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Increase Safety in Regional Networks with Decentralization – The Autonomous Route Setting Approach

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Extended abstract

3 pages min - 6 pages max

Introduction

The need for greater efficiency in the rail sector, by getting more and more trains over a certain distance in less time, is associated with high risk, especially for manual safety-critical activities. This increases the potential for human error, which is why the use of assistance systems in the rail sector as a supporting measure can reduce the risk. In rural areas in particular, larger areas are monitored by the control center, which means that not all individual events can be monitored with the same level of care.

The challenge is to provide support without influencing or even hindering people in their work and at the same time guaranteeing safety. the greatest influence and potential here are offered by setting the course. However, centralized approaches to support planning and for a larger area are associated with certain hurdles. If, for example, we are talking about systems that have to dynamically change the routes for trains due to delays or disruptions or are generally intended to defuse or even resolve potential conflicts, the project becomes correspondingly complex. The area of tension that must be kept in mind here is how to handle the capacities that will arise on the tracks in the future without sacrificing safety and achieving a continuous train flow.

As part of the EU rail project R2DATO, an innovative approach is therefore to be developed in order to fulfil the overall project objective of automation up to autonomy. For this reason, the authors of this paper propose an Autonomous Route Setting approach that looks at how a potential conflict can be resolved in a decentralized manner from each switch and, if necessary, communicates with other AnRS systems in the area to achieve effective conflict resolution. The decisive factor here is that the infrastructure and the existing interfaces do not have to be changed, but that the system should be embedded in the existing infrastructure and make use of existing interfaces.

In the final paper, the authors will first give a brief introduction to traffic management systems, their tasks and existing interfaces, and then briefly discuss automatic route setting before going on to explain the differences to autonomous route setting. In doing so, we will take a closer look at the term autonomy and which criteria characterize an autonomous system. We will focus on anomaly detection to prevent illegal access to server infrastructure from outside and show how this approach can be adapted to the railway domain. Within the paper, the authors will then take real accidents from regional networks as use cases, which should be representative of regularly occurring incidents. The authors will then derive the system architecture for the autonomous route setting and describe the general functionality. We will evaluate and conclude the paper by showing how the use of an autonomous route setting could have prevented the accidents described and give an outlook on the next steps and concrete development of the autonomous route setting.

Fundamentals

To understand the innovation of Autonomous Route Setting (AnRS) compared to existing systems and the current state of the art and how the system can be integrated into the existing system architecture of the rail infrastructure. AnRS can generally be seen as a supplement rather than a replacement for existing infrastructure components.

Traffic Management and Automatic Route Setting

Rail networks in general have centralized control centers where signalers or computer systems manage train movements (see Figure 1). One central system is the Traffic Management System (TMS) The core components of a TMS can be broadly categorized into different key areas. Firstly, train scheduling and timetabling form the foundation, where the system plans and manages the schedules of trains, optimizing the allocation of train paths and timings to balance demand and infrastructure capacity. This involves advanced planning tools and algorithms to ensure efficient use of tracks and minimize potential conflicts. Several control systems, communicating with trackside equipment such as signals and switches. This communication is essential for coordinating the setting of routes and ensuring that the track layout aligns with operational requirements.

Integration with train control systems is paramount, allowing for seamless coordination between the infrastructure and trains. The system continuously monitors train positions, adjusting routes in real-time to accommodate changes in schedules, unexpected delays, or other operational factors.

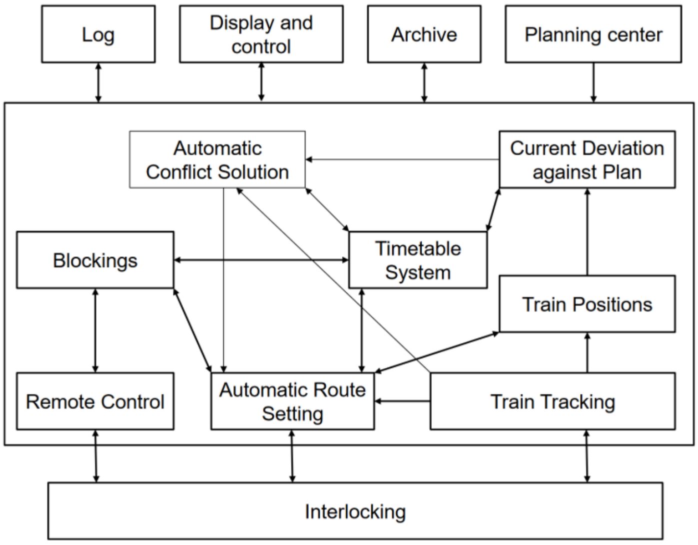

Figure 1: Overview exemplary architecture of a fully automated railway system (cf.

