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Public standards of wireless transmission wireless for safety improvement of raiway control

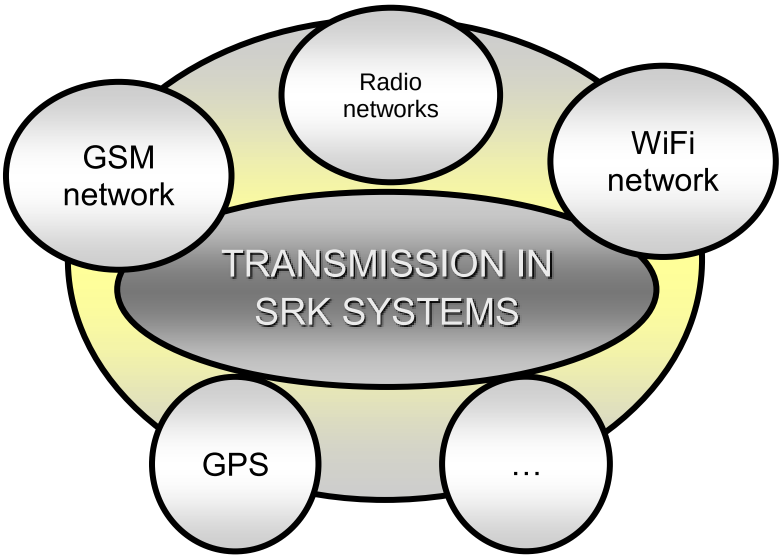
Abstract: The paper deals concepts and solutions related to application of public, open wireless transmission in railway control and management systems. Presented concepts are connected with them research works, the obtained results confirm the possibility of such applications for safety transfer in railway systems corresponding to SIL classification. In all presented systems we can observe the improvement of safety in chosen elements of railway infrastructure and control. The proposed mathematical apparatus based on Markov processes allows to estimate the reliability parameters of all presented solutions.

Keywords: Railway tra' c control systems; Open standards for transmission; Security

Open of wireless transmission in management and railway traffic control

The aim of the presented material was to show how accessible public standards of wireless transmission can improve safety on the railways. Since the norm PN-EN 50 159-2011 was published stating the rules for the application of open transmission systems in railway uses have been made attempts to application of radio public standards in the management and control of rail traffic. Proposals for such uses are being developed, among others, at the Faculty of Transport and Electrical Engineering University of Technology - Humanities in Radom and Institute of Railway in Warsaw. Such solutions may be a intelligent overlay on existing systems and devices significantly improve functionality while maintaining the required level of safety in accordance with SIL (Safety Integrity Levels). Based on the analysis of Markov processes it was possible to carry out analysis for estimate characteristic for these systems safety indicators. At work achieved the results of mathematical analysis support the use of such solutions. The paper presents both already implemented realizations of these systems (motion control system with the radio transmission between the level crossing subsystems and control track occupation subsystems), presented in many publications systems (warning drivers system at crossings level without barriers, the variable of the block system, supporting rescue system in the event of accidents and disasters), but also unpublished proposals systems (warning system, conflict of trains on the route).

