System Level Impacts of V2I-based Speed Control Strategies: the SCOOP@F project deployment scenarios.

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1 Introduction

The last decade has witnessed the evolution and advanced of new technologies for Intelligent Transportation Systems (ITS). In particular, Cooperative ITS (C-ITS) covers a large and wide range of new technologies that are deployed as part of Information Technologies (IT) systems aiming to improve road safety, driver comfort, transport efficiency and conduct to refinements in secondary effects at environmental level as well as in energy management. Impact assessment of such new technologies has been a key aspect to be estimated and analyzed [5].

The EU SCOOP@F project [10] implements the deployment of these technologies and aims to perform assessment of intelligent systems that enable and promote communication at infrastructure and vehicle technology level in transportation systems. This communication protocol is designed to interact, broadcast and collect messages between participants of a network leveraged by information technologies. In particular, this platform enables vehicle to vehicle (V2V) communication and infrastructure to vehicle (V2I – I2V) or vice versa. The main functionality of this system is to broadcast specific messages towards connected vehicles currently using a road network about emerging situations that could have potential impact on the traffic condition. Messages of this nature aim to inform about risky situations such as incidents, weather and road conditions or specific events [9]. The information is propagated upstream from the location of a specific situation (incident, work zones, slippery road, adverse weather conditions, etc.) with the support of technology infrastructure. In this work, we focus on an analysis of different variations of I2V communication policies for speed regulation. In particular, potential effects of regulated speed reduction in time and space are studied. These maneuvers are inspired from the relaxation phenomenon after lane changing described in [6] by considering the Tampere Car Following model [2]. We present the formulation of the optimal anticipation time that may have impact in avoiding specific road situations and their effects in the traffic performance.

2 Methodology

This study focuses on the potential impacts of I2V communication at the system level by introducing two main parameters. The *radius of acceptance* meaning the distance at which vehicles are able to perceive messages and *compliance probability distribution* for these messages, representing the individual driver's behavior that enables the relaxation maneuver. We conduct this evaluation by introducing the communication model embedded within a traffic micro simulator. For this study, the microscopic traffic model is considered using the Tampere Car Following model [2] where longitudinal position follows a specified behavior determined by two main components, each one associated with traffic states (congestion/free-flow) of the linear piece-wise fundamental diagram [7]. In order to introduce and simulate the effects of the speed control strategies a *desired speed* is set for a particular vehicle to modify the car-following equation behavior.

When considering the I2V communication channel, messages from the infrastructure are received in a specific area (*communication radius*) surrounding the vehicle. The full communication protocol is complex due to package loss caused by the nature of the wireless transmission. [3, 11]. We simplify the communication channel to account for a simplified model that integrates reaction time of the driver and distance to the event in order to assess the robustness of the proposed regulation strategy. In particular we consider a scenario of a straight road segment

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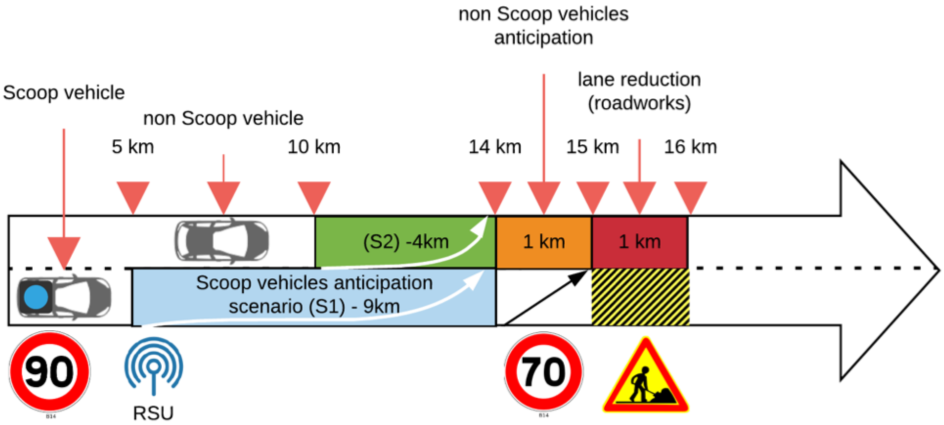


