Organic Traffic Control / Organic Traffic Control Collaborative

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Outline

- Motivation and goals
- Architecture developed
  - Modifications to Classifier System
- Experimental validation
  - Scenarios used for testing
  - Results of testruns
- Phase II: Organic Traffic Control Collaborative – OTC^2

Motivation and goals

Motivation

- Develop autonomous control system for practically relevant problem: Control of road traffic network
- Explore possibilities/limitations of decentralised adaptive control systems

Goals for phase I

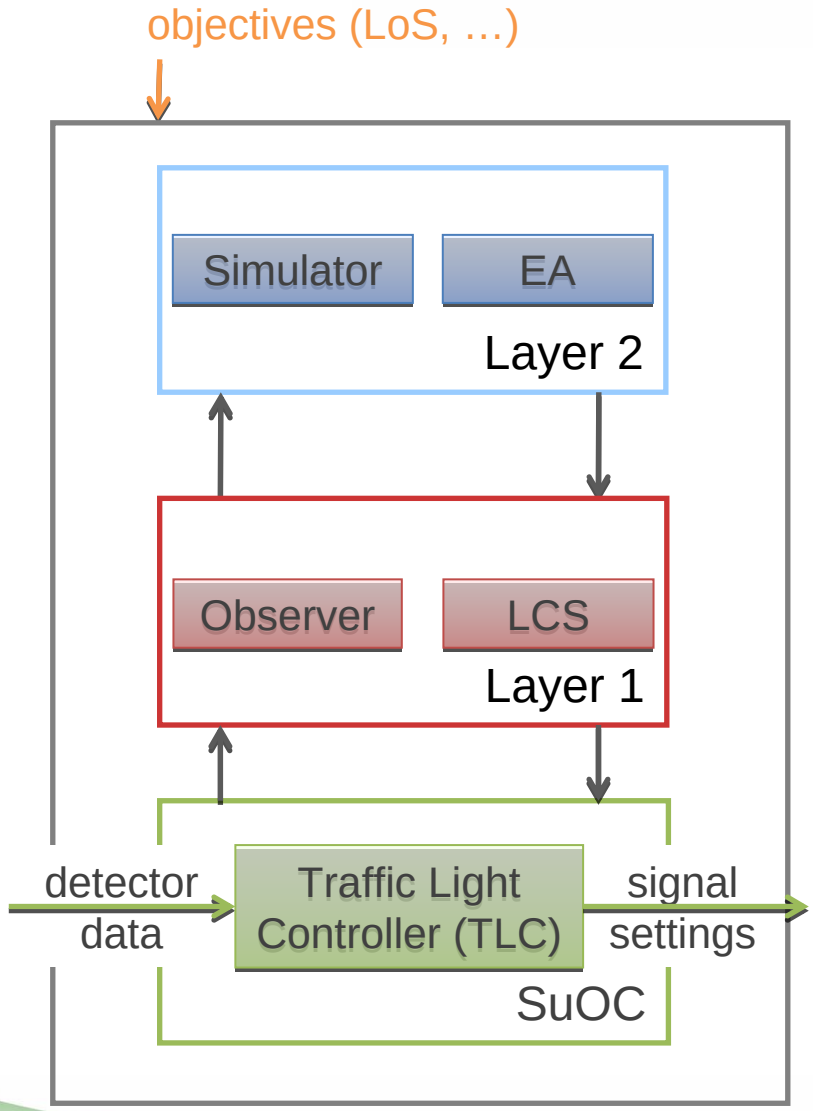
- Design generic modular architecture
- Implement for single, isolated junction
- Test, optimise

Motivation and goals (2)

Requirements

- Adapt autonomously to the environment:
  - Long term changes — continuous learning
  - Short term fluctuations, incidents — quick response
  - reuse knowledge — memory
- Safety: Limit effects of possible errors of learning component — use simulation to learn
- Comprehensible behaviour — store knowledge human-readable
- Limit necessary manual intervention and effort for setup — autonomy

Architecture



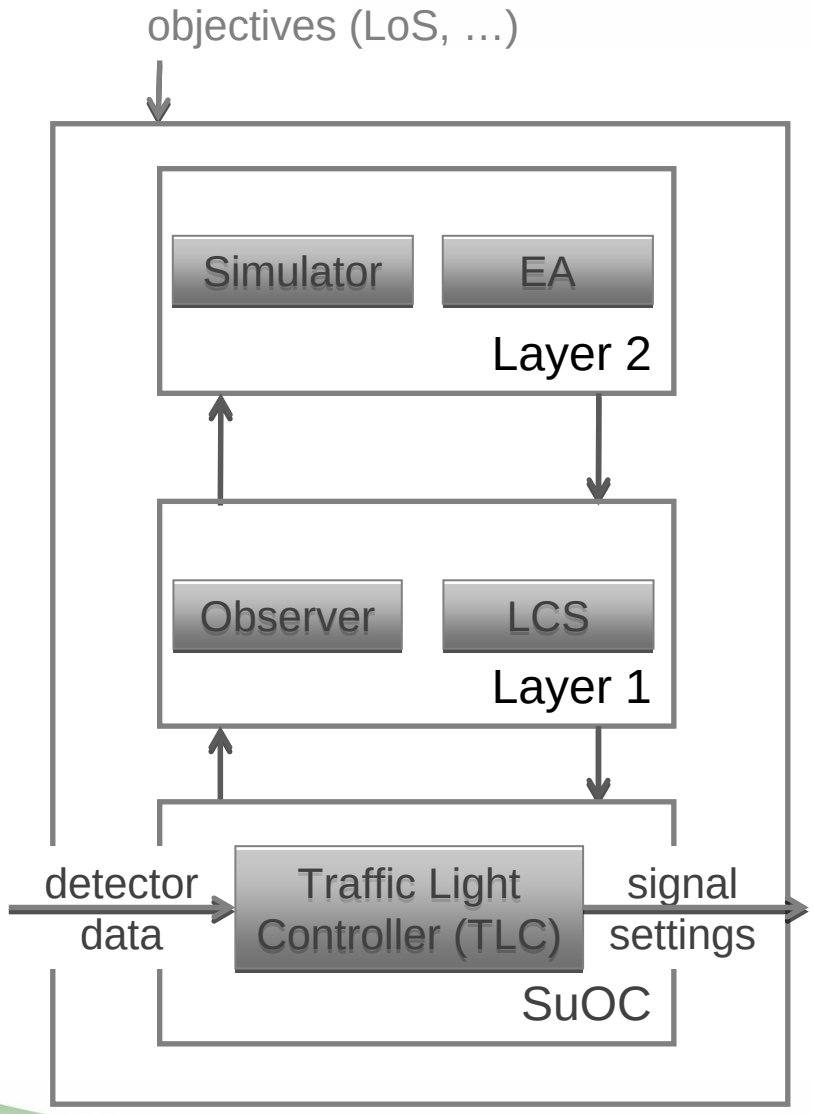
User interface
- User defines system objectives

Layer 2
- Extend behavioral repertoire of Layer 1
- Offline learning (TLC parameters)

Layer 1
- Adapt SuOC-parameters
- Online learning (rule quality)

