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ORIGINAL SCIENTIFIC PAPER

Design and Development of Comprehensive Railway Information and Communication Systems

Damir M. Zaborski
PhD Candidate at the Pan-European University "Apeiron", Banja Luka, damir.zaborski@gmail.com
Zoran Ž. Avramović
University of Belgrade, Serbia, zoran.avramovic@sf.bg.ac.rs

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Abstract: Successful operation of the railways as a large technological system is directly related to the reliable and timely transmission of data and information. Therefore, the role of the information and communication system (ICS) has irreplaceable importance for operation and functioning of the railways. Considering that the railway modernization represents an uninterrupted process, it is necessary to ensure constant technical and technological development and application of the latest achievements in the field of information and communication systems. The railway ICS, among other things, provides infrastructure for the automatic control systems, traffic management and control, monitoring and navigation systems, data processing devices, and it also provides support to other subsystems designed for safe and consistent use of the line, as well as efficient management of the modern rail transportation system.

Key words: railways, transmission data and information, information and communication system, railway ICS.

INTRODUCTION

Based on traffic and technological requirements and characteristics of the official positions at the railways, this paper gives the proposal for the *ICS* architecture with all the necessary technical systems, depending on the technological and hierarchical level on the network at the Serbian Railways (SR). The levels of nodes in the *ICS* Railway, their physical and logical organization as well as the equipment and necessary services characteristic for individual nodes were identified and defined in the paper. Also, a universal model for organization of the information and communication system of the railways is proposed.

EXISTING STATE OF IKS ON THE RAILWAY

Media transmission in the telecommunications network of the SR

Communication networks at the SR use the following types of media and transmission systems:

- transmission by cable lines,
- transmission over optical cables,
- radio transmission,
- high frequency transmission and
- *SDH* transmission.

Telecommunication networks

In general, communication services within the national railway administrations of Europe, as well as at the SR network, are realized through networks that can be classified into two basic groups:

- telecommunication networks for general purposes and
- telecommunication networks for special purposes.

The point of general purposes network is to provide telecommunication services (voice and data transmission) for functioning and coordination of the railway services and administrative units at all levels. It includes telephone exchanges *PBX* (for telephony and telegraphy) as well as Intranet network for all services (*WEB, MAIL, FTP, DNS* and *AD*) and applications belonging to the information system of SR. In addition, *PIS, PA, CLOCK* system also belongs to the general purpose network. The networks for special purposes enable exchange of voice and data information for traffic operations, for railway safety and signaling systems and for remote control of contact line powering. It includes track phone system (for traffic and power management), radio dispatching system, *PMR* (Private Mobile Radio).

Unfortunately, at the Serbian Railways, even today, both networks are mostly made up of analog systems.

GLOBAL CONCEPT OF ICS RAILWAYS

The modern information and communication system of the railways represents the infrastructure for transmission of all types of data and information on the

railways: speech, numerical data, video materials, multimedia contents and control signals.

ICS should enable connection to the existing railway communication network (ŽAT - telephony and ŽATg - telegraphy network, Intranet, all external railway dedicated systems (power system, remote control system, centralized traffic control, *OA* system, signal system) and external communication Public Switched Telephone Network (*PSTN*) systems, Public Land Mobile Network (*PLMN*) and the Internet.

Railway *ICS* should be highly reliable and scalable,

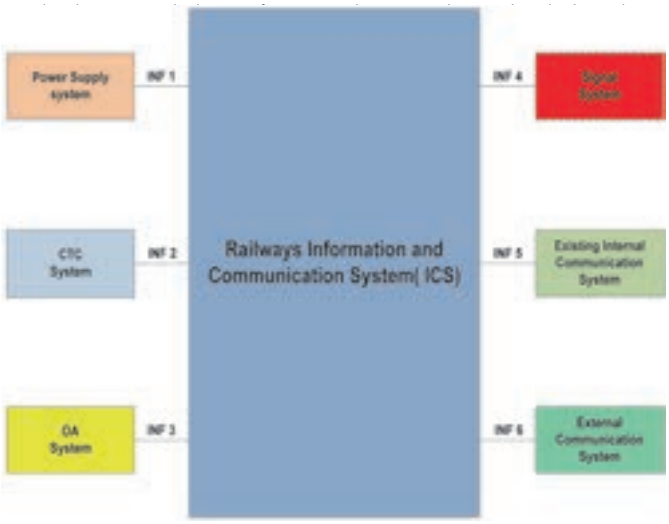

Figure 1. Global concept of the ICS system

The interfaces between *ICS* and internal and external railway systems are briefly described as follows (INFnis the identifier of the external interfaces of the information-communication system of the railway):

INF1 - interface with power supply system

The power supply system provides reliable *DC\AC* power supply for *ICS*. The Interface is set at *DC\AC* input of communication power supply equipment. *ICS* provides the communication channel for the power system controlled by dispatcher.

INF2 interface with *CTC* system

The CTC System provides external interface for database which enables *ICS* to access to the actual data related to railway transport, train departures and arrivals. The connection is performed with 10M/100M Ethernet port. The detailed format of database interface should be specified in phase of the system realization.*ICS* provides communication channel for *CTC* system to traffic control.

INF3 interface with *OA* system

IKS provides data communication channel for *OA* system, based on *IP* protocol. The connection is enabled using 10M/100M Ethernet port.

