Optimized traffic signal control strategies for emergency vehicles based on Vehicle-to-X communication

Master‘s Thesis of Natalie Sautter

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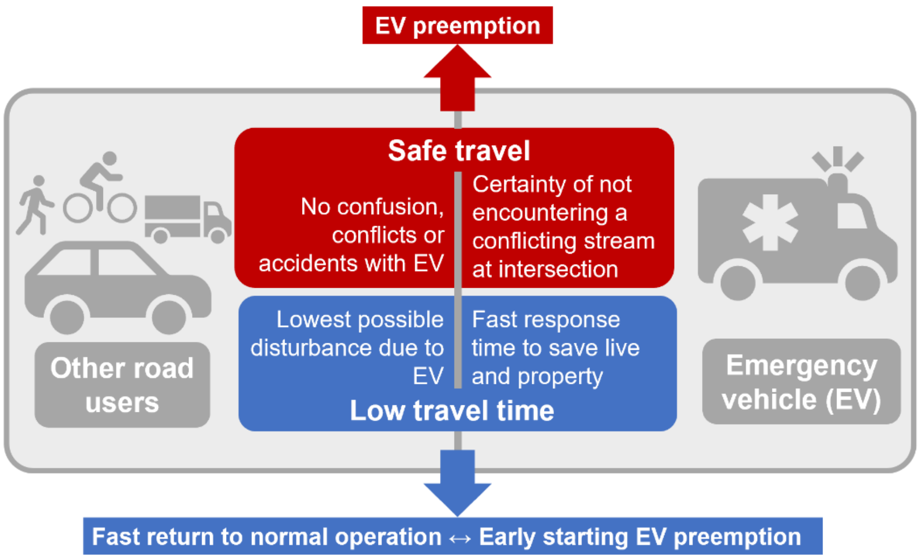
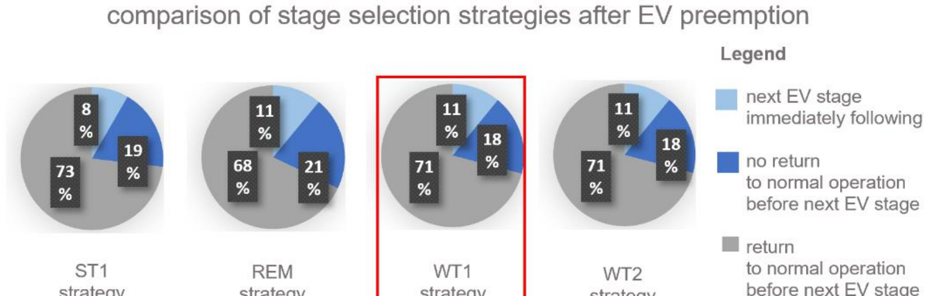


Emergency vehicle preemption for a fast and safe travel

For emergency vehicles, a low response time is essential to save lives and property. Intersections are an obstacle for emergency vehicles on their way to the incident site with a high risk of accidents. This thesis presents a traffic signal control strategy for emergency vehicles based on Vehicle-to-X communication (V2X), which enables emergency vehicles to cross intersections safe and fast. In a traffic-actuated and rule-based control, implemented via the tool *LISA*, a preemption is implemented that provides green traffic light to approaching emergency vehicles and assigns red traffic light to conflicting traffic streams. Emergency vehicle preemption has negative impacts on other road users. Therefore, besides reducing the travel time of emergency vehicles, a fast return to normal operation is an important objective. To assess the benefits of V2X communication, a regular emergency vehicle preemption based on radio-technology (*Base control*) and an emergency vehicle preemption based on V2I communication (*V2X control*) are implemented and compared. In a survey on emergency vehicle preemption in Germany, conducted in this thesis, 14 % of the participating cities report to use emergency vehicle preemption based on radio-technology. Since emergency vehicle preemption has to work in different environments, both regular emergency vehicle preemption and emergency vehicle preemption based on V2I communication are implemented for three different intersections and one network as well as different levels of traffic flow (low, normal, high and very high). For evaluating and assessing the implemented traffic signal controls, microscopic traffic flow simulations are conducted using the tool *VISSIM*.

