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THE CONCEPT OF DATA TRANSMISSION IN OPEN NETWORKS FOR DIAGNOSTIC OF RAILWAY TRAFFIC CONTROL DEVICES

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Summary: Creation of separate system for railway transport purposes entails huge investment in development, certification and implementation of this technology. Therefore, in authors opinion, it is possible to use public open radio networks to communicate among railway transport users. Such approach can significantly reduce the cost without decreasing the safety. It is necessary to develop the transmission allowing for safe exchange of information (in accordance with railway standards) via already existing public infrastructure. Thus, this paper will presents the concept of data transmission in open networks for diagnostic of railway traffic control devices using LTE technology.

Keywords: safety, transport, LTE

1. DATA TRANSMISSION IN OPEN NETWORKS IN ASPECT OF PN EN 50159:2010

Technology boom in railway traffic control system has been observed for last few years in Poland. It was mainly trigged by EU funds donated to Poland which in turn was used to modernize railway infrastructure. Besides new railway stations and rolling stock, safe and reliable railway traffic control systems basing on modern communication and computer technologies also constitute significant contribution to modernization of railway infrastructure. Still in the 20th century, the railway authorities found these technologies as unsafe and were reluctant to introduce them. At present, railway traffic control systems being used in railway transport are fully computerized. These systems are either a “shell” on existing relay based control systems or autonomous microprocessors systems. All contemporary modern interlocks are based on computer technology. This technology was introduced to railway traffic control devices at the turn of the 20th century. However, the moment of introduction of modern radio based communication systems to railway transport coincides with the appearance of GSM technology. GSM technologies, due to unique requirements occurring in railway traffic control systems were adapted for railway transport purposes as a separate GSM-R standard. Unlike GSM, GSM-R is fitted with
a broader band and allows for data transmission in two 5MHz channels. FM systems using in Poland on railway tracks, due to their specific modulation are not able to transmit data. However, some aspects of “data transmission” have been used in radio-stop system. GSM-R allows not only for transmission between the vehicle and the track but also between the track and track. Thus, it can be used in wireless control of railway infrastructure. Degradation in wire infrastructure connecting elements of railway traffic control systems forced railway authorities to seek a new medium - radio to control railway traffic control devices. The main problem with the implementation of this technology is the safety of data transmission. It should be noted that the radio based communication systems ensure the safe transmission, what is used in GSM-R standard. Creation of separate systems for railway transport purposes entails huge investment in design, development, certification and implementation of this technology. Thus, in authors opinion, it is possible to use public open radio networks to communicate in railway transport. Thanks to the use of already existing infrastructure, such approach significantly reduces the total cost. Development of data transmission satisfying PN EN 50159:2010 railway standard can significantly improve the diagnostic of railway trackside equipment. Due to limited access to data transmitted, they have to satisfy tough safety standards. The issue regarding the safety in railway traffic control systems is regulated by PN EN 50159:2010 standard [3]. Adaptation of open wireless communication for railway transport purposes should satisfy Safety Integrity Level (SIL) standard [1, 2, 3].

The next part of this paper will show threats caused by potential intruders and methods used to prevent them. Of course, presented methods have to satisfy Safety Integrity Level (SIL) standard. The paper also gives criterions using in developing the open systems for railway traffic control systems. These criterions will be used in section three of this paper to analyze proposed communication system. Next, the solution allowing for data transmission from railway trackside devices to expert system server using LTE technology and encryption methods presented in PN EN 50159:2010 standard has also been shown.

1.1. SAFETY THREAT IN DATA TRANSMISSION IN RAILWAY OPEN RADIO COMMUNICATION SYSTEMS

In order to ensure safe data transmission in open networks, it is necessary to take following measurements [4]:

– communication system should be treated with limited trust irrespective of its inner protection;
– functions allowing for the safe transmission should be applied;
– functions allowing for the safe access should be used.

The main threat for the system resulting from limited trust is a failure in providing important datagram. This situation can result from:

– repetition of datagram;
– deletion of datagram;
– datagram insertion;
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- datagram resequencing;
- corruption of datagram;
- datagram delay;
- masquerade.

These threats are consequences of an unknown number of users accessing the network as well as an unknown number and type of devices connected to the network. They can be caused by two main factors: appearance of an unknown number and type of datagrams and susceptibility to hacker attacks.