INF4 interface with signaling and security system

ICS ensures data communication channel for signaling and safety system which transfers data important for train transport management. The *PRI* protocol and *E1* link are used to connect *ICS* and signaling devices. IKS and signaling devices in the driver's cab are connected via the RS 422 serial cable. *GSM-R* interface is used for communication with the control center.

The signaling system shown into the interrupted line (Figure 1) refers to the European Train Control System Level 2, which will be built in the future.

INF5 interface with existing internal communication system

The modern *ICS* needs to be compatible with the existing internal communication system sat the Serbian Railways, as *CLOCK* system, *PBX* network and track phone system.

ICS uses twisted-pair cable to connect existing *CLOCK* system (outputs pulse 24V); the existing *PBX* network is connected via *E1* signal using *PRI* or *E&M* protocol. The track phone system is connected via *E1* link, using *PRI* or *SS7* protocol. This interface will also be specified after *ICS* subsystem is defined.

INF6 interface with external communication system

The new constructed *ICS* needs to connect to the external *PSTN, PLMN* and Internet network. The connection in *PSTN /PLMN* network should be performed via *E1*link, using *PRI* or *SS7* protocol, and the connection with the Internet should be enabled via fiber cable based on IP protocol. This interface will be also specified as soon as all *ICS* subsystems are defined.

ARCHITECTURE OF ICS RAILWAYS

Types of railway nodes depending on the technology of rail transport

From the perspective of logical functions, *ICS* consists of the transmission and *IP MPLS* networks, which represent the infrastructure for the transmission of the following services: *GSM-R, IP* telephony, video surveillance and video conferencing, *PIS, PA, CLOCK*, Intranet and track phone system.

Figure 2 shows different levels of services depending on the location and the hierarchal level in the railway network (from the center to the executive units for individual services). A detailed configuration of the equipment using hierarchical model will be given in the next chapter.

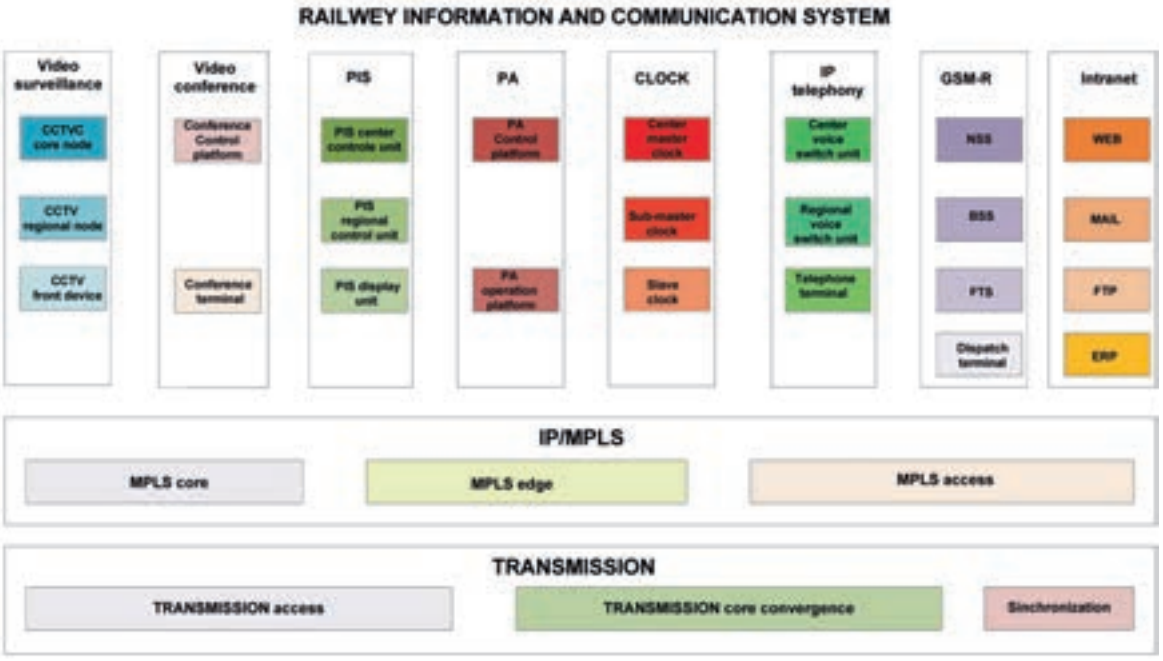

Figure 2. Railway *ICS* architecture

Function of the module in ICS subsystems

1）Transmission system

The transmission systems are composed of access layer, convergence layer and synchronization system

- Transmission access: provides various interfaces for connection of *GSM-R* and *IP/MPLS* network to implement the data transmission of communications services.
- Transmission core convergence: represents the uplink convergence of the access layer, the bearer of all services, high-speed, broad bandwidth in the backbone transmission network.
- Synchronization (Clock synchronization): provides synchronization to the whole network.

2）IP/MPLS network

MPLS network is created out of core, edge and access layer.

- *MPLS* Core–the core of the network, responsible for routing and *MPLS* fast forwarding.
- MPLS Edge – the edge of the network stores *VRF*, processes *VPN-IPv4* routing, responsible for *MPLS VPN* access.
- *MPLS* Access – access layer provides access to various services, publishes user network routing information.

