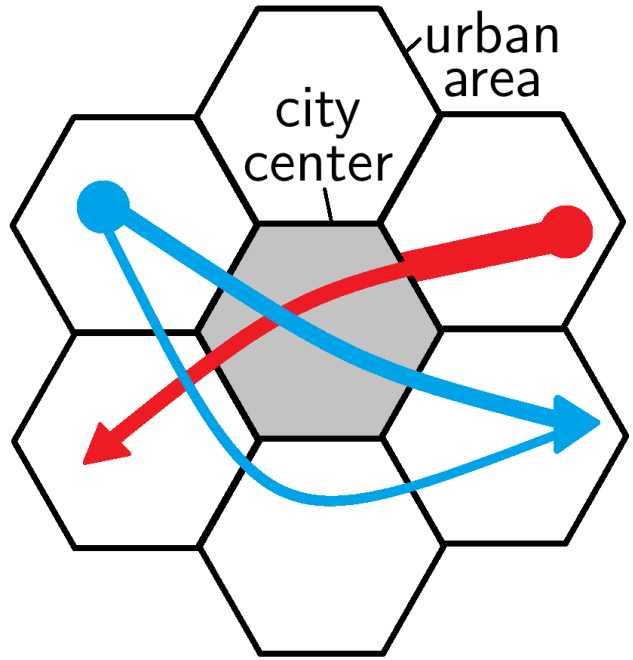
Motivation

Problem: Congestion



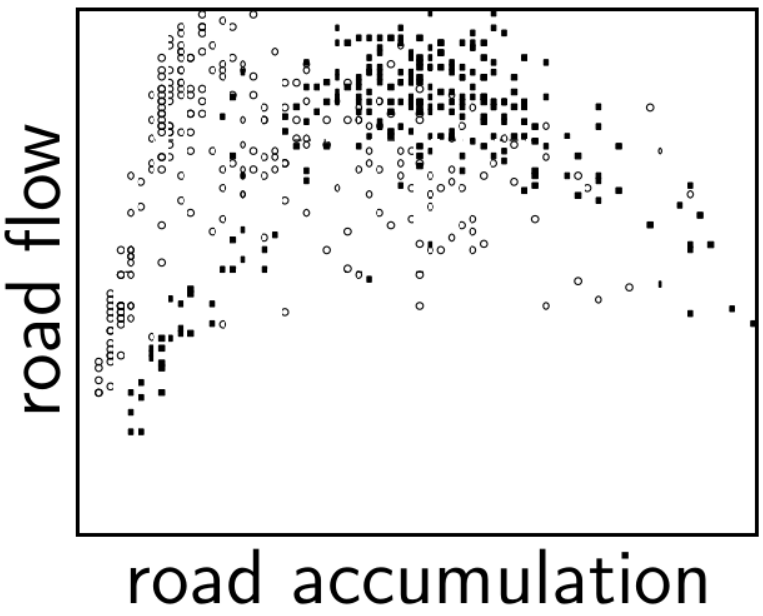
Center congested, network underused.

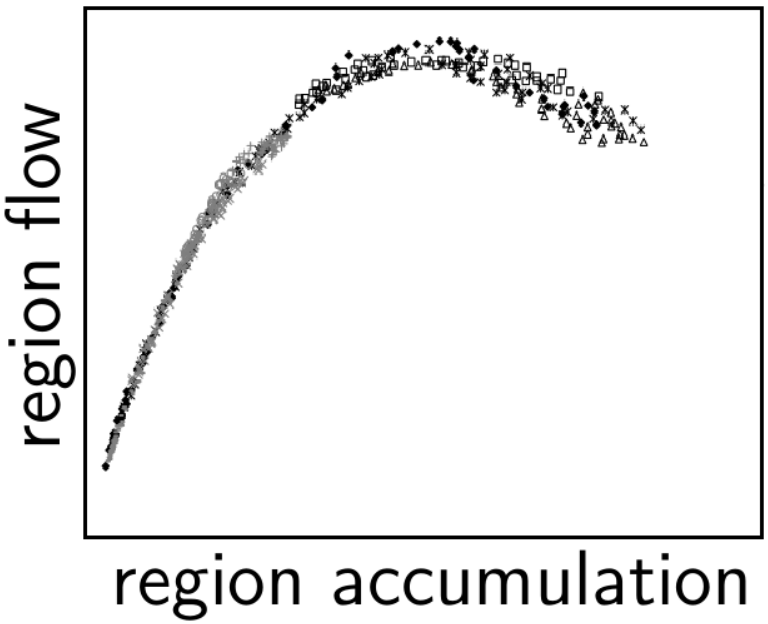
Solution: Control



Manipulate vehicle flows to use network efficiently.

