Organic Traffic Control (OTC³)

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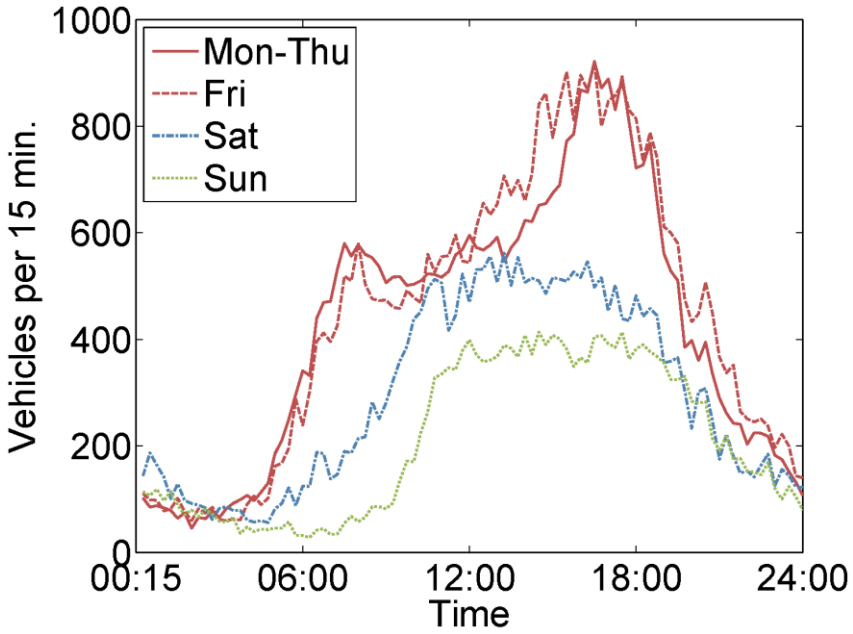
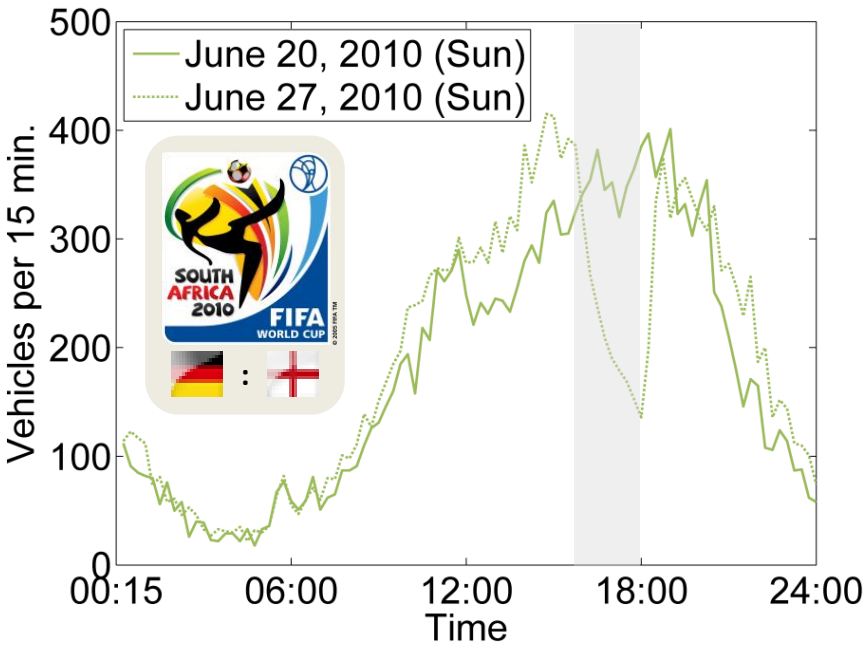
Traffic control in dynamic environments

Arterial road at Karlsruhe



Irregular demands



→ Adaptive traffic lights
→ Self-organised coordination
→ Dynamic route guidance

→ At run-time!

Agenda

Phase I – Adaptive traffic lights

Observer/controller architecture

Phase II – Self-organised coordination

- Decentralised progressive signal systems
- Hierarchical extensions

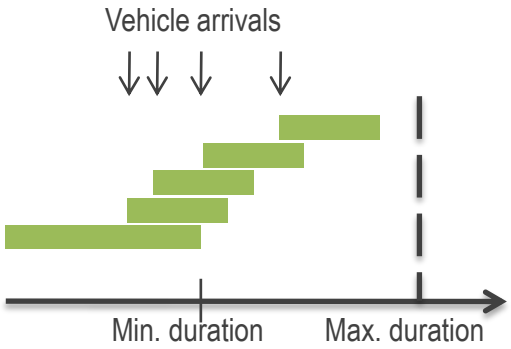
Phase III – Dynamic route guidance

- Decentralised routing
- Regional extensions

1. Adaptive Intersections

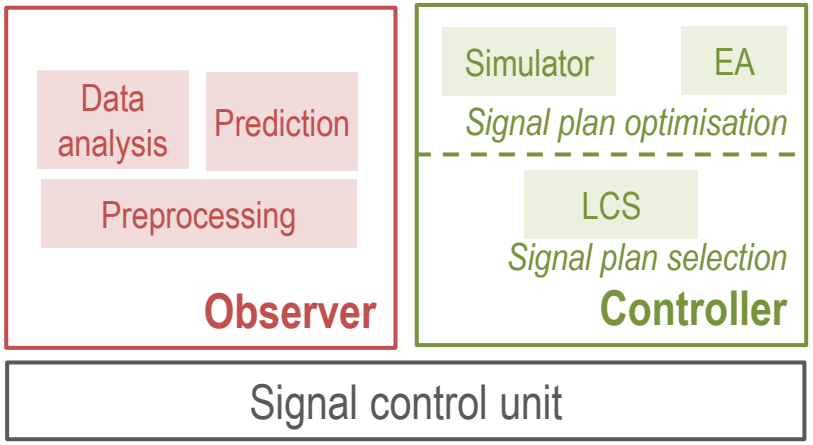
Adaptive Intersections

State of the art: Traffic-actuation



- Loss of adaptivity for high traffic demands
- Logic predefined at design time
- No optimisation at run-time