3）GSM-R network

GSM-R network consists of *NSS, BSS, FTS* and dispatcher terminal.

- *NSS*: Implements the call relay, billing, mobility management, realizes railway additional services.
- *BSS:* Implements the *GSM-R* radio link management and the conversion between wireless and wired link.
- *FTS*: Fixed dispatcher terminal system, used for dispatcher's connection, using wireless and wired communication.
- Dispatcher's terminals: contain dispatcher station, cab radio, *OPH, GPH* and other terminals; they are used for dispatcher's communication with the official staff on railway.
- *GSM-R* represents the infrastructure for *ETCS.*

4）Video surveillance

The purpose of this system is to provide higher level of safety for passengers and station staff, to contribute to the protection of material goods of the railway, to alert on incidents and to provide material evidence about them in the form of video recording.

- *CCTV* core node: Provides distribution of video information, system management, user management, stores system alarm information and important video information. It represents the central part of the system in the form of a dispatcher center for video monitoring. At this level, it should have been used equipment for controlling the overall video surveillance.
- *CCTV* regional node: Provides access to video information, distribution, forwarding and system management in the regional node, directly stores video information which are collected in the regional node, also stores regional node alarm information and important video information.
- *CCTV* access node: Represents the collection point for video information access, distribution, and forwarding, interconnection with other sys-

tems, and also stores all belonging video and alarm information.
- *CCTV* front device: Collects and encodes the video image information.

• 5）Video conference (*VC*)
- Video Conference Systems provide an opportunity to arrange meetings of two or more remote participants and they can be applied in all areas as a simple and cost–effective form of communication.
- Conference call platform edits and distributes audio and video signal to each terminal, provides background management for the whole video conference system.
- Conference terminal collects and encodes audio, video and data information.

6）IP telephony

IP telephony solution implies the installation and configuration of a *VoIP PBX* central computer unit with additional devices that would take the role of a telephone exchange for the complete client communication system. This advanced *PBX* exchange should enable activation of a large number of services that standard telephone exchanges do not offer and it also represents the ideal combination of standard telephony and Internet services.
- Center switch unit works as the central server, provides voice services for all users who exchange voice services.
- Regional voice switch unit works as the second layer node; it provides voice services for regional users when the connection with the central server is interrupted.
- IP telephone provides the voice call function for end users.

7）PIS (*Passenger Information Systems*)

The *PIS* provides basic information for passengers on the whole line. It is a complex, centralized system for generating, distribution and displaying information on the train traffic.
- *PIS* central control unit collects external information (timetable) and processes them, then sends them to regional control units, appropriate displays, and *PA* devices.
- PIS regional control unit receives information from a higher-level node and send them to the corresponding *PIS* displays and *PA* devices.
- *PIS* display shows the timetable and information on the precise time.

8）PA (*Public Announcement*)

Audio informing subsystem provides service of audio notification, transmits audio information (train information) for passengers and / or employees.
- *PA* control platform: Connected to train arrivals database, updates database and provides *PA* commands
- *PA* operation unit: Executes *PA* commands received from *PA* control platform.

9）Clock systems

Clock systems with synchronization of the precise time is a complex system for generating, distributing and displaying signals with a time message, which provides a unique service for precise time and synchronization - clock for all *ICS* systems, for stations and all official sites along the rail lines.
- Center master clock synchronizes via *GPS* and information on precise time sends to sub-master clock and salve clock.
- Sub-master clock synchronizes with center master clock and sends time information to station slave clock.
- Slave clock gets the precise time information from the master clock, and shows them to passengers or employees.

10) Intranet

At the Serbian Railways information system essential is the position of the central location with all services and applications, based on the modern data center, with all kinds of redundancies that enable their continuous operation. The data center enables the operation of ERP (Enterprise Resource Planning), timetable, cargo and passenger traffic, IS tracking and train traffic management, as well as services *WEB, MAIL* and *FTP.* A complete redundancy of the central location is realized in the form of a disaster recovery solution.

Authorized users are enabled to work with the entire Intranet at SR.

Providing E2E QoS in ICS

Generally speaking, there are different services that should be classified. The key services are guaranteed on high priority and security level. Designing the system, the complete network is planned to provide end-to-end multi-services based on *E2E QoS* assurance method.

For this project, the services are listed according to the priorities, as follows: *GSM-R*>Video Surveillance>*IP* telephony>*PA*>*PIS*>*Clock*>video conference. Different types of services use different priorities and planning strategies and at the same time indicate high priority for access to available network recourses.

ORGANIZATION AND HIERARCHY OF NODES IN ICS RAILWAYS

The official sites on railways lines, which are defined as a node in the information and communication system, are the typical geographical locations where are generated the set-point signal, traffic, control, and other

functions, that can be processed with services and applications.

At the SR network there have been identified various functional information and communication requirements generated in the main railway stations, regional stations, stops, end stations, marshalling stations, dispatcher centers and trackside.

Below are defined the functions and configuration of individual nodes.

The core nodes of ICS (level I and Ig)

A central node is located at the main railway station Belgrade Center where the cable infrastructure ends (optical and copper cables) from all main lines on the ŽS network. This is the location for the Belgrade Railway Node Management Center (without *CTC*), which represents the access point for the databases in the information system of SR.

