Real-time train rescheduling for connecting trains

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1 Introduction

Real-time Rail Traffic Management Problem (rtRTMP) consists in adjusting train timetables in the presence of disturbances, where pre-defined train timetables become infeasible. It does so by employing appropriate control measures, such as re-timing, re-ordering, and re-routing. To address this issue and assist dispatchers, several optimization strategies have been proposed in the literature [1]. Several connecting trains run throughout the day, allowing passengers to transfer from one train to another. Trains may get delayed when there is a perturbation in the network. A minimum amount of time is allotted for connections called minimum connection time. Reducing the minimum connection time between trains is one option to limit delay propagation. This is often possible thanks to buffers existing in the timetable, provided a minimum connection time is always ensured.

We propose two enhancements to the existing rtRTMP model RECIFE-MILP[2] to allow passenger transfers and limit delay propagation exploiting connections. We aim to minimize the total delay of all the trains in the system. We also examine the impact of the two enhancements on the solution time of the model.

2 Problem description

In this paper, we extend the Mixed-Integer Linear Programming (MILP) formulation at the basis of the state-of-the-art RECIFE-MILP algorithm [2] to include passenger connections. The RECIFE-MILP allows solving rtRTMP instances to optimality while taking into account all possible alternative routes that are physically present in the infrastructure of interest. In addition, it also considers microscopic representation of infrastructure with routes divided into track circuits.

Train routing, timing and ordering decisions are the problem variables to be fixed to create a feasible timetable. In large station areas, several alternative routes are typically available for each train. They may allow for two trains with passenger connections to be placed at various platforms within the station. A minimum amount of time is allotted for connections, passenger can transfer from one train to another. In RECIFE-MILP, the elapse of this minimum time is ensured between the arrival of the feeding train and the departure of the receiving one. To preserve the transfer practical feasibility, it has to be set considering a walking time which allows passengers to move between the two farthest platforms that can be used by the trains. When the feeding train gets late to the station, the imposition of the minimum connection time may bring delay propagation, unless sufficient buffer exists. By reducing the connection time, delay propagation can be reduced as well. We consider two approaches to shorten it. On the one hand, we can set a short minimum connection time and limit the set of platforms available for the trains to the ones that are very close to each other, and for which the set minimum is sufficient to allow the transfer. On the other hand, we can consider the minimum connection time as dependent on the specific platforms chosen : if two close platforms are chosen, the minimum connection time can be short, otherwise it has to be longer and longer as the distance between platforms increases.

This paper proposes two enhancements to the MILP model [2] concerning those two approaches. We demonstrate the applicability of the proposed enhancements using total train delay as the objective to be minimized. To the best of our knowledge, this is the first study considering rerouting of connecting trains in a station to allow passenger transfers, while using a microscopic representation of the railway infrastructure.

3 Enhancement algorithm

As mentioned in Section 2,in the Classic RECIFE-MILP (CR) model [2], a minimum connection time is imposed for pairs of connecting trains stopping at a station. This time is independent of the platforms used by the trains : whatever the choice, CR imposes that the receiving train does not depart before the feeding train arrives plus the fixed minimum connection time. To ensure that passenger transfers are possible, this minimum connection time must be set to the Minimum Walking Time Distance (MWTD) between the two farthest platforms where the connecting trains may stop. Hence, short buffer times are available : given a feeder train arrival (A) and a receiving train departure (D) times in the timetable, the buffer is equal to their difference minus MWTD (D - A - MWDT). As a consequence, delay propagation may be strong. However, with this model, full rerouting flexibility is kept.

In the First Enhancement (FE) that we propose, we presume that the Minimum Connection Time (MCT) is less than MWDT. For two connecting trains, we consider the pair of platforms separated by a minimum walking time greater than MCT to be incompatible : in the model, we introduce constraints forbidding the trains to simultaneously choose these platforms. Compared to the CR, this enhancement may reduce delay propagation thanks to the larger buffer time (D - A - MCT > D - A - MWDT). However, rerouting flexibility is reduced, and this may have a negative effect on delay propagation. The final impact of the FE will depend on the value chosen for MCT, i.e., on the chosen solution for the trade-off between increased buffer time and reduced rerouting flexibility.

In the Second Enhancement (SE) we propose, we consider the MCT for two connecting trains MCT as an additional variable of the problem dependent on the platforms actually chosen. This value is the minimum walking time distance between the specific platforms. In the model, this is done by adding variables and constraints linking platforms and possible MCTs. Compared to the classic RECIFE-MILP model, this enhancement will reduce the buffer time unless two farthest platforms are actually chosen for connection. Thus, it may reduce delay propagation while ensuring full rerouting flexibility. This comes at the cost of a more difficult model due to the additional variables.

We compare the relative performance of RECIFE-MILP implementing the CL, FE and SE models which will also depend on the characteristics of the instances to be tackled. For example, the number of platforms in a station or the number of trains to be dealt with will likely have an impact on performance. In this paper, we compare the performance based on the following characteristics : Reduction of total delay of trains and solution time.

Références

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