Observer/controller (O/C) architecture



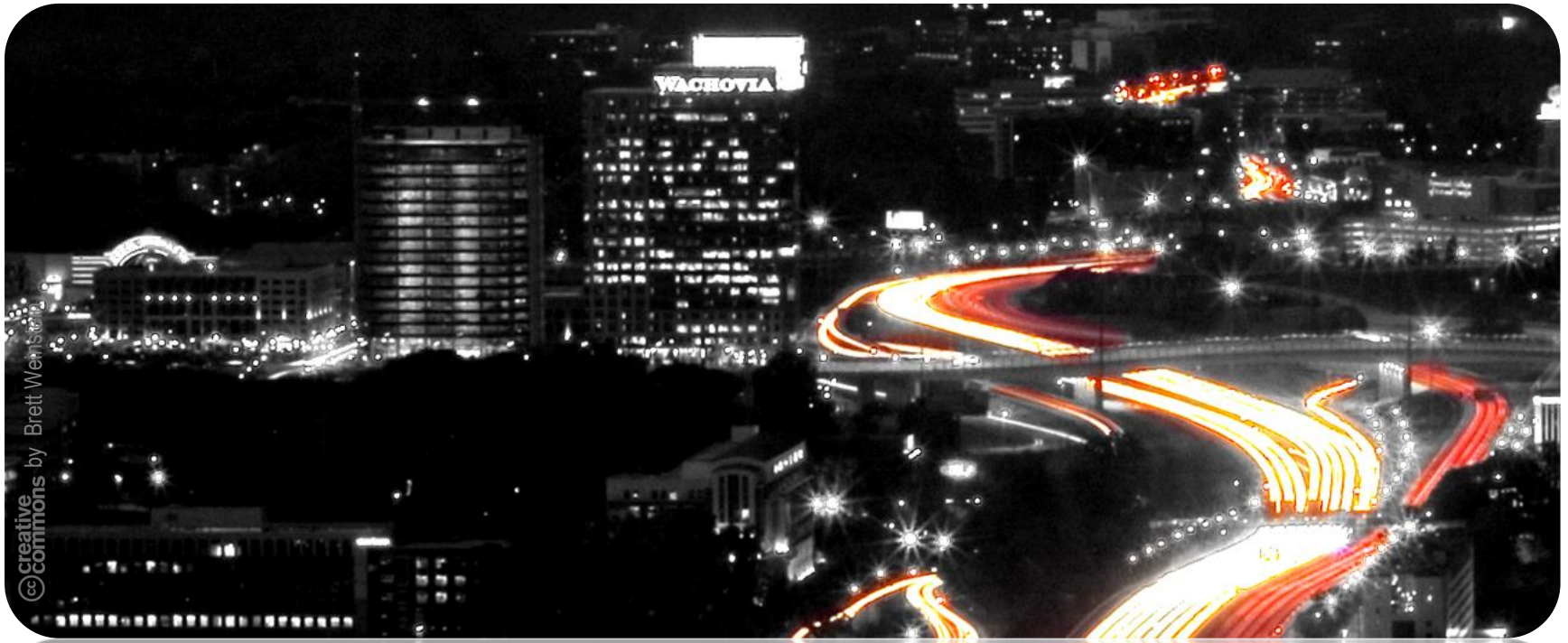
- Two-levelled learning for safety- and performance-critical systems
- Cooperation with OCCS

