The forming of truck platoons: How to make it work

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Introduction

This paper is a conceptual paper which considers one of the practical yet important challenges in truck platooning, namely the physical forming of platoons. Truck platooning involve the grouping of trucks into connected sequences of trucks in order to save fuel, and at later stages, relax rest hour restrictions. Whereas many papers have been concerned with technology aspects of platooning, e.g. how vehicles are technically connected through sensors and communication protocols, few papers have addressed the obvious practical challenges of forming platoons in the largely unpredictable and highly complex transport environment where congestion and incidences makes even short term prediction in the space-time domain challenging. However, intelligent forming of platoons is important, as it will influence the logistic performance.

In the paper, we will argue that, contrarily to what seems to be the ruling understanding, “on-the-fly platooning” on highway links is unlikely to be a successful pairing strategy. There are several reasons for this among which, safety issues and limited manoeuvre capabilities are the most important.

This led us to consider a set of alternative “docking” strategies which will be effective in providing good platooning partners and require minimal changes to the existing infrastructure. Fundamentally, we propose a “double lane-blending” technique which can be applied in harbours, at warehouses or at rest stops. The technique is based on the concept of parallel parking lanes as typically seen in harbours. For a set of Q lanes, there are potentially $Q(Q-1)$ platooning opportunities if we utilise blending when going into the lanes (e.g., when arriving at the harbour) combined with blending when going out (e.g., when boarding the Ferry).

However, to support the implementation of such a system new model tools are needed. Firstly, we need a forward looking route choice algorithm which in a probabilistic sense can predict the route of the trucks. Secondly, we need a mechanism for how common routes can be formed in a negotiation process between two or more trucks.

Double-lane blending

The “double-lane blending” approach is illustrated in Figure 1.