Secure transmission in rail traffic control systems must meet the requirements and recommendations set out in the relevant existing standards PN-EN 50159: 2010 [25]. Security of transmission is analyzed at the level of the control system of a component (PN-EN50126), and is significantly associated with hardware and software, which take into account existing systems for railway standards PN-EN 50129, PN-EN 50128. Implementation of the transmission of information must be carried out in so that it was possible as soon as possible detection of erroneous information, and a break in the transmission link should cause the system to "safe state" in accordance with the procedure laid down for the marketing system SRK. This condition is defined for different types of systems individually and ,for example, "safe state" in the systems of counting axis indicates signal status "the busy section" for crossing signaling "safe state" may mean attaching a warning of the approach of a train, and alarm systems extortion display semaphore "prohibiting signal S1". Therefore to ensure the correct functioniting of the srk systemmust be used appropriate safeguards against corruption or data loss resulting from disruptions either unconscious or deliberate (unauthorized) handling activity. In the case of secure transmission systems information must be protected with additional bits or be coded. It is allowed to use other means of protection, as long as they provide the required level of safety. Entered open transmission system using public radio networks should provide the current level of security (compatible with SIL, according to the standards PN-EN 5012x) and not worse than the level of functionality in existing systems (especially the delays and interruptions in transmission). In open transmission systems transmission is carried out with the use of the radio network, Internet or through other links shared on public access. This means that the information is transmitted by the transmission system available to unauthorized users, so that the transmitted data can be vulnerable to attacks such as. deletion or impersonate to broadcasters under the SRK devices on the network. With regard to srk systems, particular attention should be given to estimate the level of risk (standard PN-EN 50126). The intensity of damage to the set level SIL determine the PN-EN 50126,PN-EN 50128,PN-EN 50129. In open transmission systems (STO) transmission is carried out with the use of the radio network, Internet or through other links shared on public access. This is illustrated schematically in pic.1. On the first table shows the available radio standards used in the public wireless transmission with the main parameter - the speed of transmission. Are not included solutions based on licensed systems dedicated for radio transmission using authorized access (so they are not a public standards) used in various business applications (commercial), industrial, including in some systems of railway automation.



1. Open transmission standards in srk systems

Tab.1. Parameters of wireless standards (based on [7])

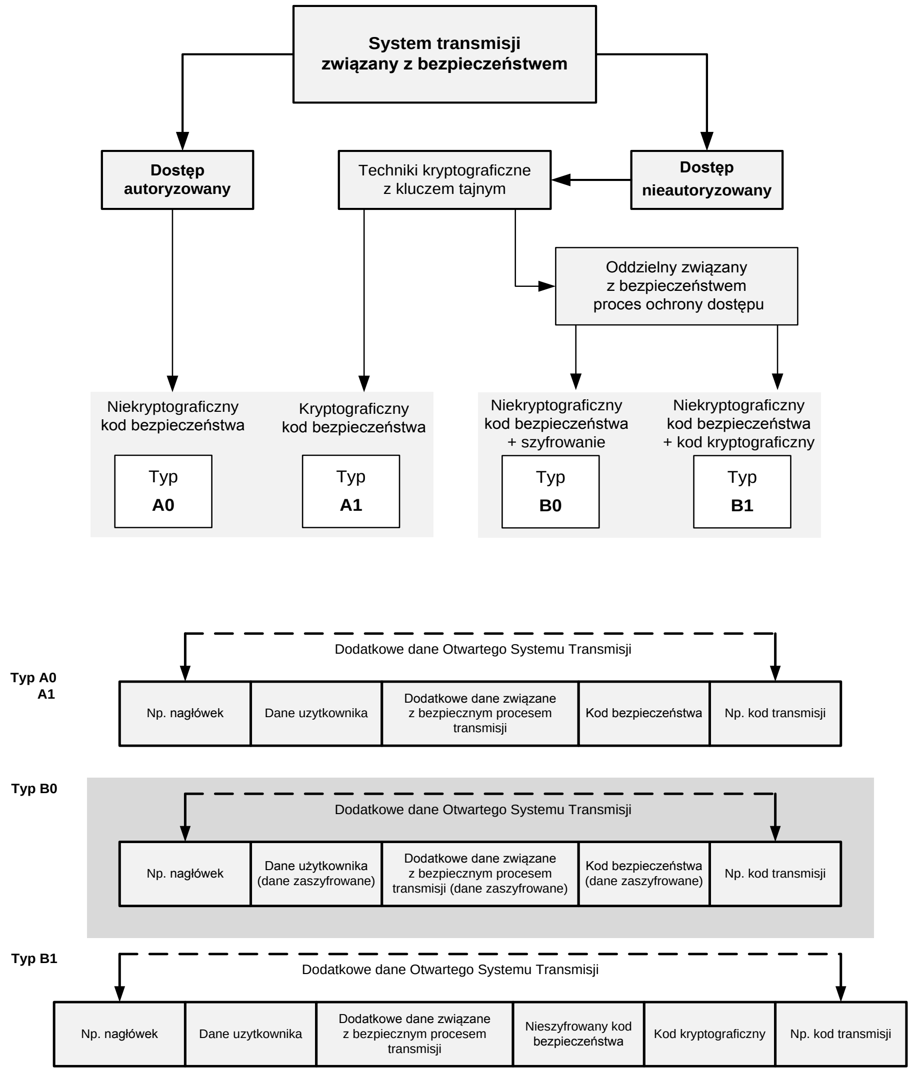
Parameter	**2,5 G**	**3G**	**LTE**	**WiMax**
Standard	GPRS, EDGE	UMTS, HSPA	3GPP Release 8	IEEE 802.16e
Reach from the transmitter	10km	2km	5-30-100 km	5-15 km
Downlink	200kb/s	384kb/s - 7,2Mb/s	43 Mb/s	2-4 Mb/s
Uplink	80kb/s	160 kb/s – 2Mb/s	5 Mb/s	512 kb/s – 2Mb/s
V_{max} of the terminal	250km/h	250 km/h	250 km/h	120 km/h
Delay	>500ms	50-200 ms	20-40 ms	30-50 ms

