Proactive Re-Routing of Urban Traffic based on Traffic Flow Forecasts

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Intelligent Traffic Management

Increasing mobility and traffic demands lead to serious congestion problems. **Intelligent traffic management** systems try to alleviate this problem with **optimised traffic light systems** and **dynamic route guidance**.

One approach is **Organic Traffic Control (OTC)**, offering a *self-organised*, *decentralised* system founded on the ideas of **Organic Computing**. **Adaptive traffic light controllers (TLC)** allow for an establishment of **distributed progressive signal systems** and an optimisation of the signalisation of existing traffic streams.

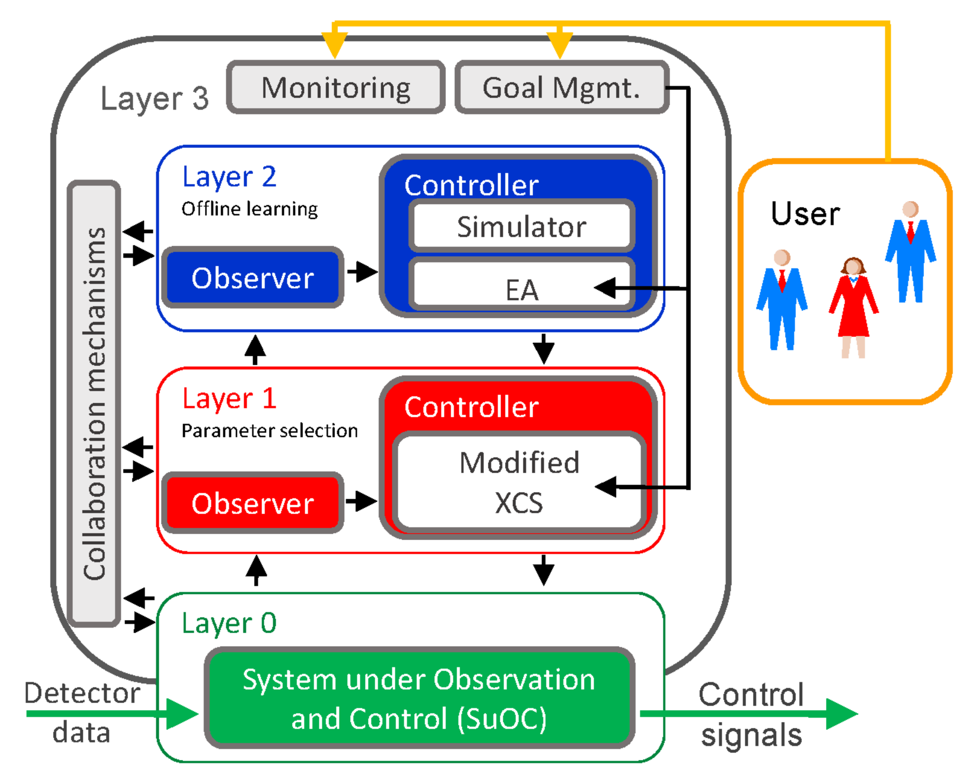


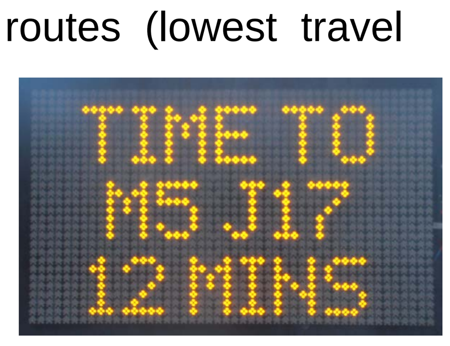
Fig. 1 Multi-layer architecture of a OTC-controlled TLC.

Dynamic Route Guidance

The fully **decentralised**, **self-organised route guidance** system calculates the fastest routes to prominent places based on current and future traffic flows.

The **routing component (RC)** of each TLC has to perform following tasks:

- Communicate its current local traffic situations to neighbouring intersections (turning delay and the estimated travel times for outgoing sections)
- Determine locally the best routes (lowest travel time)
- Manage routing tables



CHALLENGES

Only current traffic flows are considered for the route proposals: Drivers can be confronted with several route changes which might reduce the acceptance of the system.