Optimisation at run-time

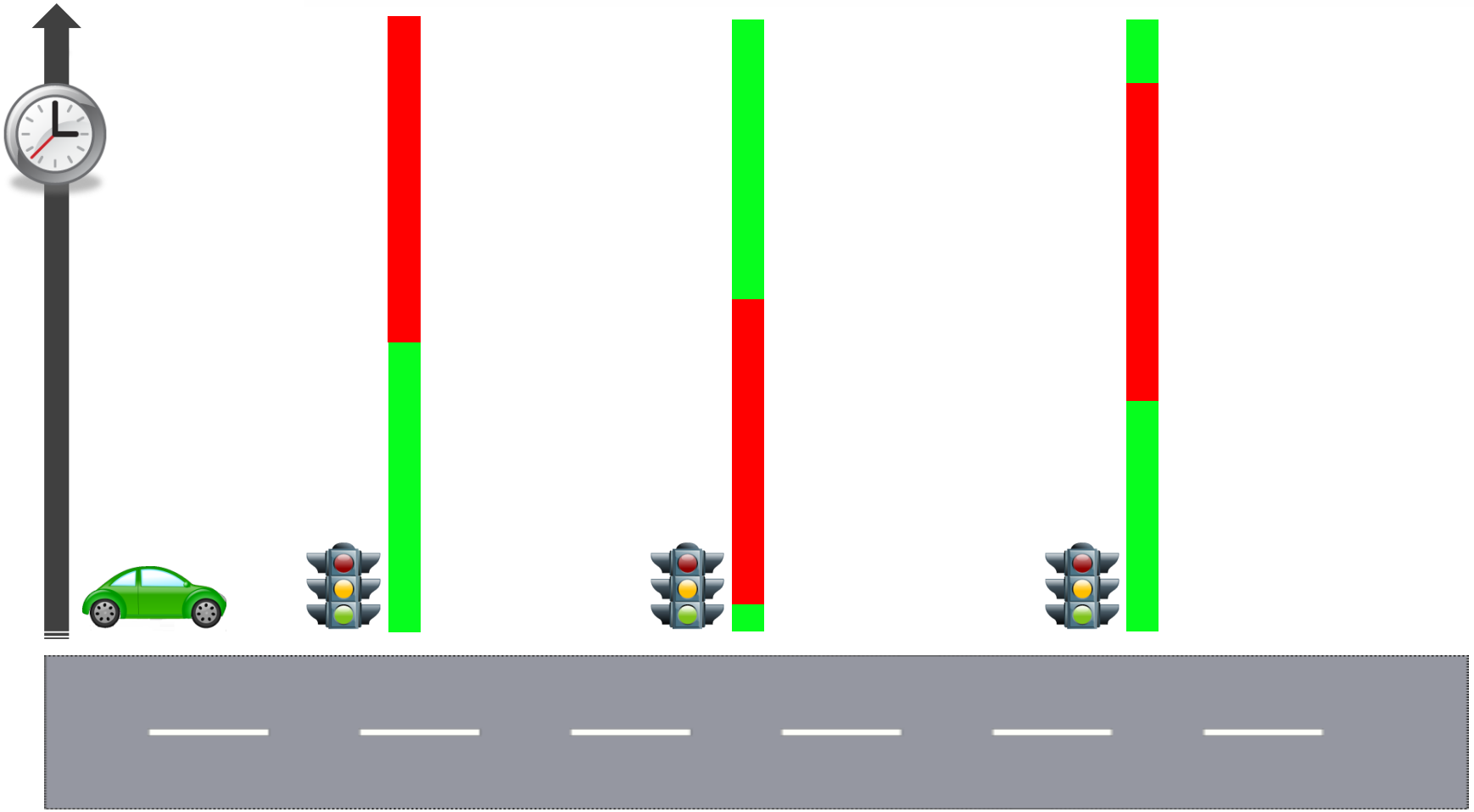
→ Reduces delays

→ Avoids costly reassessments

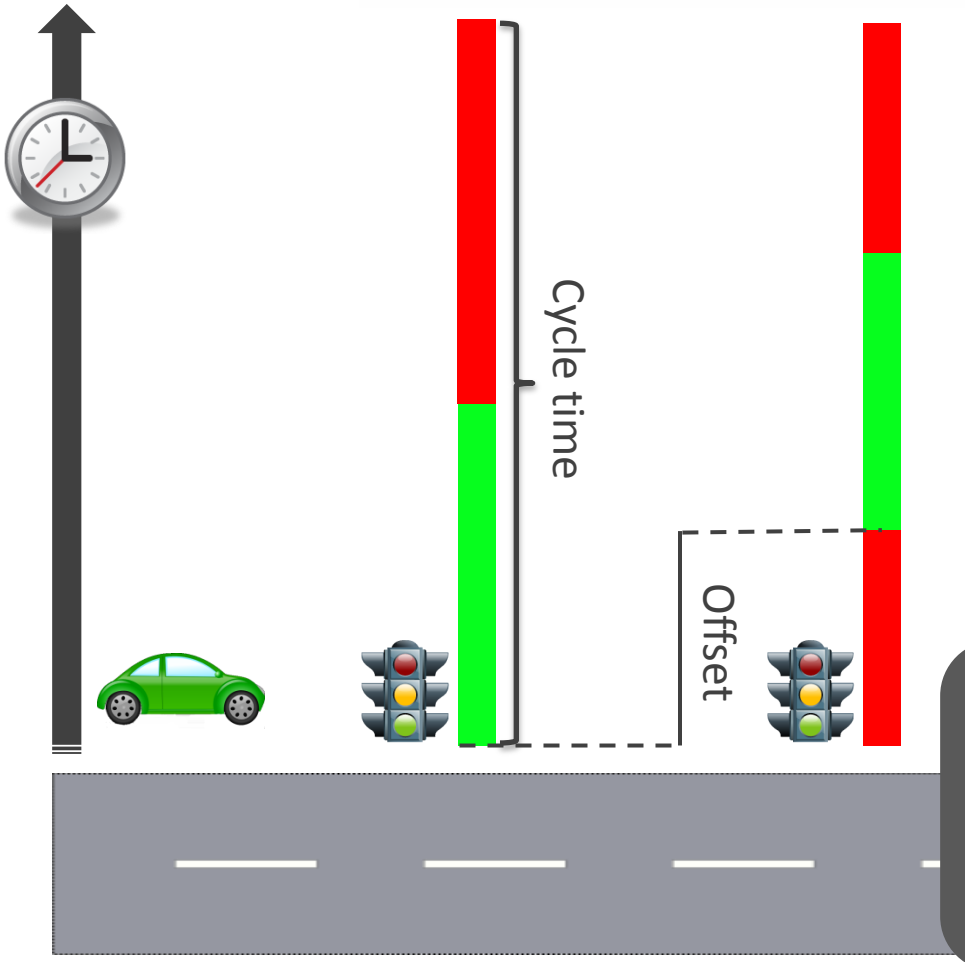
2. Self-organised Coordination



Uncoordinated signals



Coordinated signals

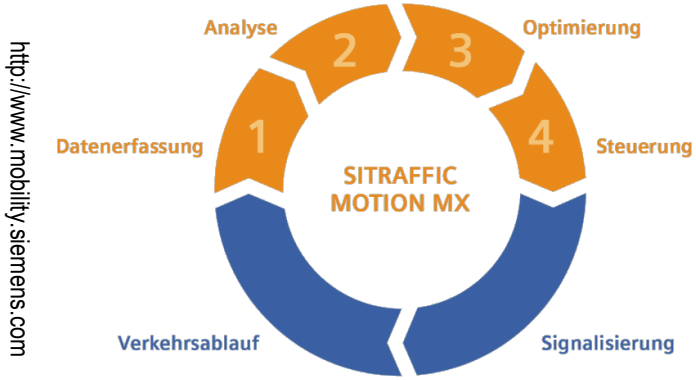


Preconditions for coordination

1. Select coordinated intersections
2. Determine common cycle time
3. Select signal plans and offsets

Self-organised coordination

