Abstract

Signaling & Train Control (S&TC) System represent the life blood of any railway. The design, installation and effective testing and commissioning of the S&TC is a safety-critical activity that can't be overemphasized. This paper looks at the background to signalling and the evolution towards digital railway in Malaysia, in particular the Communication Base Train Control (CBTC).

Control software is at the heart of the CBTC system, therefore, its development and testing plays a vital role in railway safety and the precision of its operation. The paper emphasis the significance of software validation and verification before opening the system for public use. The paper describes CBTC architecture, interfaces and integration challenges with other railway systems including Rolling Stock and track system, migration strategies from legacy systems to CBTC, system assurance, CBTC Operation, Maintenance and training regime. The contents of this paper was presented at Rail Solutions Asia conference in Kuala Lumpur in May 2017.

1 Introduction

The original signaling control system goes back to the late 1800 when the Track Circuit was first introduced by the Irish born William Robinson (1840–1921). Track Circuit is a vital component of the signalling system that is used to detect the presence or absence of trains on the track, it displays the status of the track on trackside signals to alert train drivers about the condition of the track ahead. See ***figure 1***.

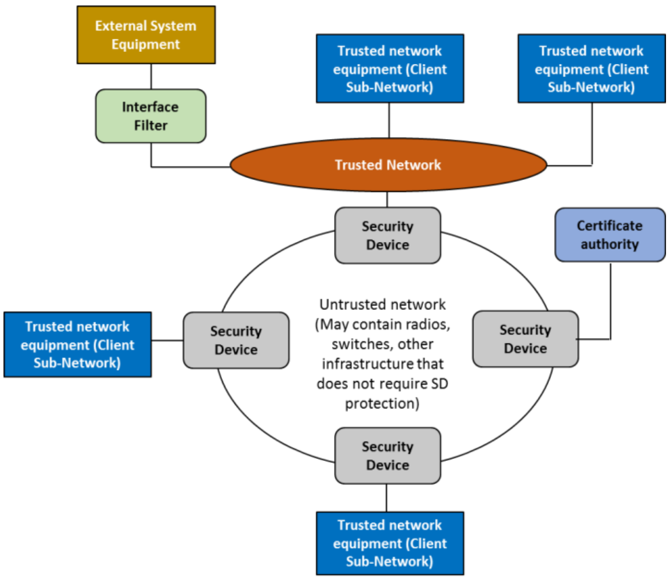

Figure 1: Management of Cybersecurity threats

The use of track circuit system with aspect signals is widespread and well used in the majority of the mainline railways and freight worldwide as well as some urban and suburban railways (e.g. Millburn Metro Trains). Track circuit system is also referred to as fixed block signalling with predetermined signaling section lengths that limits the number of trains in any one section. By and large, this system relies on the driver to interpret the line side signals and control the train accordingly.

With the advent of digitization, automation and emergence of the CBTC in the early 1980s, more and more railway authorities are adopting the CBTC system due to its superior capability to handle heavy traffic, short headway, short dwell time, and high-capacity urban transit systems such as Monorails, Metros, and LRTs etc.

The CBTC doesn't rely on the driver to interpret track conditions as the system is entirely automatic and programmed in accordance with predetermined operational scenarios. This paper gives some insight into the practical application of CBTC systems in Malaysia, it examines CBTC architecture, interfaces and integration challenges, migration from legacy to CBTC strategies, system assurance, and identify the key CBTC Operation, Maintenance and Training Regime necessary to implement CBTC.

2 Towards Digital Railway

There are various operational scenarios that govern the application of the CBTC system, all of these scenarios are digitally programmed, tested, verified and validated through the use of high-level software language that maps out the track alignment data, track parameters and commands the train propulsion system in real-time using fully redundant microprocessors based controllers. The behaviour of the train movement is fully controlled and predetermined by train on-board equipment such as Automatic Train Control (ATC) or Vehicle On Board Controllers (VOBC). According to IEC 62290 CBTC Grade of Automation (GoA), there are 4 GoA operational principles used in the CBTC system as depicted in ***table 1*** below:

