Evolution of Rail Operations Control Centres

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Contribution on the State of the Art

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Abstract: The article gives an overview of the evolution trends and stages of rail operations control centres (ROCCs) and outlines their future development and challenges in the context of the digital transformation of railway transport. It addresses the key aspects of further evolution of ROCCs in terms of closer integration of various functional layers and systems, automation of control and supervision functionalities, application of new data processing methods based on artificial intelligence.

Keywords: Railway transport, digital transformation, Rail Operations Control Centres (ROCC), rail traffic control models, ERTMS, FRMCS, artificial intelligence, deep learning, Big Data.

Introduction

The modern concept of ROCCs appeared in the late 1990s and early 2000s and was associated with the large-scale migration of railway signalling systems (electric interlocking (IXL), automatic block (AB), centralized traffic control (CTC), remote monitoring and diagnostics systems etc.) to computer-based technology, mass deployment of automated workstations (AWS) based on high-performance personal computers and construction of high-capacity fibre-optic data communication networks. The latter radically improved the automation of the collection and communication of information and, consequently, enabled a much greater centralization of supervision and control with the concentration of operating personnel in network-level (regional) centres that cover several dispatcher-controlled areas of one or several railways.

The ROCC is in many ways the “showcase” of a railway company that shows its technological capabilities. In the years to come, an even more rapid worldwide improvement of ROCC technological capabilities can be expected due to the very significant advancements in digital technology and the emergence of new solutions for collecting, processing and exchanging information, as well as the constantly improving methods of ergonomic workplace design.

Currently, different countries are at different stages of Rail Operations Control Centre development, ranging from ROCC 1.0 to ROCC 3.0. Often, those stages coexist within one and the same network, while the most advanced railways regularly upgrade their infrastructure and Operations Control Centres, thus furthering the migration towards the target state.

From ROCC 1.0 to ROCC 4.0

Traffic control came into existence in the early 20-th century due to the requirement of better rail traffic safety in the absence of well-developed technical means of supervision. Its emergence was greatly facilitated by the invention of the telegraph and telephone.

A first-generation Rail Operations Control Centre (ROCC 1.0) was a traffic controller’s individual office with a desk, on which there was a drawn train graph, a service telephone and selective communication. The length of a dispatcher-controlled areas managed by a single controller ranged from 30 to 50 km.

The development of communications and computer technology in the 1960-70s largely changed the traffic control system and allowed deploying the second-generation Rail Operations Control Centres (ROCC 2.0) that featured centralized control and supervision of railway stations. The length of a dispatcher-controlled area in some cases reached 150 km.

Another important milestone in the late 1990s was the introduction of fibre-optic communication lines in railway transport. This enabled the creation of the third-generation Rail Operations Control Centres (ROCC 3.0) that were independent of railway communications and capable of managing longer lines. Since then, the Operations Control Centres became associated with the respective networks and were located in premises in proximity to the railway headquarters. Dispatcher-controlled areas became larger with a single dispatcher-controlled area being up to 300 km in length.

ROCC 3.0 is characterized by specialized computer software that automates a traffic controller's routine operations, including an automatic train graph, the availability of automated inquiry systems that enable real-time interaction with various units of the railway company and the Control Centres of other railways, as well as with emergency response services and other public agencies. For the purpose of planning and scheduling, the Control Centres became integrated with infrastructure and traction resources management centres. The ROCC was provided with an Operational Visual Display System that visualized information on the transportation process required for operational decision-making and elements of predictive analytics based on statistical data regarding the performance indicators of the transportation process.

The control cycle as part of the ROCC 3.0 model can be conventionally divided into the following stages: prognosis, planning, traction resources management, operational management, train graph, analysis of operational activities. The overall control cycle is shown in the diagram (Fig. 1).

At the stage of ROCC 3.0, the process of association between the train schedule and centralized traffic control is automated, while dispatcher-controlled areas are equipped with in-station automatic route setting (ARS) systems. An active development of this concept along with the deployment of fundamentally new methods of real-time information processing predetermine further transition to the target model of ROCC 4.0.