Services provided by the main node

The main node provides the core convergence and access layer, and it also includes the central clock location for *ICS* synchronization.

This node is the location for the center of *GSM-R* network with *BSC*, which are the access point for all base stations in the section (BG–Nis, BG–Subotica, BG–Šid) and a backup access point for all base stations for railways in BG node.

The main node in the Belgrade Center provides monitoring at the first level for video surveillance, first level control services for the *PIS / PA* system and the main clock system for stations.

This is also the transit node of the *IP* telephone system.

All the mentioned services are provided by *IP* telephones, telepresence meeting rooms, cameras and external units for *PIS / PA*/ Clock systems.

Performance and capacity of services

The calculated number of users in *GSM-R* network in this phase of the construction is 1.500.

The number of local users in the transit node of the *IP* telephone system is 3.330, considering the reserve capacity of 4.558 users, with the possibility for extension up to 10.000 users.

Basic interfaces in the node level I

- The interfaces toward database for the archiving of the timetable, the train number and details about train delays;
- The interface between *FTS* in *GSM-R* and the existing *RDS* system is *PRI*;
- Interface between neighboring *GSM-R* networks based on *SS7*.

Regional Node (Level I)

Services provided by the regional node

- This node provides the basic convergence and access layer and represents the location of the backup clock for synchronization in *ICS*.
- It also provides access to *GSM-R* base stations and monitoring point at the second level for video surveillance.
- It represents the second-level control center for the *PIS / PA* system and master clock system.
- This node also contains *IP* telephone system transit node.