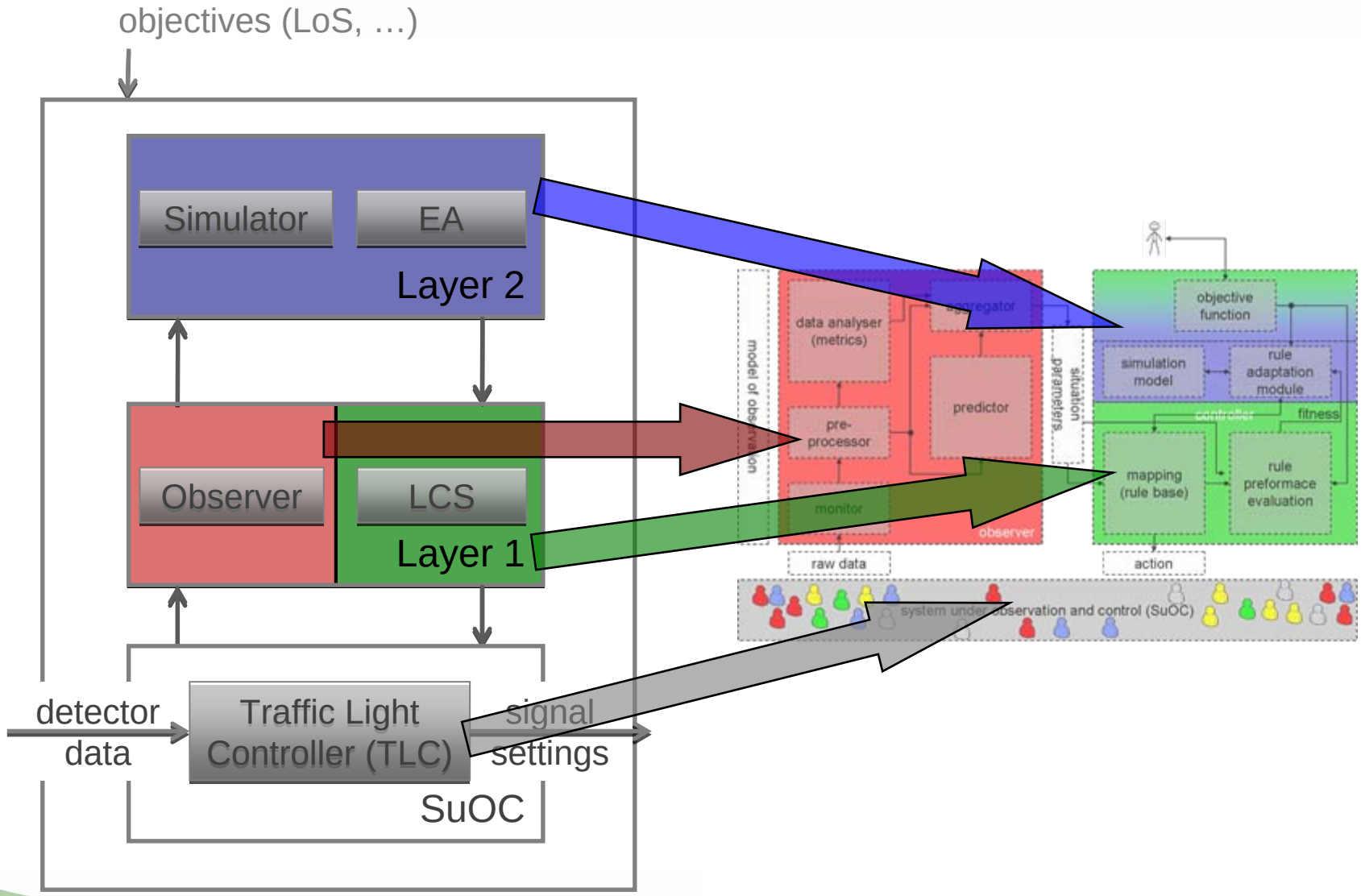
System under Observation and Control
- Control traffic signals

Architecture (2)



- Result of joint work with project QE (generic O/C-architecture)
- Modular concept:
  - Different types of TLC (fixed time to traffic responsive control)
  - Layer 2 may run on different computer
- LCS modified to suit requirements

Architecture (2)



LCS: Input, Output, Objective function

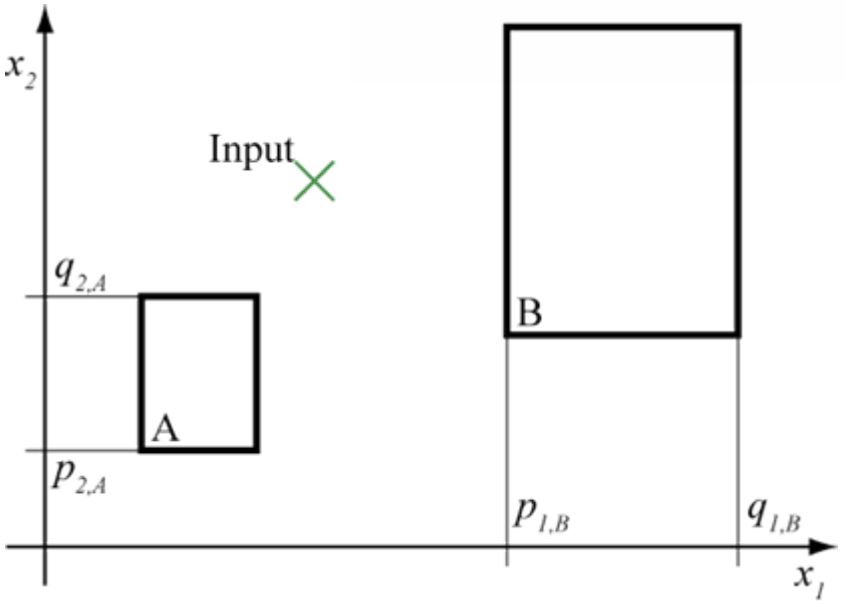
- **Input:** Traffic situation, vehicles per hour (flow) per relation in the junction (turning)
- **Output:** Parameter set describing program for traffic light controller (fixed time or traffic responsive control)
- **Objective function:** Level of Service (LOS, average delaytime per vehicle); used in Germany (HBS) and the US (HCM)
  - Optimise: **Minimise** LOS value

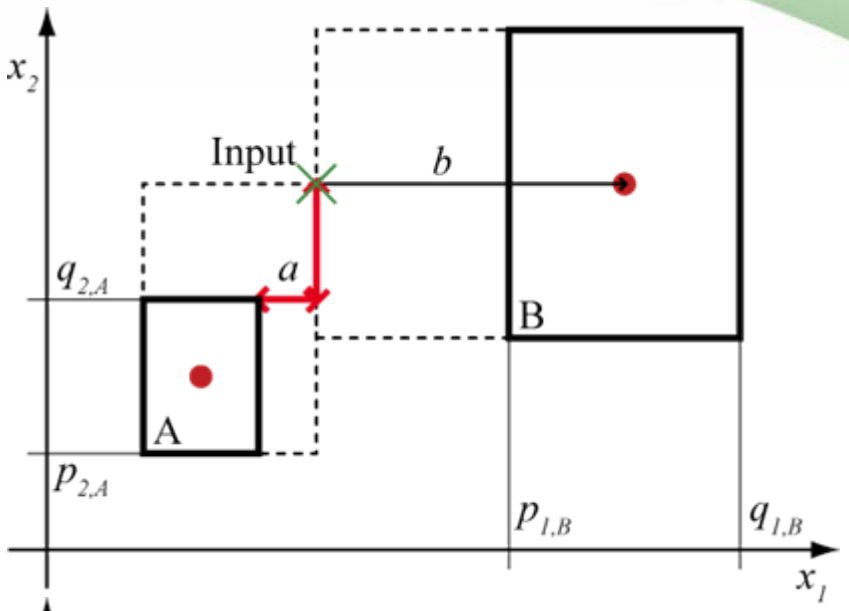
$$LOS = \frac{\sum flow \cdot t_{delay}}{\sum flow}$$

