

Cloud computing for maintenance of railway signalling systems

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Abstract

Signalling systems in railway allow the control, supervision and protection of railway traffic. These systems play an important part in a railway's capacity and availability. Thus, their reliability and maintenance are key concerns. A number of signalling systems are on the market today; these work to guarantee safety while meeting the required capacity of the network. In order to keep the railway network in an optimal state, it is critical for the signalling systems to have tools that can make data mining and analysis easier and faster. The solution described herein allows data mining and posterior analysis without depending on the elements that provide the data. This is a key factor for signalling systems, due to their complexity and continuous development. For integration purposes, a data collection and distribution system based on the concept of cloud computing is proposed to collect data or information pertaining to the assets of the railway signalling systems. From a maintenance point of view, a benefit is that information or data may be collected pertaining to the health, variability, performance or utilization of an asset.

1. Introduction

Signalling systems in railway allow the control, supervision and protection of the railway traffic. These systems play an important part in the railway's capacity and availability. Their reliability and maintenance can affect both the infrastructure and the trains. In addition, safety is a key issue. ^{(1) (2) (3) (4)}

Railway operators and managers are mining more and more data from trackside and handheld readers, onboard locomotive devices and integrated systems for an array of purposes, see Figure 1. The challenge for users is to sort these data, interpreting them and using them to get improve the movement of freight. For technology providers, the challenge is to keep abreast of the needs of an increasingly diverse customer base.

Linear assets, such as railroads, are integral infrastructures used to transport goods and people. The maintenance and improvement of these linear assets is critical to a country's economy and security. Any improvement in the maintenance management of

linear assets and the technology involved in maintenance tasks can have a substantial effect on the revenue, safety, and reliability of the linear asset. Today's railways face increasing pressure from customers and owners to improve safety, capacity, and reliability – while controlling expenses and tightening the budget. Signalling systems play a key role in meeting these new expectations.

With fewer resources and shrinking budgets, it is essential to have a proper maintenance management system in place to assist managers and engineers to get the most out of their existing infrastructure assets. For a linear asset, such as a railway, much information needs to be captured and analysed to assess the condition, maintenance, capital spending, and inspection of the railroad.

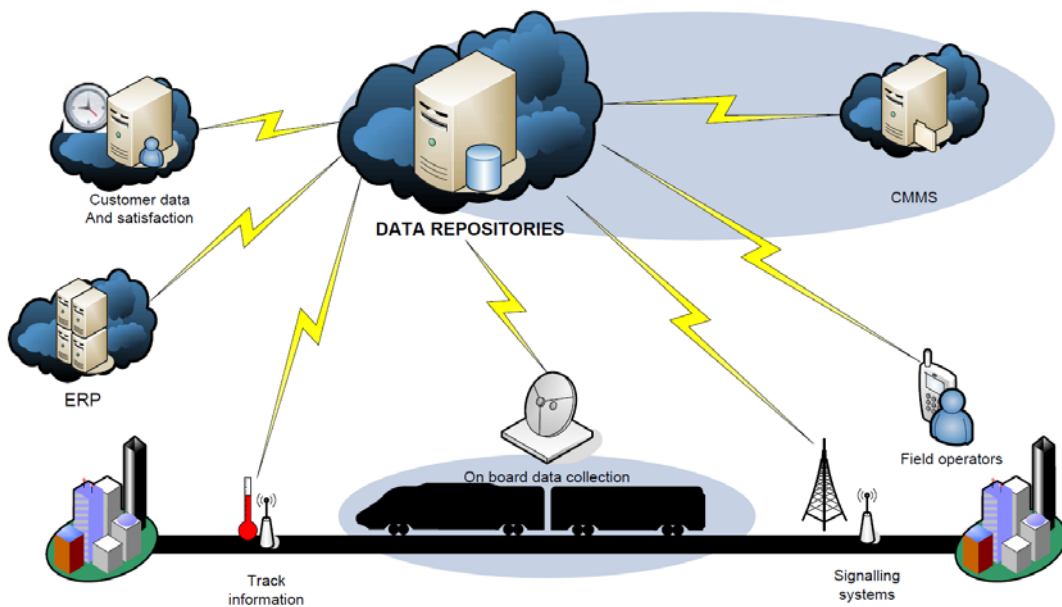


Figure 1. Information data sources to be considered in railway data mining.

