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Distributed Perimeter Control for Urban Road Network Considering Heterogeneous Cordon Traffic Conditions

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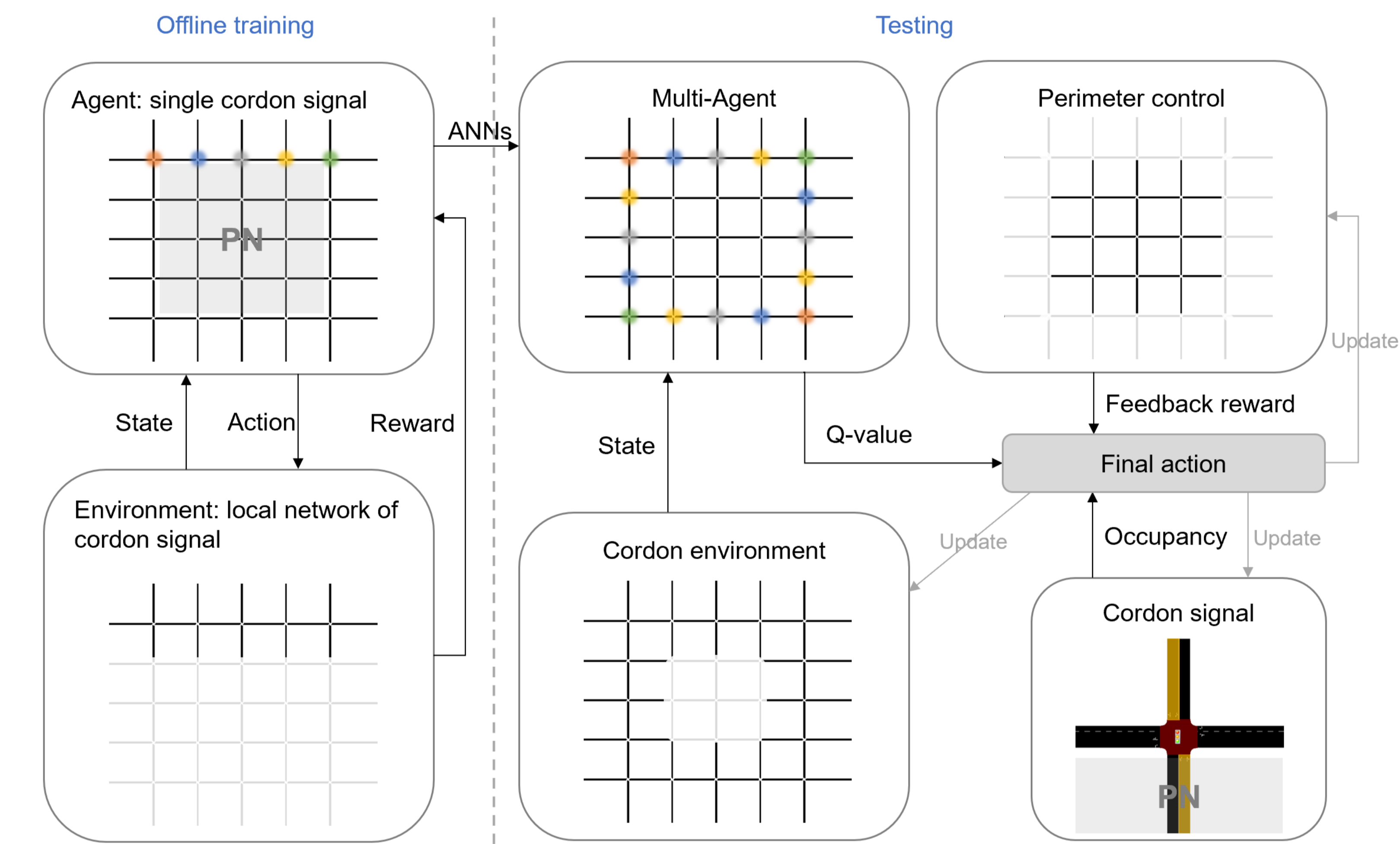
Motivation

In most existing Perimeter Control (PC) studies:

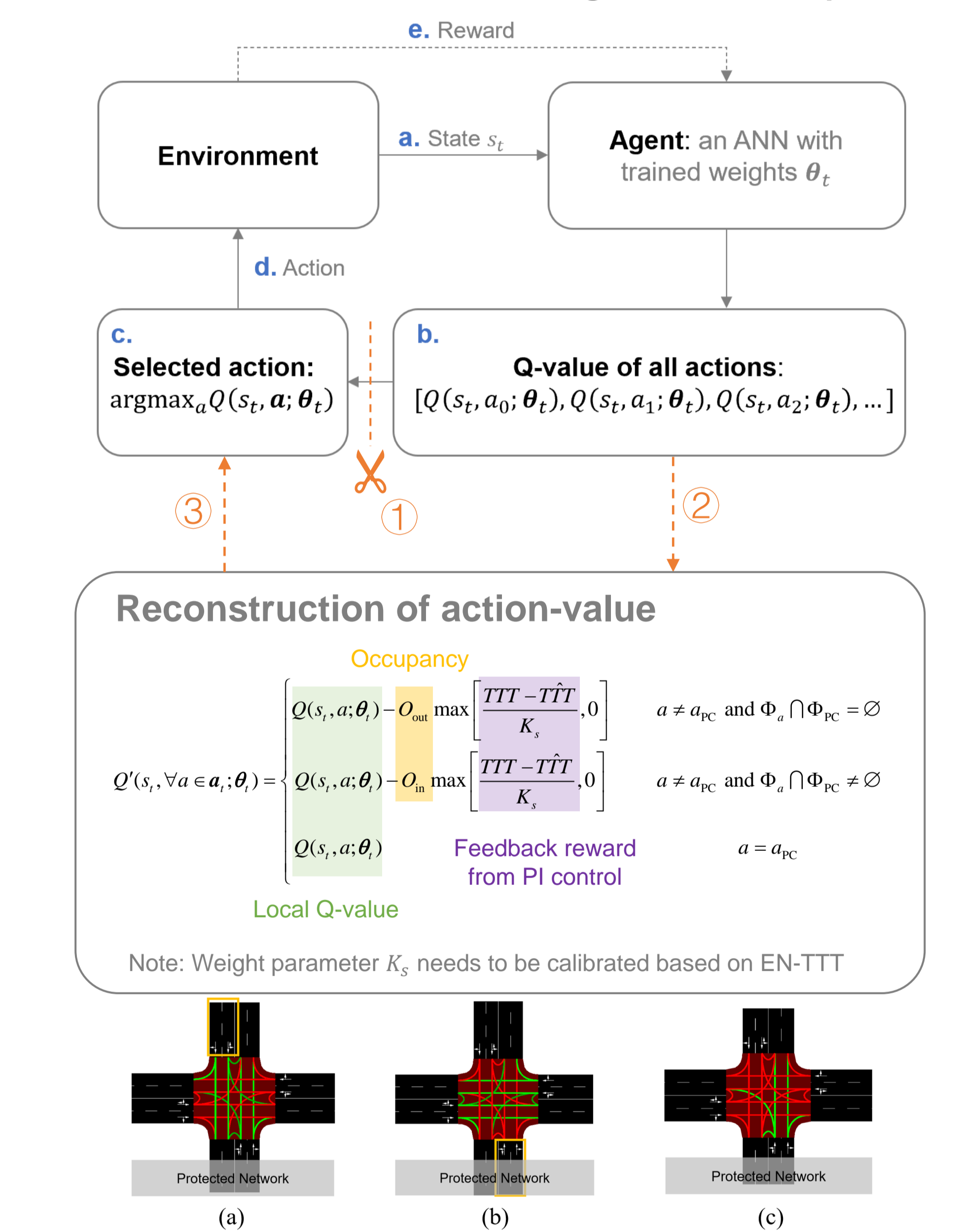
- Uniform metering rate for cordon signals ignores the variety of local traffic states at the intersection level
- Centralized control framework lacks scalability and transferability
- RL techniques have the potential to enhance PC with model-free and responsive properties

A distributed PC strategy based on a semi-model dependent Multi-Agent Reinforcement Learning (MARL) framework is proposed, enabling heterogeneity in the response of cordon signals.

Semi-model dependent MARL framework



Testing process - Integration of local RL-based and global PI-based policies



Offline training - Local signal control agent

State

- Total waiting time $D_{i,t}$
- Occupancy $O_{i,t}$
- Number of yellow phases in last 10 decision steps $n_{i,t}^y$
- Last actions of the agent and its neighbors

Action

- Predefined phase
- Yellow phase for switch

$$\text{Reward } r_{i,t} = r'_{i,t} + r''_{i,t} + r'''_{i,t}$$

Reduction degree of total waiting time

$$r'_{i,t} = \begin{cases} 1 & , D_{i,t} < D_{i,t-1} \\ 0 & , D_{i,t} = D_{i,t-1} \\ -1 & , D_{i,t} > D_{i,t-1} \end{cases}$$