urban intersection (three legs), return to normal operation, normal traffic flow, comparison of stage selection strategies after EV preemption

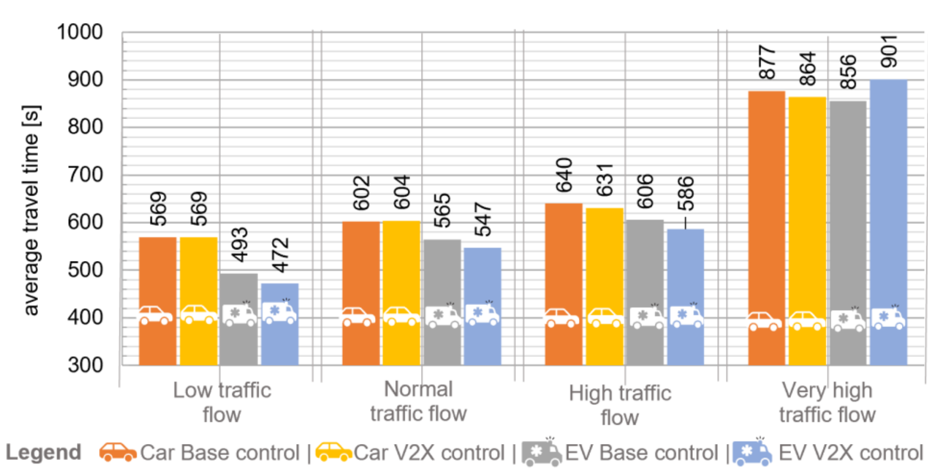


Return to normal operation before next EV stage				
48	50	39	49	Average duration [s]
255	242	168	184	0.95 quantile duration [s]

A good stage selection strategy can promote the fast return to normal operation after emergency vehicle preemption

Four different strategies were considered for the stage selection after emergency vehicle preemption: transition to Stage 1 (ST1), transition to the stage active at the time of the preemption request (REM), transition to the stage with the highest average travel time (WT1) and transition to the stage that serves the signal group with the highest average time at intersection (WT2). The ST1 strategy was chosen for the network, assuming that it is the best strategy to quickly regain a functioning coordination after preemption. The WT1 strategy was chosen for the isolated intersections, as it performs best when evaluating average travel time, average queue length and return to normal operation at normal traffic flow. With the WT1 strategy at normal traffic flow, normal operation is regained in 71 % of the cases before the next preemption starts, taking an average of 39 seconds after preemption for the return to normal operation.

urban intersection (three legs), average travel time



V2I communication enables dynamic pre-start time calculation

Emergency vehicle preemption is started when the remaining travel time of the emergency vehicle is less than or equal to the sum of stage transition time and pre-start time. At *Base control*, the pre-start time is predefined to 30 seconds. At *V2X control*, the potential of V2I communication is used to calculate the pre-start time dynamically based on the information from V2I communication, considering the number of vehicles ahead of the emergency vehicle that will slow it down. The evaluation confirms the successful dynamic pre-start time calculation. With *V2X control* at the isolated intersections, the duration of the preemption is greatly reduced. Further, a faster recovery from the preemption is provided. The average duration for the return to normal operation decreases by up to 60 %. *V2X control* reduces the number of vehicle stops at intersection by up to 31 % as well as the average cycle based queue lengths in the sub direction. Basically, emergency vehicle preemption in both *Base and V2X control* can reduce the average travel time of an emergency vehicle by up to 17 %, compared to cars. The urban intersection (three legs) performed best in emergency vehicle preemption based on V2I communication and decreases the emergency vehicle’s travel time by up to 4 %, except for very high traffic flow. At the outer urban intersection, the average travel times of cars and emergency vehicles hardly changed with *V2X control*. For the urban intersection (four legs) and the network, V2I communication does not improve the average travel time of emergency vehicles at preemption.