Investigating travel time aspects of autonomous vehicle platoons used in city logistics

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The demand for transportation is constantly increasing. This is true not only with respect to the transportation of people but also with respect to the transportation of goods. The flourishing of eCommerce in the last decades, has simplified many commercial transactions, thus contributing to the accelerated increase in freight transport.

In parallel to the increase in demand, we are witnessing in recent years a great technological evolution. This evolution has not gone unnoticed also in the transportation sector, and is responsible for the development of several new concepts in this field. These concepts are partly designated to assist in mitigating the increasing demand. Platooning is one such a concept.

Platoons are usually considered for freight purposes (Ramakers et al., 2011; Alam et al., 2015; Liang et al., 2016). The use of platoons is particularly promising due to their ability to increase road utilization and road safety (Varaiya, 1993; Alam et al., 2015), and to assist in reducing fuel consumption (Tsugawa et al., 2011; Janssen et al., 2015; Van De Hoef, 2015).

In this work we describe a setting, where platoons are used for delivery purposes in city environment. Each platoon consists of a human-driven leader, and followers - a number of autonomous vehicles. We assume that platoons are traveling in fixed short routes in the network. In order to perform a delivery task, a vehicle joins a platoon for the relevant section of the way that will bring it closer to its destination. Once the platoon is no longer relevant for the joining vehicle (continues in a different direction), the vehicle will leave the platoon, and will look for the next relevant platoon to join, until reaching its destination. Note, that in this simple scenario the only vehicles in the system are the platoon vehicles and the additional joining vehicle.

With respect to the presented setting, we are interested to examine the effect of different platoon configurations (i.e. the number of vehicles per platoon and the total number of platoons) on the travel time of the joining vehicle, and its waiting time while switching platoons. Both these operational measures are tested in different scenarios, while varying the number of platoon vehicles in the system: starting with a total number of 24 platoon vehicles, increasing it to 36 and eventually to 48 vehicles.

The presented setting is examined using a microscopic traffic simulation. The chosen microsimulation tool for that purpose was SUMO (Behrisch et al., 2011), combined with PLEXE (Segata et al., 2014), an extension to SUMO that implements the functionality of platoons in a road network. As a case study, a small network was constructed, which includes two straight sections, 620 m each, connected by a roundabout, as presented in Figure 1. Each one of the straight sections represents a fixed route of a platoon. Platoons are traveling along each route in a circle constantly. In this example we assume a single delivery task has to be carried out by an additional vehicle. This vehicle travels the network by joining a different platoon each time and traveling towards its destination. In our example, the vehicle travels from point A to point B, indicated in Figure 1, and has a single transfer in point C, where it switches platoons. The transfer is executed in the following manner: after arriving at point C, the vehicle waits until it detects a platoon approaching, which travels in the direction of point B. When this platoon is close enough, the vehicle starts moving in its direction, and eventually joins it.

