Migration Directions of Components, Functions and Operations in Train Control Systems

Sanja Jevtic

Abstract—Train control systems surpassed trivial route settings and from classic solutions using discrete communication, detection and interaction are evolving in online systems with continual communication, with multiple systems and subsystems oriented towards full control, safety and security.

Although apparently the previous period was more than exciting in the regulation, standardization and harmonization of railway traffic, the near future seems equally exciting. Multiple directions of development, intensive support of projects oriented towards new solutions, emergence of new solutions and improvements bring new levels of stability and give a good railway tone to the second quarter of the century.

Paper distinguish several subsystems widely used and point out current trends and research and development directions.

***Key words*—train control, protection systems, migrations.**

I. Introduction

The very word control defining the processes of checking, dominance, operation, monitoring, and restraining, sometimes introduces ambiguity. But in the end, train control does include all these actions and more. TC (train control) not only monitors train location and movements, but in hazardous situations prevent train collisions. But the primary aim is to ensure that the train is operating in a safe and efficient mode. TC systems are considered to be a building block in railway systems, along with others.

Thus, TC is not working alone; it is connected to Interlocking (IXL) devices, ensuring that visualization and location are confirmed, with reliable communication systems ensuring continuous train-to-ground (T2G) communication [1-6].

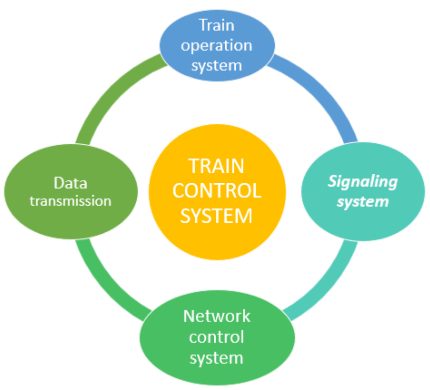

Fig. 1. Generic architecture of train control systems.

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In train control, several subgroups of systems are common for all variants of train control systems: trainborne equipment, trackside/wayside equipment, data communication system, and operation control system.

II. Automation Variants

With increased speed, automatization became mandatory, and only afterwards TC. So, several solutions for achieving safety appeared: first ATP (Automatic Train Protection), then ATS (Automatic Train Supervision), and ATO (Automatic Train Operation). ATP, ATS, and ATO could be depicted through functions that enable safety in real-time. ATP is related to monitoring the speed at a defined point (or continuously) and applying emergency braking if necessary (Indusi I60, the system used in Serbia). ATP is based on braking curves (a mathematical model of braking based on train type, speed, distances, etc.). ATS is used as a monitoring system for tracking and visualization of train movement (train dispatchers). ATO is the system that effectively operates a number of driver's controls according to trackside signaling equipment and the traffic control system, unburdening the driver. It is clear that the speed and other movement parameters should be monitored - on train and on the ground. In these conditions, the driver cannot react quickly in some situations, so ATP is mandatory, ATO can be introduced for some actions, ATS is mandatory. All this is called ATC, or Automatic Train Control. It is a system used to cover, among other, on-board automation that, in some (or many) actions replaces the driver (ATC=ATP+ATO). In order for the ground to have full monitoring status of the on-board equipment, it is necessary that ATS, as a centralized system, have related data provided from ATC on-board. So, all the terms are interlocked and interleaved and should be treated one function at a time, not as entities or equipment/subsystems. But one is certain – ATC or TC is best defined by a set of functions provided in implemented railway systems, equipment used, and operations divided between the driver and the system itself (modes of operation) [1-4]. -

Momentum in rail automation is increasing, and the leader in frequency and demands is urban rail (metro, subways, sub-urban, commuter trains, etc.). Urban rail was one of the first to demand differentiation in definitions. Today versatility in automation solutions is vast. The standard IEC 62290-1:2014 [5] defines five levels of automation:

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- GoA 0 – Line of sight Operations – no ATP. and all functions are based on information seen or collected by the driver,
- GoA 1 – Non-Automated Train Operation – manual driving with ATP functions, no ATO functions,
- GoA 2 – Semi Automated Train Operation – Driver is on board, APT and some ATO (start/stop of the train) functions,
- GoA 3 – Driverless Train Operation (DTO),
- GoA 4 – Unattended Train Operation (UTO).