Wireless medium is much more susceptible to eavesdropping than wired medium, which is sensitive to the adverse effects of unauthorized persons whose purpose is to get unauthorized informations and often the introduction of malicious data to the network. According to the current standards PN-EN 50159 open transmission system is exposed to the following basic types of threats:

• Intentional or unintentional "impersonating" another system in srk system
• attacks to gain access to transmitted information or sending processed packages
•Deletion, modification or redirect telegrams,
• Rearranging or repeat telegrams,
• Delays of telegrams.

This means that the information is transmitted by the transmission system available to unauthorized users, so that the transmitted data can be vulnerable to attacks such as the deletion or impersonate to broadcasters under the SRK devices on the network. With regard to srk systems, particular attention should be given to estimate the level of risk (standard PN-EN 50126). The intensity of damage to the set level SIL determine the PN-EN 50126,PN-EN 50128,PN-EN 50129th The use of radio transmission in railway systems allows for the development and implementation of new solutions, especially on lines with a lesser importance to transport. Details of the use of these transmission are included in a dedicated for railway transport PN-EN 50159: 2011 (Railway applications. Communication systems, signaling and processing systems. Safety connectivity in transmission systems).

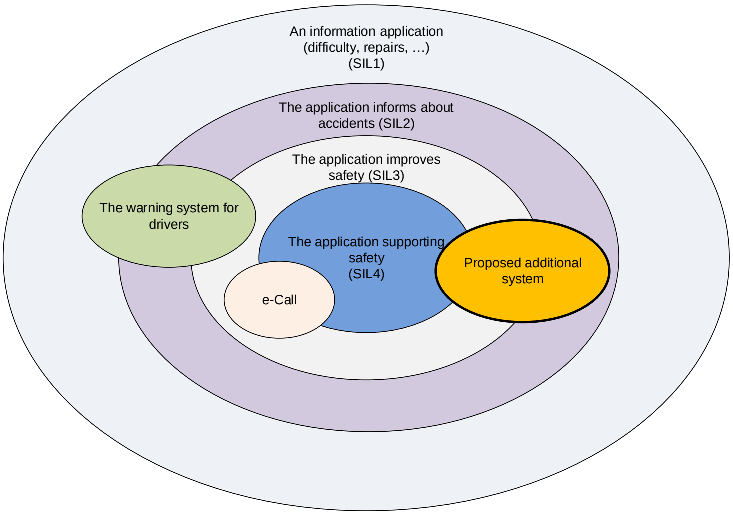
In order to combat such threats in the said standard PN-EN 50159 are recommended special procedures for encryption of transmitted messages, depending on the authorization and connection quality, as shown in pic.2.a. A0 basic standard applies in principle closed transmission with full authorization of the sender and recipient information. This transmission method is used in all currently operating rail traffic control systems in order to increase the reliability is used for checking data integrity CRC 32 for the body of the telegram and CRC 8 telegram header (the formatting information is presented in pic. 2.b). The selected standard B0 is currently the main method for secure telegrams in open transmission, applications management and railway traffic control.