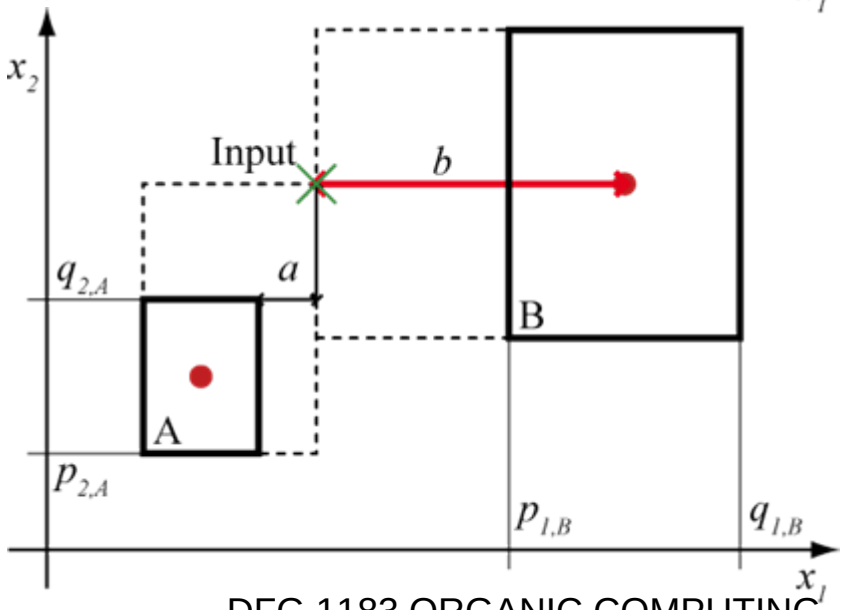
Modifications to LCS

- Generation of new rules extracted to separate component (Layer 2, off-line learning)
- Representation of input as real-valued intervals
- Covering: Trade-off between “use only tested solutions” and quick reaction time
- Building of Matchset: Trade-off between “use only matching solutions” and competition needed for learning
- Shift in focus: Instead of generating new knowledge, learn where existing knowledge is applicable (and refine evaluation, no start from scratch)
- Challenge: Handling of large multi-dimensional search spaces