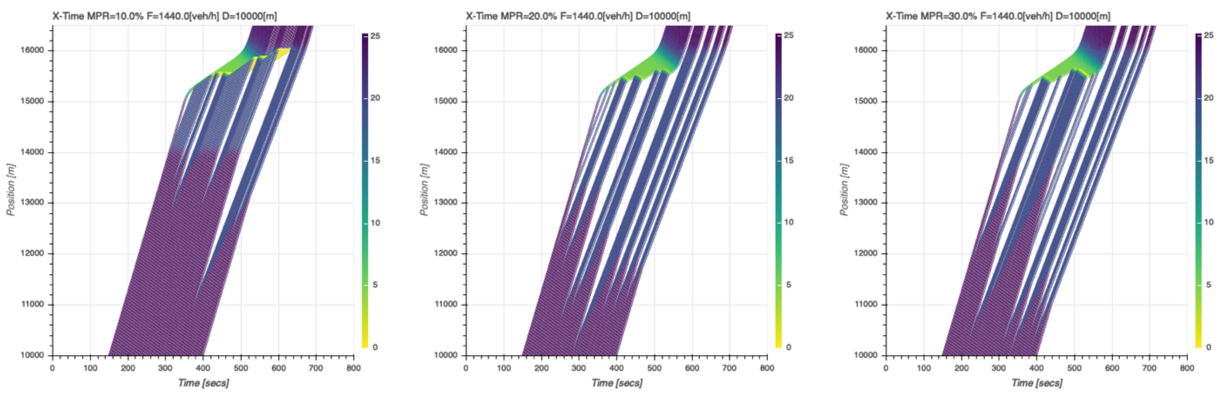
Figure 1: Scenario under test

Figure 1. The Road Side Unit (RSU) is placed upstream, 5Km/10Km before roadwork zone and broadcasts in a range of 500 meters (*communication radius*). The compliance probability distribution provides a model to decide the moment at which the policy contained in a received message is applied. This random characteristic of the system integrates (i) the time to reach the position of message activation, (ii) the compliance time of the driver (time between the message reception and maneuver execution) and (iii) possible delays/retransmissions from the infrastructure side, all of them in an aggregated way. The coherence of the physical traffic model and the compliance time of the driver is important at this point. For this reason, we consider this probability distribution of as a function of the distance to the emitter (exponential law for a single draw).

3 Results

Many use cases have been considered within the EU SCOOP@F project [9]. Here, we consider the roadwork zone use case corresponding to a lane closure with upstream signage ordering to slow down (from 90 km/h to 70 km/h) over 1 km. For regular vehicles, we consider speed drops starting 1 km upstream from roadworks, where signals and downstream congestion are at glance. For connected vehicles, speed drops are implemented when a message is received at a specific moment in time and space. The point in time and space depends on the RSU location, and acceptance probability distribution [1].

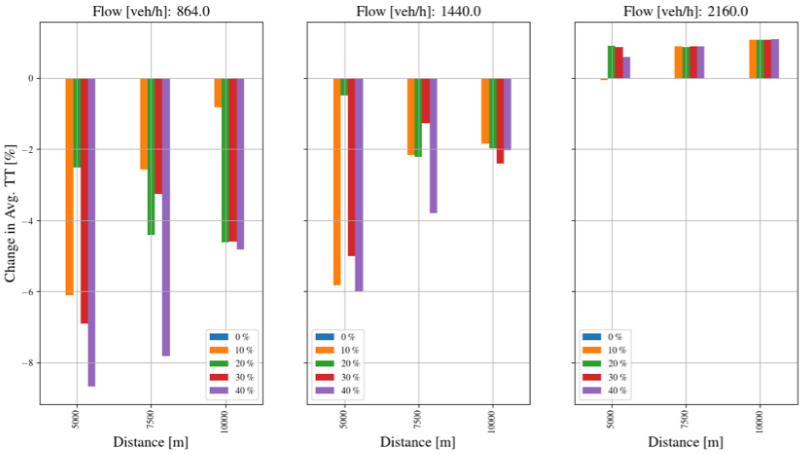
Inspired by [1] boundaries in acceleration where fixed to emulate drivers traffic behavior, e.g. mean acceleration is around 1 m/s^2 while maximum accelerations where constrained to 3 m/s^2. We have considered the analysis on several traffic parameters such as *market penetration rate* (MPR), *Traffic Demand*, *Distance to Event*.



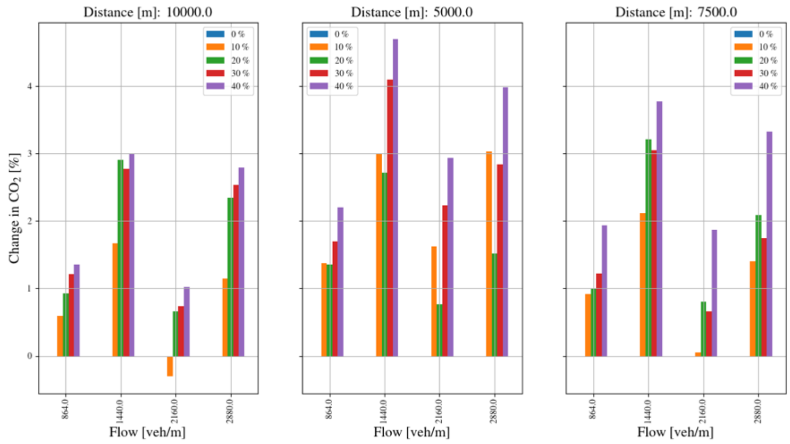
(a) MPR - 10% (b) MPR - 20% (c) MPR - 30%

