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KOMUNIKAČNÁ PLATFORMA INTELIGENTNÉHO CESTNÉHO DOPRAVNÉHO SYSTÉMU

THE COMMUNICATION PLATFORM OF THE ROAD INTELLIGENT TRANSPORT SYSTEM

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Anotace: Článok je zameraný na analýzu a návrh architektúry komunikačnej platformy inteligentných dopravných systémov v oblasti cestnej dopravy. Architektúry dopravných podsystémov, staníc a ich komponentov sú podrobne analyzované a zrozumiteľným spôsobom prezentované. Technické údaje nevyhnutné pre výpočet výkonových pomerov na prenosovom kanály sú rovnako uvedené.

Klíčová slova: Inteligentný dopravný systém, referenčná architektúra ITS stanice, ITS podsystém dopravného prostriedku, ITS podsystém dopravnej infraštruktúry

Summary: The article is focused on the analysis and design of the architecture of the communication platform of intelligent transport system (ITS) in road transport domain. The architectures of road ITS subsystems, stations and their components are precisely analyzed and presented in understandable way. Technical data necessary for link budget calculations are involved at the end of the paper as well.

Key words: Intelligent Transport System, ITS-station reference architecture, vehicle ITS-subsystem, roadside ITS sub-system

INTRODUCTION

Referring to rapid communication technologies as well as microelectronics development, reliable and low energy consumption intelligent devices in the world of transportation started being applicable. This circumstance brought technology revolution in the field of the intelligent transport systems (ITS). Applications and services development on the basis of road ITS infrastructure requires sophisticated communication platform allowing reliable connectivity among all of sub-systems and components of the ITS to improve safety and traffic efficiency in the road transport domain.

The fundamental component of the intelligent transport road system is represented by ITS station. The station is basic part of all sub-systems of the road ITS. Its reference architecture follows the principles of the OSI model (1) for layered communication protocols which is extended for inclusion of ITS applications. The ITS station consists of the host and optionally interceptors which are mutually interconnected via internal network. The internal

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network is connected to the external infrastructure via interceptors, e.g. border router, station gateway, etc. Informative interconnections among external networks and ITS station internal one are presented in figure 1. The analysis of ITS communication (ITSC) platform architecture is subject of interest of the article.

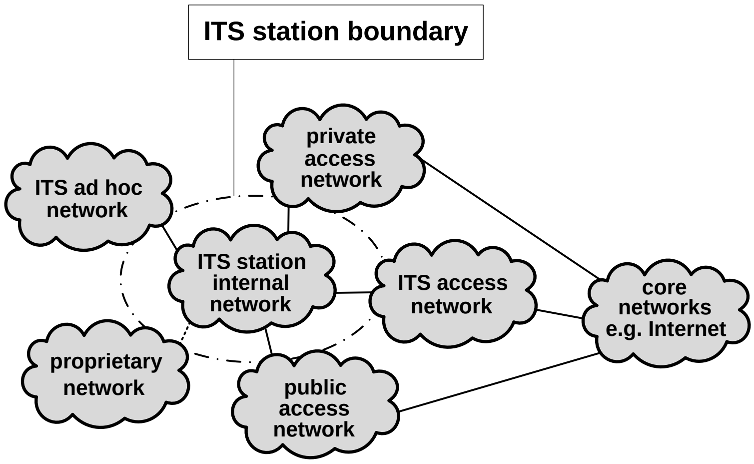

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Fig. 1 – ITS station boundary from networking point of view

1. ITS STATION REFERENCE ARCHITECTURE

ITS station reference architecture consisting of 4 basic blocks: applications entity, communication OSI protocol stack (access, network & transport and facilities layer), management and security entity is presented in figure 2, (2). The presented architecture represents fundamental one of the ITS station. Corresponding with practical requirements, the architecture of ITS station could be extended by additive elements and units connected via internal bus. General description of ITS station reference architecture depicted in figure 2 is presented in following sub-paragraphs.

2.1 ITS applications

An ITS application is an association of two or more complementary ITS station applications, e.g. server and client ones. ITS applications are grouped into 3 classes: road safety, traffic efficiency and other applications. ITS communication (ITSC) standards shall support multiple classes of ITS applications which impose more or less stringent requirements on ITSC, with respect of: reliability, security, latency and other performance parameters.

Referring to functional and operational requirements of the ITS application, priority and a specific logical channel is assign to an application for transmission of data packets. Maintenance of ITS applications, i.e. installation, de-installation, updates shall be performed in a secure way utilizing facilities layer and registration authority support.