➔ **Time-dependent route guidance protocols** consider upcoming traffic flows before drivers traverse the network.

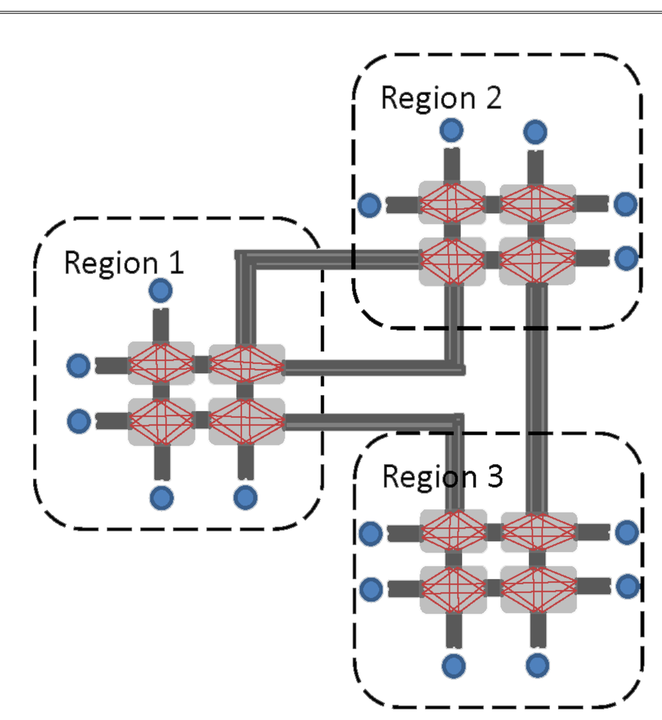


Fig. 3 Regional view of a network (junctions in red, destinations in blue).

Prediction of traffic flows

The traffic prediction works in the steps:

1) The *Observer* on Layer 1 receives raw traffic data from sensors located on Layer 0, and processes them (Figure 1).
2) Processed data is passed on to the *Prediction Component* (which forecasts traffic flows for future points in time) and the *Situation Analyzer* (derives performance measures for the intersection's signal plan).
3) The description and the forecasts are combined by the *Situation Descriptor* based on the accuracy of previous forecasts (higher accuracy → higher influence).

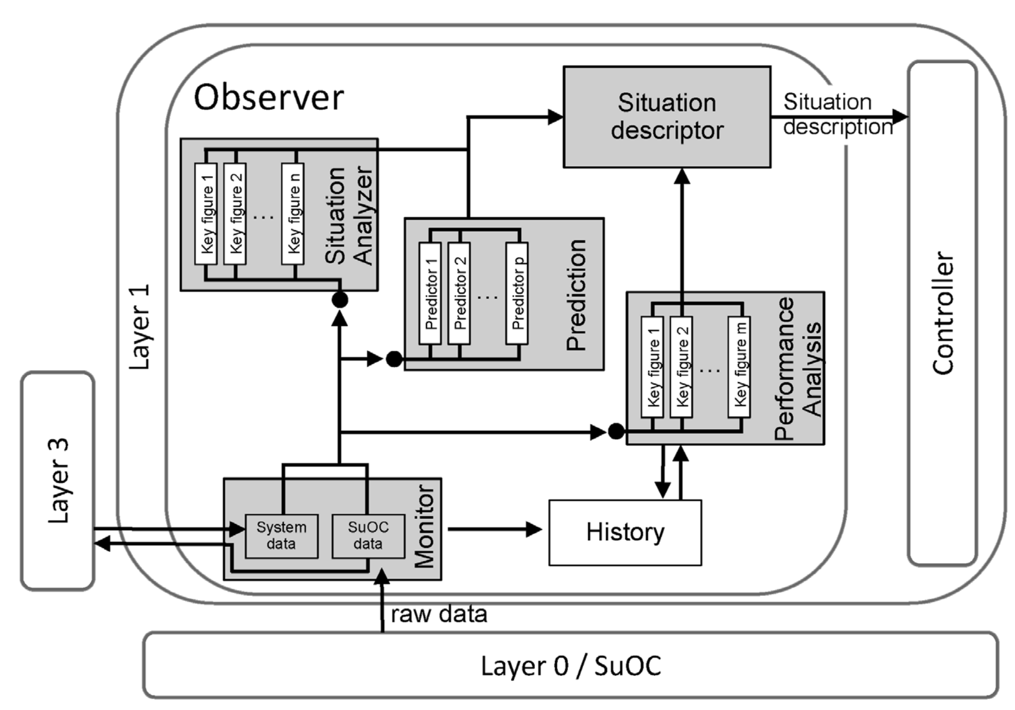


Fig. 2 Close-up on the Observer on Layer 1.