Modifications to LCS

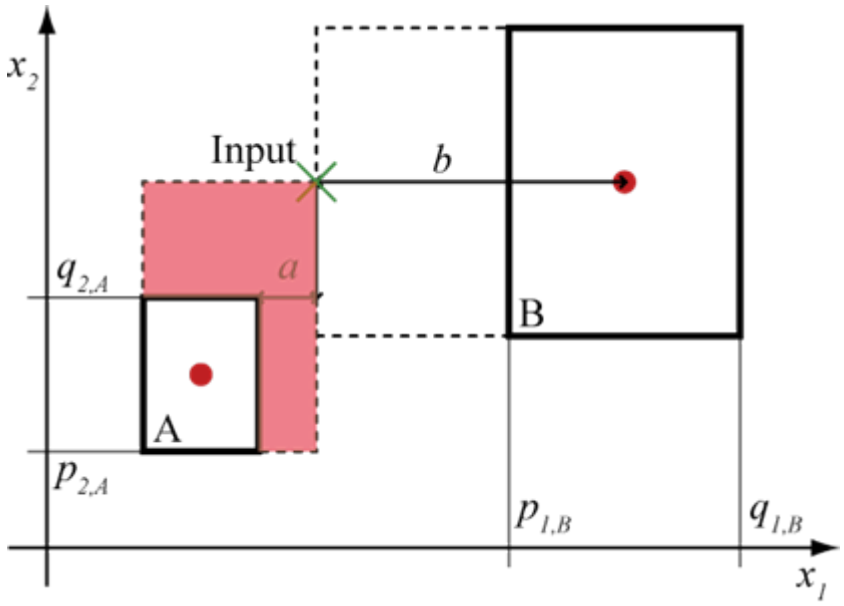


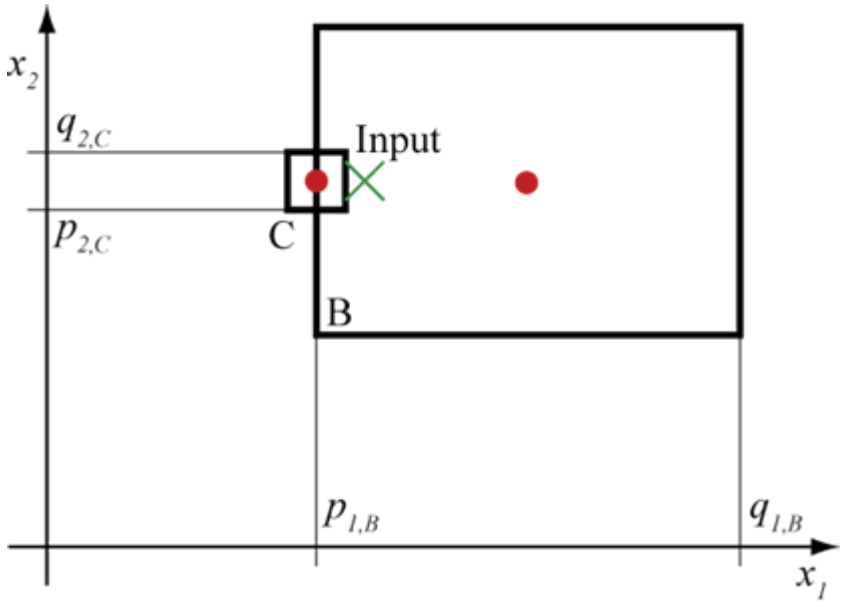




Select “closest” rule, copy, widen condition
Activate rule generation

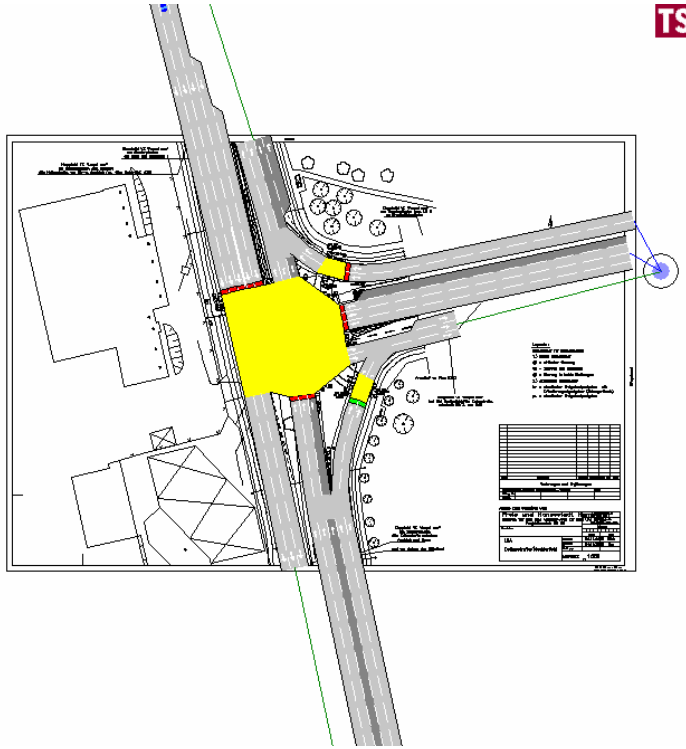
Modifications to LCS



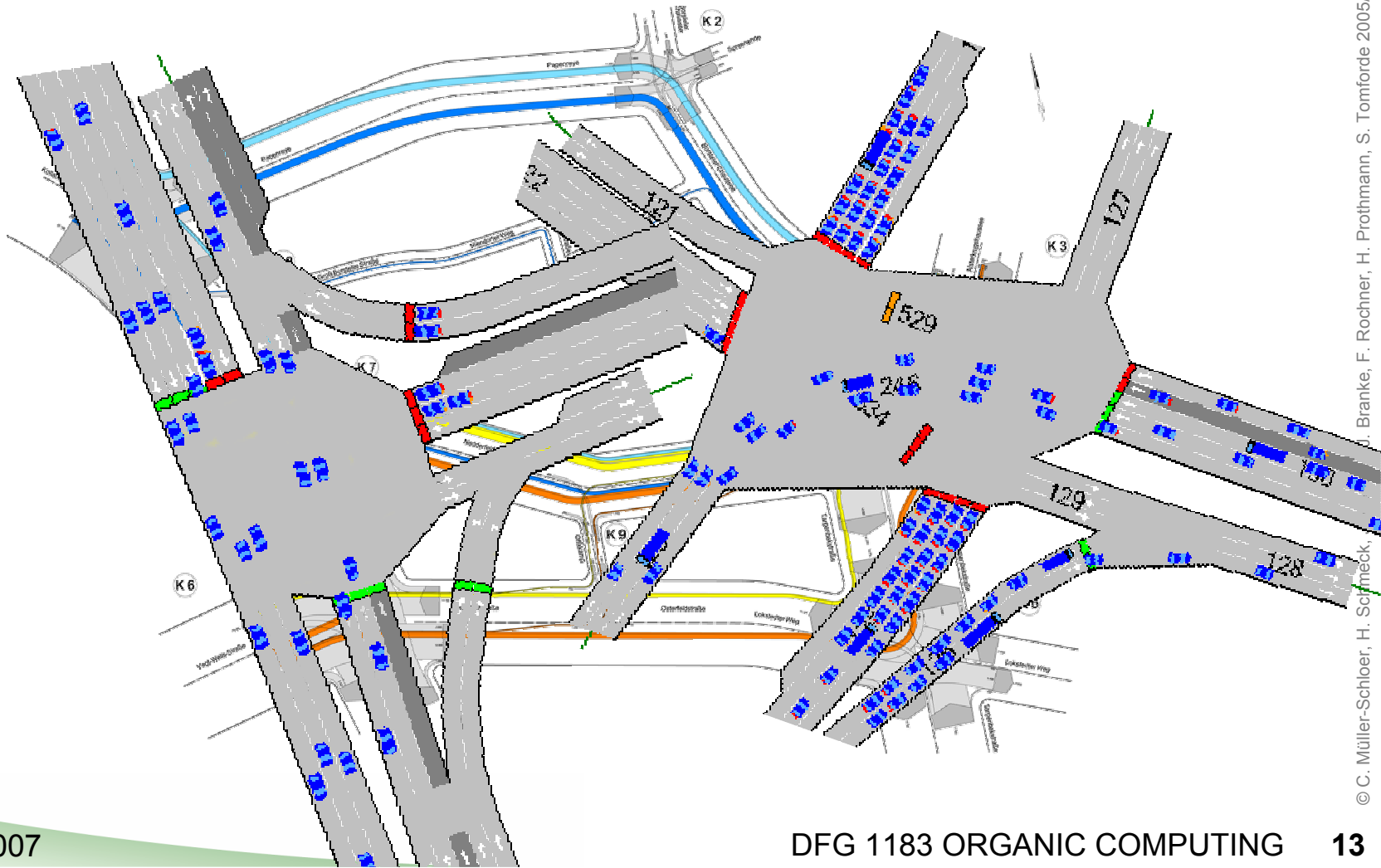


Scenarios used for testing

- Goal: Compare performance to **real** controllers
- Realism: Use **real** traffic data where possible
- Assess influence of different parameter settings
- Measure reaction times
- Models and traffic data for subnets at Hamburg and Hannover (by courtesy of Schmeck Ingenieurges. mbH / ivh, LUH) available (fixed time controllers)