Signalling is an important part of the railway system. Train movement safety depends on it, as does the control and management of trains. Over the years, many signalling and train control systems have evolved, creating a highly technical and complex industry⁽⁵⁾. Signalling is increasingly relevant for the operation and maintenance of trains. A good, safe, and secure operation is expected. In addition, the transport of goods or passengers must now be made through a number of countries without changing trains. Given the number of new demands, the development and implementation of signalling systems remains challenging; not all problems have been optimally solved.

Railway signalling is a system used to control railway traffic safely, essentially to prevent trains from colliding. Being guided by fixed rails, trains are uniquely susceptible to collision; furthermore, trains cannot stop quickly, and frequently operate at speeds that do not enable them to stop within sight of the driver. Most forms of train control involve movement authority being passed from those responsible for each section of a rail network to the train crew. Not all methods require the use of physical signals, and some systems are specific to single track railways.

The signalling system is based on the ability to locate the trains operating in the network, applying restrictions on their operation to assure the safety of the network, and trying to optimize the line's capacity. After the trains are located, the traffic can be controlled through signalling block systems and other devices.

2. Data mining on railway signalling systems

Data mining can be defined as the exploration and analysis of large data sets to discover meaningful patterns and rules. Data are what we collect and store, while knowledge gleaned from those data helps us make informed decisions. The extraction of knowledge and information from data is called data mining. The ultimate goal of data mining is the prediction of future events.

Considerations of railway systems should take both functional and structural perspectives into account ⁽⁶⁾. The former involves the mission of the system, while the latter focuses on its subsystems and their relations. In signalling systems, identifying this division is critical to understand the system and to maintain it. A particular characteristic of signalling systems is that the structural perspective is further divided into software and hardware.

Since the elements that are part of the system are mostly electronic devices, the software is critical; it is essential to keep control of the configurations and changes in the software installed in the various system elements through the life cycle of the whole system. Signalling systems are meant to ensure safety on the railway network. Recently, complex systems integrate signalling control systems on the track and in the train (onboard).

For the reasons mentioned above, the amount of information to manage during the service of a signalling system installed on a railway network is complex, with different equipment on the track and onboard the train. In addition, the system includes both hardware and software. Finally, the software comes in different formats and needs different tools to compile and analyse data.

The management of railway signalling systems should consider information from both the onboard systems and the track. This paints a complete picture of the whole system, since both signalling systems are part of the control of the railway network. This requires a new vision of the railway; until now, independent management and maintenance systems for the track infrastructure and the train have been the norm. But sharing information means a better diagnosis of the system's behaviour is possible.

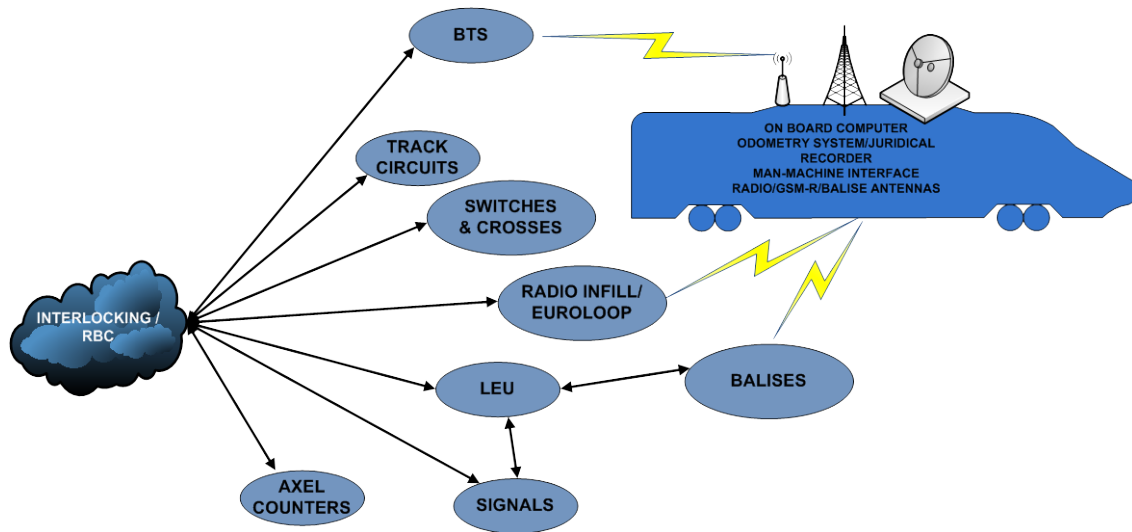


Figure 2. Different signalling subsystems and their interfaces.