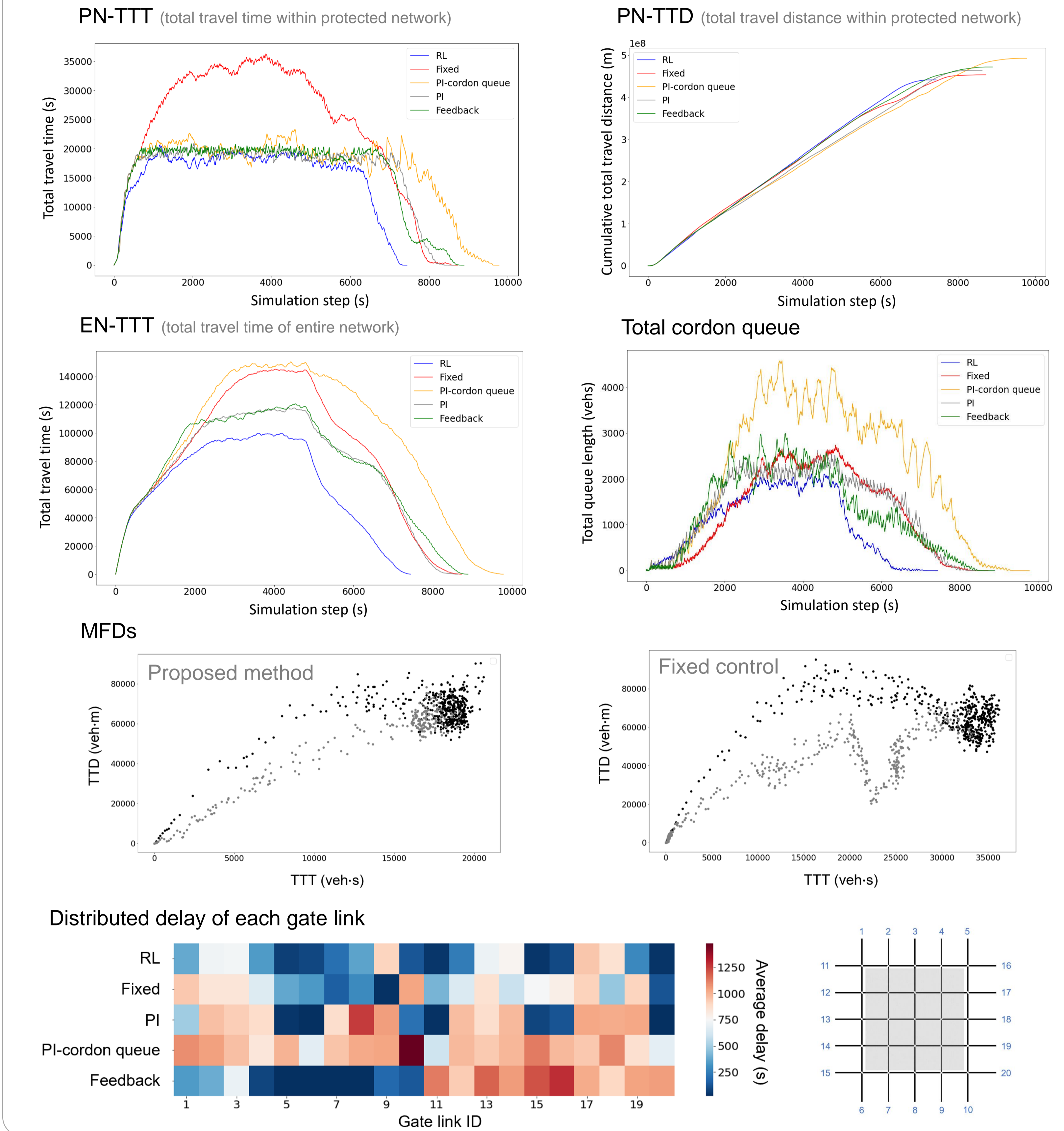
Occupancy of incoming lanes

$$r''_{i,t} = \begin{cases} 0 & , O_{i,t} < 0.5 \\ -1 & , O_{i,t} > 0.5 \end{cases}$$

Stability of phase switching

$$r'''_{i,t} = \begin{cases} 0 & , n_{i,t}^y \leq 2 \\ -1 & , n_{i,t}^y > 2 \end{cases}$$

Simulation tests



Control Strategy	PN-TTT (10 ⁵ veh·s)	PN-TTD (10 ⁶ veh·m)	EN-TTT (10 ⁵ veh·s)	Total cordon queue (10 ⁵ veh·s)
Our study	57.75	22.06	239.93	75.02
Fixed	102.10	22.67	373.86	108.26
PI	69.41	23.19	327.35	114.96
PI-cordon queue	79.50	24.63	457.73	203.34
Feedback	69.98	23.59	340.43	113.05

Conclusions

Compared with benchmarks, the proposed method:

- decreases the total travel time by 26.71% and the total cordon queue length by 30.70%.
- improves both the global network performance and the distributed traffic state of each gate link.



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