Macroscopic fundamental diagram (MFD)[1]





$$\underbrace{G_i(n_i(t))}_{\text{trip completion flow (veh/s)}} = a_i n_i^3(t) + b_i n_i^2(t) + c_i n_i(t)$$

$n_i(t)$: accumulation (veh)

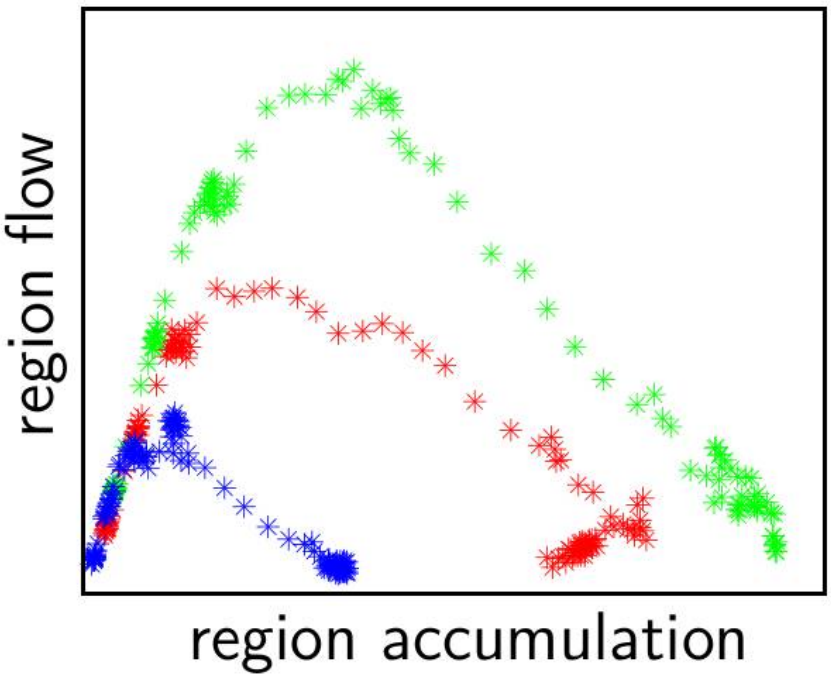
[1] Nikolas Geroliminis and Carlos F Daganzo. *Transportation Research Part B: Methodological* 42.9 (2008), pp. 759–770.

Spatial partitioning[2]

network map (accumulations)

network map (partition)