State of the art:
Adaptive network control systems



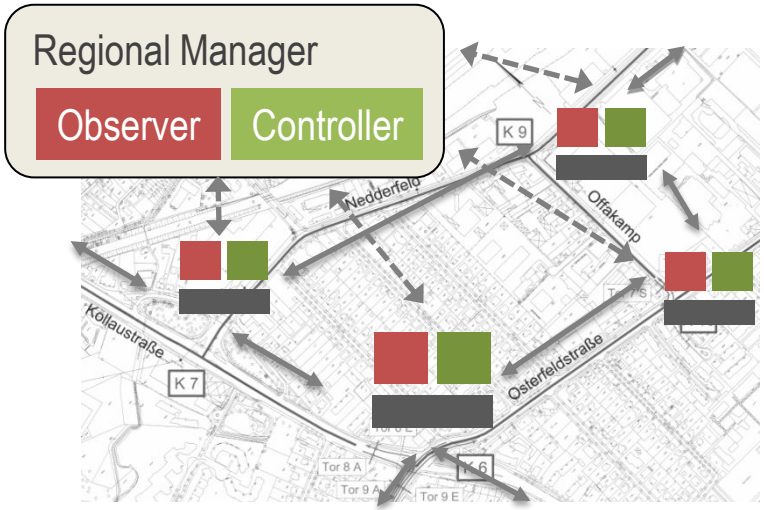
- Network-wide control loop
- Local traffic-actuation

→ High effort for communication

→ High susceptibility to failure

→ Not always cost-effective

Self-organised coordination



Distributed O/C components

- Local communication
- Local signal plan selection

→ Reduction of stops

- *Optional:* Regional Manager (conflict resolution)