As it was mentioned before, the functions are what ATP, ATO, and other solutions are defined for. Table 1 provides the minimum mandatory functions defined for GoA levels. GoA 0 (Train Operations on sight - TOS) is considered a dark system meaning that all train movements and control of wayside (trackside) elements are managed by operational procedures.

TABLE I
MANDATORY FUNCTIONS DIVIDED BETWEEN DRIVER AND THE SYSTEM, X – DRIVER, S- SYSTEM [3]

Mandatory functions		GoA0	GoA1	GoA2	GoA3	GoA4
Ensuring safe movements of trains	Safe route	x	S	S	S	S
	Safe separation of trains	x	S	S	S	S
	Safe speed	x	x*	S	S	S
Drive the train	Control acceleration and braking	x	x	S	S	S
Supervise guideways	Prevent collision with obstacles	x	x	x	S	S
	Prevent collision with persons on track	x	x	x	S	S
Supervise passenger transfer	Control passenger doors	x	x	x	S	S
	Prevent injuries – between cars or platforms and trains	x	x	x	x	S
	Ensure safe starting conditions	x	x	x	x	S
Operate a train	Put in or take out of operation	x	x	x	x	S
	Supervise the status of the train	x	x	x	x	S
Ensure detection and management of emergency situations	Detect fire/smoke and detect derailment, detect loss of train integrity, manage passenger requests (call/evacuation, supervision)	x	x	x	x	S and/or staff in OCC**

*PARTLY SUPERVISED BY SYSTEM
**OPERATIONS CONTROL CENTER

The GoA1 (Manual Trains Operations - MTO) is a conventional signaling system common for all subway or metro systems. System will determine if it is safe to proceed (block, IXL, signaling), but the driver and other traffic staff are responsible for keeping the system safe. In the table, the *ensuring safe movements of the train* is the most important function of all. The Goa1 is divided into category GoA1a and GoA1b, with punctual and continuous supervision of the train's movement along the line.

The GoA2 (Semi-Automatic Train Operations – STO) is a variant in which technical systems control traction power and brakes. The driver is present and responsible for closing the doors of the train at stations (passenger safety). Trip monitoring is the responsibility of the driver, who has authority to intervene in an emergency.

The GoA3 (Driverless Train Operation – DTO) implies that the driver is still on the train, and the term used is *operator*. His presence in the cab is not necessary all the time. In the event of a malfunction of the automation systems, it is expected of him to take over control. The doors could be automated or operated manually from any location on the train.

The GoA4 (Unmanned Train Operations – UTO) describes the full automation of train operations. No operator is needed onboard the train. This is valid for movements without passengers and with passengers. In the latter case it is mandatory to have remote control in case of a control systems' failure. Good communication with the train is mandatory. The route is protected against the intrusion of unauthorized persons, and technical systems for obstacle detection are required [3,4].

III. GENERATIONS OF SIGNALING SYSTEMS

The evolution of signaling systems connected the stations as islands, further leading to centralized monitoring and operation of traffic. As noted, the automation also brought some demands. And at the end, interoperability was the topic of the day, being a painful process for certain countries because it led to big changes. But over the years variants of demands, costs, and other factors brought to life more than one possible solution dealing with the safety of railway traffic. During the years different generations of TC appeared [1].

A. First generation

This generation was based on track circuits (detecting the train location), wayside components (giving indications to the driver), and onboard components. The modes appearing were limited to manual driving modes. Track circuits were related to fixed block and wayside (trackside) signals. On-board train equipment in this generation is limited to stop indication, while all control equipment is situated on the wayside.