2.2 ITS communication OSI protocol stack

Referring to ITS communication (ITSC) OSI protocol stack, the three layers (access, network & transport and facilities layer) contain functionality of the OSI communication

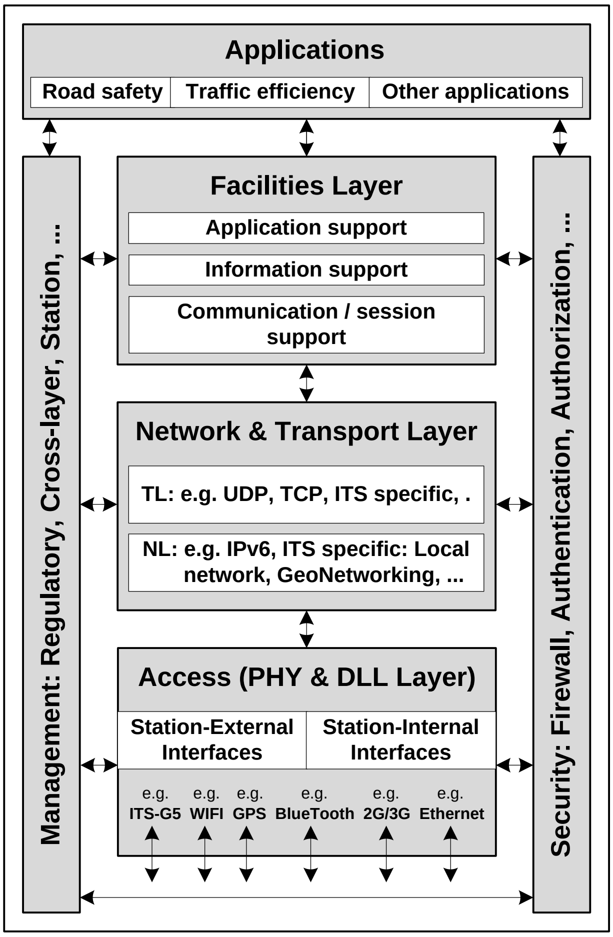

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Fig. 2 – ITS station reference architecture

protocol stack:

- access layer representing ITSC's OSI layers 1 and 2,
- networking & transport layer representing ITSC's OSI layers 3 and 4,
- facilities layer representing ITSC's OSI layers 5,6 and 7.

2.2.1 Access layer (AL)

AL consists of, (3):

- a physical layer (PHY) connecting physically to the communication medium,
- a data link layer (DLL), which may be sub-divided into a medium access control sub-layer (MAC) managing the access to the communication medium, and a logical link control sub-layer (LLC),
- a layer management of the AL (which is not a part of management entity of the ITS station presented in figure 2), directly managing PHY and DLL.

There are formally distinguished station-internal communication interfaces (CIs) and station-external CIs in figure 2. From a protocol point of view there shall be no difference in managing a CI via the management, security and network interfaces.

An ITS station CI shall provide the functionality of one or more logical channels (LCHs) which are to be identified e.g. for the following purposes: basic station management, service advertisement, ITS application data exchange, information dissemination, general purpose usage, e.g. internet, video streaming, etc. Logical channel types shall be treated as properties of a communication interface (CI) or a virtual instance (VCI) of it. CIs and VCIs are uniquely identified by identification number of them. A mapping of logical channels onto physical channels shall be performed in compliance with the related standards dedicated to the AL technologies.

Prioritization of transmission requests typically may be handled on DLL or PHY layer. Figure 2 presents typical communication protocols dedicated to ITS applications: ITS-G5, WIFI, Bluetooth, GPS, 2G/3G and Ethernet.

2.2.2 Networking and transport layer (N&TL)

The ITS communication networking & transport layer contains functionality from the OSI network layer and the OSI transport layer with amendments dedicated to ITS communications:

- one or several networking protocols,
- one or several transport protocols,
- a network and transport layer management which is not part of management entity of the ITS station.

Following networking protocols are defined for ITS communications by today:

- GeoNetworking protocol,
- IP v6 networking with mobility support,
- IPv6 over GeoNetworking,
- CALM FAST protocol,
- Other ways of IPv6 networking and other protocols.

Each networking protocol may be connected to a specific dedicated ITS communications transport protocol or existing transport protocol, e.g. UDP, TCP.

2.2.3 Facilities layer (FL)

The ITS communication FL contains functionality from OSI application layer, the OSI presentation layer (e.g. ASN.1 encoding, decoding and encryption) and the OSI session layer (e.g. inter-host communication) with amendments dedicated to TIS communication: application, information, communication, session support and a facilities layer management. The ITS communication FL is providing support to ITS applications.

The facilities may include: generic HMI support (information presentation to the user, e.g. car driver), data presentation support (data coding and decoding), addressing support (selection of the addressing mode at lower layers), position and time support (information on the geographical position and the actual time), Local dynamic map support (LDM; database about station status, traffic signs, traffic lights, bicycle path and so on), support for relevance checking (evaluated relevancy of received data), support for station capabilities management and data provision (station type: vehicle or roadside units), support of repetitive transmission of messages, channel selection, support for common message management for data exchange between ITS stations applications (decentralized environmental notification messages, event service messages and periodic messages (co-operative awareness messages) and the other supports.