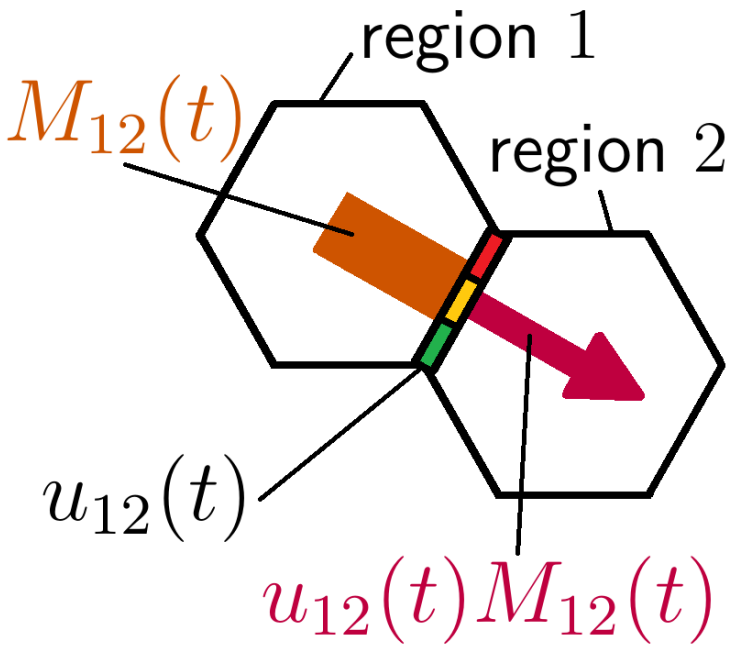
region MFDs



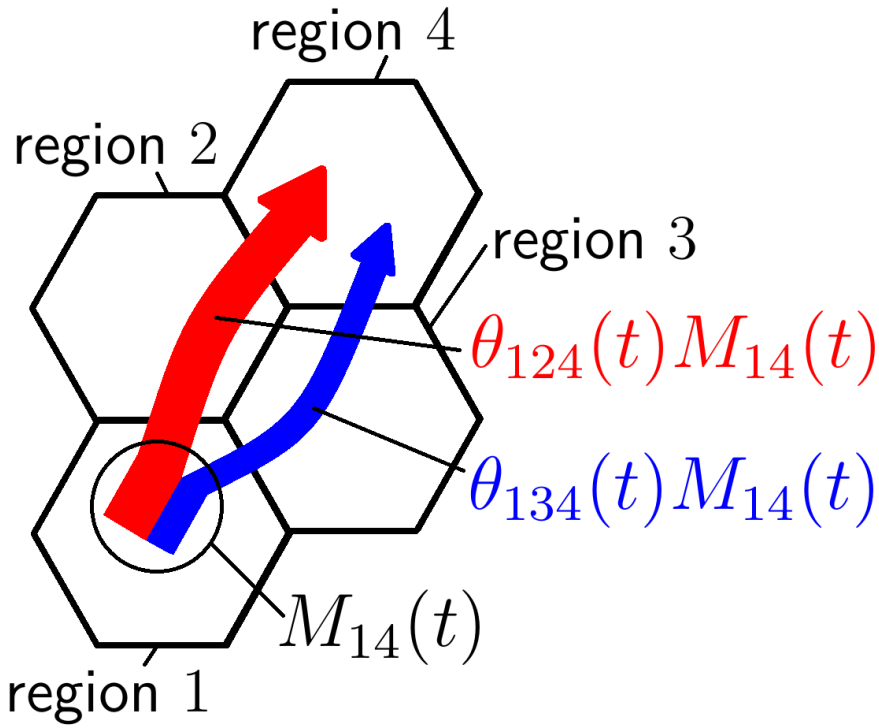
[2]Yuxuan Ji and Nikolas Geroliminis. *Transportation Research Part B: Methodological* 46.10 (2012), pp. 1639–1656.

Actuators

1) Perimeter control[3]



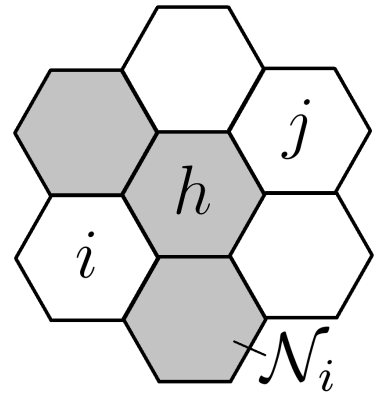
2) Route guidance[4]



[3] Nikolas Geroliminis, Jack Haddad, and Mohsen Ramezani. *IEEE Transactions on Intelligent Transportation Systems* 14.1 (2013), pp. 348–359.

[4] Mohammad Hajiahmadi et al. *16th International IEEE Conference on Intelligent Transportation Systems-(ITSC)*. IEEE. 2013, pp. 1022–1028.

MFDs network model[5]



$$\dot{n}_{ij}(t) = \overbrace{q_{ij}(t)}^{\text{inflow demand}} + \overbrace{\sum_{h \in \mathcal{N}_i^j} M_{hij}(t)}^{\text{inflow}} - \overbrace{\sum_{h \in \mathcal{N}_i} M_{ihj}(t)}^{\text{outflow}}$$

$$M_{ihj}(t) \triangleq \underbrace{u_{ih}(t)}_{\substack{\text{perimeter} \\ \text{control}}} \underbrace{\theta_{ihj}(t)}_{\substack{\text{route} \\ \text{guidance}}} \frac{n_{ij}(t)}{n_i(t)} \underbrace{G_i(n_i(t))}_{\substack{\text{trip} \\ \text{completion} \\ \text{flow}}}$$

[5] Mehmet Yildirimoglu, Mohsen Ramezani, and Nikolas Geroliminis. *Transportation Research Part C: Emerging Technologies* 59 (2015), pp. 404–420.