Grade of Automation (GoA)	Type of train operation	Setting train in motion	Stopping Train	Door closure	Operation in event of disruptions	Application in Malaysia
GoA 4	Unattended Train Operation	Automatic	Automatic	Automatic	Automatic	MRT Line 1&2 Kelana Jaya Line (Kuala Lumpur)
GoA 3	Driverless Operation	Automatic	Automatic	Train Attendant	Train Attendant	
GoA 2	ATP and ATO with a driver (SATO)	Automatic	Automatic	Driver	Driver	Ampang Line
GoA 1	ATP with a driver	Driver	Driver	Driver	Driver	

Note: The terms used are defined as follows: UTO – Unattended Train Operation, ATP – Automatic Train Protection, STO – Supervised Train Operation or SATO - Semi-Automatic Train Operation

In Malaysia Kelana Jaya Line and MRT line 1 are fully automatic using GoA4 control, whereas the Ampang Line uses GoA2 and the MRT Lin2 that is currently under construction will be GoA4.

The CBTC system is based on the moving block principle, in which the system creates a protection envelope for each Light Rail Vehicle (LRV), which is dynamically updated based on train location, speed and direction. This means it is possible to berth many trains on the line thereby improving the headways, increasing the train fleet size and catering for higher ridership capacity. **Figure 2** depicts the CBTC System Architecture that was used on the Ampang Line. The system was equipped with Zone Controllers (ZC), track mounted tags and uses radio communication between trackside equipment on the train. Zone Controllers are displaced and located at strategic locations on the trackside and interconnected via a fibre optics backbone network.

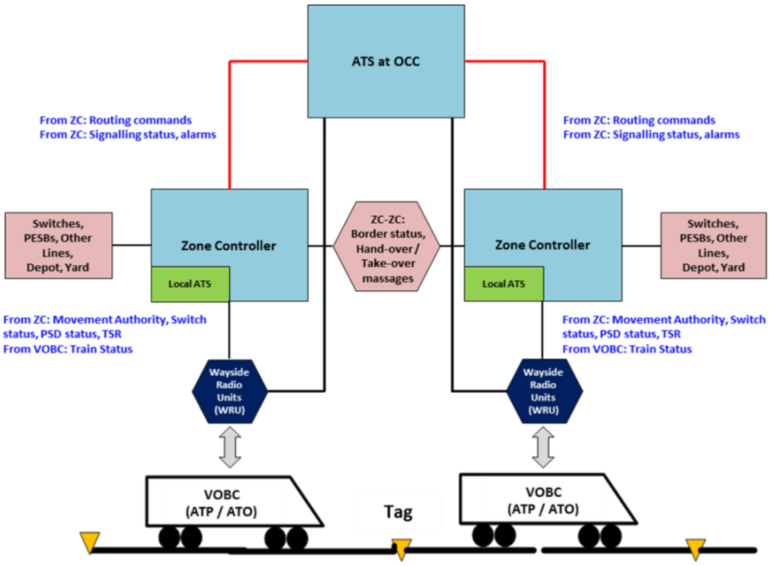

Figure 2: Management of Cybersecurity threats

The entire railway system is controlled from Operation Control Centre (OCC) that monitors the movement of trains in accordance with a commercial timetable. See **figure 3** showing the OCC at Ampang.

Figure 3: Management of Cybersecurity threats

Protection of the network from Cyber threats is an essential component of the CBTC design, in the Ampang Line the CBTC system had inherent cybersecurity safeguards that includes three levels of protection, namely: Security Devises (SD) which controls access to the network e.g. wayside backbone or On-board network, Certificate Authority (CA) which supplies all SD information and their configuration and finally Interface Filter (IF) which acts as a border gateway and safeguard against external sub-networks. Figure 6 shows the extent of the cybersecurity protection.

Migration from Legacy to CBTC

The migration strategy to convert a legacy system into digital CBTC system is based on a collaborative approach between the CBTC system suppliers and the operator and maintainer, without which it would not be possible to deliver a successful migration plan particularly when the existing railway operations are kept running.

For the Ampang line the strategy was based on three pillars:

a) Communication with the public to inform them about the system upgrade to CBTC ;
b) Collaborative working with operators and maintainers and coordinate the programme of implementation especially when most of the work was performed during engineering hours; and
c) System Integration Test (SIT) that covered all operation scenarios.