Security measures are incorporated to prevent unauthorized access or tampering, emphasizing the importance of maintaining the integrity and safety of rail operations. Redundancy is also a key consideration, ensuring reliability by implementing backup mechanisms in case of system failures.

The Automatic Route Setting (ARS) as one building block follows more of a rule-based approach in order to automate the setting of the track. However, the decision-making authority and responsibility still lies with the human being. This means that the ARS draws on existing information that is made available to the ARS and executes decisions automatically according to predefined rules. Accordingly, the ARS does not claim to be a safety-critical system, but rather to take over manual process sequences and thus relieve the signaler. The general principle is as follows. based on a timetable server, the points are triggered if the train position and timetable match, the change to the control and safety technology (LST) can at least be made within the scope of the requirements. Otherwise, a warning or enquiry is communicated to the signaler via a human-machine interface (HMI) in order to resolve the conflict situation manually. The ARS can thus be embedded in the TMS as a supplement. This is intended to reduce the workload of the signaler. This process is therefore automated if no incidents or conflicts arise.

Criterias of Autonomous System

The planning and transport tasks in the transport sector will be generalized and broken down into three levels in order to better understand the area of application of the AnRS.

1. strategic level
2. command level
3. control level

Strategic planning is more of a long-term timetable planning horizon. At the planning level, the tasks are essentially the timetable, train composition and infrastructure planning. The operations management level is the same as dispatching. These levels have a medium-term time horizon. The lowest level is the control level, which includes the tasks of dispatching and interlocking systems (both internal and external). These are tasks with a short time horizon.

In order to better understand and categorize the concept of autonomy, the use case of anomaly detection in safety-critical infrastructure such as server environments will be described first. Autonomous anomaly detection in server environments prevents hacker attacks by continuously monitoring and analyzing various data sources like network traffic, system logs, application logs, and user behaviour. The system begins by collecting this data and using it to establish a baseline of normal activity through historical analysis. Once the baseline is set, the system continuously monitors real-time data, comparing current activities against the established norms. It uses statistical methods and machine learning algorithms to detect any deviations from the normal behavior. When an anomaly is detected, such as multiple failed login attempts or unexpected network traffic patterns, the system flags it and alerts administrators.

In response to detected threats, the system can automatically take measures to mitigate risks. This might include blocking suspicious IP addresses or isolating compromised servers to prevent further damage. The system also continuously improves by updating its models with new data and feedback, enhancing its ability to detect and respond to emerging threats over time. This proactive approach ensures that potential security threats are identified and addressed swiftly, reducing the likelihood of successful hacker attacks.

In summary, it can be said that no target is set, but the system for recognizing unwanted access learns what it should look for and makes decisions without intervention.

To transfer this concept of autonomous anomaly detection into the railway domain, three criteria that need to be fulfilled to call a system really an autonomous system. Firstly, there must only be a target for the system, without defining the process and how the target is to be achieved (adaptability). Autonomous systems exhibit a higher degree of adaptability, adjusting their behavior based on real-time information and learning from experience. Automatic systems, on the other hand, follow predefined rules without the ability to adapt dynamically.

Secondly, there should be no possibility of external intervention that could override the system and its decision-making authority (independence). Autonomous systems are designed to operate independently for longer durations, requiring less frequent human intervention. Automatic systems typically need regular human oversight and intervention, especially in exceptional cases.

That leads to the final criterion, the system must learn continuously and find a way to achieve its goals (decision-making). Autonomous systems have decision-making capabilities and can respond to unforeseen situations. Automatic systems rely on predetermined instructions and lack the ability to make complex decisions beyond their programmed parameters. With such systems, the question of security, reliability and trustworthiness inevitably arises. While both automatic and autonomous systems involve automation, the key distinction lies in the level of independence, adaptability, and decision-making capability. Automatic systems follow predefined rules and require more frequent human oversight, whereas autonomous systems operate with a greater degree of independence and can make decisions based on real-time data and learning algorithms.

Autonomous Route Setting Architecture

Figure 2 shows a possible high-level integration of the AnRS into the existing traffic management infrastructure. The aim is to concentrate the decision-making processes and to place the AnRS as middleware between traffic management and interlocking for one specific coordination area. The coordination and cooperation on a macroscopic level will be realized as a distributed, decentralized system that enables greater flexibility and scalability. One challenge is to use the existing interfaces and continue to operate them unchanged. In doing so, we realize that two additional components are also required. An environment capturing unit and an information management system that ensures the correctness of the underlying database.