Model predictive control (MPC)

$$\underset{u_{ih}(\cdot),\ \theta_{ihj}(\cdot)}{\text{minimize}} \quad \int_t^{t+T} \sum_{i \in \mathcal{R}} n_i(\tau) d\tau$$

subject to $\quad \forall i, j \in \mathcal{R}:$

$$n_{ij}(t) = \hat{n}_{ij}(t)$$

$$\forall \tau \in [t, t+T]:$$

MFDs network model

$$0 \leq n_{ij}(\tau),\ n_i(\tau) \leq n_{i,\text{jam}}$$

$$u_{\text{min}} \leq u_{ih}(\tau) \leq u_{\text{max}},\ \forall h \in \mathcal{N}_i$$

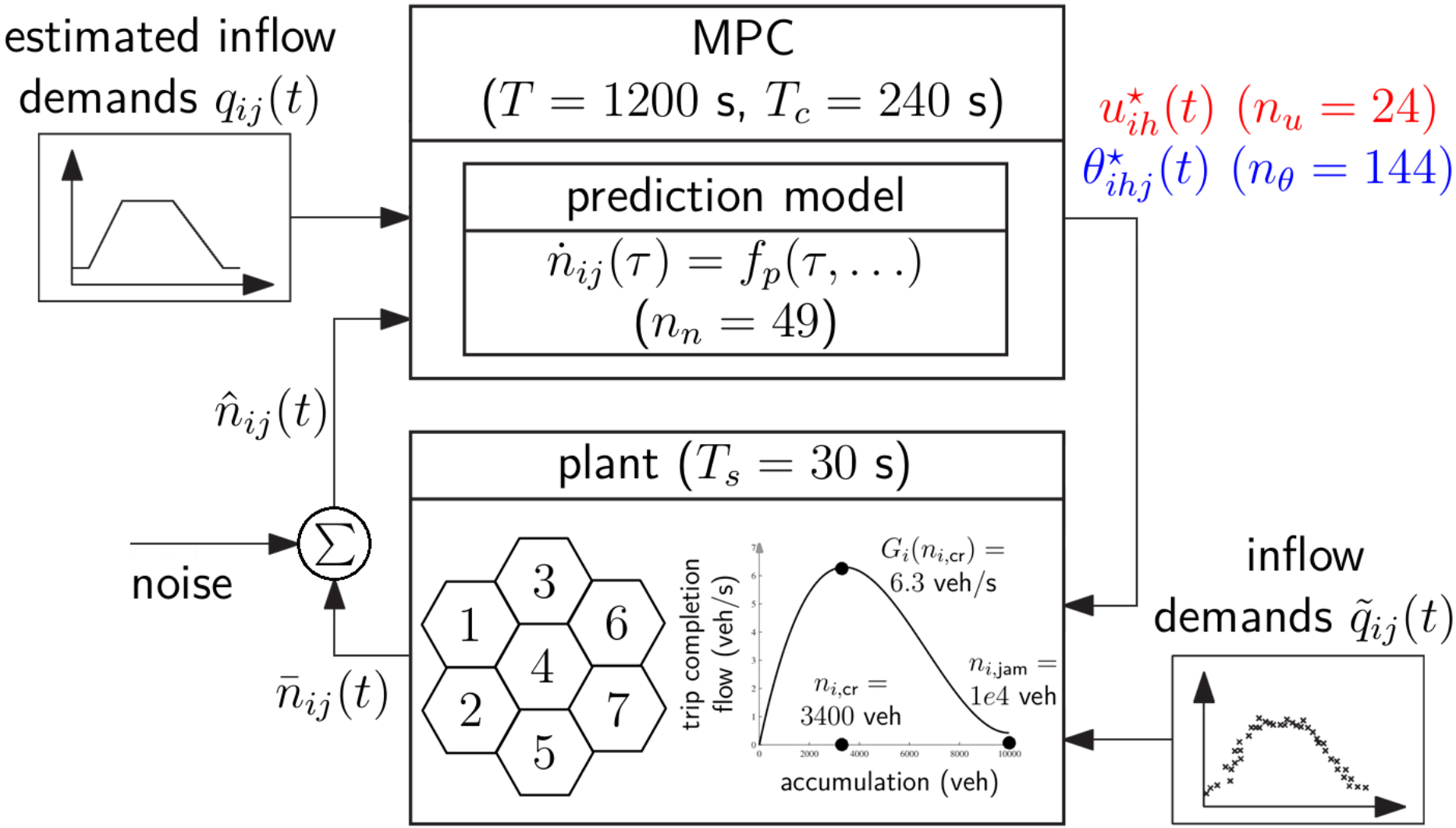
$$0 \leq \theta_{ihj}(\tau) \leq 1,\ \forall h \in \mathcal{N}_i$$