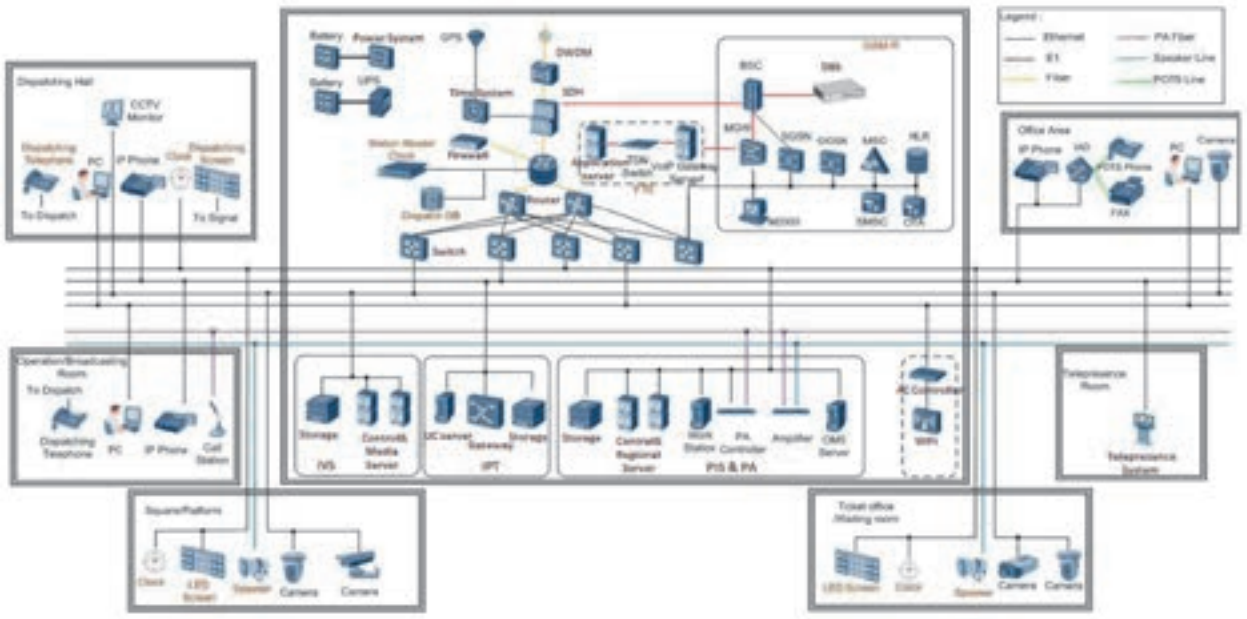

Figure 3. Configuration of the equipment stored in the main node

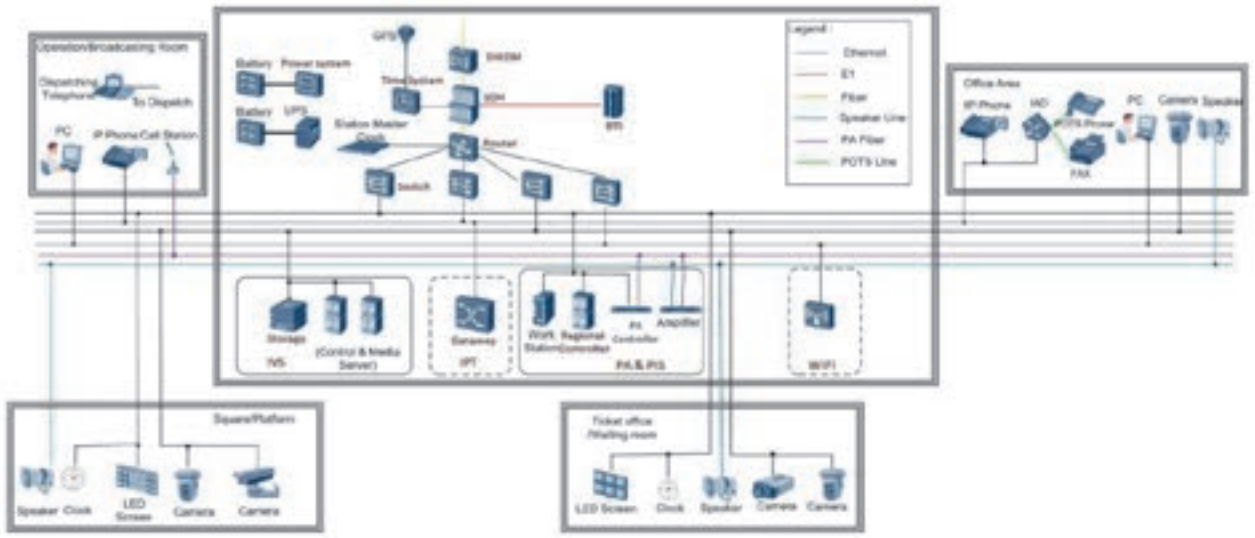

Figure 4. Equipment located in a regional node

- In this node are located: telephones, telepresence systems, cameras, dispatcher phones and executive units of the *STS* (*PIS* displays, speakers, clocks).

Node in the end stations (level II)

Services offered by the node in the end station

It provides an access layer for the data network and open access to *GSM-R* base stations.

It offers the third level of monitoring for video surveillance and access to *VoIP* and *STS* execution units.

The mentioned services at the stated location are enabled by cameras, *PIS* displays, clocks, speakers and *IP* phones.

Nodes in Stand Station (Level III)

Services offered by the stand station node

The node provides an access layer for the data network and open access to *GSM-R* base stations.

It represents the fourth point of monitoring for video surveillance and access to *STS* executive units.

Performance and capacity of services

The node contains the interface between *IP* phone and *PSTN / PLMN*: *PRI* (*PSTN*: 60, *PLMN*: 30) and the interface from the neighboring *GSM-R* networks: *SS7*.

The mentioned services at the stated location are enabled by cameras, *PIS* displays, clocks, speakers, *IP* phones and dispatcher phones.