2. Classification of security for the transmission of open transmission systems (a) Structure of information in secure transmission systems in accordance with PN-EN 50159 (b)

Characteristics of available wireless standards used in the polish railway.

The first studies related to the possibilities of the use of public in railway automation were taken at the beginning of the twenty-first century. The first was published application system warning drivers system on the unguarded railway crossings and crossings without barriers (category C) [2], the next was train driving system based on mobile space of the blocks. Another application associated with the implementation of the railway emergency number 112 [3], and the next, presented in this paper proposition concern the use of public standards of radio communications in raising the level of safety in rail traffic. This state of research was presented in picture 3.



3. Proposals for the use of wireless standards in management and railway traffic control

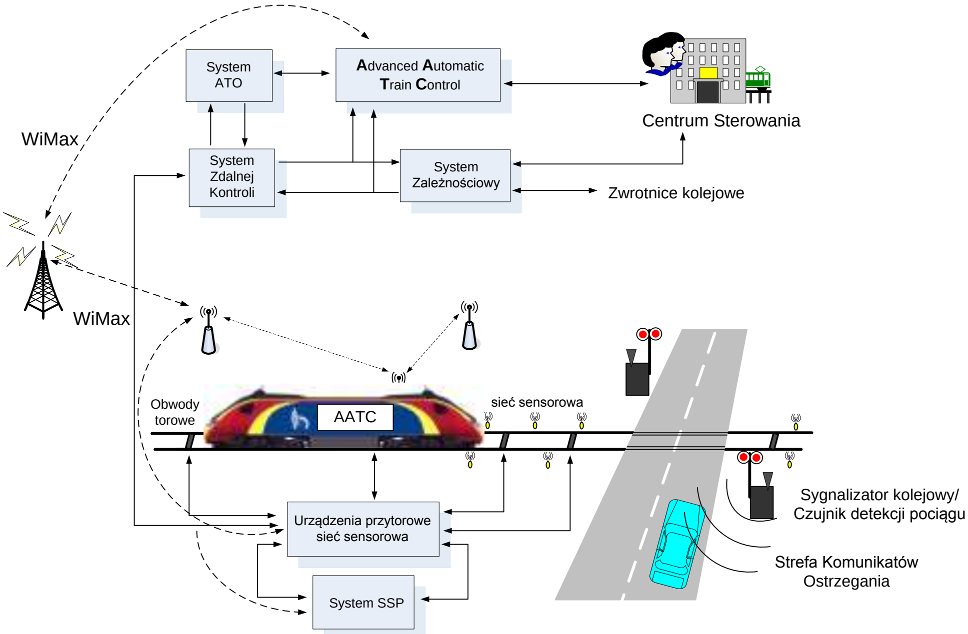
The extension of the e-call for railways

A natural extension of the e-call application developed for road transport was analogous proposition for rail transport [3] shown in Pic.4. In case of a detected failure of the train or crash the system should pass to the dispatcher (traffic controller) by the system GSM / GSM-R information about the location on the trail (GPS location to an accuracy of 10 m), the type of incident (failure / disaster), number of passengers, etc., this information can be generated automatically (without the use of the train staff) on the basis of the sensors installed in the vehicle.