B. Second generation

This generation brings cab signaling, with track circuits still in use. Some of the control functions were introduced to the train.

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C. Third generation

The accuracy of train movement was the issue of this generation, bringing it to higher levels. New, automated driving modes were also introduced, but the wayside still held the decision-making for train movements.

D. Fourth generation

In this generation, the main targets are safety and efficiency. A lot of new modes (automated) were introduced. Onboard equipment got more functions and meaning, and the communication network was brought to a whole new level. Most of the known TCs are in this generation, first of all ETCS (European Train Control System). ETCS was the offspring of large cooperation among institutions and industry and it was one of the building stones of harmonization of EU. The standardization behind it is vast, but other countries did their own projects. China built CTCS (Chinese Train Control System) for main lines, USA developed PTC (Positive Train Control) for main lines and CBTC (Communication Based Train Control) for transit/urban rail was developed.

All these systems have minor or major differences among themselves in on-board and wayside subsystems, and all share common goals [1-10].

IV. CBTC, ETCS AND PTC

Currently, several directions in development of the train control are established, each unique in its own way, yet all sharing certain components and functions. For starters, the diagram of TC data flow (fig.1).

All migrations in TC development always emphasize the importance of tracking moving objects (trains). But TC waited for ICT (Information and Communication Technology) to catch up with the requirements of TC in the areas of sensor integration, wireless communication, information management, and real-time acquisition and data processing. The emergence of Internet of Thing (IoT), the Big Data concept, new wireless networks, and further enhancement of existing networks, and global systems such as GPS with sufficient accuracy were crucial in the evolution of already high tech TCs.

In order to fully establish the main functions and elements/entities, further discussion of TC variants is beneficial. Currently, the most interesting systems are CBTC, ETCS, and PTC [6-16].

A. CBTC – Communication Based Train Control

The CBTC is, as its name states, based on communication system enabling real-time continuous bi-directional telecommunication links between train and ground. The train position is very accurate in this system making it possible to improve headways in metro systems. The ATP, ATO, and ATS functions are implemented in this TC. The fixed block systems are a limiting factor, so CBTS achieves better features using moving block (fig.2) [11].

The CBTC is an example of a system varying from GoA1 to GoA4. The system has a good immunity against interference and good optimization for achieving the best line capacity. The architecture of this system is similar to PTC (presented later): on-board ATP and ATO, radio communication system, interlocking, wayside ATP, ATO, and ATS. So basic functions are the protection of train movements, driving the train, supervising passenger transfers (gaining complexity with increase of the GoA level), guideway supervision, train operation, detection and management of the emergency situation [4].

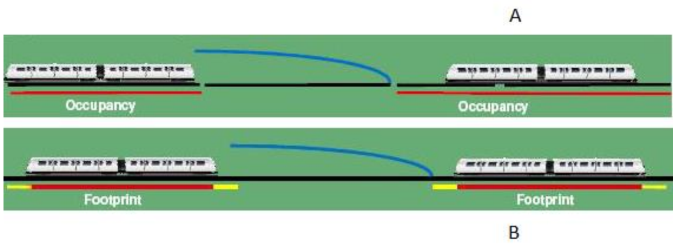

Fig. 2. Train occupying part of the track (red) with braking distance (blue) and endangered part of the track (yellow) in the CBTC system. The occupied part of the track in A) the fixed block and B) the moving block is different (in latter, called the footprint) [11].

The CBTC is organized around protection of train movements, driving the train, supervision of passenger transfers, supervision of guideways, train operation and detection and management of emergency situations.