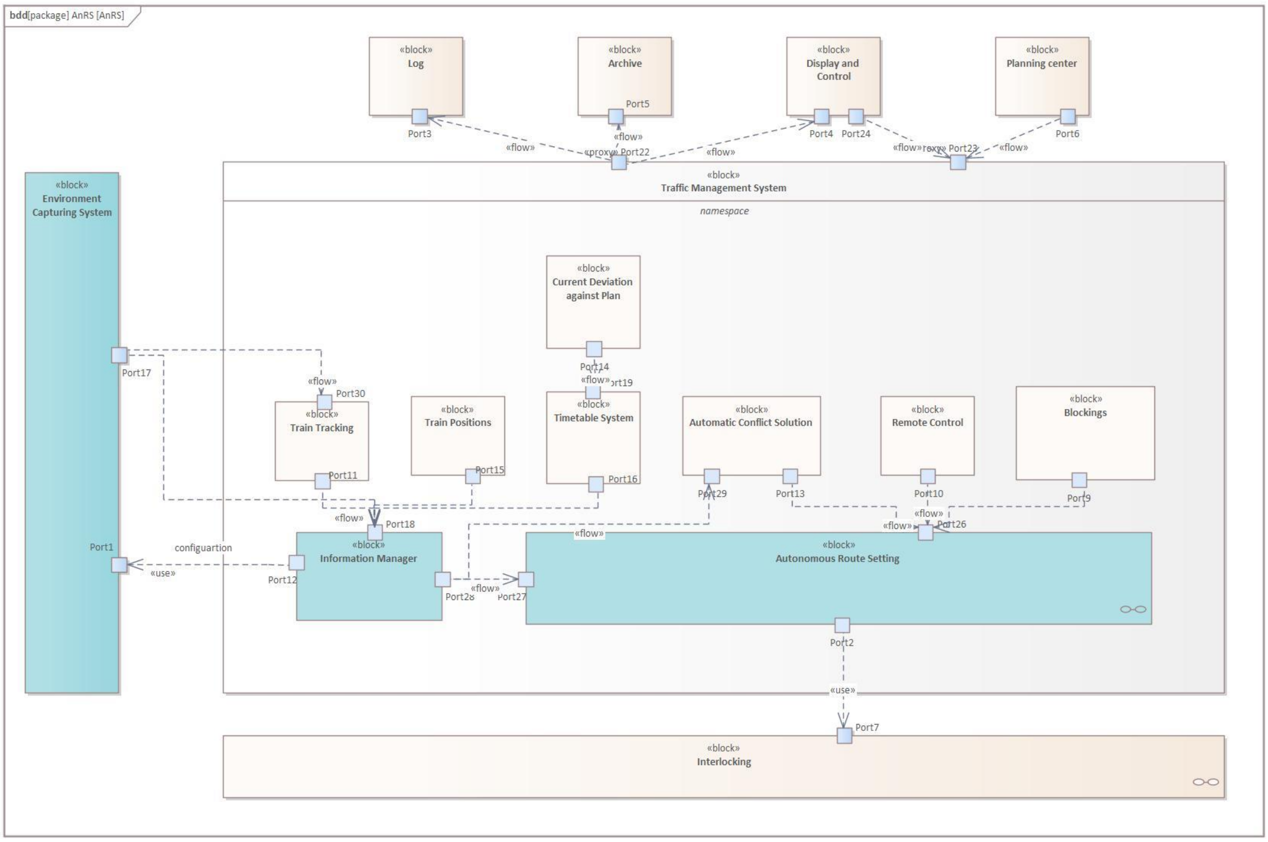

Figure 2: Draft overview about the AnRS integration into a fully automated railway system

Another challenge of this approach is in decentralized traffic management. In situations where no centralized control system along the line exists, each AnRS unit communicates directly with others at the edge, collaboratively establishing routes based on predefined Real Timetable Plan (RTTP) guidelines. This decentralized approach fosters agility and adaptability, allowing trains to navigate complex network configurations with ease. The integration of AnRS with RTTP also opens up opportunities for future advancements in rail transportation. By leveraging technologies such as artificial intelligence and machine learning, the system can continuously optimize routes, considering factors such as traffic patterns, weather conditions, and infrastructure capacity. This predictive capability not only improves efficiency but also enhances safety by proactively mitigating risks.

In conclusion (and explaining the functionality into more detail in the final paper), the integration of Autonomous Route Setting with Real Timetable Planning represents a paradigm shift in rail transportation. By decentralizing control and leveraging collaborative communication protocols, this approach offers a scalable and adaptable solution for managing train routes in diverse operational environments. As technology continues to evolve, so too will the capabilities of AnRS-RTTP systems, driving innovation and shaping the future of rail transportation.

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