3. Dynamic Route Guidance

Dynamic route guidance

Driver information

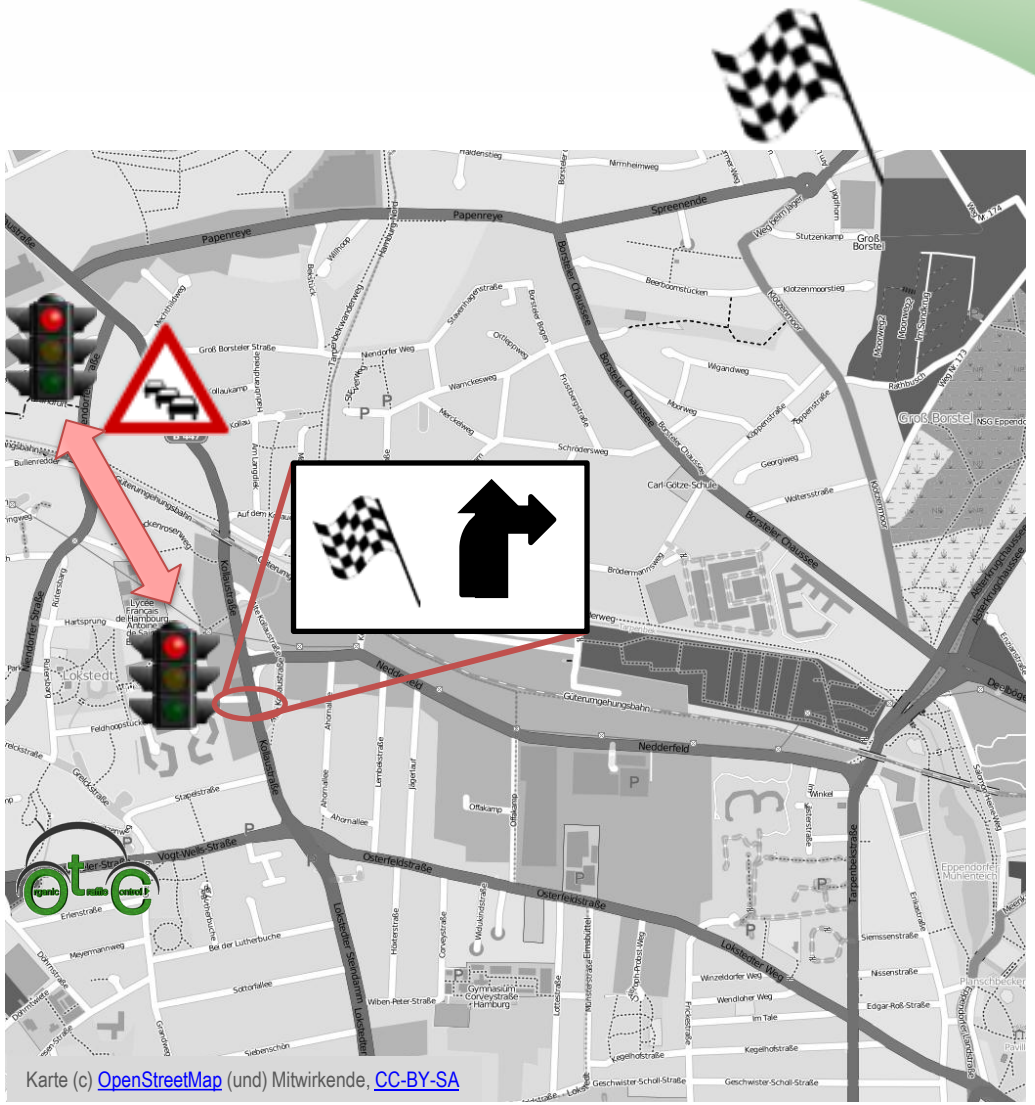
O/C components

- Estimate local delays
- Derive recommended routes using adapted Internet protocols
  - Distance Vector Routing
  - Link State Routing