Protection of train movements consists of several basic and other functions:

- Route locking - revolving around avoiding collisions (conflict movement with other rail vehicles – flank, rear, and front, external objects, conflict movement of non-rail vehicles – intersections) and derailments (locking the movable track elements, protections against unsteady sections in the track),
- Safe train separation where distance depends on speed and other factors,
- Overspeed protection, also protection against derailment due to high speed and collisions,
- Generation of movement authority, considering maximum permissible train speed – considering train length, maximum overspeed, max speed measurement error, max possible acceleration, worst-case reaction time for traction cut-off and emergency brake activation, guaranteed braking deceleration of the emergency brake, gradients, all influencing the safety envelope,
- Monitoring the vehicle movement within the permissible limits (speed, location, comparison, requesting and withdrawing of emergency brake command).

Driving the train has two basic functions:

- Calculation of the optimum speed profile – ATS assists in optimizing the speed of the train and can optimize the driving with all the data it receives. There are two strategies for optimization: time-optimized driving and energy-optimized driving.
- Control of trains depending on an optimum speed

profile based on measurements influencing both the vehicle and the wayside equipment.

Supervision of passenger transport (mandatory for DTO and higher) envisages monitoring and control of vehicle doors, prevention of injuries to persons between cars, prevention of injuries between platform and train and ensuring safe starting conditions.

The prevention of collisions with obstacles and people on tracks is a part of the guideway supervision process. Train operations (for ATO) require depot work, reversals and supervision of the train (faults, malfunctions, etc.). The increased safety and security in all aspects of transport today include detection of fire and smoke, evacuation i.e., handling of emergency situations and obstacle and derailment detection as part of the railway safety spectrum.

Modes of operation in CBTC are adapted to the needs of the system, and several are recognized: ATO (automated train operation), STO (semi-automated train operation), SM (supervised manual mode), RM (Restricted mode), AR (Automated reversal mode), and AR2 (automated reversal mode 2).

Based on the requirements of the system, equipment consists of [4,13]; as shown in the Fig 3.:

- Trainborne equipment – vehicle computer (central element), cab display, sensors and antenna for odometry, transmitting and receiving devices (radio);
- Wayside equipment – transponders, controllers for the movable track elements, equipment for secondary track vacancy detection, CBTC zone controller;
- Data communication system – here fundamentally different technologies are being used – WLAN based systems, TETRA (Terrestrial Trunked Radio), 4G (LTE – Long Term Evolution), and 5G (5th generation) which is expected to enter the scene soon. WLAN manufacturers even developed a special roaming algorithm;
- Operations Control Center (ATS) – complete monitoring of the urban rail transport system, as well as diagnostics of trackside, vehicle, and communication systems. Other systems are included in the work of this ATS – PIS (Passenger Information Systems) and SCADA (Supervisory Control and Data Acquisition). The functions of this system consist of at least: operation and display, automatic train tracking, automatic route setting, and automatic train regulation (determination of the headway deviation and control of the train speed). The surrounding systems of the automatic train control system are shown in Fig 4., which enable CBTC to build automation, include data in and from PIS and PAS (Passenger Announcement System), signaling systems, TCMS (Train Control and Management System), engineering structures and railway tracks, traction power supply, and Maintenance.

B. ETCS – European Train Control System

ETCS is defined by TSI (Technical Specification of Interoperability), as a set of specifications in different subjects. ETCS relies on GSM-R as a radio communication network, together forming the ERTMS (European Rail Traffic Management System), and the scarcely mentioned ETML (European Traffic Management Layer). The concept of this system is, at first glance, a bit different. Most of the functions mentioned for CBTC are also implemented, but ETCS is responsible for ensuring interoperability on main railway lines. Interoperability is thus interleaved down to the functions and interfaces of the equipment used, standardizing it and making it possible for different vendors to stay in the market. ETCS is best explained through its levels. Optimal opportunities for the system are achieved at level 2, but lesser levels like 1, NTC, and 0 are also in use, each handling a specific situation on the line. Above level 2 is level 3, using the different organization of the underlying block system [15]. Some of the specifications in related documents are mandatory, while others are optional, offering multiple solutions for implementation.