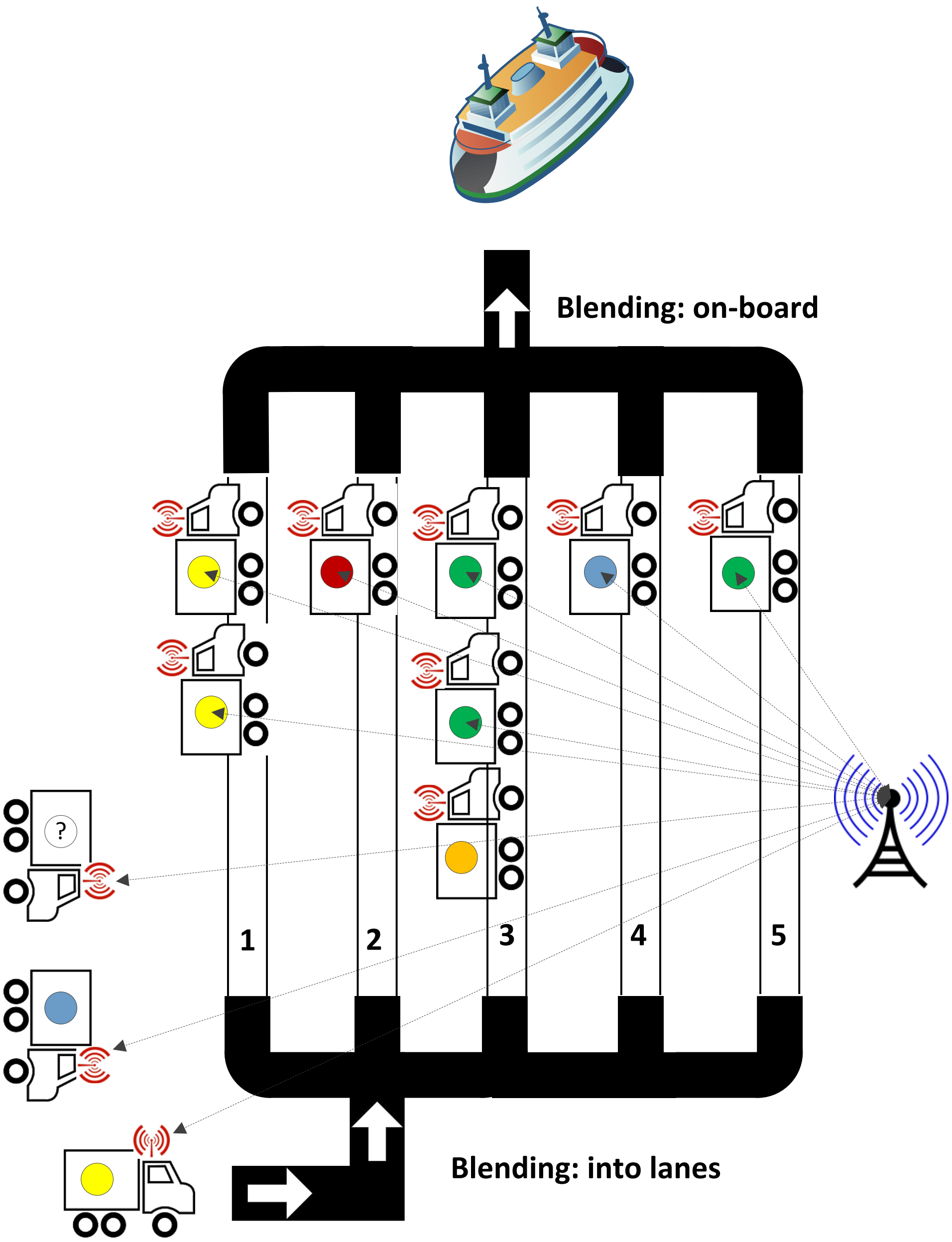

Figure 1: A platooning system in a ferry port with multiple lanes.

Harbours are locations where many trucks meet and have idle time. However, more importantly, trucks that is to depart with the same ferry already implicitly share vital route choice decisions which make them likely to be better platooning partners than trucks chosen at random in the motorway system. As an example, trucks on the ferry between Gedser and Rostock often travel south and are likely to have similar routes a long way through Germany. The next thing that makes harbours an excellent docking area has to do with the physical infrastructure. The typical set-up in a harbour is that trucks are lined up in many parallel 'columns'/lanes and this can be utilised in the forming of the platoons as described.

Path-based assignment model

A core element when evaluating the quality of different potential platooning partners is to align and compare the forward-looking path of the trucks. In this paper we suggest using a path-based traffic assignment model, which has been recently developed (Rasmussen et al., 2017). This traffic assignment model allows a disaggregate in-memory representation of all used routes and their flow-share between all OD-pairs in large-scale network. This makes it straightforward to evaluate the probabilistic overlap. The paring of platoons will be carried out in two stages. In a first screening phase we evaluate the similarity of (planned) routes using a modified Jaccard Index. This produces a limited consideration set of platooning partners. In a second stage, we initiate a route negotiation process based on optimal via-points for all sets of platoon compositions in the consideration set (see below). This leads to the best platoon pairing in the consideration set.

Optimal route negotiation

In the decision of forming a platoon a route negotiation process is carried out. As trucks will typically have different destinations, the trucks needs to negotiate on a common route from the harbour to a common via-point. Hence the platoon will be kept together to the via-point and then hereafter change composition or be resolved. In the following we will refer to link h as the origin of the platoon and d_t the destination link for truck t in the set of t=1,2,…, *T* trucks. Moreover, let;

$i_{r,t} \in I_{r,t}$: The set of road links i belonging to route r of truck t.

$q \in \bigcup_{r,t} I_{r,t}$: The set of possible via-points defined as the union of all links on all routes for all trucks as calculated in the path-based assignment.

The choice of optimal via-point for a set of potential platooning trucks involves two considerations. Firstly, the benefits of staying in the platoon up to the point where it is resolved, hence link q. Secondly, the dis-benefit or detour a via-point may cause when compared to the optimal route. Hence, the scoring function of choosing q can be written as

$$Z(q) = \sum_{k=1}^{K} \sum_{z=1}^{q} \theta_k L(i_z) + \sum_{k=1}^{K} \|r^*(h, d_k)\| - \|r^*(h, q) - r^*(q, d_k)\ \|$$

Here $L(i_z)$ is the length of link i_z and θ_k a parameter representing the benefit of platooning for truck *k* in the platoon consisting of K trucks. The second term represents the detour from the shortest path between h and d_k given by $\|r^*(h, d_k)\|$. As the consideration set is small and the computations very simple, it is straightforward to find the optimal via-point by simply evaluating all possibilities.

Results and simulation experiments

Based on a recent European freight model we investigate the quality of parings in different contexts and evaluate the economic benefit of good parings compared to on-the-fly pairings. All of this is analysed with a recent path-based assignment and the above scoring-function for calculating optimal via-points.

Keywords: *truck platooning; platoon formation; path-based route choice; logistic systems; connectivity, benefit-sharing*

References

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