4. E-call system for a railway transport

The warning system at level crossings without barriers

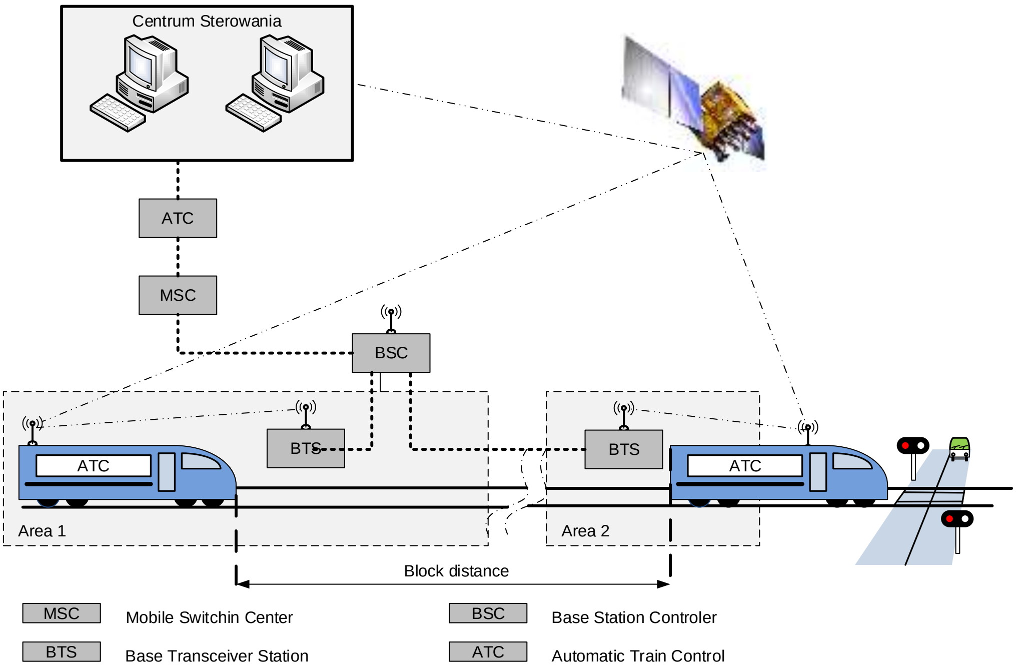
Another suggestion was alert system at level crossings [4] (shown in picture 5), where information about the train within the intersection was transferred through the WiFi network to the vehicle near the crossing without barrier (area about 1-3 km).



5. The concept of the warning drivers system on the unguarded level crossings without barriers

Variable space of blocks

Pic. 6 shows the concept of a system using the method of variable space of blocks in the management and control of the movement of trains. The idea of this solution is updated with the GPS positioning of the train and having emergency braking (according to the inhibition curve) matching speed to the real position of the train before actually moving and recommendations of the control center [5]. This system significantly improves functionality while maintaining the required level of safety (SIL4).