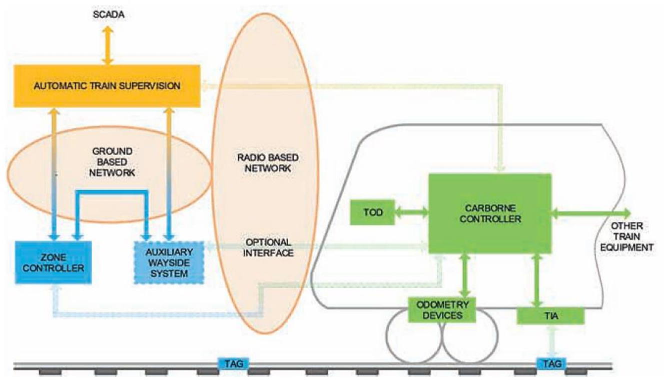

Fig.3. CBTC system overview [13]

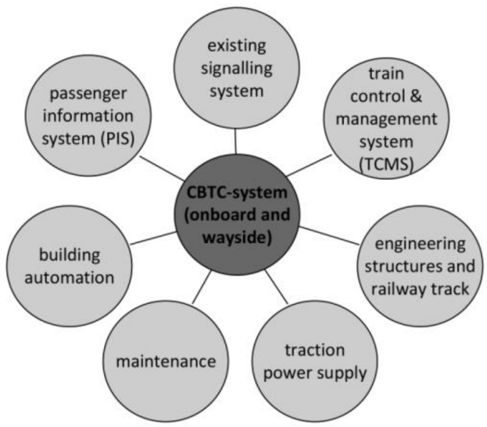

Fig.4. System context of CBTC systems [4,14]

So, ETCS is mainly defined by definitions of interfaces (subsets mostly named FIS or FFFS). The equipment used is different for each level and is divided into:

- Trackside subsystems – balise (Eurobalise), lineside electronic unit LEU, radio communication network GSM-R, Radio Block Center RBC (responsible for movement authority MA), Euroloop, Radio Infill Unit (RIU);
- On-board ETCS equipment and on-board part of the GSM-R system. ETCS on-board is based on EVC – European vital computer, Driver Machine Interface

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DMI, Odometry, BTM Balise transmission module and LTM Loop transmission module, TIU Train Interface Unit and STM Special Transmission Module.

- Although ETCS does not include a signaling and interlocking system, a KMC Key Management Center or control center, it is connected to them, using data they provide and providing them data in return. On-board Juridical Recording Unit JRU is used. This equipment is not part of the ETCS on-board equipment, but the interface and data supplied through it is defined in subsets.

Levels ranging from Level 0 (trains equipped but the line is not), Level NTC (national level using some of the existing national class B mostly using ATP/ATC), Level 1 (with or without infill transmission), Level 2 (train with ETCS and line with RBC, and GSM-R, Fig.5) and Level 3 (similar to Level 2 but with train position and train integrity supervision based on information received from the train). Downward compatibility is established, except for the NTC, which is not part of this compatibility chain [16].

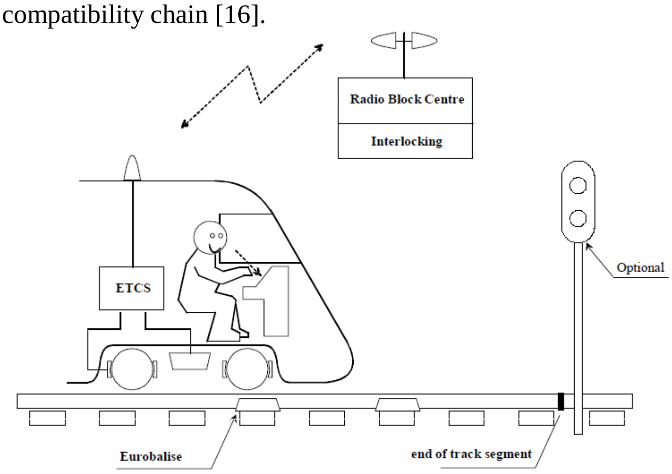

Fig.5. ETCS application level 2 [16]

The principles of ETCS operations are based on: balise configuration and linking, and the management of radio communication, providing movement authority to the train based on different train data. Here, functions are divided between trackside and on-board elements.