→ Minimise travel times

→ Prevent congestions

→ Improve robustness wrt incidents



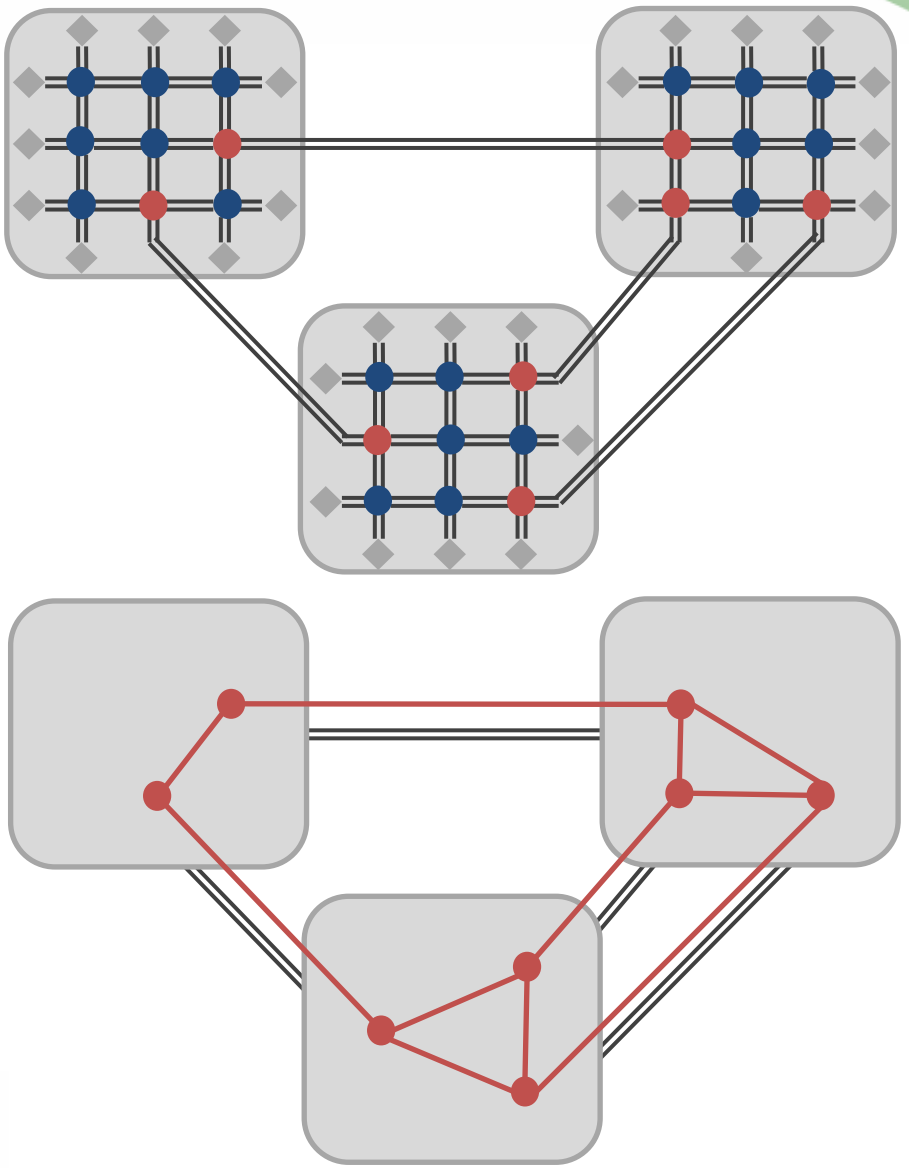
Regional routing

Two types of routing components

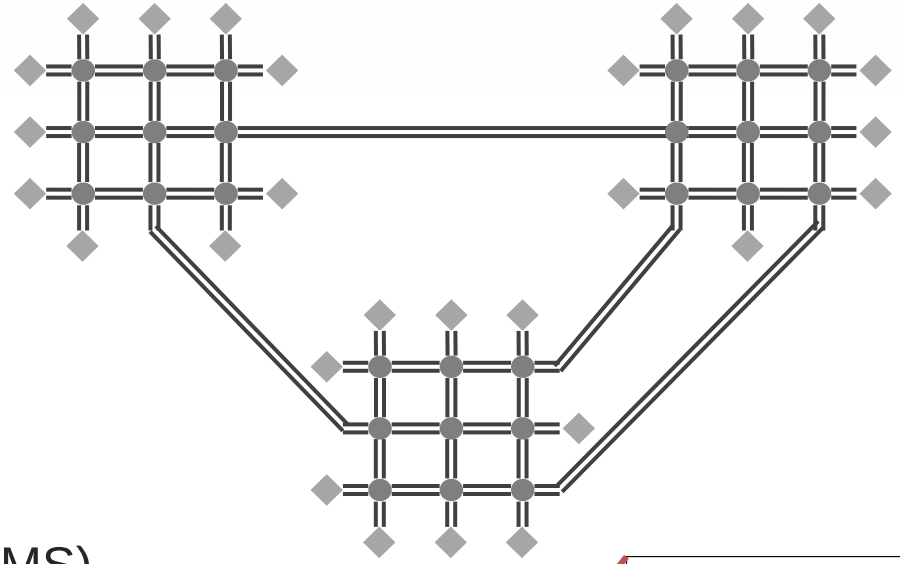
1. Intra-region: DVR/LSR (●)
2. Inter-region: Border gateway routing (●)

Advantages

- Reduced routing table size (→ fewer routing messages)
- Tables become partly static (destinations in other regions)
- Reduced number of hops per message (depends on topology)



Test scenario

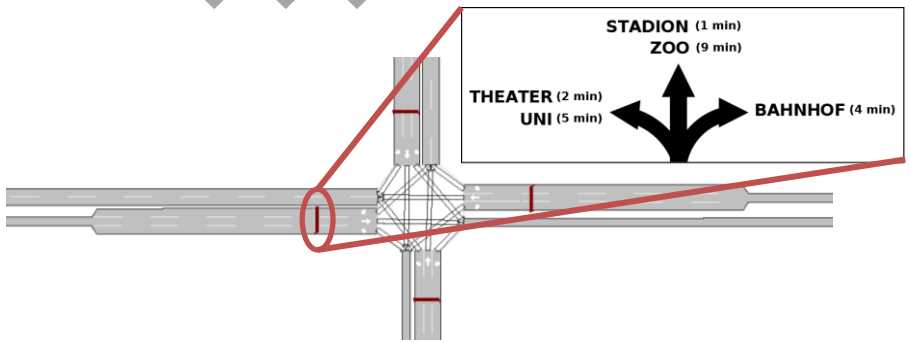


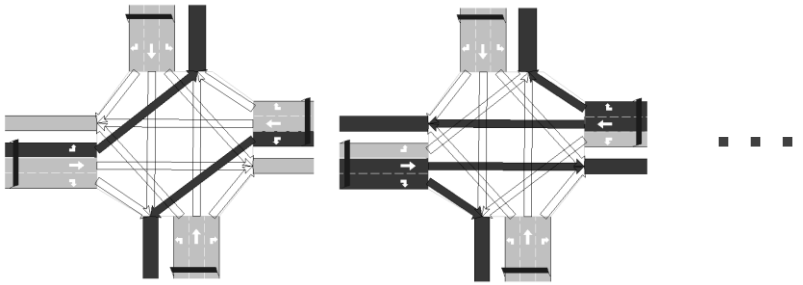
Network

- 3 regions
- 27 intersections (●)
- 28 destinations (◆)

Signalised intersections

- Variable Message Signs (VMS)
- O/C architecture
- 4-phased signal plans



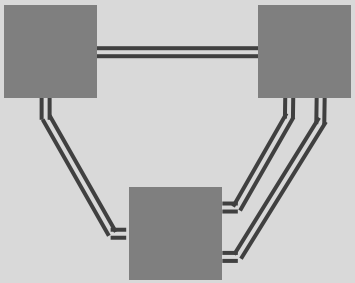


Traffic demand

- 6000 veh/h (equally distributed among destinations)
- **L**ow (12.5%) , **M**edium (37.5%), and **H**igh (75%) compliance