Due to the rapid development of signalling systems, many different systems are available. All comprise a number of subsystems to ensure the required capacity of the network in a safe environment ⁽⁷⁾. The interactions between the systems and their subsystems depend on the individual railway network. The infrastructure manager must ensure that the entire network is in optimal condition; therefore, the manager must take into account all systems with their various subsystems, see Figure 2.

Also problematic is the fact that signalling systems have no standardized tools. Every manufacturer provides its customers (infrastructure or rolling stock managers) different solutions. Controlling a system requires both software and hardware; the same signalling equipment from different suppliers may produce similar (but not the same) data.

Last but not least, in most cases, the data collected may not be used, or even properly stored for the following reasons: the maintenance managers may not have sufficient time to analyse the computerised data; the complexity of the data analysis process may be beyond the capabilities of the relatively simple maintenance systems commonly used; there is no well-defined automated mechanism to extract, pre-process and analyse the data and summarise the results so that site managers can use it.

For all these reasons, in order to improve the process of keeping the railway network in an optimal state, particularly the signalling systems, it is critical to have tools that can make data mining and analysis easier and faster ⁽⁸⁾.

Examples of information that can be collected include track availability, use of track time, track condition, performance history, and work performed. Measurements of the condition of a linear asset, such as the track, typically include continuous and spot measurements from automatic inspection vehicles, visual inspections from daily walking inspections, and records of in-services failures. The records of the train recording units can provide data from the routes, kilometres, speed curves, and driving modes of the train, among others.

Signalling systems, like most electronic equipment, must have their hardware maintained; when parts are replaced, the software should be updated or not, depending on whether the new electronic device is configured by the factory or must be adapted to the particular specifications of its location and functions. Therefore, it is critical for the network to establish a good management process. Data mining can help, improving the management process and helping to diagnose any discrepancy.

The developed mining system will provide and collect information through a distributed computer network; it may include new ways to diagnose failures or ways to improve the network, for example, increased line capacity. Data mining provides the possibility of analysing or even simulating possible changes in the configuration of the signalling system, making it possible to determine whether a change will be successful before implementing it. A central data store can integrate information on the linear asset. For railway signalling systems, the database can integrate railway information in the following areas:

- Layout-Configuration of rail line elements along a rail route, including such aspects as number of lines, location of bridges, tunnels, signals, balises, track circuits or axel counters, etc.
- Inventory of the track and train signalling system component descriptions, including devices to locate the train, to perform protection and/or control, to determine location and installation date, to find software versions and codes of the various hardware, to find information pre-recorded on the balises, etc.
- Onboard information recorded, such as speed, drive modes used, train configuration, wheel profiling, information provided by the track, driver actions, etc.
- Maintenance Input-Location and date of maintenance action taken, including spare parts or full equipment replaced or repaired, software updated on new devices or new software versions updated, etc.
- Traffic-Accounting of frequency of usage, maximum train speeds, and types of traffic.
- Cost Information, such as train delays, maintenance, signalling system's components.

The central data store may be derived from a variety of data sources, such as the track side or the rolling stock, and may provide information to multiple system users, including track infrastructure managers, rolling stock providers, or maintenance railway companies.

2.1 Data fusion: A need in maintenance of processes

A data collection and distribution system, known as asset cloud, is proposed to acquire data from the disparate sources of data provided by the different subsystems which form the signalling system.

The different formats are converted to a common format or structure; the data, as needed, are run through any of a suite of applications run at a computer system or disbursed between workstations throughout the process control network ⁽⁹⁾.

This information may then be sent to different users to inform them of the present state of the signalling systems, equipment failure, or even future problems discovered thanks to the cloud's correct diagnosis of the available information.