The main trackside ETCS functions are:

- Knowing each train equipped with and running under ETCS within an RBC area by its ETCS identity;
- Following each ERTMS/ETCS controlled train's location within an RBC area;
- Determining movement authorities according to the underlying signaling system for each train individually;
- Transmitting MA and track description to each train individually and
- Handing over the train control between different RBC's at the RBC-RBC border.

The main on-board ETCS functions are:

- A train reads Eurobalises and sends its position relative to the detected balises to RBC;
- A train receives a MA and track description via Euroradio relating to a balise;
- Selection of the most restrictive value of the different speed permitted at each location ahead
- Calculation of a dynamic speed profile, taking into account the train running/braking characteristics that are known on-board and the track description data;
- Comparison of the train speed with the permitted speed and commanding of the brake application if necessary.

ECTS has defined variables, messages, and its own language, reducing the amount of data transferred trough radio link using secure Euroradio [16].

Modes of operation are multiple, giving flexibility to the driver and enabling fast adaptation to the scenario at hand. Operating modes, which define specific scenarios and the division of responsibility between driver and system, are: Isolation (IS), No Power (NP), System failure (SF), Sleeping (SL), Stand By (SB), Shunting (SH), Sull Supervision (FS), Unfitted (UN), Staff Responsible (SR), On Sight (OS), Trip (TR), Post Trip (PT), Non-Leading (NL), Reversing (RV), Limited Supervision (LS), and Passive Shunting (PS).

C. PTC – Positive Train Control

All TCs have as one of their primary tasks to avoid collisions, but this TC was designed around this premise. Among other things, it prevents derailment (high speed) and accidents in established work zones and movement through a switch in an improper position [6]. These four mandated functions PTC must perform, but the way systems are designed is not pre-decided. It could be certified as a vital overlay system, non-vital overlay system, a stand-alone and a mixed system.

As is stated several times, TC must have an exact location and train speed. Control of the braking process is a forced operation in case of emergencies. Besides all previously said PTC will not prevent accidents related to:

- *Train-to-train collisions at or below restricted speed* – PTC will prevent moving through a red signal, but it was detected that in some situations where it is allowed to pass a red signal (approval), a rear-end collision is possible, when train was moving below the speed limit (on-sight intervention was impossible because of the limited visibility);
- *Overspeed derailments at or below restricted speed* – PTC restricts speed on switches (turnouts), but not all variants will prevent overspeed movement through turnouts if the speed limit of the area is not exceeded;
- *Intrusion into a work zone* – the issue here is the proper establishment of the work zone during maintenance and awareness of these borders during maintenance (*maintenance of way* workers so called MOW);
- *Movement through a switch in the wrong position* – PTC restricts speed when approaching the main line switch in unknown or improperly aligned position for the set route, but the train derailed on some occasions.

The PTC has 5 recognized variants I-ETMS (Interoperable Electronic Train Management System), ACSES II (Advanced

Civil Speed Enforcement System II) and ASES II (Advanced Speed Enforcement System II Enhanced Automatic Train Control (E-ATC), ITCS (Incremental Train Control System), and CBTC (Communication Based Train control). I-ETMS uses GPS and radio communication. The ACSES II and the ASES II use transponders and radio system overlaying a cab signal and/or ATC system. The E-ATC uses track circuits with ATC, ITCS radio and transponders, and last of all CBTC track uses circuits and a transponder-based system [6].

Among the On-board (On-board computer, event recorder, antennas/transponders, radio and GPS elements), track elements (wayside interface units WIU, transponders, and switch monitoring systems), communication (radio /cellular towers, GPS antennas, fiber backbone – sometimes copper) and Back office (Back office servers BOS, dispatch center), PTC (Fig. 06) agrees on development directions with other TC systems currently used around the world: radio network, braking algorithms and control, upgrades on central sites, enhancement of train integrity detection, and TCMS on-train [6-10,13].