The *Prediction Component* consist of several prediction methods that each make forecasts (e.g. Kalman Filters and Artifical Neural Networks). All forecasts F_1 to F_n are accumulated into one comprehensive forecast:

$$\hat{F} = \frac{w_1 \times F_1 + w_2 \times F_2 + \cdots + w_n \times F_n}{\sum w_i}$$

with $n > 1$ and $\sum w_i = 1$.

NOTE Combinations of different forecasts result on average in lower forecast errors than single forecasts.

Temporal Link State Routing

The LSR protocol is a known protocol from the Internet domain, here applied to urban road networks:

1) **Estimate local delays + flow forecasts** for future points in time for each turning and outgoing section of the intersection.
2) Communicate those to other RCs using **broadcast messages** (so-called *advertisements*) which contain *link states* (path from a source to a sink and its estimated travel time).
3) Having received all advertisements from other RCs, each RC **builds a network graph** representing the **topology** and the **current and future traffic flows** within the network connecting the subgraphs obtained from the link states.
4) Locally **compute the best routes** to all reachable destinations with the **Dijkstra algorithm** based on the previously generated graph.
5) **Update the interior routing table entries** with the determined best paths to all reachable destinations.

Temporal Distance Vector Routing

In contrast to the basic DVR protocol, the Temporal DVR protocol tries to cover the *time-dependent traffic conditions* for future time steps in considering traffic flow forecasts:

1) **Estimate arrival time** starting from the previous RC. **Make forecasts** for turning's delays and travel times for outgoing sections to neighbouring prominent destinations for this time step.
2) **Forward the updated request** to nearby RCs until a cycle is detected. Return discovered routes to the sender.
3) **Update routing tables:** Add a new route or update an existing one if the new costs are lower.

Evaluation

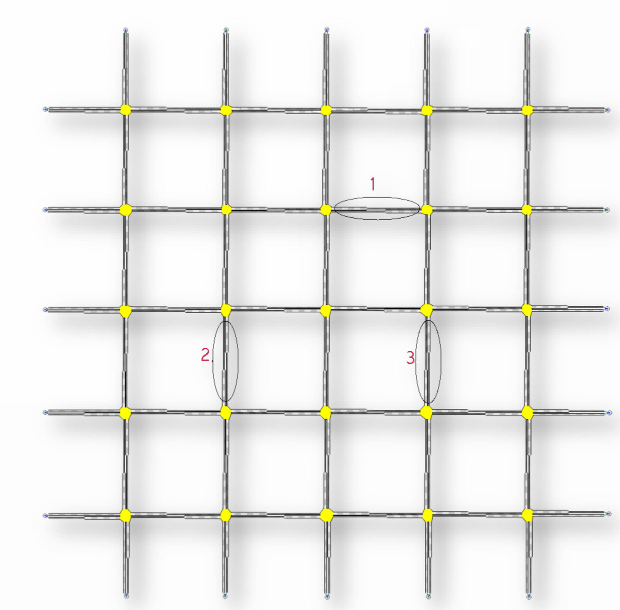


Fig. 4 Manhattan-style network with 25 junctions and 20 destinations. Incident locations marked with ellipses.