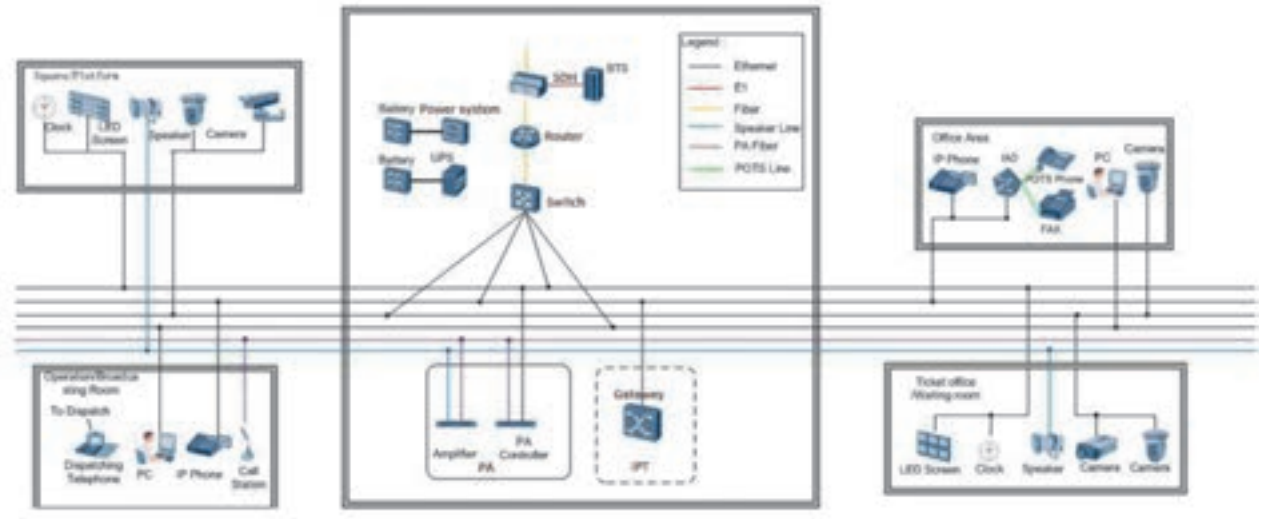

Figure 5. Equipment placed in the node at the end station

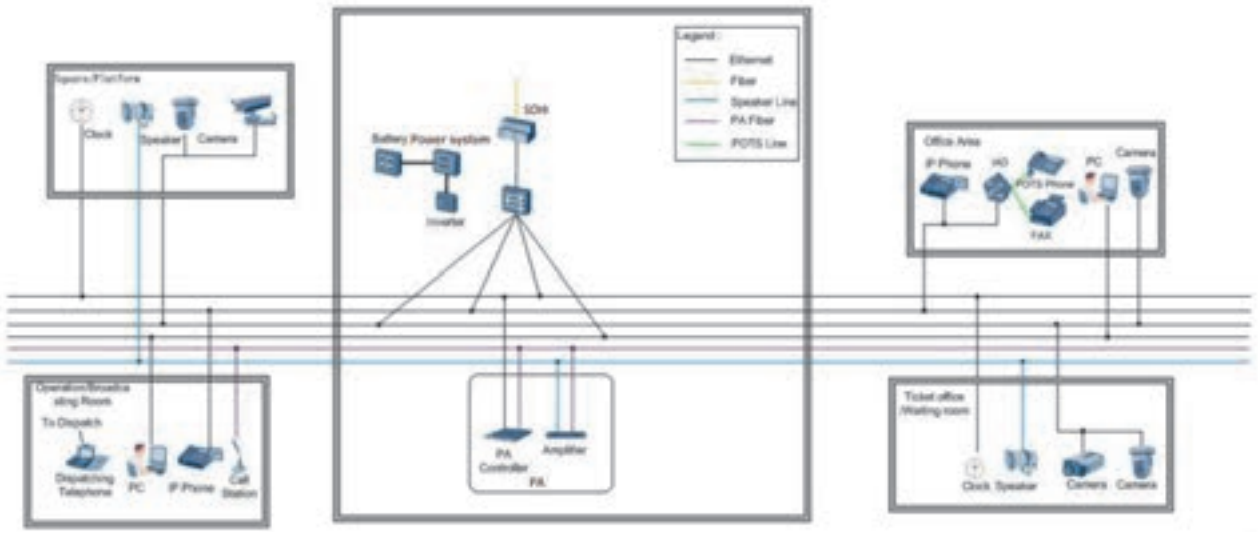

Figure 6. Equipment placed in the stand station

Node in the Shunting station (level II)

This is a freight station and the center for shunting and shipping of trains for directions: Belgrade – Sid, Belgrade – Subotica, Belgrade –cargo transport lines and Belgrade–Lapovo (two sections over Mladenovac and Mala Krsna).

Services offered by the node at the shunting station

This node provides an access layer for the data network and open access to *GSM-R* base stations.

It also provides the third level of monitoring for video surveillance and access to the *PA* / clock system.

Providing services at the stated location is allowed by using cameras, clocks, speakers, *IP* phones and dispatcher phones arranged at the corresponding locations.

Trackside (III level)

Services that offer a node at the trackside

The equipment located at the trackside provides an access level in the data network (optical / electrical conversion).

GSM-R wireless network for *GSM-R* terminals (Cab radio and *GPH* / *OPH*) covers all railway lines.

Video surveillance is granted at the fourth level of supervision and the service of dispatcher telephony along the track sides (access to the *FTS*).

5.6.2 Performances and capacity of services:

On the electrified lines of the Railway Station there are 1100 railway phone lines placed through the official sites and connected with the stations and dispatcher centers.

The services on the distance between the stations are provided by cameras, *GPH* / *OPH* and dispatcher phones.