Fig.1 presents the structure of the system connected to the open network. From a safety point of view, radio communication can be regarded as unconfident medium. In order to limit potential threats caused by the open system, the designer of open network should take into consideration:

- authenticity of datagram;
- integrity of datagram;
- delivery time of datagram;
- datagram sequencing.

Fig. 1. The structure of the system connected to the open network [3]

PN EN 50159:2010 standard includes methods ensuring the safety in open networks. They are presented in the form of safety functions [3]:

- sequence number;
- timestamp;
- time-out;
- source and destination identifier;
- feedback message;
- identification;
- safety code;
- cryptographic.
2. CHARACTERISTIC OF LTE SYSTEM

The development of LTE technology is strictly related to the progress in data transmission in cellular systems. Fig. 2 presents the development of data transmission technology published by European Telecommunications Standards Institute (ETSI).

![Fig. 2. The development of data transmission technology published by European Telecommunications Standards Institute (ETSI)](image)

It clearly results from it, that the future of data transmission technology (starting from Rel.8 document) is strictly related to LTE technology. This document specifies some of selected parameters for data transmission:

- maximal speed of the data transmission DL 100 Mbps and UL 50 Mbps at maximal bandwidth 20 MHz;
- MIMO solution: DL 4x2, 2x2, 1x2, 1x1
  UL 1x2, 1x1;
- At least 20 user in every cell;
- Delay of small packets 10 ms (in practice 10 – 50 ms);
- Cell radius up to 5 [km], without power correction on the basis of BLER (Block Error Rate). If BLER is higher than assumed value (10%) then base station (eNodeB) increases SIR (Signal to Interference) for mobile terminal UE up to the power of noise for selected cell;
- Operation in FDD (Frequency Division Duplex) and TDD (Time Division Duplex) modes;
- Preservation of data transmission parameters for mobile users moving with the speed up to 120km/h.

Fig. 3 presents simplified architecture of LTE system. Simplified architecture in fig. 3 exemplifies the main idea of this system. This idea can be described in following words: maximum of throughput, minimum of data and minimum of delay.
2.1. DATA TRANSMISSION IN UP-LINK AND DOWN-LINK

The LTE system is a descendant of UMTS system. The data transmission is performed in FDD standard thus duplex transmission is used in LTE [6, 7]. Fig.4 presents this idea.

High speed of data transmission in LTE requires both a broad band as well as sophisticated modulation techniques. An increase in the throughput of transmission causes occurrence of multipath phenomena which can be limited using OFDM (Orthogonal Frequency Division Multiplexing) technique. OFDM ensures proper PAPR (Peak-to-Average Power Ratio) [5]. In OFDM, instead of one fast data transmission, data are divided into smaller parts which in turn are transmitted separately with lower speed. This approach reduces transmission distortion. OFDM is mainly based on FDM (Frequency Division Multiplexing) in which data are transmitted on separate subcarriers using PSK.
(Pulse Shift Keying) and QAM (Quadrature Amplitude Modulation) modulations. Distances among subcarriers allow for elimination of interference between data transmitted by these subcarriers. This technique is mainly applied in down-link [6, 7]. Up-link transmission uses SC-FDMA technique. The main advantage of SC-FDMA compared with OFDM is a better PAPR ratio. The use of one subcarrier in the data transmission enables to improve PAPR ratio. Fig. 5 presents graphical comparison of these methods.

![Graphical presentation of OFDMA and SC-FDMA methods](image)

It should be noted that DFT (Discrete Fourier Transform) blocks have been added to both transmitter and receiver in SC-FDMA. Similar to OFDMA, SC-FDMA uses different subcarriers to transmit data. However, unlike OFDMA, data are transmitted sequentially instead of simultaneously. It is illustrated in Fig. 5.

### 3. CHARACTERISTIC OF MODEL – TRANSMISSION BETWEEN STATIONARY RAILWAY TRAFFIC CONTROL DEVICES – CONDITIONS

In order to model the transmission between railway traffic control devices and database server in open radio network, the following assumptions have been made:

- Every traffic control device is defined by its unique functionality and characteristic;
- Every device ensures an appropriate Safety Integrity Level (SIL);
- The change in transmission medium from the wire to the radio should have no influence on behavior of the device;
- Radio transmission is performed in LOS and NLOS conditions;
- The load of the network is natural, we have only the influence on network traffic generated by us – actual conditions.

At the first stage of research, the transmission between railway traffic control devices and database server used to collect maintenance data and perform inference has been analyzed.

