A New Dynamic Traffic Management Method using V2X-Communication

Daniel Schmidt*
Institute of Transportation and Urban Engineering,
Technische Universität Braunschweig, Brunswick, Germany

Bernhard Friedrich
Institute of Transportation and Urban Engineering,
Technische Universität Braunschweig, Brunswick, Germany
* Email: dan.schmidt@tu-braunschweig.de

1 Dynamic Traffic Management

In urban areas, the infrastructure often represents a bottleneck due to traffic demand exceeding available road capacities. Here, dynamic traffic management is necessary in order to provide strategies for efficient control, e.g. by applying time-dependent signal plans.

The traffic load typically varies strongly throughout the day. Therefore an adaptation of the traffic management according to the actual demand is essential. To enable dynamic approaches within urban areas, a detailed knowledge of the actual traffic state is essential (Section 1.1). Furthermore, an optimization of traffic signal plans is required (Section 1.2). The use case and the results are shown in Section 2.

1.1 V2X-Communication

Wireless communication allows a continuous exchange of information between vehicles and between vehicles and infrastructure. IEEE 802.11 wireless LANs have turned out to be the enabling technology for these communication systems that offer a higher potential to improve traffic safety and efficiency. The vehicles' capability to periodically broadcast Cooperative Awareness Messages (CAMs) which contain status information like position, speed and driving direction as well as message generation time allows the real-time estimation of current traffic conditions.

In [1] the impact of communication parameters like communication range, packet generation rate and penetration rate on the quality of the Traffic State Estimation is analyzed in detail.

1.2 Traffic State Estimation

A fundamental requirement for every kind of traffic-dependent control is the availability of information about the actual traffic state.

Within the work presented here the capabilities of communicating vehicles for traffic state estimation in terms of delay times and level of service, LOS [1] are used. The collection of vehicle generated messages at the traffic management center (TMC) enables the measurement of the mean travel time on a road segment. The traffic state at every road (section) for each time interval (e.g. a cycle, every 5 minutes, etc.) is computed according to the following algorithm:

1. For each vehicle i, collect the timestamps $t_{in;i}$ and $t_{out;i}$ for the vehicle entering and leaving a given road section.
2. Compute the mean travel time t_{mean}:

$$t_{mean} = \frac{1}{n} \cdot \sum_{i}^{n} t_{out;i} - t_{in;i}$$

   where n is the number of vehicles traversing the section in this time interval.

3. Compute the ideal travel time t_{ideal}, which is the time a vehicle would require to traverse the section during free, uncongested traffic:

$$t_{ideal} = \frac{l}{v_{opt}}$$

   where l is the length of the section and v_{opt} is the optimal speed.

4. Calculate the mean delay time[1] t_{del}:

$$t_{del} = t_{mean} - t_{ideal}$$

5. Identify the current LOS by using the classification of the delay time t_{del} according to the following table:

t_{del} $[sec]$	≤ 20	≤ 35	≤ 50	≤ 70	≤ 100	> 100
LOS	A	B	C	D	E	F

TABLE 1: classification of delay times [2]

[1] ASSUMPOTION: All delay is induced by traffic lights.

1.3 Optimization of Traffic Lights

The objective of traffic management systems is to detect different states of traffic flow and to react accordingly in order to preserve or improve the supervised network's overall performance. This work combines a new dynamic traffic control approach, the reduction of intergreen times by elimination of phases and phase changes, with the well-known procedures of traffic planning: signal plan adjustment [3].

A signal plan consists of phases and phase changes. The duration of the phase change is determined by the decisive intergreen time, i.e. the longest intergreen time among all combinations of ending and starting signal groups. A recent study shows that there is a potential of a capacity increase up to 7 % by reducing intergreen times and thus phase change times [4].