$$\sum_{h \in \mathcal{N}_i} \theta_{ihj}(\tau) = 1$$

Actuation schemes

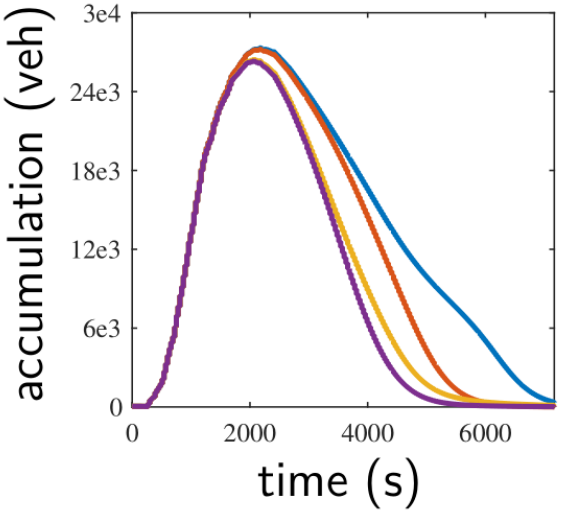
1. No control (NC)
   - $u_{ih}(t)$ fixed to $u_{\max}$; $\theta_{ihj}(t)$ via route choice
2. Perimeter control MPC (PC)
   - Control input: $u_{ih}(\cdot)$; $\theta_{ihj}(t)$ via route choice
3. Route guidance MPC (RG)
   - Control input: $\theta_{ihj}(\cdot)$; $u_{ih}(t)$ fixed to $u_{\max}$
4. Perimeter control and route guidance MPC (PCRG)
   - Control input: $u_{ih}(\cdot)$ and $\theta_{ihj}(\cdot)$