Once the above was implemented and successfully completed the CBTC providers issued a Safety Certificate for opening the system for use.

CBTC System Assurance

The CBTC is a microprocessor based system, therefore, the validity, integrity, reliability and safety of the software developed for the project application is fundamental to safe operation of the railway. Sufficient testing and simulations as well as trial testing must be performed as a matter of necessity and prerequisite to acceptance of the railway. Witnessing the simulations and field test are important for the operator and maintainer familiarization and understanding of the system. The following prerequisites are essential prelude for acceptance of the software:

- Confirm that software source code has been verified and approved by a recognized third party test house.
- Check that software for the Automatic Train Supervision (ATS), on-board equipment, trackside equipment are all compatible and correctly interfaced (e.g. radio and Data Communications System (DCS), Passenger Information Display System (PIDS), ATS, Points and Crosses (P&C)).
- Rolling Stock brake system behaviour and response is compatible with CBTC software with no long time delays that affect the behavior of the brake system
- Software configuration is controlled and software versions and issues are monitored and controlled
- Ensure that Software is tested through laboratory test simulations and demonstrate all timetable operating scenarios under normal and degraded modes.

The overarching standards covering the entire CBTC system are depicted in **Figure 4**.

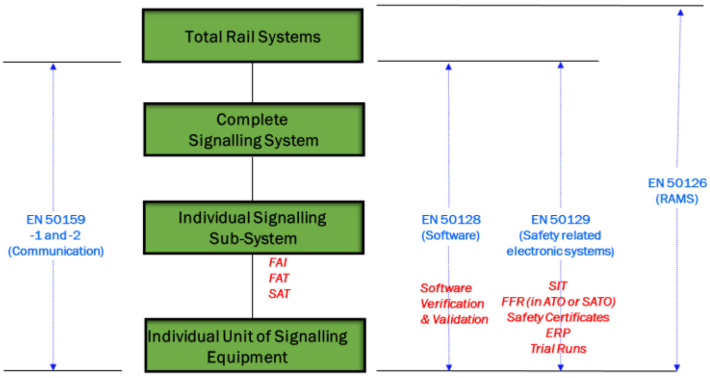

Figure 4: Overarching Approach to CBTC Functional Safety Systems Assurance based on International Standards

Interfaces and integration challenges

The entire railway subsystems such as track, signaling, rolling stock, communication and power should all work in consort to ensure a fully integrated railway that is operationally responsive and predictable. Key aspect of CBTC delivery is the on-board antennas and their interaction with lineside radio, this aspect of integration is critical to the working of the railway. Refer to **Figure 5** for illustration of the challenges.