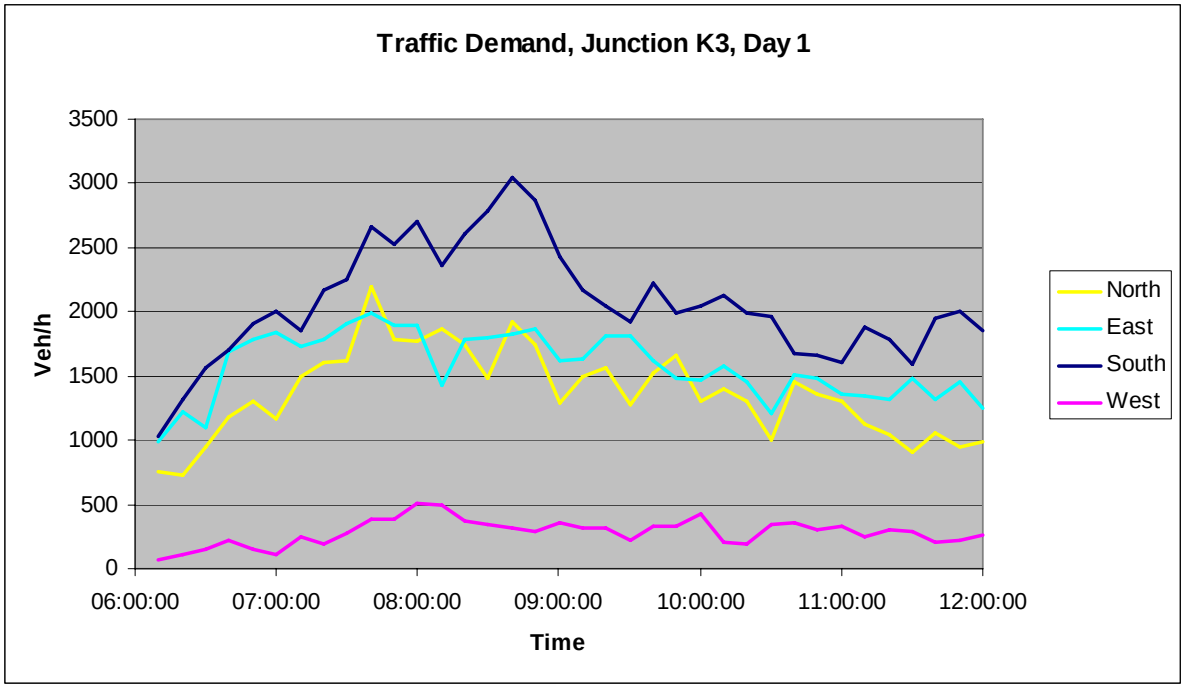


Hamburg

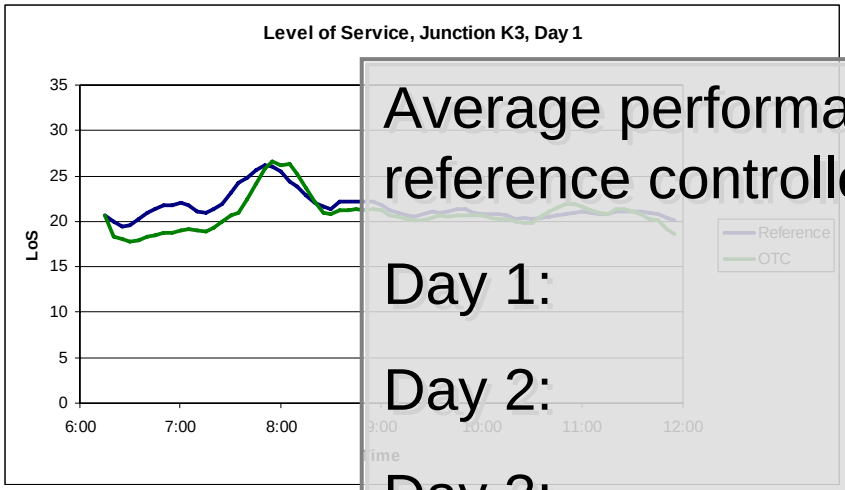


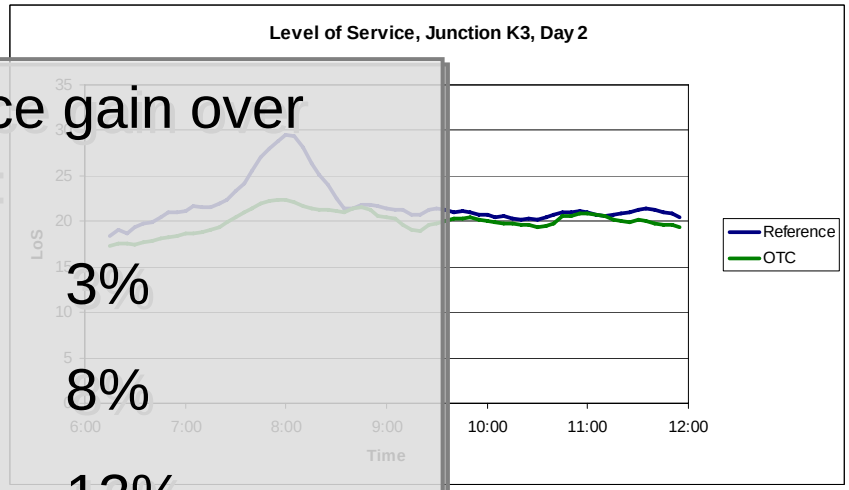
Hamburg (2)

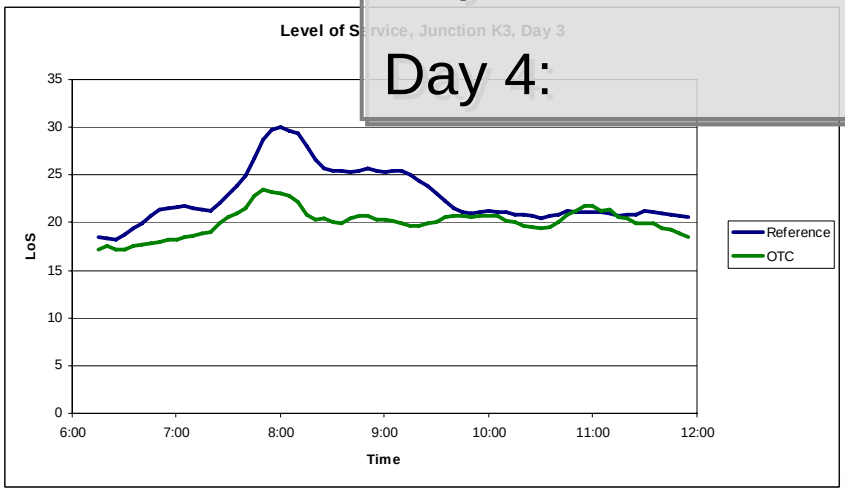
- Traffic situation: Morning period (6:00 – 12:00, including peak), data from traffic census, 15 minutes resolution
- Dynamic change (large scale), fluctuations (small scale) due to stochastic traffic entry (varied using different seeds)

