Utilisation of cooperative, automated vehicles with external HMI as part of traffic signal control

Robert Oertel robert.oertel@dlr.de | +49 30 67055650
German Aerospace Center (DLR) | Institute of Transportation System | Rutherfordstr. 2, 12489 Berlin, Germany

1. Motivation

One main goal of traffic signal control is to minimise waiting times for road users by an optimised green time allocation. The options for redistributing signal times are limited, since a control was planned in advance for the traffic conditions that typically exist at a junction. If the traffic conditions change fundamentally, even a traffic-dependent control cannot compensate for this.

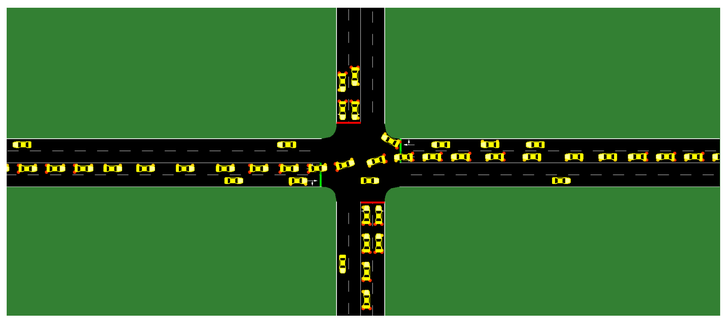

Fig. 1: Some traffic situations can normally only be improved by structural measures at a junction.

2. System setup

To avoid fundamental changes to the traffic signals, a new approach was developed:

- The potential of cooperative automated vehicles (CAVs) in combination with an external human-machine interface (eHMI) is utilised for this purpose.
- With their eHMI, the CAVs take over some of the control and signalling tasks of the traffic signals. The traffic signals themselves remain untouched, the existing green times are still signalised with the existing signal heads, no adjustments are made.
- The CAVs with eHMI intervene non-invasively in this existing system through their status and display behaviour, creating new signal phases with assigned green times.

Fig. 2: One of DLR's cooperative automated vehicles (CAV) with a green bar as external human-machine interface (eHMI).

3. Simulation use cases

The novel approach was implemented and tested for two initial use cases in SUMO:

- Use case 1: An additional, separated left-turn phase is required. The CAVs remain at their position for a certain time at the start of the actual green phase and signal the possibility of a safe left-turn via their eHMI.
- Use case 2: A bus is given priority in the same way so that it can ideally pass without stopping.

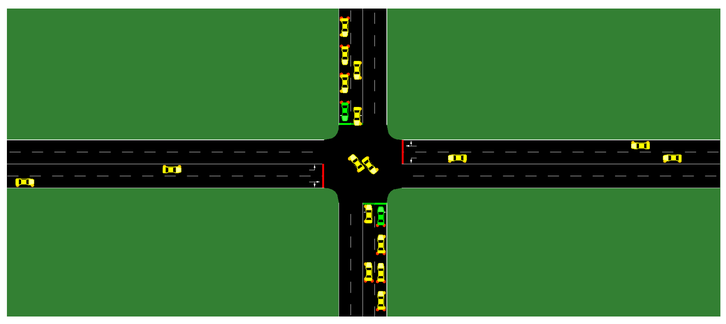

Fig. 4: CAVs with eHMI create an additional phase for left-turning within the existing green phase (use case 1).

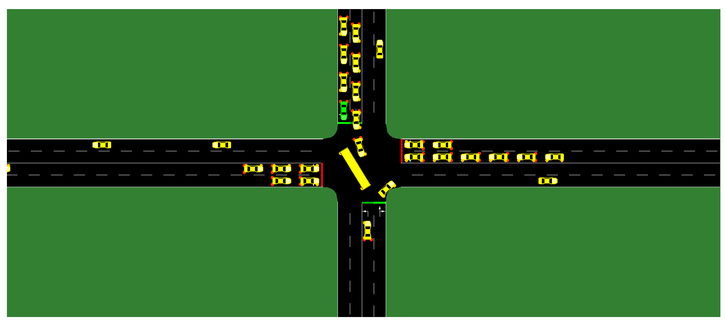

Fig. 5: CAVs with eHMI give priority to the bus within the existing green phase (use case 2).

- Both use cases were simulated for a simple two-phase system.
- One left-turn lane and one combined straight ahead/right-turn lane are available on each approach.

