Network-centric approach to adaptive real-time train scheduling

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Abstract

When solving complex railway management automation tasks, one constantly has to deal with a lot of disruptive events, which differ in intensity and source and can lead to conflicts and fluctuations in schedules of passenger, suburban and cargo trains. This makes matters even worse in large-scale railway systems with a high level of connectivity. Today solving conflict situations in trains deviating from the standard schedule completely depends on the experience of the dispatcher in charge, which often leads to irrational placing of trains in the traffic, especially in stressful situations. The constantly growing intensity and speed of the passenger traffic, and hence, the growing scale of the task to be solved, results in increasing complexity of disruptive situations and provokes a question as how to reduce dependency on the human factor by automating the decision-making process and introducing intelligent systems, enabling fast and effective adjustments in case of a disruptive event.

The network-centric approach to solving the task of adaptive real-time train scheduling implements the logic of reacting to events when every event triggers a wave of resource rescheduling, as well as pro-active plan optimization, which allows to improve solutions as long as there is time for system to run.

The input data includes: the infrastructure of the railway network with detailed infrastructure elements; requirements for specified train schedules; requirements for maintenance works; updates on the current situation on train movements and the states of infrastructure elements (signals of occupation and information on the unavailability of infrastructure elements).

The main limitations are the traffic security requirements, the normative requirements of routes planning, train priorities, the dispatching rules etc. However, apart from the limitations listed above, there are also ones that are hard to formalize (no thickening of train schedule lines, no unjustified changing of tracks, no traffic jams between stations, no unjustified train stays on the main tracks and so on), which should be taken into consideration while planning.

At the same time, the implementation of any kind of requirements depends on the current situation, that is, decision making is situational. In order to make a balanced decision in such situations we suggest using collectable virtual currency (similar to potential energy), which is used for rewarding successful decisions and, on the other hand, can be spent on fines in case of bad decisions, compensating for the change of the route and the train schedule. This way, all the requirements and limitations which are hard to formalize, can be reduced to a universal measure and be considered in the scheduling of train routes.

The result of the multi-agent system work is a high detailed train schedule, which allows solving emerging conflict situations with the same precision in real time.

The system architecture is based on the network-centric principles, where every subsystem carries out its own task, and the final result is reached by negotiating among individual decisions.

Each subsystem builds a train schedule on its own level of understanding of the scene in such way that the initial rough decision is transformed into a more precise one. A decision made at every stage, is conflict-free for its level of understanding of the scene (no converging train routes, the security requirements are intact). This layer-based train scheduling eliminates the combinatorial explosion of possibilities, makes the scheduling process more stable to disruptions due to reducing the scale of the task on higher levels and step-by-step considering all possible limitations according to the level of importance and impact on other layers. Solving the task in each subsystem is based on the method of conjugate interactions for managing resource allocation in real time [1] and on a modification of the task exchange protocol [2, 3].

The network-centric approach to train scheduling can be applied for large-scale railway systems with strong connectivity and allows for considering all the varieties of limitations and factors of real-world

systems. The network-centric principles allow for building well scalable solutions which are easy to develop further and add new limitations and ontological conditions.
The expected results of implementing the suggested network-centric approach are: reduced reaction time, increased flexibility and speed in decision making in response to disruptive events, higher effectivity in railways real time resource management and accurate arrival and departure scheduling, reduced man-hours in train rescheduling.
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