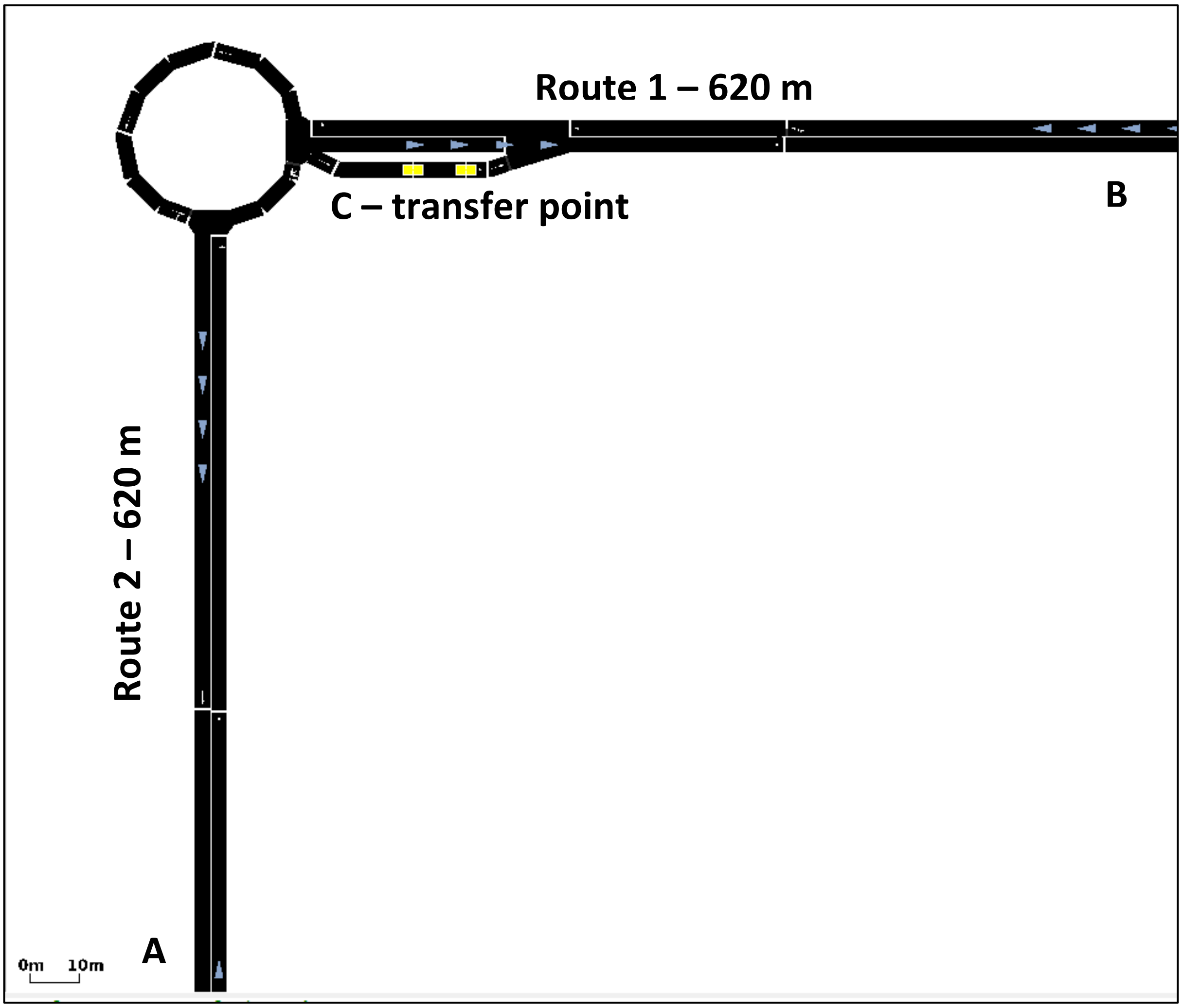

Figure 1 – the case study network

9 scenarios were tested in total as described in Table 1, and the total traveling time (including the waiting time in point C) ranged from 116 sec. to 151 sec. (for a speed limit of 50 kph).

Table 1 – the examined scenarios

Number of platoons in the network (in both sections)	Number of vehicles per platoon	Total number of platoon vehicles
4	6	24
6	4	24
8	3	24
12	2	24
6	6	36
12	3	36
8	6	48
12	4	48
16	3	48

The results show that the total number of platoon vehicles does not necessarily affect the total travel time, as a total traveling time of 116 sec was observed for scenarios with different number of platoon vehicles. However, changing the platoon configuration has an effect on both the traveling time and the waiting time. As the number of platoons increases, so increases the travel time from point A to C (up to 50%). An opposite effect is observed with respect to the waiting time in the transfer point C; the greater the number of platoons in the system, the shorter the waiting time at the transfer point (up to 87%).

The above findings can be explained by the fact that the traveling time in the roundabout is hardly affected by the number of vehicles per platoon. Therefore, while increasing the number of vehicles per platoon shortens the waiting time at the entrance to the roundabout, it barely affects the travel time in the roundabout. The waiting time in point C, on the other hand, is directly affected by the number of platoons. Increasing the number of platoons in the system implies more frequent arrivals of platoons close to point C. This allows for a shorter waiting times at point C.

The contribution of this work lies in its ability to pinpoint the effects of different platoon configurations on operational measures as the total travel time and / or waiting time in the network, when used in similar settings to the one presented in this work.

In addition, an important by product of this work is the treatment of platoons in roundabouts. Since platoons cannot be split, there is a need for a special treatment of platoons once approaching a roundabout, with respect to the right-of-way. While one of the inherent features of microsimulation tools is the treatment of the right-of-way for single vehicles, this is not the case for platoons. Therefore as part of this work an algorithm was developed and implemented to provide the right-of-way of platoons in roundabouts.

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