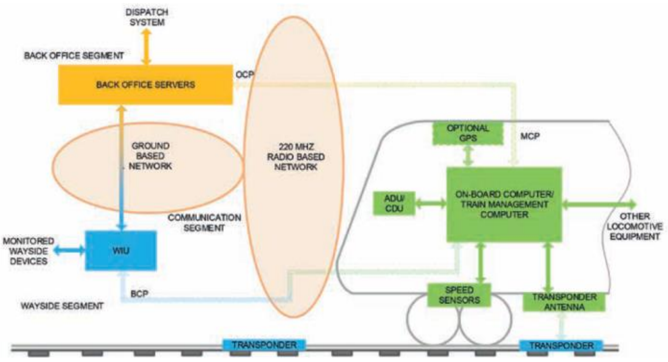

Fig. 06. Typical system architecture of PTC system [13].

V. MIGRATIONS

Looking at previous facts, it is clear that different TCs have, up to the current technology maximum, the most of their equipment maximally developed. Currently, the trends of research and development are driving the railways towards new TCMS systems, using enhanced variants of GPS based systems and towards enhanced braking algorithms.

There is also a net zero drive that has included this new philosophy in all current projects [17].

Braking curves i.e., the mathematical models dealing with efficiency and effectivenes (both time and energy driven) are more part of the mechanical department in railway environment and will not be discussed in this paper. In the growing awareness of self-sufficiency, efficient and effective power consumption have also become mandatory, and are also another topic.

The TCMS as a system provides on-board computer connection to other systems on the train. It also communicates with supporting systems operating along the trackside. Since it is connected to multiple systems on the train it mostly uses standardized interfaces. Common components of these systems besides the computer or CCU (Computer Control Unit) are connected using some of the standard buses: MVB (Moving Vehicle Bus, usually RS 485), Ethernet, or some other (i.e. CAN Controller Area Network, WTB Wired Train Bus, ECN Ethernet Consist Network). Usually, it is connected to some HMI (Human Machine Interface) and has one or more mobile communication gateways (GSM-P, WiFi, and GPS). This system provides numerous diagnostics and monitoring capabilities. The data it provides could be used by PIS, as well. This system is flexible and adaptable to the developing requirements of its surroundings. But its common implementation and flexibility are also a source of threats, thus involving enhanced cybersecurity options in its development and newer solutions. Monitoring the train systems is mandatory, and confirming the train integrity on train is one of the newer functions [18,19]. Establishing a bus is complicated on freight trains. All roads lead to TCMS – its NG proposed solution, new functions, it's monitoring, ease of communication with wireless, joint functions with train, and providing data to the ground - all point out that TCMS is the number one system to be enhanced and transformed to meat the growing demands of the TCs.

The *Drive-by-data* system integration and architecture, mixing both critical and non-critical rolling stock functions, have already begun. This work will use architectures similar to those in aerospace (IMA Integrated Modular Avionics). This will bring TCMS what is most needed: lesser costs, and easy reconfiguration, while not cutting the critical functions and all in an Ethernet environment.

VI. DISCUSSION AND CONCLUSION

TCs are a necessity. They provide security as well as speed and efficiency. All systems included in its implementation will eventually grow and change perhaps dramatically, but only few are currently in the spot. TCMS being the system that could provide train integrity information on the train itself, could solve a problem that has been present for a long time and provide an easy solution for ETCS Level 3 implementation.