Control structure/simulation setup

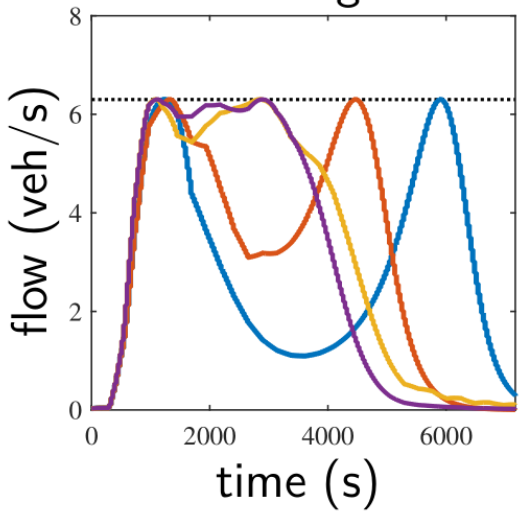


Congested scenario

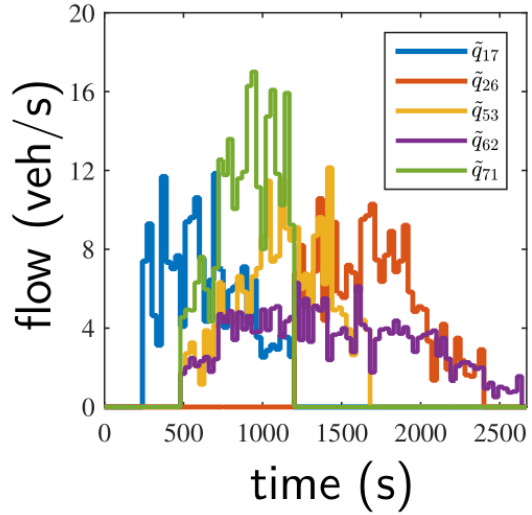
network accumulation



trip completion flow of region 4

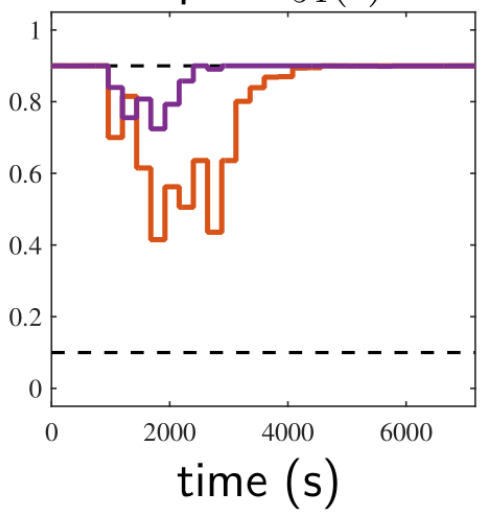


inflow demands $q_{ij}(t)$

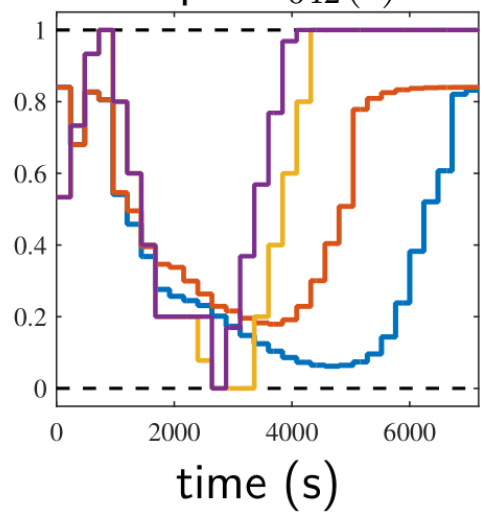


control scheme	imprv. over NC (%)	max. comp. time (s)
NC	0	–
PC	14	1.6
RG	27	6.1
PCRG	31	7.2