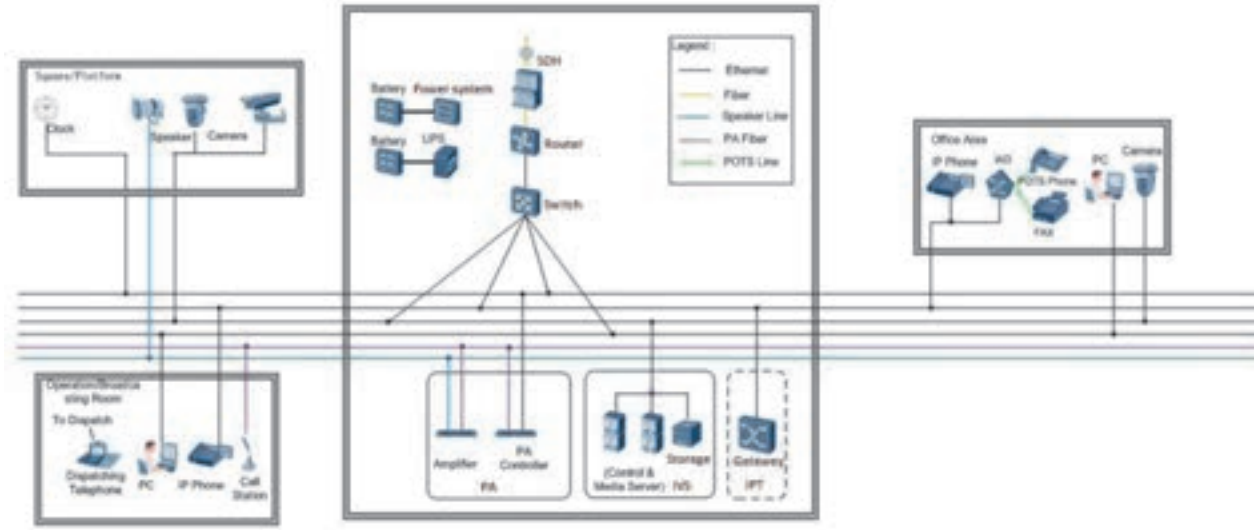

Figure 7. The equipment located in the shunting station

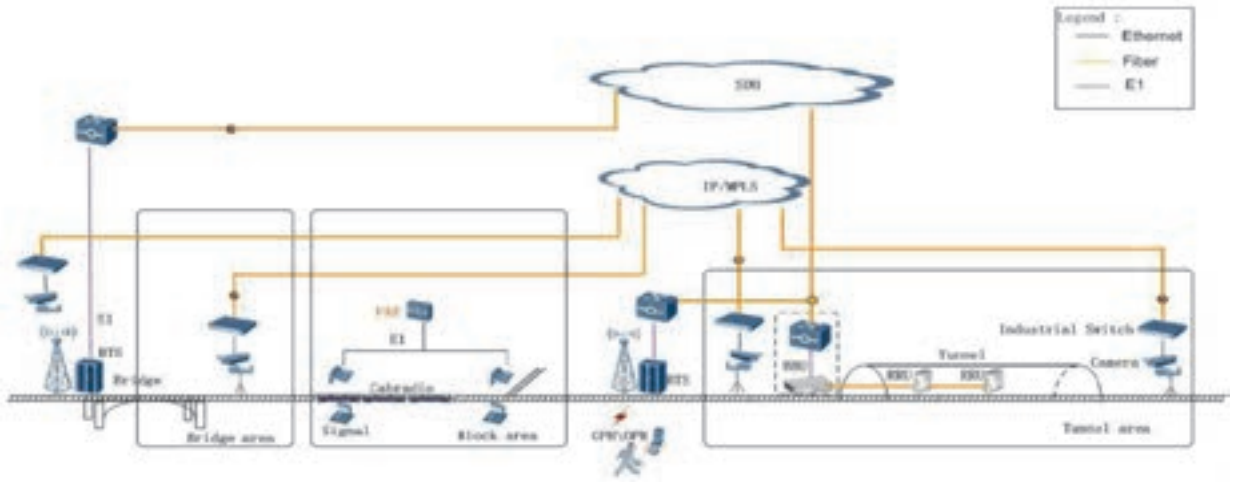

Figure 8. Equipment located at the trackside

ORGANIZATIONAL SCHEME OF THE RAILWAY ICS

The solution of the whole system

In accordance with the previous exposure and decomposition of the functional railways *ICS* subsystems, we will implement different functional subsystem modules at different physical locations (stations and trackside), and then we will generate a comprehensive physical architecture of the information communication system.

Figure 9 shows the organizational scheme with possible hierarchical levels at the railways *ICS*, depending on the traffic and technological level on the lines at the Serbian Railways. The displayed levels are: main stations (centers), geographic redundant center, regional stations, end stations, stops, trackside and shunting stations.

In Figure 10, nodes are sorted on the railway line Šid -Belgrade-Niš, including the Belgrade and Niš railway junction. There are also highlighted the central nodes of the I and Ig levels Belgrade Center and Belgrade Marshalling Yard, regional nodes and levels of Ruma, Belgrade Center, Lapovo and Niš, as well as all other nodes of II and III levels in end stations, stands, shunting stations and trackside.

Based on the proposed model, it is possible to sort all the official points on the railways network at the Serbian Railways and anticipate the necessary equipment that will enable the required services for regular and safe operation of the railway transport and placing the complete rail service to a higher level.

CONCLUSION

The paper defines the place of the information and communication system in the entire railway technology and transport system, as well as the need of connection with