Another way to reduce intergreen times is the elimination of one or more phases and corresponding time-consuming phase changes. Using this approach, the validity of the remaining signal plan has to be assured: There has to be either a green time or a close alternative route for every traffic participant in the network. To calculate a new signal plan the following algorithm is used:

1. Calculate a reference signal plan with all phases by using the procedure of the RiLSA [3] and benchmark it.
2. For all phases of the actual signal plan do:
    a. eliminate this phase from the actual signal plan and in doing so eliminate some corresponding turnings
    b. check whether the new signal plan is valid (see above)
    c. determine an optimal signal plan by using the procedure of the RiLSA [3]
    d. calculate the benefit of this signal plan[2]
3. Choose the best signal plan and switch to it.

Before switching to the new signal plan all affected traffic participants have to be informed about the elimination of turnings by using V2X-Communication. The individual vehicle may react to this new information and redefine their route through the network.

2 Use Case and Results

A model of the road network in the southern part of Hannover is implemented in the microscopic traffic simulation software AIMSUN. Traffic flows and traffic signal programs are

[2] The benefit of a new signal plan can be measured in terms of capacity increase or performance improvement (e.g. LOS improvement).

parameterized according to empirical traffic data as well as control programs being in operation.

The traffic state estimation results show a high concordance of the results given by AIMSUN and our V2X-Communication based algorithm for totally covered road sections. The maximum gap between both is not higher than 2%. The results also show that, while the penetration rate and the communication range significantly affect the Traffic State Estimation accuracy, a packet generation rate of one packet per second should be sufficient when all vehicles are equipped.

Because of the delayed reception of the first CAM at not totally covered road sections a systematically underestimation of the traffic state is obtained (see FIGURE 1: 15dbm). Hence both the real entrance time $\tilde{t}_{in;i}$ and the real leaving time $\tilde{t}_{out;i}$ have to be estimated:

$$\tilde{t}_{in;i} = t_{in;i} - \frac{s_{in;i}}{v_i}$$

$$\tilde{t}_{out;i} = t_{out;i} + \frac{s_{out;i}}{v_{mean;i}}$$

Where ~ marks the estimated times, $s_{in;i}$ and $s_{out;i}$ the locations of the first and the last received CAM, v_i the actual speed and $v_{mean;i}$ the mean speed of vehicle i.

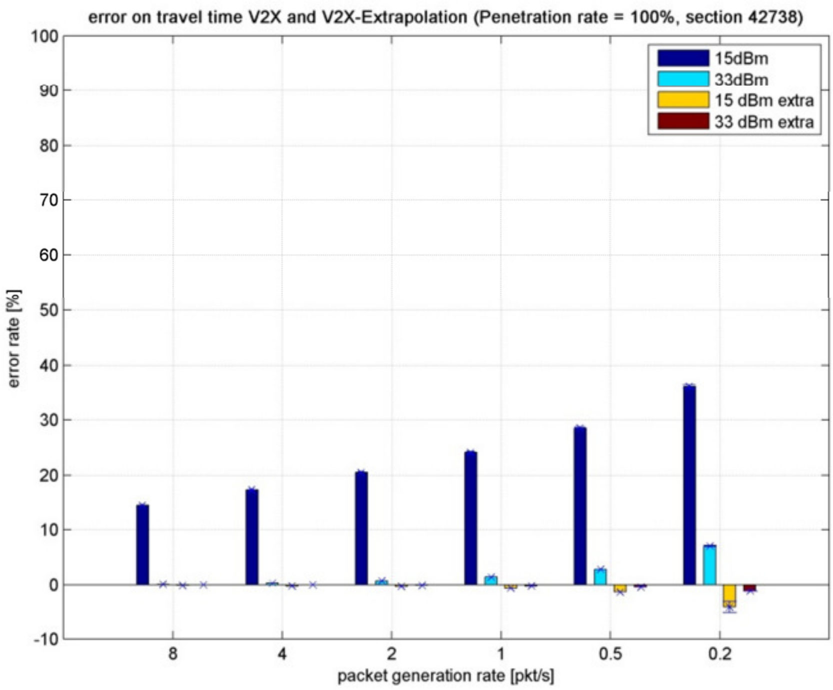

FIGURE 1: error rate on travel time V2X and V2X-Extrapolation

First results for the signal plan optimization show a capacity increase of more than 16%. Thus congestions at this intersection can be cleared or even avoided without worsen the traffic situation of the whole network.

References

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