Target state of ROCC 4.0

What characterizes target state of ROCC 4.0? The distinctive features might include the following (see Fig. 2):

- Storage and processing of information in the cloud;
- Adaptive planning and management using deep learning and digital twins;
- A single multi-agent hardware and software platform with deep software integration of planning, train timetable correction, management of traction resources, locomotive crews,

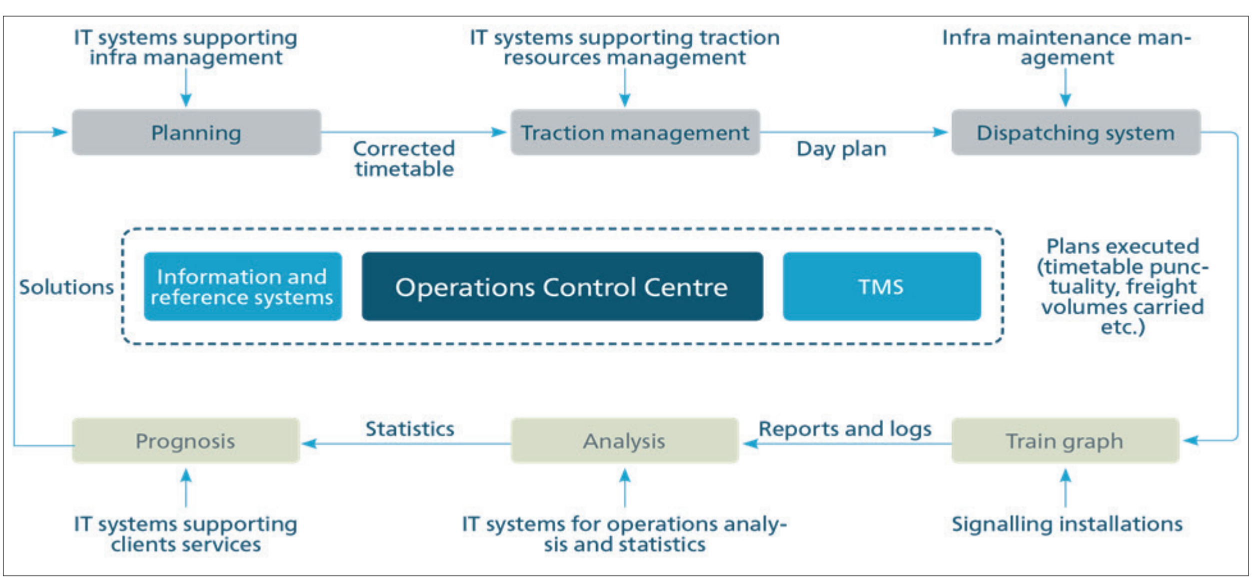

Fig. 1. Control cycle in the ROCC 3.0 model

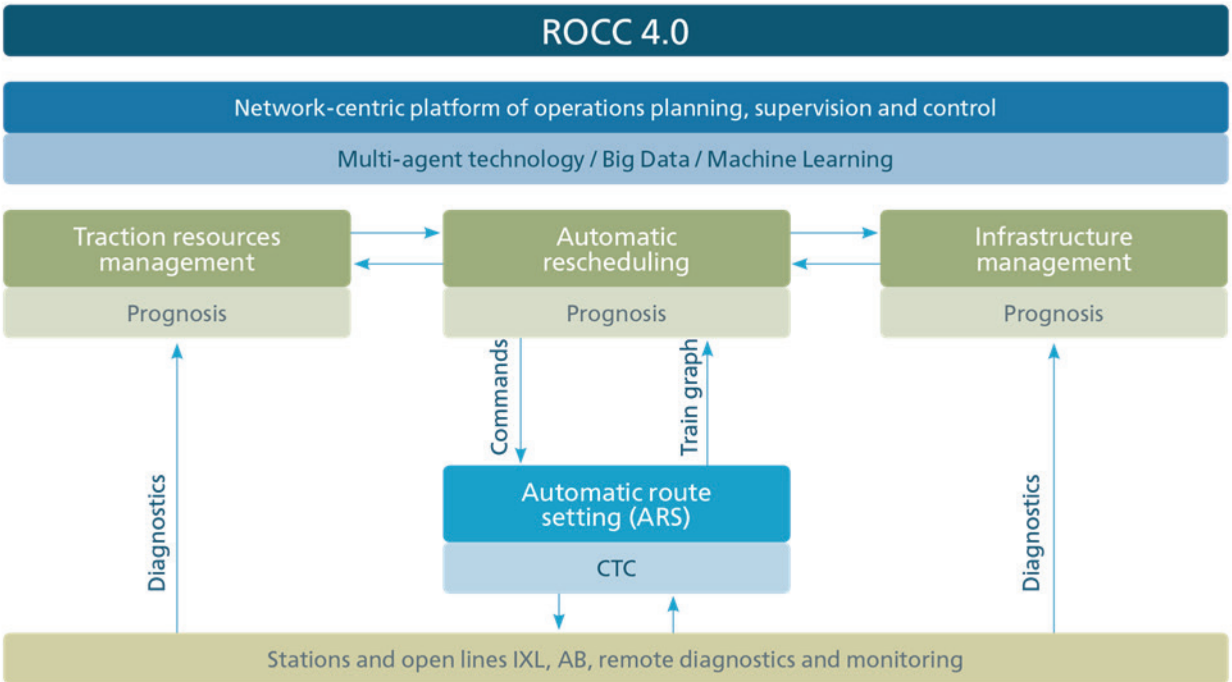

Fig. 2. *ROCC 4.0 architecture*

infrastructure, etc.;

- Implementation of real-time command and control mode through integration with ARS systems;
- Integration with on-board ATO units.

Obviously, implementing the above principles of ROCC 4.0 will cause further consolidation of the existing Control Centres with possible migration towards new models of traffic control that are not associated with the geographical boundaries of railway networks (with the size of controlled regions of up to 1500 km).

On a separate note, the further evolution of Rail Operations Control Centres (at least in the EU) will largely depend on the development of the European Traffic Management Layer (ETML) of ERTMS that is responsible for schedule-based train running. Such developments might be encouraged by the ongoing testing and standardization of "ATO over ETCS" functionality and equipment and the expected migration towards GoA3 and GoA4 train operation (i.e. autonomous trains) [1]. In some countries, national control systems are also developing along these lines. The introduction of the FRMCS next-generation railway radio communication standard will greatly contribute to further development.

It should also be noted that, with active deployment of the ARS mode and driverless train driving, an ever-growing part of vital functions related to train safety could be transferred to ROCCs, which might raise the matter of ensuring the required level of functional safety of the control hardware and software system. In different countries, the requirements for such system in term of the safety integrity level (SIL) may vary from SIL0 to SIL4. Such requirements are currently not internationally standardized, but the discussion is ongoing as part of projects funded by Shift2Rail, the European program for innovative development of the railway industry, that are aimed at developing and testing the above technologies.