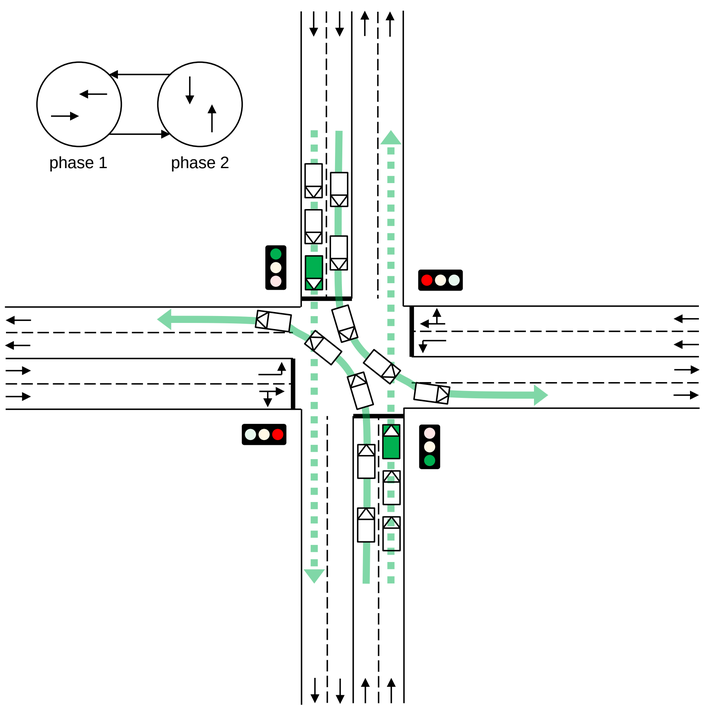

Fig. 3: CAVs with eHMI (green vehicles) are utilised for controlling and signalling tasks at a signalised junction.

4. First simulation results

The new control approach was analysed and evaluated in terms of its impact on traffic flow. The average journey and/or waiting time was used as evaluation parameter. A classic fixed-time control served as the comparison scenario:

- Use case 1: It was possible to minimise the previous tailbacks of left-turners, which significantly reduced the travel times of all road users.
- Use case 2: The waiting time for the bus was completely eliminated, which corresponds to absolute priority. This had no negative impact on the travel times of other road users.

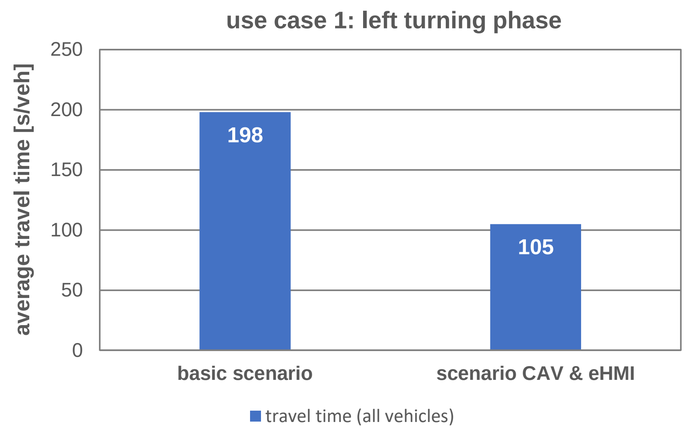

Fig. 6: Simulation results for use case 1.

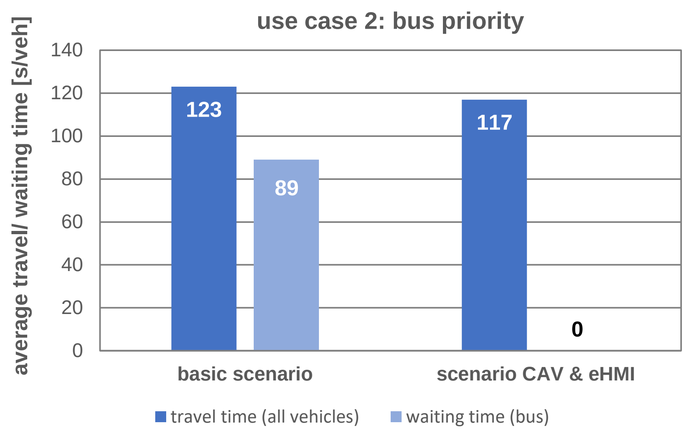

Fig. 7: Simulation results for use case 2.

5. Next steps

The new approach has been verified in a proof of concept. This will be followed by:

- Examinations for more complex junctions, traffic-dependent traffic signal controls and varying penetration rates of CAVs with eHMI.
- The consideration of e.g. non-motorised road users or emergency vehicles.
- Use cases for other situations which require fundamental modifications in traffic signal control.

SUMO User Conference 2024
13-15 May • Berlin