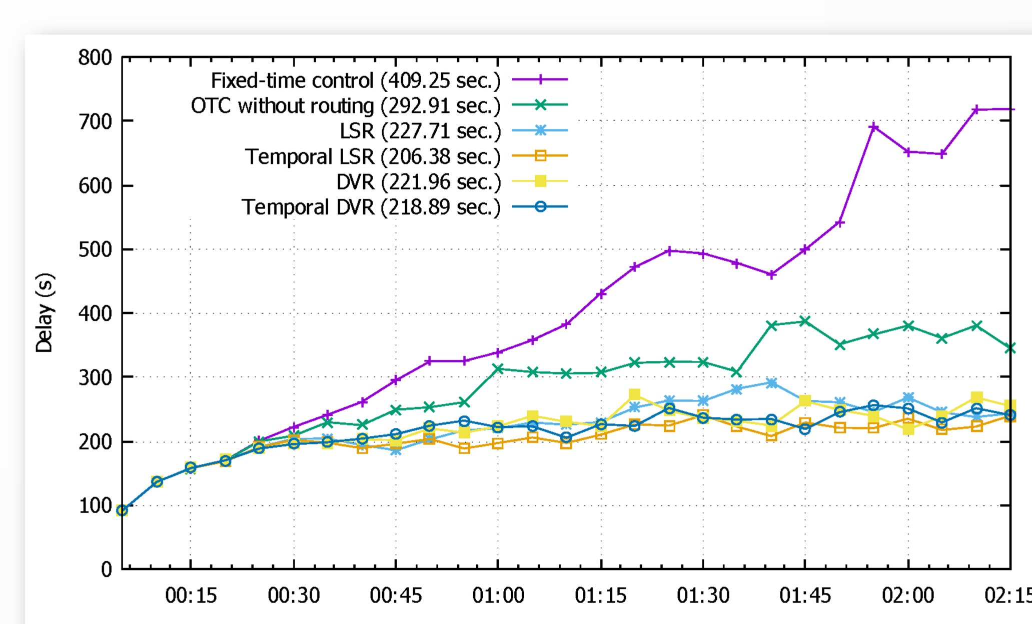


Fig. 5 Results under free flow conditions: Temporal LSR had the lowest delay (206.38 sec.).

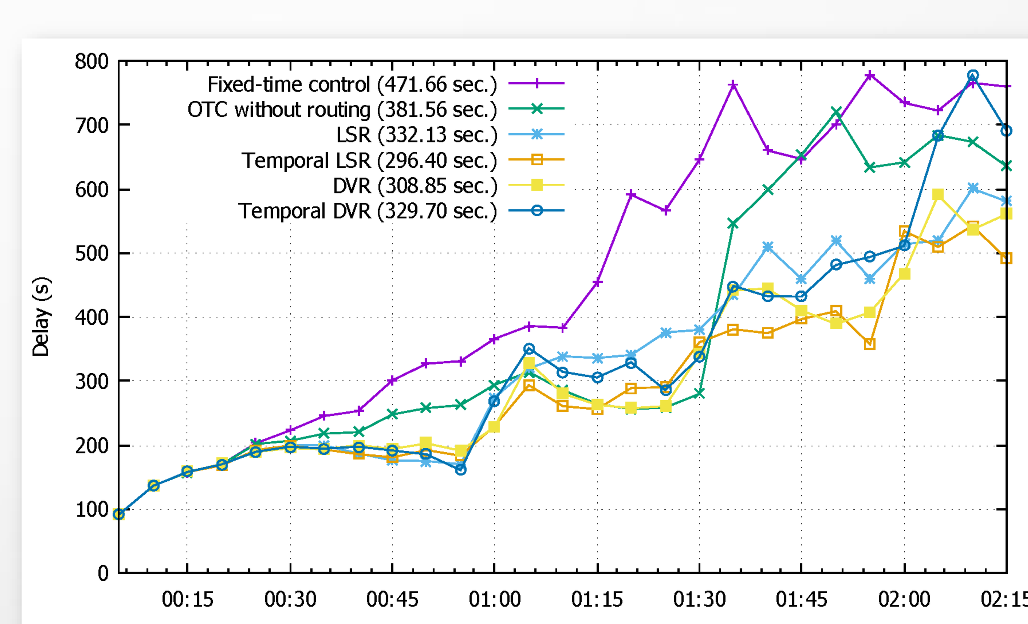


Fig. 6 Results under congested conditions: Temporal LSR performed best, reducing the overall delay to 296.40 sec.

References

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[2] Sommer et al.: Learning to predict: Automated management and correction of prediction techniques for traffic flows within a self-organised traffic control system. In: Proc. of 11th Int. Congress on Advances in Civil Engineering (2014)

[3] Prothmann et al.: Decentralised Route Guidance in Organic Traffic Control. In: Proc. of SASO'11. pp. 219-220. IEEE (2011)