The TCMS will obviously slide to wireless communication solutions, but besides TCMS wireless solutions will be used by safety functions, CCTV, and infotainment. Wireless always brings all sorts of issues – architecture, safety protocols, and the life span of the solution. However, that is a whole new problem that will be studied for a number of years because rail industry does not use new solutions that have not been sieved

REFERENCES

[1] Tanuja Patgar and Kavitha Devi CS, “On-board design models and algorithm for communication-based train control and tracking system”, CRC Press, Boca Raton, 2022.
[2] S. Jevtić, “ETCS - Evropski sistem kontrole vozova”, Belgrade, Serbia, ATUSS, 2022
[3] https://railsystem.net/railway-signalling-terms/.
[4] Lars Schneider, “Communications-Based Train Control (CBTC), Abstract”, PMC Media House GmbH, Hamburg, Germany, 2019
[5] *Railway applications - Urban guided transport management and command/control systems - Part 1: System principles and fundamental concepts*, IEC 62290-1:2014.

 ISBN 978-86-7466-969-3

[6] *Information Guide on Positive Train Control in 49 CFR Part 236, Subpart I*, Issued Dec 12th, 2022. US Dpt. Of Transportation, FRA, 1200 New Jersey Av. DE, Washington, DC, USA, 2022

[7] *Highlights of R&D Activities for PTC Implementation*, FRA R&D Program Review, Washington DC, USA< 2009

[8] *Signal and Train Control*, FRA R&D Program Review Washington DC, USA, 2008.

[9] *Higher Reliability and Capacity Train Control*, Technical Report FRA, R&D, Washington, DC, USA, 2022.

[10] *Research Publications on Positive Train Control (PTC): January 2015-July 2018*., Reference materials, FRA, Washington DC, USA, 2018

[11] https://railsystem.net/communications-based-train-control-cbtc/

[12] Brückner, Detlef. *"Lösungen für das automatisierte Fahren im Nahverkehr."* Signal+ Draht 109.6 (2017): 6-11.

[13] G.Theeg, S.Vlasenko (eds.), "*Railway Signalling and Interlocking*", PMC Media House GmbH, Hamburg, Germany, 2020

[14] *Railway applications - Urban guided transport management and command/control systems - Part 1: System principles and fundamental concepts*, IEC 62290, 2014

[15] Sanja Jevtic, Marko Bursac, Goran Trickovic, Dragan Jevtic, "The Role of Block Systems in ETCS Levels", Proc.of VII Intern. Simp. New Horizons 2021, pp.213-219.

[16] ERTMS/ECTS System Requirements Specification, Chapters 1-9, ERA, Subset-026, v.3.6.0, 13.05.2016.

[17] S.Jevtic, D.Jevtic. M. Vuksic Popovic, N.Ratkovic Kovacevic, "The future of renewable energy in railways", Proc.of 10th International conference on MKOIEE, SMEITS, 2022, pp.85-89

[18] Shift2Rail, https://shift2rail.org/

[19] M.Jakovljevic, A. Geven, N. Simancic-John, D. Mete Saatci, "Next-Gen Train Control / Management (TCMS) Arhitectures: Drive By Data System Integration Approach", ERTS 2018, Jan 2018, Toulouse, France. ffhal-02156252

APSTRAKT

Sistemi kontrole kretanja vozova su prevazišli puko postavljanje puta vožnje i od klasičnih rešenja sa diskretnom komunikacijom, detekcijom i interakcijom postaju onlajn sistem sa kontinualnom komunikacijom, mnoštvom sistema i podsistema orijentisanih ka punoj kontroli, bezbednosti i sigurnosti.

Iako je naizgled prethodni period bio više nego uzbudljiv u regulaciji, standardizaciji i harmonizaciji železničkog saobraćaja bliska budućnost deluje podjednako uzbudljivo. Više smerova razvoja, intenzivno podržavanje projekata orijentisanih ka novim rešenjima, pojava novih rešenja i poboljšanja unose nove stepene stabilnosti i daju dobar železnički ton drugoj četvrtini veka.

U radu se izdvaja nekoliko podsistema koji se često koriste i ukazuje na aktuelne trendove i pravce istraživanja i razvoja.

Pravci migracija komponeti, funkcija i operacija u sistemima kontrole vozova

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