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Station Level Refinement of Train Unit Network Flow Schedules

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1 Introduction

Train unit vehicles have to be scheduled at both network and station level once the train timetable has been determined. Usually, these two levels are treated as individual scheduling problems [1, 2]. This paper connects the two levels together and mainly focuses on the train unit shunting at station level to resolve network scheduling solution given by the two-phase approach [3] which first schedules the train units as a network flow problem with each station simplified as a single point not considering infrastructure details. A branch-and-price method [4, 5] is proposed to solve the flow level of assigning limited units to prescribed train trips (trips). Its solution yielded is a unit-type assignment for each trip and the tentative linkages between arrivals and departures. Two operational aspects are left open to be determined at the station level . The first aspect is the unit coupling order in a trip served by multi-units, which has no impact on the network flow but must be finalized at the station level to prevent blockages. The second aspect is the precise conflict-free shunting movements for implementing the linkages between arrivals and departures. The station level gives feedback dynamically to the flow level to refine the solution into being operable.

2 Feasibility of Shunting Plans

An individual shunting plan is feasible if it is operable within the permitted time, which can be checked by the duration of its corresponding tentative linkage. A feasible shunting solution means a group of shunting plans which can schedule all the units without conflicts between any two shunting plans. The shunting plan is affected by station layouts and unit coupling orders because it may involve a series of operations such as coupling and decoupling, reordering shunting, platform transferring, sidings shunting and this is a time-consuming process.

The tracks in a passenger station may have some specialized functions: usually, platform tracks operate simple or time-limited shunting such as unit coupling; siding lines deal with more complex shunting and units with long turnaround time; the other tracks such as switches assist units to move among platforms/sidings smoothly. Different tracks have distinct approaching methods, especially for the platforms and sidings: a dead-end track can only be approached from one direction but a free track can be approached from both directions. Obviously, different types of platform lead to distinct shunting plans, which means they consume different amounts of time. For example, suppose there are two possible shunting plans to implement a tentative linkage according to the station layouts, but only one may be feasible because of the given shunting time. On the other hand, the unit order may lead to different shunting plans if coupling or decoupling operations are involved. For instance, a trip served by two units (front and rear) of different types arrives at a dead-end platform, and these units will serve two different departure single-unit trips. If the timetable and tentative linkage indicate the rear unit must leave before the front unit, it is feasible; but if the front unit must leave before the rear unit, the rear unit must be shunted to somewhere else to let the front leave first, which requires more operational time than the first case. Moreover, the path of a shunting plan locks a series of tracks, such that they cannot be occupied by other units until they are released by this shunting plan, which means an individual shunting plan is not independent but is related to other shunting plans, e.g. if two shunting plans corresponding to two linkages occupy the same track at the same time, the shunting solution with these two shunting plans are infeasible.

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3 Combinatorial Problem and Solution Approach

In this paper, we mainly focus on how to refine the flow-level solution at the station level particularly in the aspects of linkages and the order of coupled units. In other words: given a timetable which describes the arrival and departure times and platforms, the flow-level solution as well as the layout of stations, how can the tentative linkages and the unit positions in all multi-unit trips be finalized? The flow level computes the unit-type assignments for the trips and tentatively links arrivals and departures to be shunted precisely at each station. For a tentative linkage, there may be many different ways to implement it according to the layouts and the unit positions in multi-unit trips, leading to a very large number of possible shunting plans. Thus, a tentative linkage corresponds to a set of potential alternative shunting plans. For each tentative link, only one potential shunting plan can be selected for real-world operation. Usually, a large number of linkages are operated at a station, and our problem considers a rail network containing a set of stations. Selecting one potential shunting plan for each linkage forms a shunting solution. Obviously, this is a huge combinatorial problem.

For this problem, the most straightforward method is brute force enumeration. All possible shunting plans for all linkages and all possible unit coupling orders should be enumerated firstly and then check the compatibility between any two shunting plans. The combinations are likely to be out of control. According to the empirical shunting of real world, a shunting plan is usually operable if there is enough time. Therefore, we propose an approach of narrowing down the problem size by estimation first and solve the remaining problem with precision. Firstly, we categorise different scenarios according to the type of linkage temporarily assuming the unit order in each multi-unit trip is organized in the best way. For each scenario, an estimated operational time is set according to the real-world operational principles. For example, one type of tentative linkage connects a two-unit arrival to a single-unit departure at the same platform. There is at least one decoupling operation needed even if the other factors (position, platform type, directions etc.) are favourable. If the duration of some linkages in this scenario is still below the time allowance required, those links are physically unworkable, and this infeasibility has to be resolved. Those long duration tentative linkages would be feasible for the station-level operation because there is likely a method to shunt them. After this estimation process, the link whose duration is just slightly longer than the minimum required must be scrutinised. They are the most critical tentative linkages in this railway network. These critical tentative linkages will be assigned with the precise shunting plans and coupling orders. Under the precondition of guaranteeing those restrictive shunting plans and fixed coupling orders, then the impact of these restricted links on the other links will be analysed. If any unworkable shunting plan corresponding to a specific linkage or a certain unit order shows up, this negative feedback will be used to resolve the infeasibility.

4 Remarks

Our research in this paper is ongoing. Experimentation with real-word data and the latest results will be presented during the conference.

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