6. Variable space of blocks system

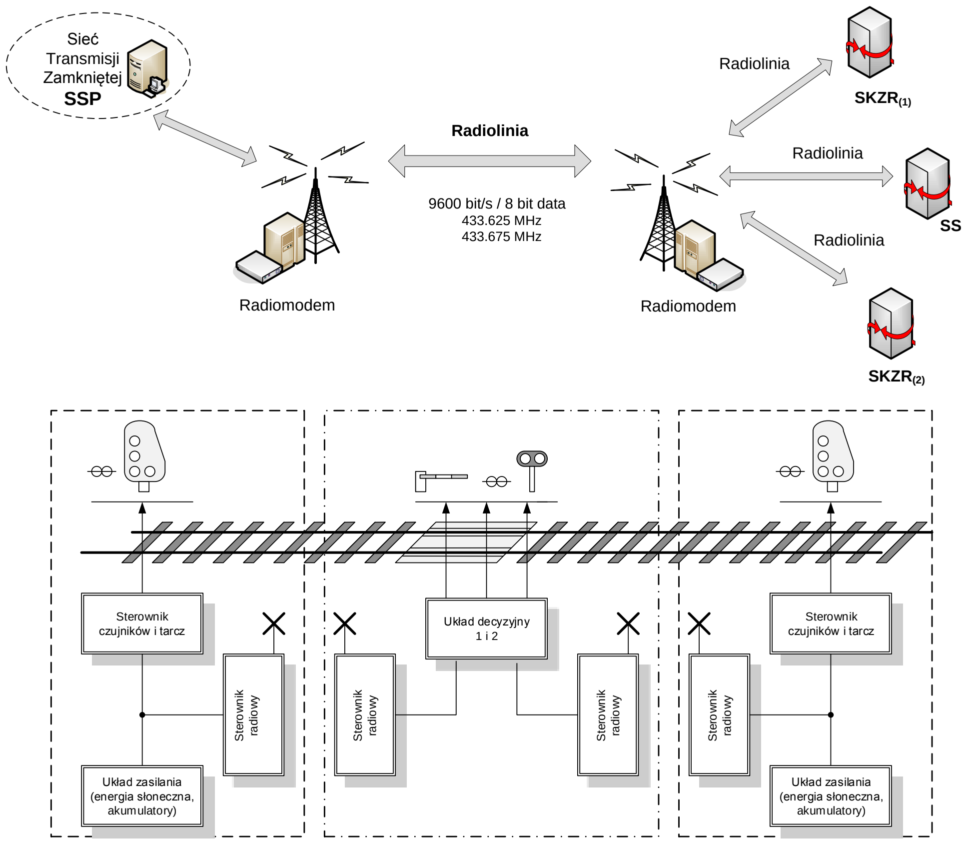
Implementation of Traffic Control System with radio transmission

In recent years, surveys were conducted on the use of public transmission standards for railway traffic control. An important example of this type of application is a ESTER system developed in the KOMBUD company [3], [7] and installed on the Radom - Tomaszów Mazowiecki. In this proposal, the concept of a secure transmission system was used radio channel (open broadcasting system) to provide information on the impact of subsystem devices. The analysis was conducted with respect to the security system of the railway crossing.

The overall concept of the radio transmission between the subsystems

The adopted model the radio channel is used to transmit information between controllers cooperating with wheel sensors and system ssp drivers placed in the container. This configuration eliminates the need for cable connections between distant points from a passing impact (sensors). In this case accepted method of comparing standard parameters characterizing the ssp system based on a system of exchange of telegrams by network in a closed system (cable network) - these systems are generally operated on a network of PKP PLK SA - And to set the parameters for the transmission network in an open system (so it is possible to determine if it has been breached lowered SIL level). In the present case the open transmission channel has been based on a separate radio link, which provides, among others,access authorization control. Pic. 7.a shows similar radio links to communicate with controllers station (SS) and control system unoccupied tracks.

In the system ESTER adopted telegrams in accordance with the type of transmission B0 (not preclude the use of unauthorized access, encryption is required, it is not required cryptographic security code) using cryptographic techniques with the secret key and the encryption of datas in total including code of data integrity. As the encryption algorithm adopted standard AES with 128-bit key, to the so encrypted datas is attached additional code data integrity CRC, which protect against accidental errors allowing detection of single or series of errors. In the system ESTER adopted telegrams in accordance with the type of transmission B0 (not preclude the use of unauthorized access, encryption is required, it is not required cryptographic security code) using cryptographic techniques with the secret key and the encryption of datas in total including code of data integrity. As the encryption algorithm adopted standard AES with 128-bit key, to the so encrypted datas is attached additional code data integrity CRC, which protect against accidental errors allowing detection of single or series of errors.