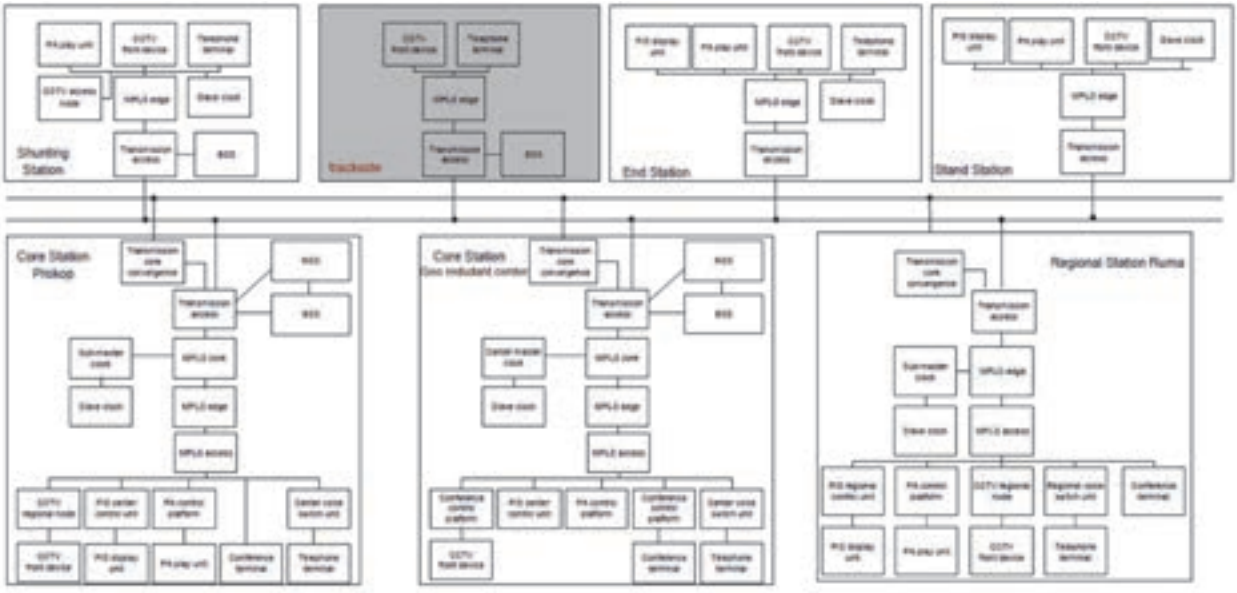

Figure 9. *ICS* organizational model

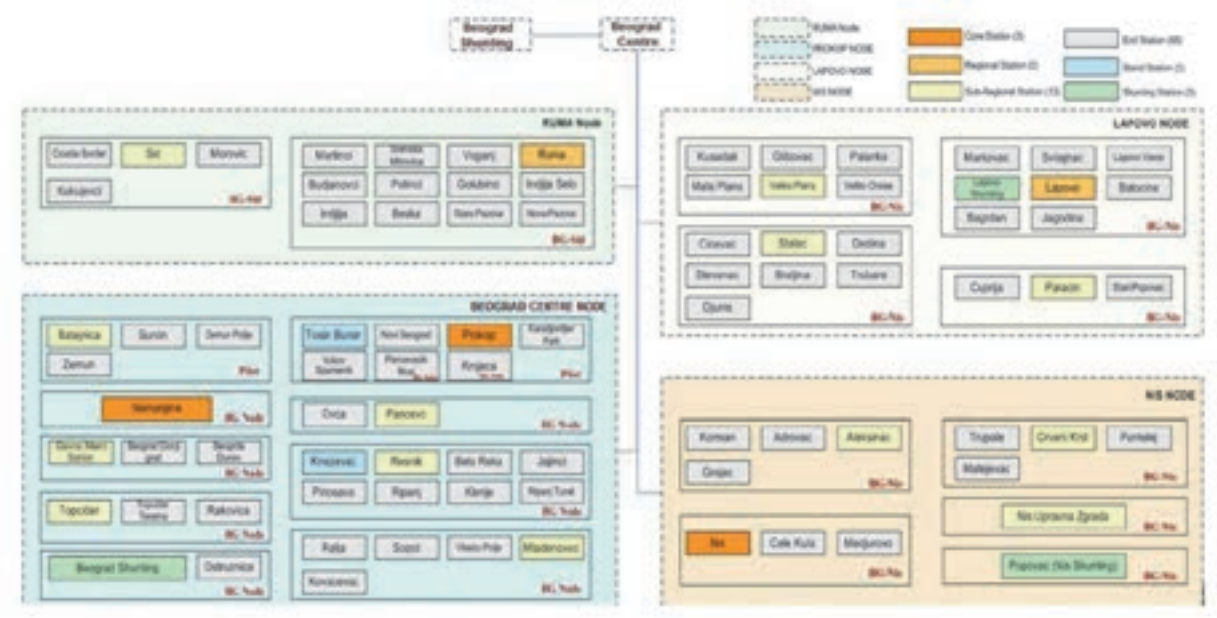

Figure 10. Nodes in ICS on the railway line Šid–Belgrade (Belgrade Node) – Niš (Niš Node)

other railway technological systems and external communication and other systems of interest for the functioning of the railway.

On the basis of traffic and technological requirements and characteristics of the official positions on the lines, the paper gives the proposal of *ICS* architecture with all the necessary subsystems, and depending on the technological and hierarchical level of the railway network in the Republic of Serbia. The levels of nodes in the railway *ICS* and their physical and logical organization were also identified, as well as the equipment and services characteristic for the individual nodes. An organizational model is proposed for the information and communication system of the railways, which would be applicable at the railways network of the Serbian Railways and other modern railway administrations, especially in our region.

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LIST OF ABBREVIATIONS AND ACRONYMS

A&A	NAME IN ENGLISH LANGUAGE
BBU	*Baseband unit*
BSC	*Base Station Controller*
BSS	*Base Station Subsystem*
BTS	*Base Transceiver Station*
CCTV	*Closed Circuit Television*
CTC	*Centralized traffic control*
E2E	*End to End*
ERP	*Enterprise Resource Planning*
ETCS	*European Train Control System*
FTS	*Fixed Terminal Sub-system*
GPH	*General Purpose Hand-portable*
GPS	*Global Positioning System*
GSM-R	*Global System for Mobile communications – Railways*
ICS	*Information and Communication System*
IS	*Information System*
MPLS	*Multi Protocol Label Switching*
NSS	*Network switching subsystem*
OA	*Office Automation*
OPH	*Operational Hand-portable Radio*

A&A	NAME IN ENGLISH LANGUAGE
PA	*Public Announcement*
PBX	*Private branch exchange*
PIS	*Passenger Information Systems*
PLMN	*Public land mobile network*
PRI	*Primary Rate* Interface
PSTN	*Public Switched Telephone Network*
QoS	*Quality of Service*
RDS	*Radio dispatch system*
RRU	*Remote Radio Unit*
SDH	*Synchronous Digital Hierarchy*
SPEV	*Stable electrical welding plants*
SS7	*Signaling System No. 7*
STS	*Station Telecommunication System*
VC	*Video Conference*
VoIP	*Voice over Internet Protocol*
VPN	*Virtual private network*
ŽAT	*Railway automated telephone exchange*
ŽATg	*Railway automatic telegraph exchange*
ŽS	*Serbian Railways*