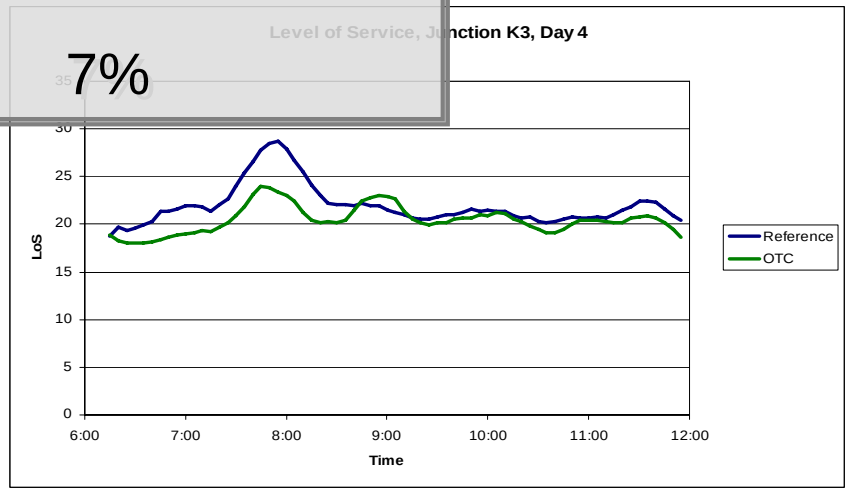


Hamburg: K3





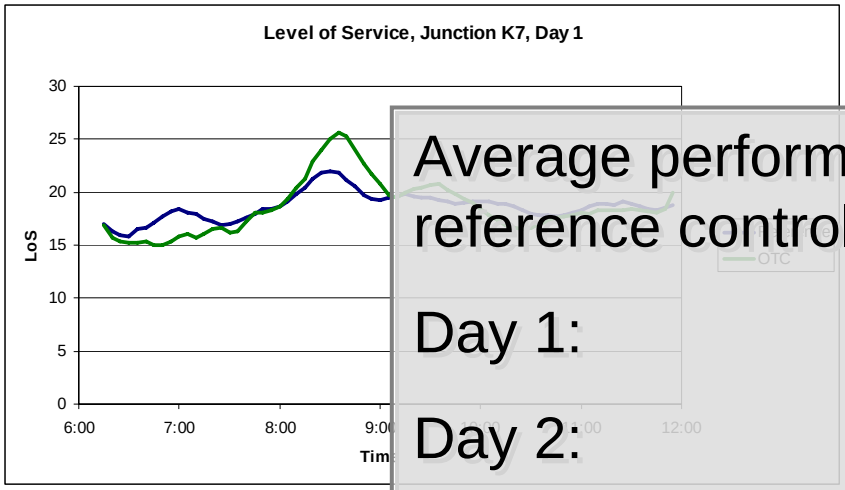


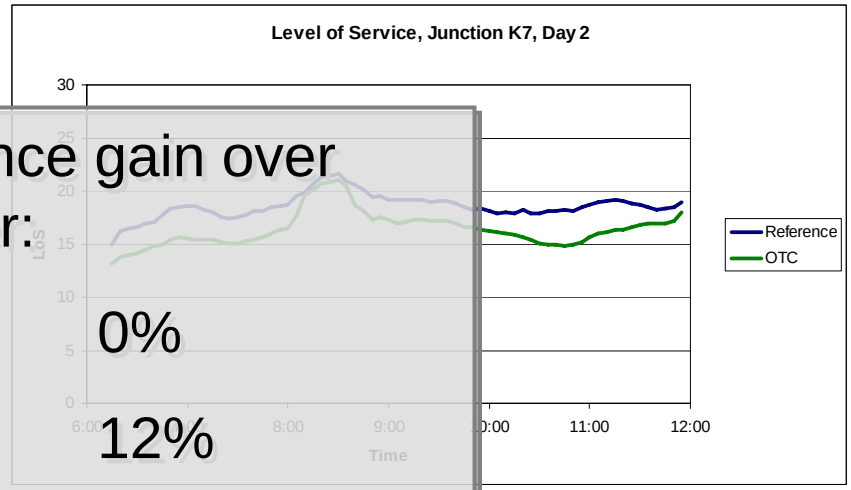


Average performance gain over reference controller:

Day 1:	3%
Day 2:	8%
Day 3:	12%
Day 4:	7%

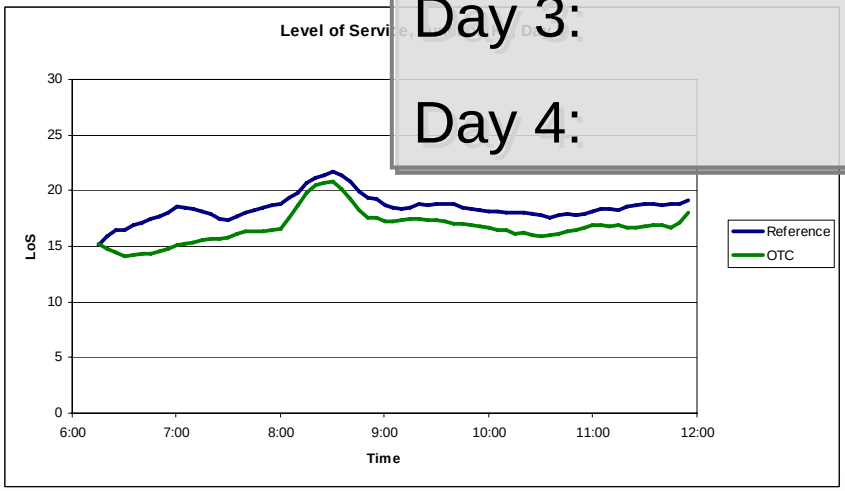
Hamburg: K7

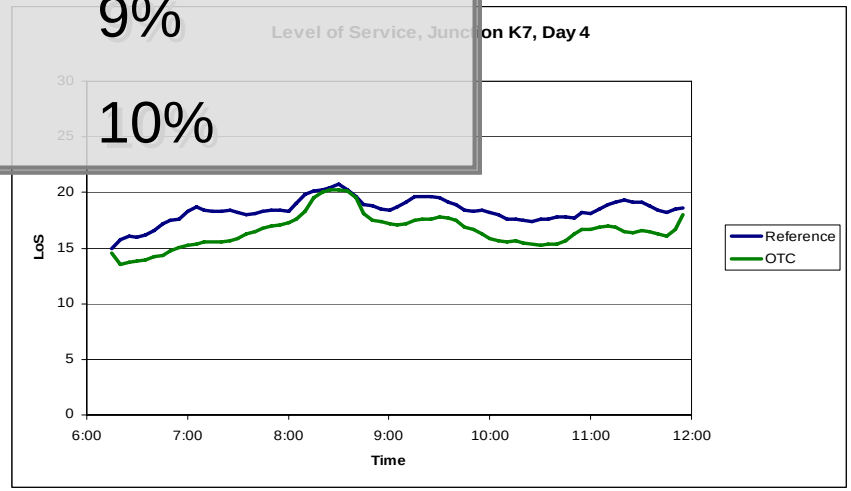




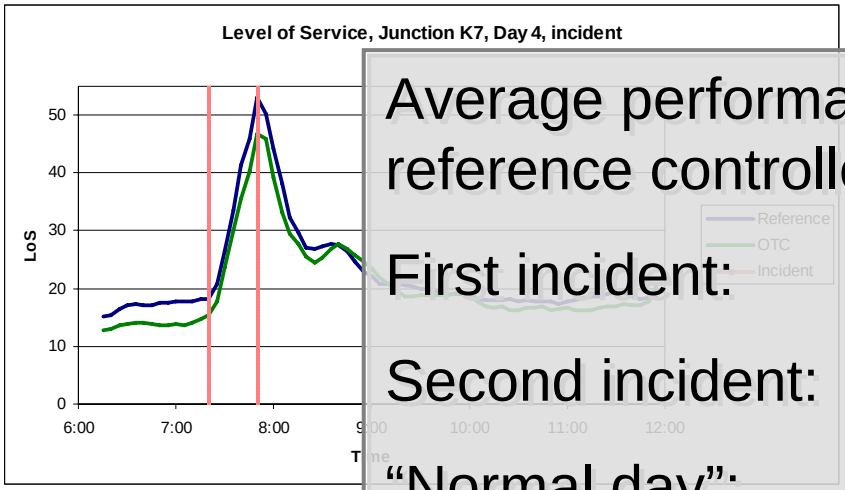
Average performance gain over reference controller:

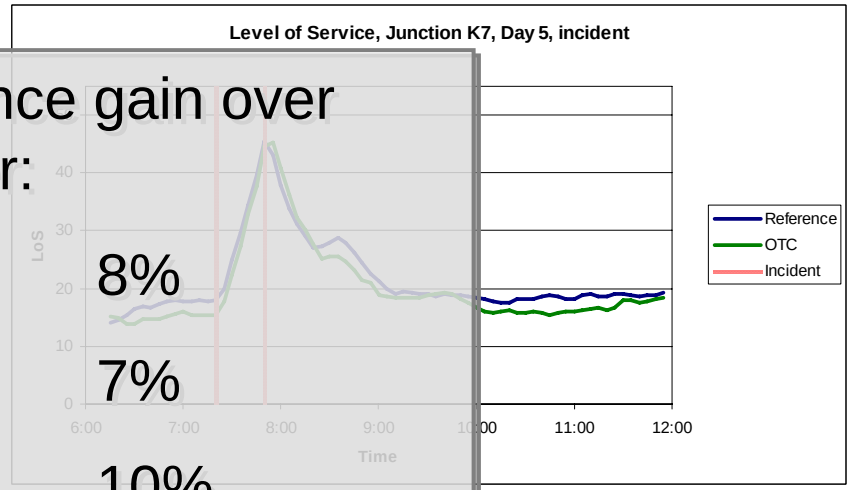
Day 1:	0%
Day 2:	12%
Day 3:	9%
Day 4:	10%