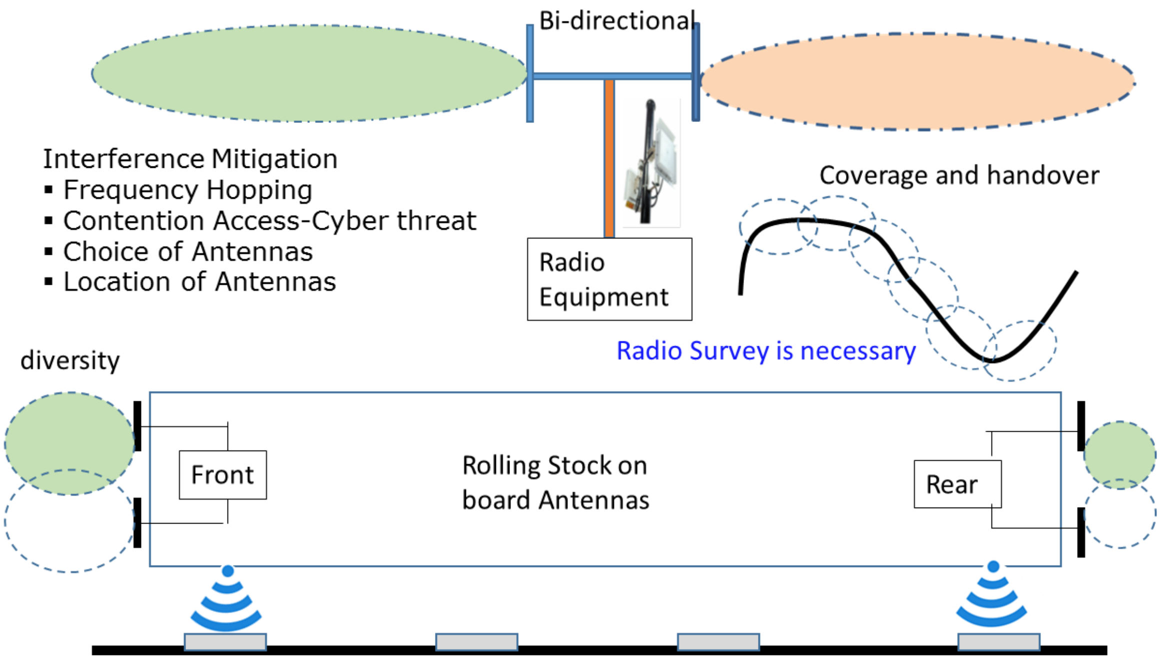

Figure 5: Integration and interface: Antennas compatibility
WIFI Based 2.4GHZ (or 5.1-5.8GHZ)

Operation and maintenance requirements

The adoption of CBTC system is not just a change in technology, it is an organizational change that requires operators and maintainers to be familiarized and competent in the operation and usage of CBTC technology. Knowledge of computer based technology including management and modification of the CBTC application software is necessary to keep the railway running to an optimum standard and meeting the regulatory authorities Key Performance Indicators (KPI).

The CBTC microprocessors based equipment and components are so designed to provide intelligent information about their status and also ensuring the system is fail safe. Failure management competency is necessary to cater for the three possible failure scenarios as follows:

- ATS failure at OCC;
- Trackside failure of CBTC components; and
- Train onboard equipment failure such as VOBC or ATC.

Operational Management of a fully-automated metro system- Training

Training of the operator and maintainer (O&M) on the new CBTC system is paramount, and investment in such endeavour over weighs the cost. The O&M strategy adopted in Malaysia covers three critical layers of management as follows:

- Supervision and management of operations;
- Control of operation; and
- Securing Operation.

Figure 6 illustrates the O&M strategy.

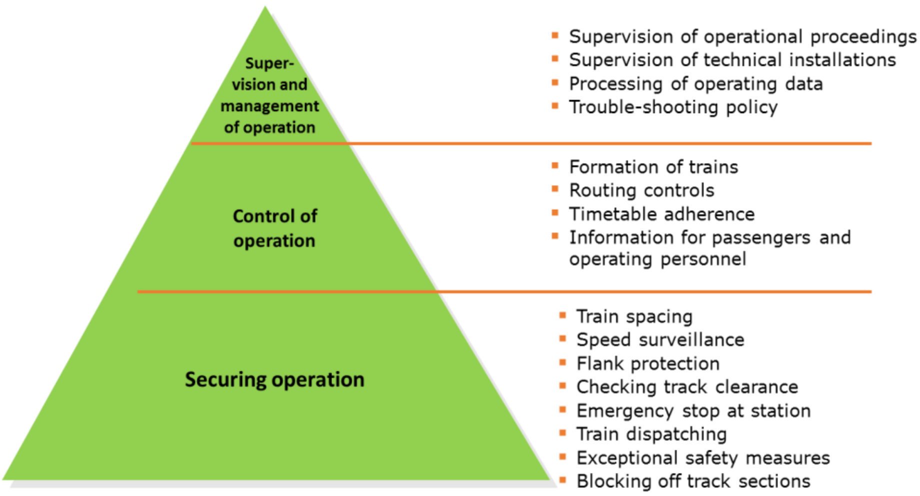

Figure 6: Operational Management of a fully-automated metro system- Training

Conclusions

This paper has provided an outline of the development of the CBTC system, provided an insight into practical examples that have been implemented in Malaysia. The CBTC continues to improve particularly with regards to radio communications, track data management, configurability of the system, adoption of WI-FI and LTE communications. Keeping up with technological changes is a key organisational development of modern O&M organisations.

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