The proposed application can fuse or integrate data from previously disparate and separate systems to provide better measurement, viewing, control and understanding of the entire signalling system ^{(10) (11)}.

3 Cloud computing in asset management

The cloud is a set of hardware, networks, storage, services, and interfaces that enable the delivery of computing as a service ^{(12) (13) (14)}. For the asset management of signalling systems, the cloud seems to be the solution, given the large amounts of dispersed data in different repositories. The end user (maintenance or operators) do not really have to know anything about the underlying technology. The data collection and distribution applications may be dispersed throughout the network and data may be collected at a number of locations.

Figure 3 illustrates a simplified functional block diagram of data flow and communication associated with or used by the asset cloud. In particular, the diagram includes the data collection and distribution system which receive data from numerous data sources.

The cloud can maintain and store these data in the central working data store. At the same time, a user interface can provide a powerful analysis tool because of its ability to integrate layout, inventory, conditions, maintenance input, traffic, weather, and cost influences at any location along a linear asset. The ability to have this combined view is helpful to resolve track deterioration and choose corrective action.

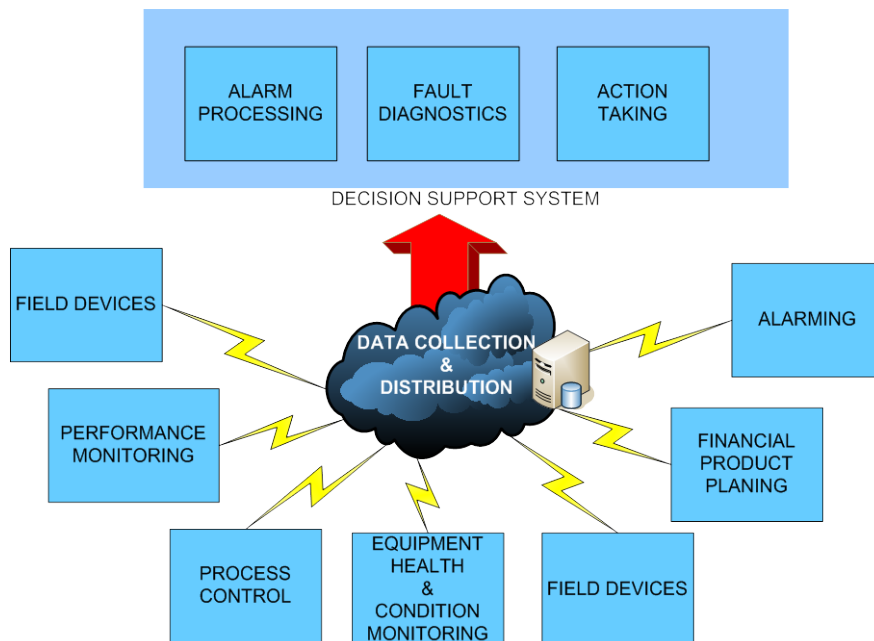


Figure 3. Services provided by the asset cloud ⁽⁹⁾.

The main goal is to provide a system and method to combine the data on a linear asset, with a view to extracting additional information from the data. Data must be analysed for different functions and from different points of view.

3.1 Asset Cloud in railway signalling systems

Because of its complexity, cloud computing can solve most of the problems in the data mining procedure as it is applied to the railway⁽¹⁵⁾, particularly signalling systems.

Cloud computing can use the collected data to generate new information or data which can be distributed to one or more of the computer systems associated with the different functions of the railway signalling systems network; it can execute or oversee the execution of other applications that use the collected data to generate new types of data to be used within the process control, see Figure 4.