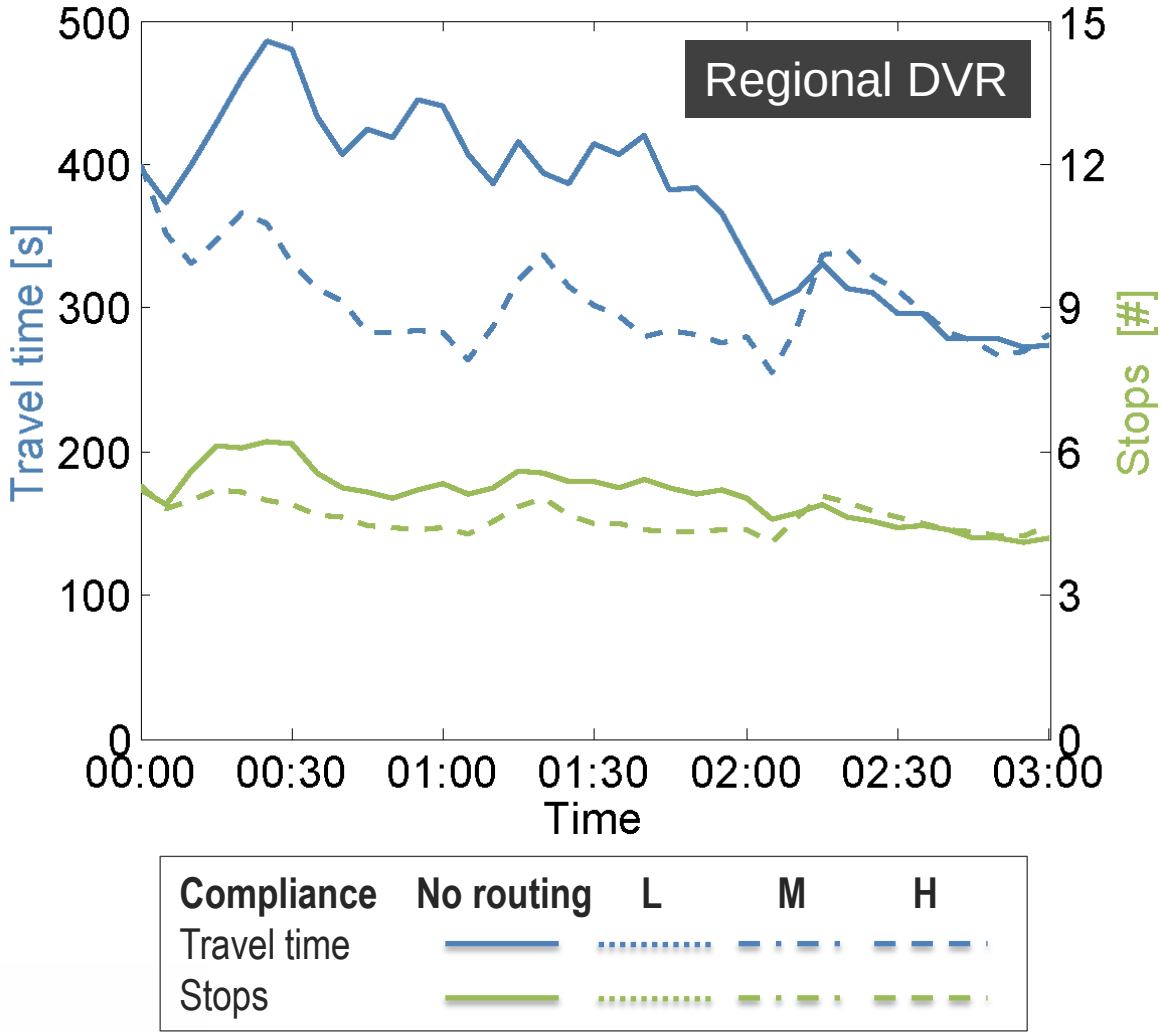
Simulation results

No incidents



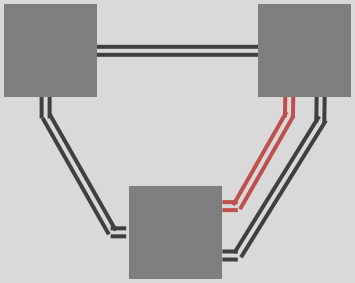
Reductions

Compliance	L	M	H
Travel time	9%	17%	20%
Stops	3%	8%	10%



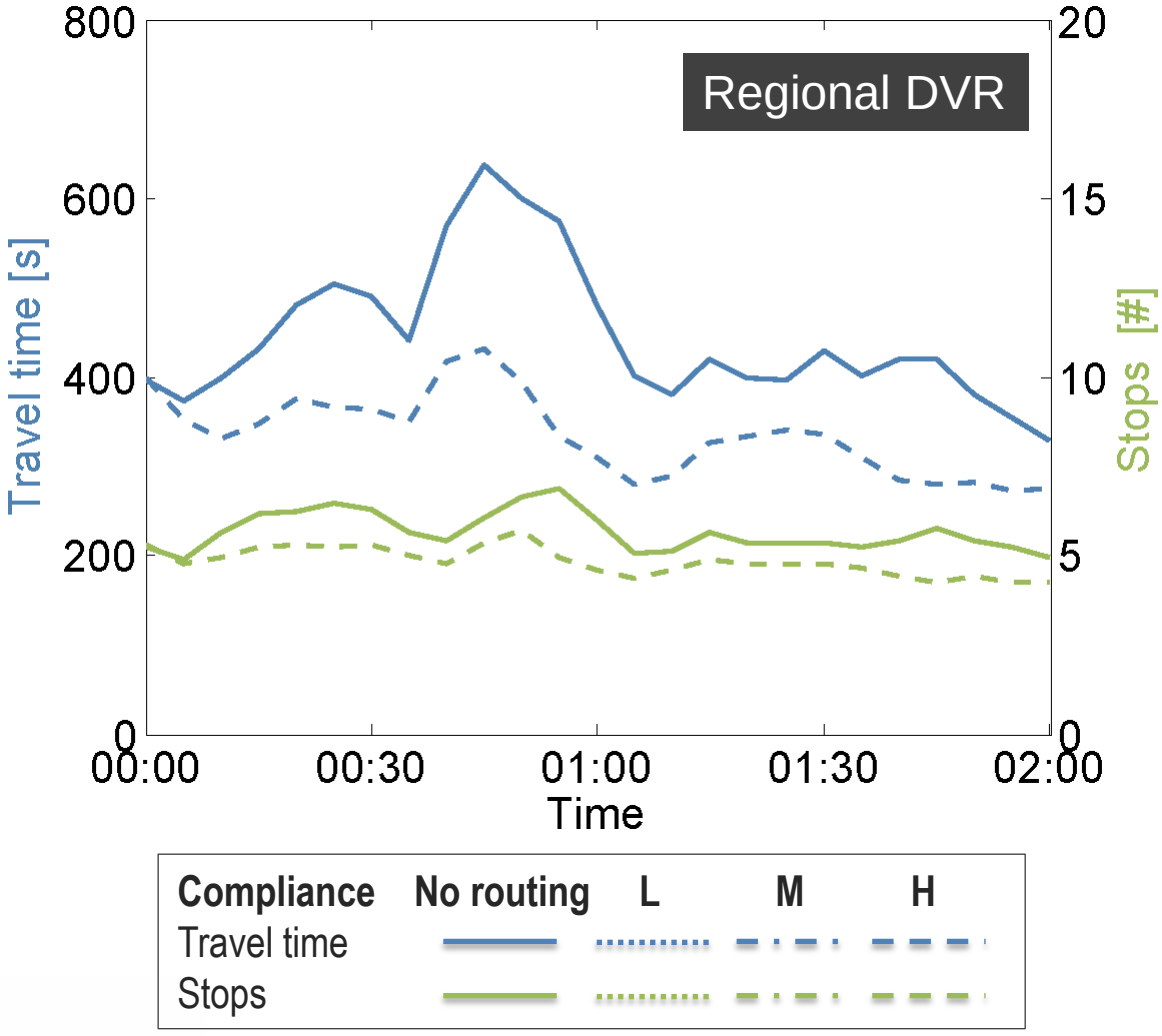
Simulation results

Incidents



Reductions

Compliance	L	M	H
Travel time	6%	23%	27%
Stops	3%	13%	15%



SUMMARY

Summary

Adaptive traffic lights

- O/C architecture supporting two-levelled learning
- Optimisation of signal plans *at run-time*
- Reduced vehicular delays

Self-organised coordination

- Decentralised or hierarchical coordination mechanisms
- Traffic-responsive progressive signal systems
- Reduced stops, fuel consumption and emissions

Dynamic route guidance

- On-line routing based on current intersection delays
- Adapted Internet routing protocols
  - Link State Routing
  - Distance Vector Routing

→ Reduced travel times

Optional: Regional Routing (BGP)

- Reduced effort for computation and communication
- Reduced routing table size

Selected publications

2010 - 2011

H. Prothmann, H. Schmeck, S. Tomforde, J. Lyda, J. Hähner, C. Müller-Schloer, and J. Branke. Decentralised route guidance in Organic Traffic Control. In *5th IEEE International Conference on Self-Adaptive and Self-Organizing Systems (SASO 2011)*, 2011. *Accepted for publication.*

S. Tomforde, H. Prothmann, J. Branke, J. Hähner, M. Mnif, C. Müller-Schloer, U. Richter, and H. Schmeck. Observation and control of organic systems. In C. Müller-Schloer, H. Schmeck, and T. Ungerer, editors, *Organic Computing – A Paradigm Shift for Complex Systems*, chapter 4.1, pages 325–338. Birkhäuser, 2011.

H. Prothmann, S. Tomforde, J. Branke, J. Hähner, C. Müller-Schloer, and H. Schmeck. Organic traffic control. In C. Müller-Schloer, H. Schmeck, and T. Ungerer, editors, *Organic Computing – A Paradigm Shift for Complex Systems*, chapter 5.1, pages 431–446. Birkhäuser, 2011.