This analysis allowed for determination of delays which result from the use of non-real time systems. Due to the use of non-real time system (Windows), it was necessary to determine an average delay. This parameter was calculated on the basis of datagram transmission within the area of the computer. The program written by authors used to
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Transmit datagram (according to PN EN 50159:2010 standard) allowed calculating an average delay. It composes of two modules. The fig.6 and 7 present the server and client modules, respectively.

**Fig. 6.** Server module (1 – IP address for TCP/IP protocol, 2 – encryption mode, 3 – the type of encryption algorithm, 4 – the length of key in bits, 5 – datagram to be sent, 6 – time stamp, 7 – the number of the subsequent message, 8 – contents of the message, 9 – the port for the transmission port, 10 – encryption mode, 11 – cycle of sending message)

**Fig. 7.** Client module (1 - the port for TCP/IP transmission, 2 - the choice of encryption algorithm, 3 - password for data encryption, 4 - the length of key in bits, 5 - data logging (data are logged to the text file), 6 - content of logfile, 7 - encryption mode, 8 - declaration of acknowledgement)
Fig. 8 presents block diagram for the algorithm used to transmit datagrams.

![Block Diagram](image)

**Fig. 8.** The block diagram for algorithm used to transmit datagrams

Server module sends datagram whose structure composes of following elements:

- datagram number;
- time stamp;
- contents of datagram;
- CRC.

Encryption is realized in AES (Advanced Encryption Standard) for which the length of encryption key is equal to 128, 192 or 256 bits. The key is automatically generated on the basis of the password.

Client module performs following tasks (fig.9): receiving datagram, decrypting data, checking integrity and sending acknowledgement (to the server module).

![Test of Delay](image)

**Fig. 9.** The test of delay of transmission for damage message for the length of datagram equal to 64 bits
Next, all experiments were performed on the basis of the schematic presented in Fig. 10. This configuration can cause the following safety threats:

- repetition of datagram;
- deletion of datagram;
- datagram insertion;
- datagram resequencing;
- corruption of datagram;
- datagram delay.

![Fig. 10. Schematic for point to point LTE transmission](image)

The datagram presented fulfills safety requirements both for open and closed systems specified in PN EN 50159:2010 standard. The proper choice of hardware and software has an immense impact on the safety of the system [2,3]. In order to ensure the proper SIL (Safety Integrity Level) the transmission between the transmitter and the receiver should allow:

- detecting transmission errors;
- repeating transmission when timeout occurs.

![Fig. 11. OnCell G3470A-LTE modem manufactured by Moxa](image)

The OnCell G3470A-LTE modem manufactured by Moxa and designed for railway market (fig.11) has been used in the experiment. It ensures two-path transmission both in up-link and down-link.
4. CONCLUSIONS

Basing on the literature and propagation conditions for GSM-R and LTE standards, it is possible to say that LTE technology can be applied to transmit datagrams among railway traffic control devices. The use of the proper SIL level along with encryption methods presented in PN EN 50159:2010 standard allows for right transmission within a given time. The results obtained show that LTE technology can be utilized in railway transport, what in turn can make wireless railway traffic control systems cheaper. Thus, the data transmission among modern railway traffic control devices using LTE technology is one of the main tasks of the research project commissioned by NCBiR PBS3/A6/29/2015 and realized at University of Technology and Humanities in Radom.

References

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KONCEPCJA TRANSMISJI DANYCH W SIECIACH OTWARTYCH DLA POTRZEB DIAGNOSTYKI URZĄDZEŃ STEROWANIA RUCHEM KOLEJOWYM

Streszczenie: Stworzenie odrębnego wydzielonego systemu na potrzeby kolei wiąże się z ogromnymi nakładami na projektowanie, badanie, certyfikację a na końcu wybudowanie i wdrożenie takiej technologii. Dlatego też, możliwe jest w mniemaniu autorów wykorzystanie publicznych otwartych sieci radiowych na potrzeby kolei, co w znaczy sposób może wpłynąć na ograniczenie kosztów bez zmniejszenia bezpieczeństwa. Należy więc opracować taki sposób przesyłania informacji spełniający wymagania transmisji bezpiecznej w rozumieniu kolejowych systemów sterowania ruchem a wykorzystujący infrastrukturę zewnętrzną. Dlatego też w dalszej części artykułu zostanie przedstawiona koncepcja transmisji danych w sieciach otwartych dla potrzeb diagnostyki urządzeń sterowania ruchem kolejowym z wykorzystaniem technologii LTE.

Słowa kluczowe: bezpieczeństwo, transport, LTE