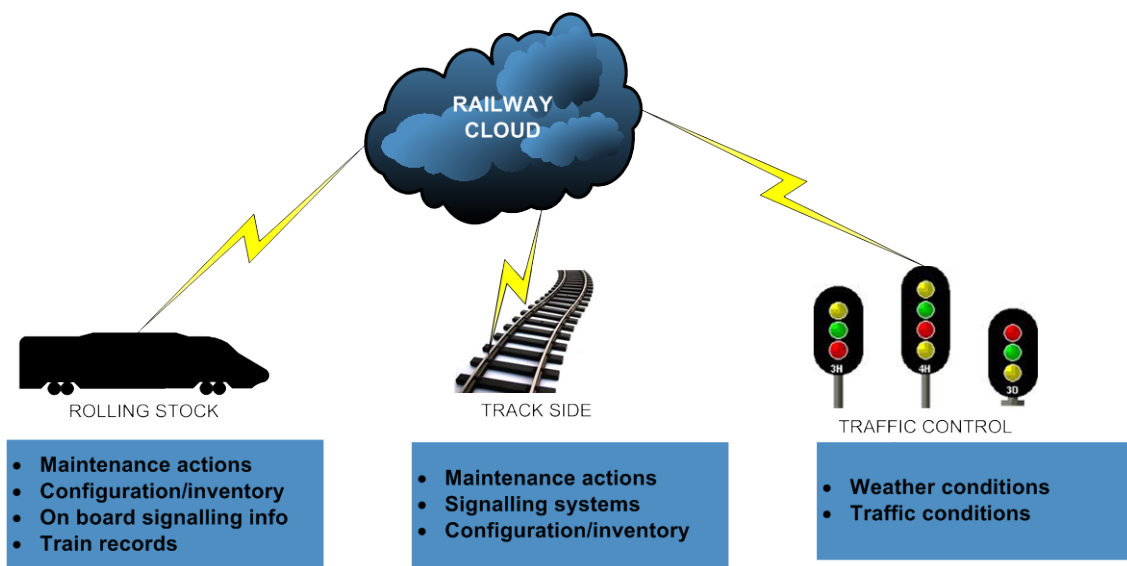


Figure 4. Asset cloud in railway network.

The cloud should include or execute index generation software that collects or creates indices of devices. These indices help optimize the process control and provide business persons with more complete or understandable information about the operation. They allow easier control of the configuration of the signalling systems as well as the management processes of the different systems and subsystems that comprise the signalling system.

A central office computer server (cloud) that is connected to the railway control centre will provide a repository for all data related to the linear asset. Data are collected from multiple sources. For example, in the context of a railway signalling system, data may be collected from including existing computer systems, train records (track, train and driver information), paper records (e.g., maps), experts (e.g., inspectors, supervisors, district engineer), and sensors (e.g., traffic and weather).

Analysis of how these affect the signalling systems in terms of reliability and maintainability can be done to determine possible improvements in the capacity of the railway network.

There are a number of be reduced with the access to the right information in a shorter time; improved software configuration and control management; improved failure diagnosis due to the established relations between data to perform quick root cause analysis; improved coordination between operation and maintenance; possible harmonization of maintenance procedures.

4. Conclusions

Data mining should not depend on the elements providing the data. This is a key factor for signalling systems, due to their complexity and ongoing development.

In the past, the different functional areas, e.g., process monitoring, equipment monitoring and performance monitoring, were performed independently; each tried to "optimize" its functional area without regard to the effect that its actions might have on other functional areas. As a result, a low-priority equipment problem may have caused a larger problem in achieving a desired or critical process control performance, but was not corrected because it was not considered important in the context of equipment maintenance.

Data mining can be used in asset management. Knowing when a system or a component will break before it does so, in plenty of time for repairs to be conveniently and cost-effectively scheduled and executed, is an exciting application of this technology. Today's maintenance managers are concerned with highlighting areas of existing or potential maintenance problems to improve the performance of assets, satisfy customers and minimise the operational cost of maintenance.

Applying data mining techniques to signalling systems' maintenance data can help isolate critical issues and derive solutions; this will significantly improve the management of the asset's life cycle. It will also help managers discover weak points in the various procedures. Such discoveries can be used to modify maintenance and repair procedures, thereby reducing downtime, increasing uptime, and reducing the costs of maintenance and repair.

The asset cloud is a feasible solution to the problem of limited or no access to data from various external sources; it collects data and converts that data if necessary into a common format or protocol that can be accessed and used by applications. Cloud computing can solve most of the problems involving data mining for railway signalling systems.

Configuration and change control management processes are enhanced by data mining and cloud computing; the different information of the signalling systems is gathered, making it possible to easily and effectively control configurations and changes, and to improve the diagnosis of discrepancies.

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