S. Tomforde, H. Prothmann, J. Branke, J. Hähner, C. Müller-Schloer, and H. Schmeck. Possibilities and limitations of decentralised traffic control systems. *In IEEE World Congress on Computational Intelligence*, pages 3298-3306. IEEE, 2010.

2008 - 2009

H. Prothmann, J. Branke, H. Schmeck, S. Tomforde, F. Rochner, J. Hähner, and C. Müller-Schloer. Organic traffic light control for urban road networks. *International Journal of Autonomous and Adaptive Communications Systems*, 2(3):203-225, 2009.

. Prothmann and H. Schmeck. Evolutionary algorithms for traffic signal optimisation: A survey. In *mobil.TUM 2009 - International Scientific Conference on Mobility and Transport,* 2009.

. Tomforde, H. Prothmann, F. Rochner, J. Branke, J. Hähner, C. Müller-Schloer, and H. Schmeck. Decentralised progressive signal systems for organic traffic control. In *2nd IEEE International Conference on Self-Adaption and Self-Organization (SASO 2008)*, pages 413-422. IEEE, 2008.

H. Prothmann, F. Rochner, S. Tomforde, J. Branke, C. Müller-Schloer, and H. Schmeck. Organic control of traffic lights. In *5th International Conference on Autonomic and Trusted Computing (ATC-08)*, volume 5060 of LNCS, pages 219-233. Springer, 2008. *BEST PAPER AWARD*

2006 - 2007

J. Branke, P. Goldate, and H. Prothmann. Actuated traffic signal optimization using evolutionary algorithms. In *6th European Congress on Intelligent Transport Systems and Services (ITS07)*, 2007.

F. Rochner, H. Prothmann, J. Branke, C. Müller-Schloer, and H. Schmeck. An organic architecture for traffic light controllers. In *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 *2nd International Symposium on Leveraging Applications of Formal Methods, Verification and Validation (ISoLA 2006)*, pages 185-191. IEEE, 2006.