Recent Research on Application of ICT for Railway

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This paper outlines problems relating to the joint application of railway operation information and recent research and development into information networks, train operation control and telecommunication systems. This paper presents the basic concept underlying a network platform for railway operation and its benefits for train operation control, maintenance of facilities, etc. It also describes how the network platform will enable the integration of various types of data from relevant fields, and increase efficiency of maintenance thereby creating new value drawn from big data analysis or computer simulation. Finally, the paper introduces recent research into precise and adaptable train operation control methods and applications using millimeter wave radio.

Keywords: information network platform, real-time train operation control, maintenance, ground-train communication

1. Introduction

The safety and stability of railway transport depends on various functions namely: traffic control, safety related control performed by signaling system, facilities maintenance, detection of wayside disasters and subsequent traffic management, information sharing and communication between dispatchers, crew and station staff and information service for passengers. All of these functions rely on information exchange. Current systems, however, are built with closed communication working in each sector, making a cross-cutting sharing of information difficult. This can be overcome by applying fast-developing ICT (Information and Communication Technology) solutions such as networks, radio communication, etc., and new value will be added to railway services. This paper discusses research and development being undertaken at RTRI on the utilization of ICT and future prospects of this technology for the railways.

2. Information exchange in railway operation

Figure 1 illustrates the various types of information, e.g. train operations and state of facilities that are required for smooth railway operation and proper facilities maintenance.

These functions rely on the exchange of information often by word of mouth or on paper. Figure 1 indicates the directional flow of information with arrows. Apart from the blue arrows indicating voice communication, there are many vertical arrows concentrated around dispatchers and on-site maintenance depots. This suggests firstly that horizontal or cross-cutting information exchange needs to be improved, and secondly, that railway operations need to be more efficient, this is especially relevant considering the expected decline in the working population, in order to improve the ease of use of railways whilst properly maintaining its facilities.
Given this background, digitized data is increasingly used these days in an attempt to manage and analyze information swiftly and objectively. However, in the case of facilities maintenance for example, information gathered and recorded in the field is often digitized only after taking it back to a maintenance depot and input into the system by a staff. In order to gather large volumes of data efficiently with as few people as possible wireless sensor network technology [1], for example, which is a kind of M2M (Machine to Machine Communication) / IoT (Internet of Things) technology, can be a solution.

Railways are a system comprising various elements that interact, making the timely sharing and utilization of information between technical areas or sectors, highly necessary. Building and utilizing an information network platform which can be shared by all relevant parties, could be an answer to that need. In addition, a big data analysis may offer new values. The true value of such technique lies not just in the ability to analyze vast amounts of data but in combining many different types of data and retrieving new knowledge in the process. For this reason, too, a platform enabling the sharing of information across the technical area or sectors is a must.

Chapter 3 of this paper describes an information network platform capable of integrated management of various types of information. Ground-train information exchange in the future is expected to demand even higher-capacity telecommunications not only for safety but also for passenger services and other anticipated requirements. This will be discussed in Chapter 4.

3. Information network platform

3.1 Utilization objectives

Currently at RTRI, development is underway for network platform technology based on the concepts shown in Fig. 2 that is capable of integrated handling of various railway information. The envisaged information network platform is expected to facilitate operations through advanced real-time train operation control, energy saving resulting from train control, train control adaptable to changing conditions such as wayside disasters [2] and advanced maintenance of facilities. Figure 3 shows how railway operations could be managed through the information network platform.

As part of ongoing research and development into the information network platform, RTRI analyzed current railway operations from an information flow point of view, as shown in Fig. 1, and extracted requirements for proposing data transfer control procedures across the network. In future, a demonstration system will be installed at RTRI for testing and verification purposes.

In using ICT across a wide range of operations, it is also important to consider cybersecurity issues. Along with research and development on the envisaged information network platform, RTRI will investigate requirements for cybersecurity in a railway system.

3.2 Anticipated benefits

Among the benefits described in 3.1 to be drawn from an information platform infrastructure, train operation control and facilities maintenance will be discussed below.

On train operation control, the radio based train control system has realized advanced functions such as a train control primarily executed onboard, and moving block. The system enables continuous monitoring of train details including its position and speed, and direct and continuous transmission of control command to trains. By using those features more actively beyond just safety related control, the system is expected to offer new possibilities such as advanced traffic control and functional integration of train operation and safety related control, which are essentially closely related to each other. RTRI’s research and development efforts related to those areas will be discussed later in 4.2. Train operation records and running data are highly useful not only for train operation control but vehicles and facilities maintenance and other areas. The information network platform enables utilization of detailed data collected through ICT-based signaling systems such as radio based train control systems, offering tremendous benefits.

On facility maintenance, efforts are being made for CBM (Condition Based Maintenance) using ICT in each technical area. RTRI is therefore developing maintenance methods based on sensing of facility conditions and data analysis, for vehicles, overhead contact lines, structures,
tracks, etc. Introducing an information network platform to these areas can bring progress and greater efficiency to maintenance.