7. The radio transmission between subsystems in the System ESTER (a), the radio transmission between the systems in the dependence subsystem for the station (b)

Radio transmission between subsystem layouts

In the system ESTER also uses radio transmission between distributed components - drivers maneuvering shields, as shown in Pic. 7.B. Radio channel with the use of industrial radio modem replaced in this case a standard cable connection based on the PROFIBUS standard (IEEE 485).

Proposals for the use of public transmission standards in order to improve the safety of the railway system - a system to prevent collisions

An additional element of increasing the security of train driving can be a system based on industrial networks, WiFi or WiMax, pic. 8. In the case of regional lines where the train speed is below 120 km / h, such solutions may be helpful. Assuming that the minimum block distance between the vehicles is 1600 m, the use of networks within 10km may be sufficient.

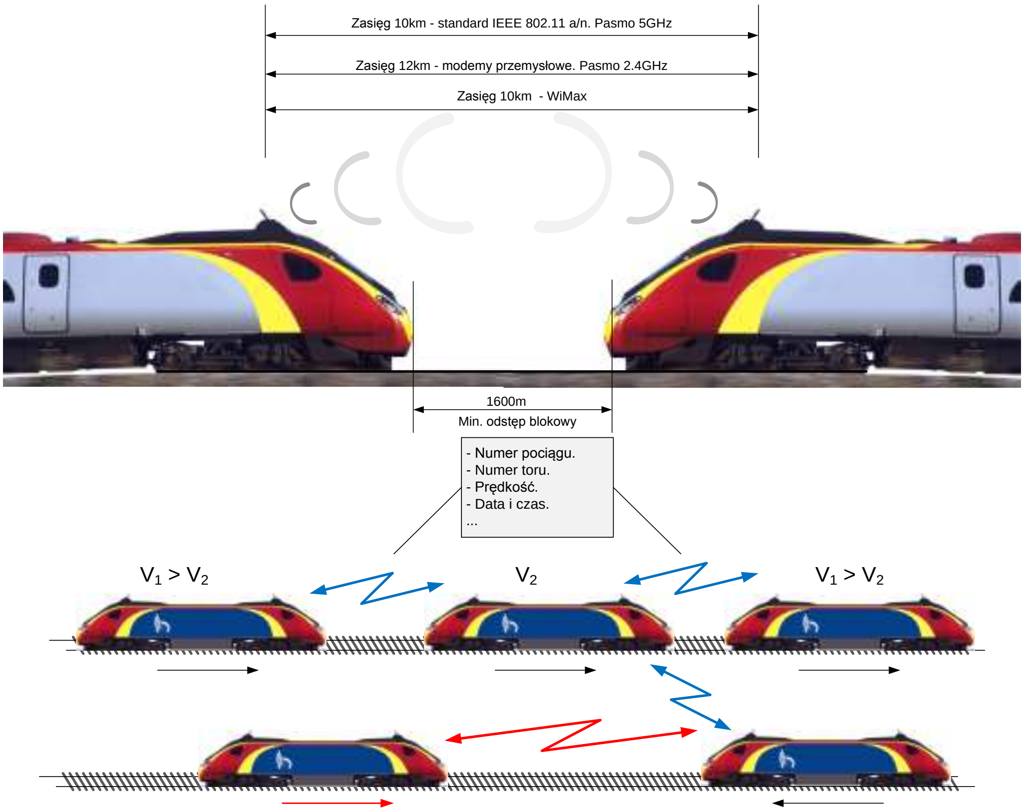
The overall concept of the system

An additional panel installed in the driver's cab can tell an approaching train, or approaching to it. Other information, as shown in pic. 9, allow the identification of a vehicle and indicating the path which it is running.

The proposed solution does not interfere with the existing railway infrastructure, and not part of the management and control of rail traffic. It can only be an additional system for better assessment of the situation by the driver on the trail. Current solutions allow for the preview only duty of traffic on a given stretch.