Figure 2: Space time trajectories under the effect of V2I speed policies

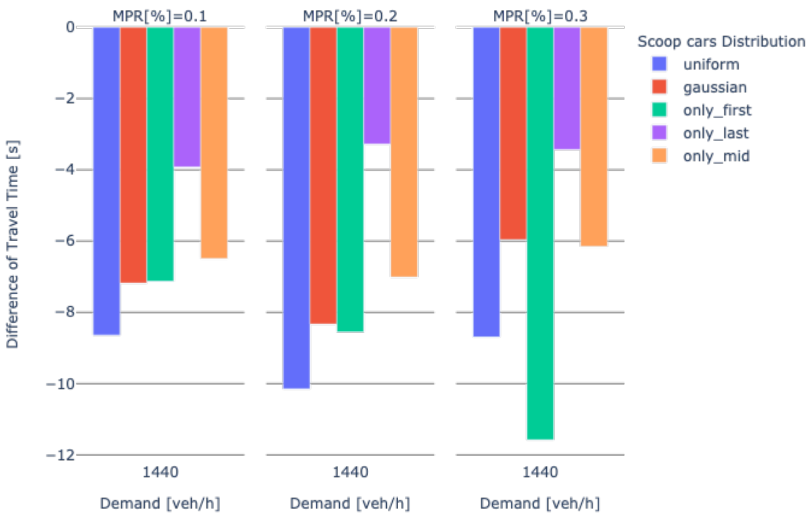
[1]All the results can be reproduced using the simulation code in this link: `https://github.com/aladinoster/I2Vspeedcontrol`



(a) Change on average travel time



(b) Savings in CO_2 emissions



(c) Change on average travel time according to spatial distribution of SCOOP cars

Figure 3: Relative change of traffic indicators

Figure 2 illustrates a summary of one case. We observe the effects on the time-space trajectories when the strategy is activated in a distance range of 5 Km upstream from the event with MPR variation and constant demand. From the figure it can be observed that for a percentage of the demand the congestion event created by the roadworks can be avoided.

In order to perform a more robust assessment we consider variations in MPR and demand. Figure 3a illustrates the effect on the average travel time for different conditions. In general we observe that the system produces better benefits at higher penetration rates but it reaches its limits when the demand is very high close to the road capacity. Figure 3b illustrates the side effects in terms of CO_2 emissions when the Passenger car & Heavy-duty Emission Model (PHEM) is coupled with the traffic simulation [8]. It can be observed the positive effect of the MPR to reduce traffic emissions when the maneuvers are applied (Figure 3b). Figure 3c focuses on the impact of the spatial distribution of Scoop vehicles on the average travel time. The objective is to relax the assumption of homogeneously distributed scoop cars within the global flow. By comparing different kind of distributions it highlights the fact that the positive impact on traffic previously observed is highly dependant on the spatial distribution of the cars. In the context of mixed traffic, the road managers, who are broadcasting instructions and warning messages, can expect better performance when the connected vehicles are homogeneously distributed in the global flow, while Scoop vehicles, who are tending to platoon together, will prevent the spread of the instructions upstream.

4 Conclusion

In this study an impact traffic assessment has been implemented at simulation level to better understand the effects of messaging policies from infrastructure towards vehicles. Speed control regulation has shown to be an efficient policy to avoid particular roadwork events at relatively high penetration rates. This research was carried out at simulation level to better understand scaling effects of these technologies. We consider random distributions of connected vehicles in the network to better emulate real traffic conditions. The impact was assessed in terms of travel time, environmental and safety aspects. It can be seen that the introduction of this technology causes part of the traffic to avoid the effects of road works at a cost of a slight degradation in the average travel time for all users of the road network. Despite the missing results, the safety of the full system can be enhanced via the introduction of V2I-enabled vehicles, full results will be included in the extended version of this research.

As a trade off, the overall throughput performance of the network may be degraded conducting to a Pareto evaluation in some cases. Fixing speed limits on the network conducts a regulation of vehicle's acceleration and consequently improvements in CO_2 emissions. For the scenario studied in this case it was observed that also emitting messages at intermediate distances (5 Kms) may have a positive impact on the emissions of CO_2. Nevertheless, the main key aspect to contribute emission reduction is the market penetration rate that seems to reduce marginally the average emissions of the system and therefore the accumulated ones.

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