Hamburg: K7, lanes blocked



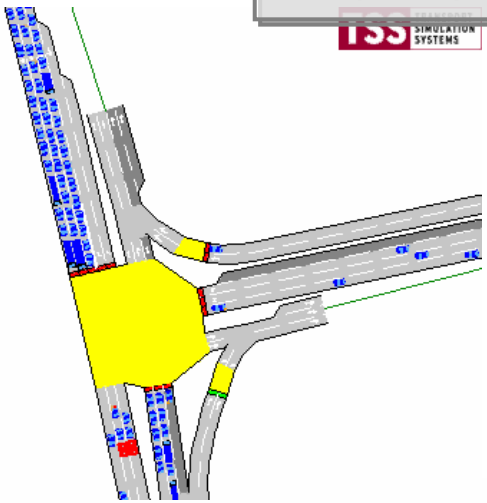


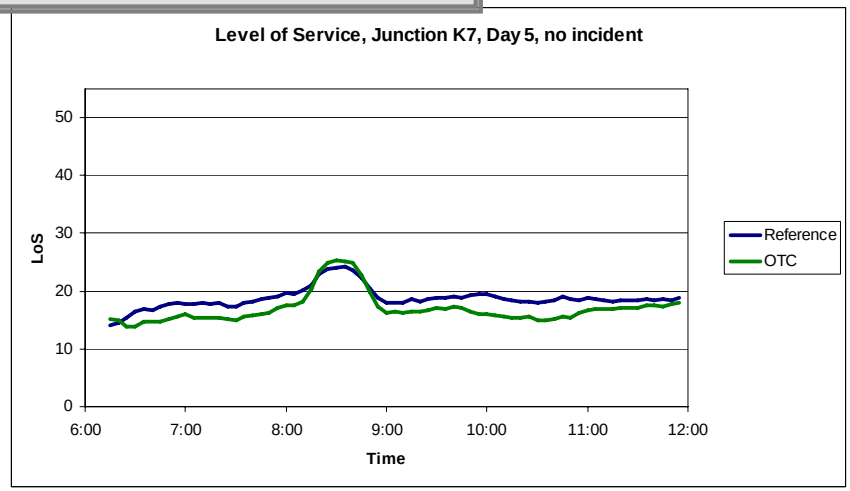
Average performance gain over reference controller:

First incident: 8%

Second incident: 7%

"Normal day": 10%

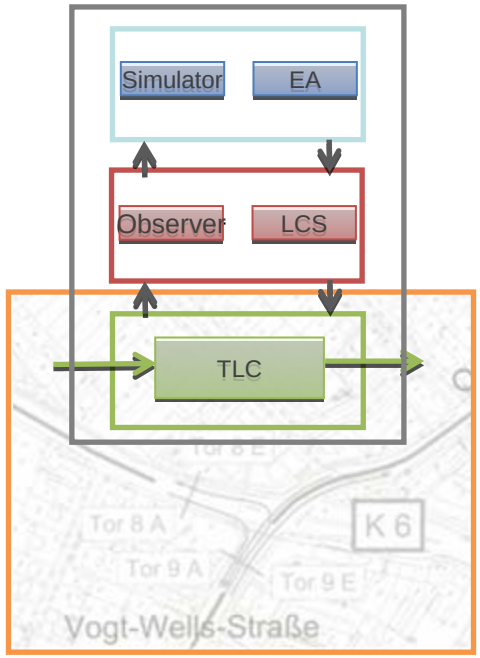




Phase II

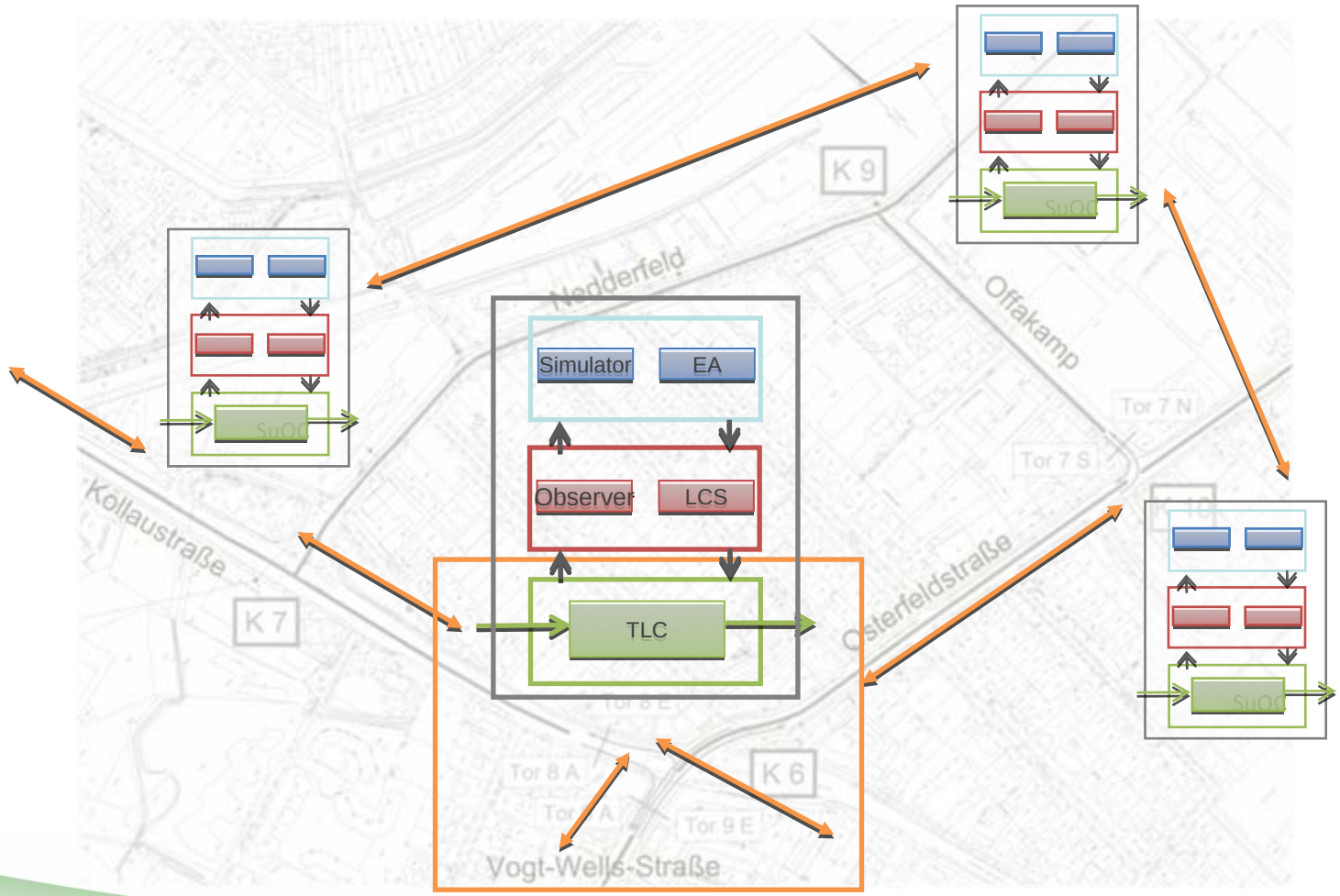
Phase II:
Organic Traffic Control Collaborative