Analysis of availability and security

In order to analyze the proposed Markov processes. Due to the special characteristics of systems for control and traffic management station and associated with the restrictive regulations, Markov processes comply with these standards, as one of the tools of safety analysis. Pic.10 shows a model position when not exist any additional system improving safety.



8. Information about trains in the environment (a) the concept (b) information structure

An undesirable state of the system is a state of unavailability due to failure (disaster). Solving a suitable system of differential equations for system's model availability expressed by the formula: $A = 1 - \lim_{t \to \infty} P_{nieb.}(t) = \frac{\mu_3}{\lambda_1 + \mu_3}$ (1)

Where:

λ_1 – the intensity of critical applications,

μ_3 – time to return to full fitness, the movement restoration.

With the introduction of additional information system, availability defined like this is:

$$A = 1 - \lim_{t \to \infty} P_{nieb.}(t) = 1 - \frac{\lambda_1 \mu_2}{(\mu_1 + \mu_2) \cdot \mu_3 + \lambda_1 \cdot (\mu_2 + \mu_3)} \quad (2)$$

Where:

λ - intensity applications - sent reports on the line,

λ - the intensity of critical applications,

p - the probability of a critical situation,

μ - service time,
μ_1 - service time of an emergency,
μ_2 - intensity go to the state of emergency,
μ_3 - time to return to full fitness, the movement restoration.

In order to make the analyze made appropriate calculations based on typical parameters and estimates typical for railway lines, including those modernized.

Comparison of the safety system of the traditional system with additional system

Table 2 presents the typical parameters of the proposed warning system in relation to the average traffic of the train on the route. Assumed value of the probability of a correct response service train PFC at 0.999 (typical value taken for analysis in the EU).

Table 2. Assumptions for collision warning system.

L.p.	Parameter	Value
1.	λ	12/h
2.	λ_1	$\lambda 1 = \lambda * p$
3.	p	0.001%, 0.01%, 0.1%, 1%, 10%, 50%
4.	μ_1	30/h
5.	μ_2	$\mu_2 = \mu_1 \cdot (1 - p_{FC})$
6.	μ_3	4h

Table 3 shows a comparison of results from the analysis of both systems, the additional warning in function of the basic parameter - the probability of a dangerous situation (higher values correspond to the limitations caused by eg. excluding the trail due to modernization.

Table 3. Comparison of the results.

L.p.	The probability of a dangerous situation	The value of the availability of A Model without additional system	The value of the availability of A Model with additional system
1.	0.001%	0.999520230289461	0.9999999840005975
2.	0.01%	0.995223	0.9999998400117581
3.	0.1%,	0.954198	0.999998
4.	1%	0.675676	0.999984
5.	10%	0.172414	0.999846

The results confirm the assumption that the use of the proposed solutions can help to improve the safety of trains. Implementation of a dedicated GSM-R and additional solutions based on WiFi networks, radio networks or GSM, additionally can contribute to increase the level of safety. The proposed model based on Markov processes allowed to estimate the value of the availability of and compare the estimated results of the proposed models. An important issue in the case of the use of open wireless networks is a security problem, but using the appropriate security mechanisms of transmission in open networks and using conventional transmission elements (eg. Modems), it is possible to achieve transmission security level SIL-4.

Conclusions

The authors have proposed a number of solutions to improve safety on the rai, with the use of public wireless transmission standards. The concepts are a natural extension of the solutions used in other modes of transport. Conducted analysis and simulation studies clearly show that in any case apply additional transmission link using an open (public) broadcasting standards reduce by at least two orders of magnitude probability of emergencies. But, as in the management and control of rail traffic based on the principle of moving block, it is possible to significantly improve the functionality (increasing the capacity of the line) while maintaining the required level of safety in accordance with the requirements of the applicable standards PN-EN 5012x.

Wireless transmission standards are developing dynamically applies not only to speed the transfer of data (for example, which has an impact. LTE), but also significantly reduce the time latency and coverage especially on such non-urbanized areas crossed by railway lines.

Source materials

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