Figure 4 shows an example of possible applications. Maintenance staff may want to analyze data on the condition of a structure that has been collected by sensors, while excluding any influences resulting from the passing of trains or condition of the track. As it stands today, it may often be the case that either data necessary for such analysis is not available, or needs to be obtained from elsewhere which takes time. Whereas if data on the condition of facilities and passing trains are available for reference, it would be easier to analyze and identify causal factors for faults and deformation of facilities and it would then be possible to carry out maintenance more swiftly and appropriately and plan more advanced, prediction-based maintenance. This means that the accuracy of simulation, which is an important prediction tool, would be improved. This in turn would mean that maintenance could be prioritized more easily and carried out where required swiftly and in a timely manner (See Fig. 5).

4. Research and development in signaling and communication areas

4.1 Information network platform

RTRI’s planned research and development on ICT and an information network platform was discussed in 3.1. With regard to facilities maintenance discussed in 3.2, RTRI has been pursuing research and development on wireless sensor network technology for application to the railways.

4.2 Train operation control based on real time information

Train schedule disruptions can be reduced as much as possible by a real-time train operation control adaptive to the traffic condition. Such a measure can also contribute to energy-saving train operation control and more flexible adaptation of train operations to disasters, that were discussed in 3.1.

On urban lines, for example, trains may delay due to congestion etc. Should this happen, headways can be reduced to a minimum by predicting the departure time of the preceding train stopped at a bottleneck station and control the following train accordingly to slow down below the permissible speed limit before it reaches the station [1] (See Fig. 6). In the case of this type of control, the rescheduling of train can be more efficient by using variable running time between stations. In many cases, however, the rescheduling is performed by sliding the “line” without changing the angle, i.e. retaining the predefined running time between stations (See Fig. 7).

Given the above, RTRI has been studying a train control method using detailed control commands, equivalent to train performance curves, for trains running between stations. In this method, safe train operation is guaranteed by not overlapping “bands” which take into account braking distance calculated from the detailed commands [3] (See Fig. 8).

To realize this method, the running status of trains must be predicted as accurately as possible. RTRI has therefore been studying a method to predict train operation, the number of passengers at each station and on each train, etc. down to a certain point in time based on data on train operation records including the position and speed of each train and the number of passengers passed through ticket gates. Based on this prediction, the best rescheduling plan is defined and positions and speeds, equivalent to train performance curve, to meet the plan are sent to the train as the control command. RTRI plans to establish the prediction method and to verify the accuracy and effects of this train operation control, through simulation.

4.3 High capacity ground-train telecommunications

Currently, the following frequency bands are used for railway applications in Japan: LF (30 kHz–300 kHz), VHF (30 MHz–300 MHz) and UHF (300 MHz–3 GHz). Those bands would not be sufficient to accommodate the extension of applications such as safer and more advanced train control, railway operator business communications and passenger services or the demand for high-capacity data communication.

While there is a growing shortage of available radio
waves across industries in Japan, millimeter waves (30 GHz–300 GHz) and other high frequency bands, which thus far have not been used as much, are gaining attention. Millimeter waves have a wide usable bandwidth and can accommodate communications consisting of several hundred Mbps. With its high straight advancing property, millimeter waves are suitable for railway applications where data communication is performed along the track. The drawback with millimeter waves is that they are attenuated substantially by rain, which makes it necessary to install radio base stations closer to one another, increasing initial set-up costs. However, this and other challenges associated with millimeter waves can possibly be overcome by recent developments including high performance O/E (optic-electric) conversion and RoF (Radio over Fiber) technology, shown in Fig. 9, whereby radio signals are transmitted over optical fiber.

On millimeter waves, the October 2012 revised version of the Action Plan for Frequency Reallocation by the Ministry of Internal Affairs and Communications listed the 40 GHz band as an option for more advanced and broadband railway radio communication, and, with RTRI participation, relevant technical standards were developed. Currently, RTRI working on the development of a radio circuit design method and system configuration for railway applications at 40 GHz, for practical application in the next several years.

Also RTRI is studying on the utilization of the 90 GHz millimeter wave band, which enables even higher capacity data transmission, with its practical application expected to be achieved in about ten years. That project is being pursued as part of an open initiative entitled, “Backhaul technology for high speed mobility using millimeter wave bands” by the Ministry of Internal Affairs and Communications, which is one of the ministry’s research and development projects for expanding radio wave resources.
5. Conclusion

This paper discusses the utilization of ICT for railways, centering around RTRI’s efforts in the area of signaling and communications. Expanding knowledge and new technologies resulting from the development of the radio based train control system, as well as information network technologies, should serve as a backbone for creating new values to further enhance safety, reliability, convenience and operational efficiency across the entire railway sector. RTRI will continue to strive to added value of railways, through cooperation with relevant sectors.

Fig. 9  Radio communication system using millimeter waves

References


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