Probably, over time, closer towards the middle of the 21-st century, a new paradigm of ROCC 5.0 will come in life, that for now appears to be very futuristic That would be a multi-feedback, Big Data based adaptive control model that essentially involves automatic generation and optimization of the market demand (in both the freight and passenger segments) based on historical data analysis, close integration with various systems for collecting and aggregating customer data and notifying (maybe individually as well) passengers and consignors/shippers on the optimal routes, services, discounts, etc. [2-3]. In other words, this is a case of practical implementation of "mobility as a service" (MaaS), i.e. on-demand transportation with automatic optimal distribution of network loading by smoothing the amplitude of client requests and route optimization in terms of time and itinerary. Within this paradigm, the concept of "planning" and "initial timetable" might become redundant. A distributed, real-time, multi-feedback artificial intelligence system that is continuously analyzing historical data, self-updating and self-learning may replace the ROCC and traffic controllers. This transformation may be impeded by the limitations associated with the chosen control model, computational power, communication channel capacity, cyber vulnerabilities, as well as the requirement of transportation safety and evacuation of people, freight and equipment in emergency scenes or failure of robotics.

Conclusion

If one takes into consideration today's digital trends, the current stage of Rail Operations Control Centres development could be defined as ROCC 3.0. This stage is characterized by a trend towards the integrated management of train flows, traction resources, infrastructure and transport safety. However, at this stage of development, train handling and conflict resolution still primarily depend on the expertise and experience of traffic controllers.

Further evolution of Rail Operations Control Centres, taking into account the target state of ROCC 4.0, involves the automation of intelligent control functions, i.e. the implementation of real-time control systems based on artificial intelligence (machine learning), Big Data processing methods and predictive analytics [4]. ROCC 4.0 is in fact a control model with constant feedback, and the target state can be achieved by expanding the feedback and increasing the efficiency and reliability of information through the application of different control, monitoring and diagnostics tools, including mobile (for example, drones with computer vision and other tools for video and photo recording) and fixed devices (computer vision systems at passenger and freight stations, integrated checkpoints for diagnostic and monitoring rolling stock at marshalling yards, distributed acoustic sensing systems for fiber optic lines, etc.).

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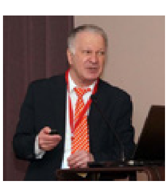

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