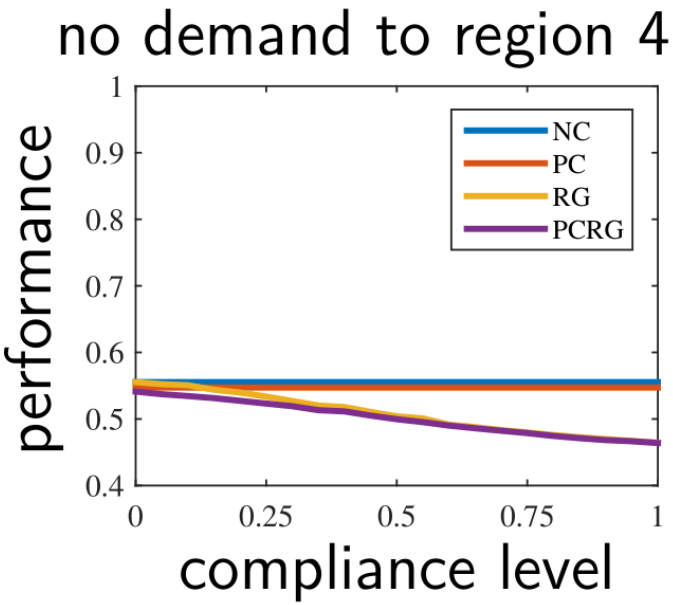
perimeter control input $u_{54}(t)$

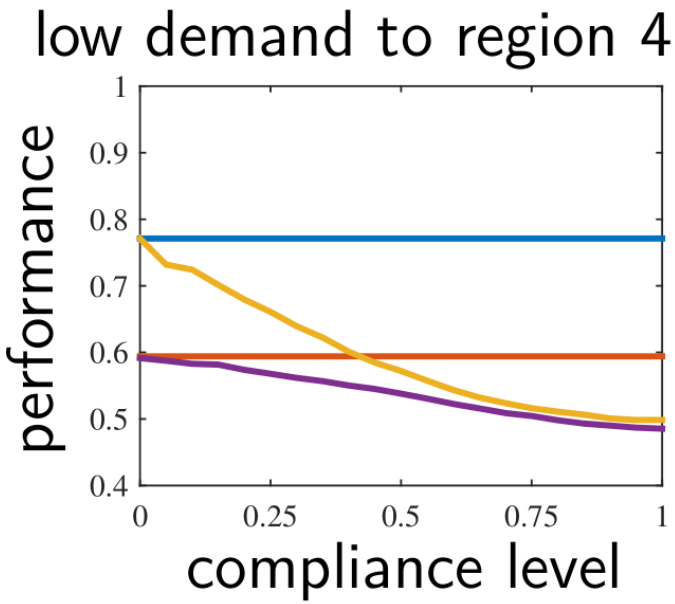


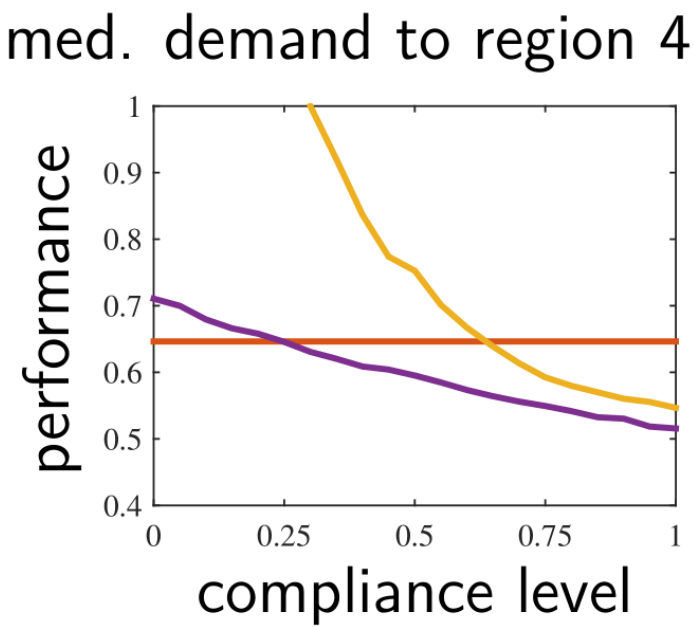
route guidance input $\theta_{642}(t)$

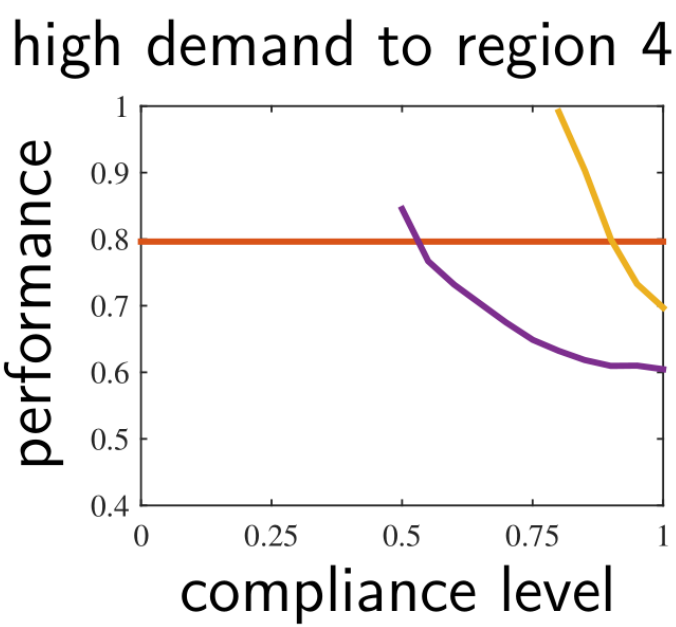


Driver compliance analysis









Conclusion

Contribution:

- MPC with perimeter control and route guidance

Results:

- Improvement via route guidance
- Perimeter control to avoid severe congestion

Future work:

- How to realize $\theta_{ihj}(t)$? Assign drivers to paths

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