OTC: Adaptive learning control system for single junctions



Phase II:
Organic Traffic Control Collaborative

OTC2: Collaborative control of street networks

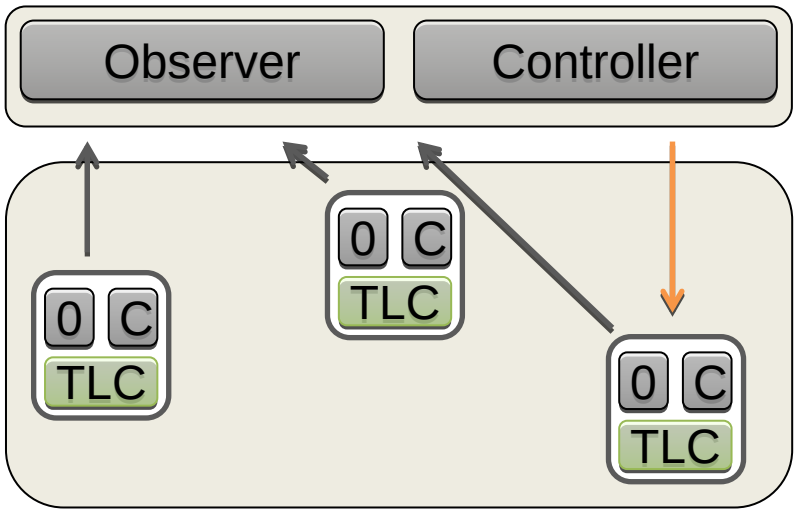


Phase II:

Organic Traffic Control Collaborative

Comparison of different architectures

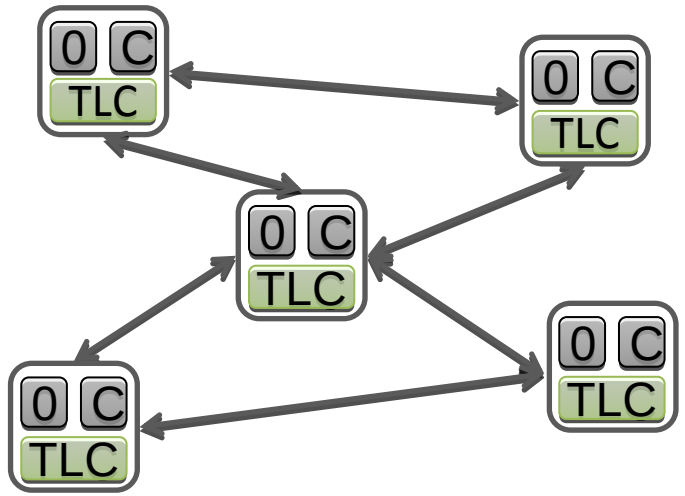
a. Hierarchically organised



A network-O/C

- observes network-wide traffic and
- Influences node-O/Cs with respect to network-wide goals.

b. Decentrally organised



- Node-O/Cs provide data to their neighbours, which
- consider this data in their decisions.

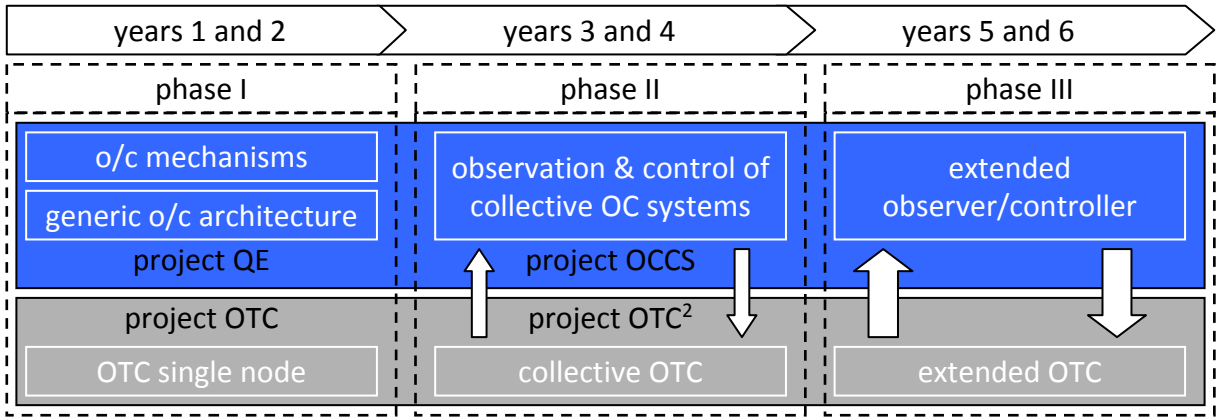
Summary and outlook

Summary: Phase I

- Generic modular architecture developed and implemented
- LCS adapted to specific requirements
- Experimental validation using real data

Outlook: Phase II

- Extension: Collaboration to control network of junctions
- Optimisation of parameters, performance tuning
- Collaboration with OCCS



Publications

First ideas presented in:

- F. Rochner and C. Müller-Schloer. Adaptive decentralized and collaborative control of traffic lights. In P. Dadam and M. Reichert, editors, *INFORMATIK 2004 – Informatik verbindet*, volume P-51 of *LNI*, pages 595-599. Köllen Verlag, 2004.

Publications of project‘s results:

- F. Rochner, H. Prothmann, J. Branke, C. Müller-Schloer, and H. Schmeck. An organic architecture for traffic light controllers. In C. Hochberger and R. Liskowsky, editors, *Informatik 2006 – Informatik für Menschen*, volume P-93 of LNI, pages 120-127. Köllen Verlag, 2006.
- J. Branke, M. Mnif, C. Müller-Schloer, H. Prothmann, U. Richter, F. Rochner, and H. Schmeck. Organic computing – Addressing complexity by controlled self-organization. In T. Margaria, A. Philippou, and B. Steffen, editors, *Proceedings of the 2nd International Symposium on Leveraging Applications of Formal Methods, Verication and Validation (ISoLA 2006)*, pages 200-206, 2006.
- J. Branke, P. Goldate, and H. Prothmann. Actuated traffic signal optimization using evolutionary algorithms. In *Proceedings of the 6th European Congress and Exhibition on Intelligent Transport Systems and Services (ITS07)*, 2007.
- H. Schmeck. Optimierungstechniken des Organic Computing in der Verkehrstechnik. In A. Pfingsten and F. Rammig, editors, *Informatik bewegt! Informationstechnik in Verkehr und Logistik*, pages 11-38. Fraunhofer-IRB-Verlag, 2007.

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