2.3 ITS communication management entity

The ITS communication (ITSC) management entity is a part of the ITS station reference architecture as illustrated in figure 2. It contains management elements which are grouped in following manner:

- cross-interface management,
- inter-unit management communications,
- networking management,
- communication service management,
- ITS application management,
- station management,
- general congestion control management,
- service advertisement management
- management of legacy system protection,
- a common management information base (MIB).

The management elements support reliable and secured communication services as well as database upgrades, firmware reloading, etc. Detailed description of the entity is outside the scope of the paper. For more information, please, read literature (2).

2.4 ITS communication security

The ITS communication security entity presented in figure 4 contains security functionality related to the ITSC protocol stack, the ITS station and ITS applications:

- firewall and intrusion management,
- authentication, authorization and profile management,
- identity, crypto key and certificate management,
- a common security information base (SIB),
- hardware security modules (HSM).

For more information, please, read literature (2).

2. ITS SUB-SYSTEMS AND STATION

ITS road system consists of four basic ITS sub-systems illustrated in figure 3, (2):

- vehicle ITS sub-system: in cars, trucks, etc., in motion or parked,
- roadside ITS subsystem: on gantries, poles, etc.
- personal ITS subsystems: in hand-held devices,
- central ITS subsystem: part of an ITS central system.

Each of these ITS sub-systems contains an ITS station. The ITS station is represented by a single physical unit or several physical units interconnected by station's internal network representing a node. The functionality of an ITS station is possible to structure such that it is divided into individually addressable entities within the same physical unit.

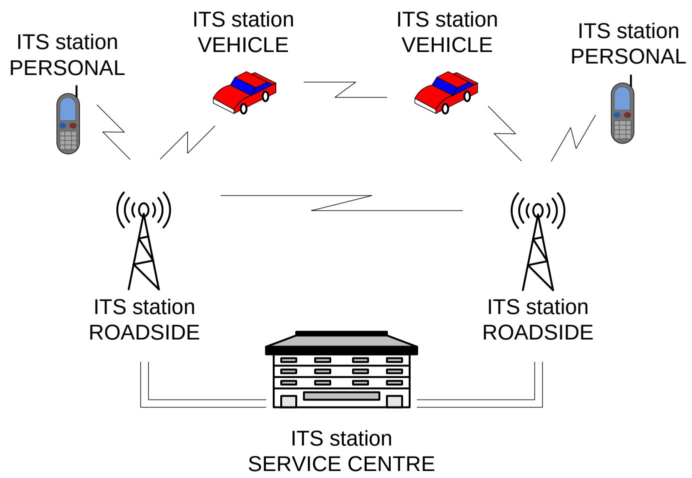

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Fig. 3 – Sub-systems of the ITS

Basic component of ITS station (ITS-S) is ITS-S host (presented in figure 2) which allows ITS applications to be realized in the environment of the intelligent transport systems. ITS communication networking is realized via interceptors such that ITS-S gateway, ITS-S router, ITS-S border router presented in figure 4. ITS-S host, gateway, router and border router represent fundamental building blocks of ITS-S architecture.

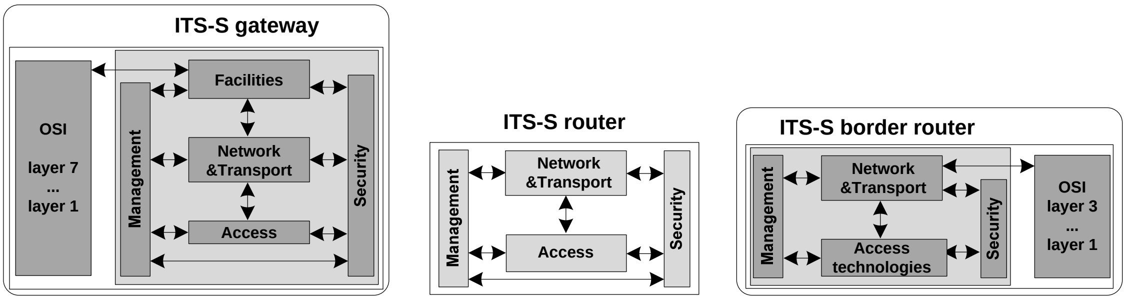

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Fig. 4 – Networking interceptors: ITS-S gateway, router, border router

ITS-S gateway interconnects two different OSI protocol stacks at layers 5 to 7. It shall be capable to convert protocols. The protocol stack on the right hand side in figure 4 is typically connected to the ITS station internal network. The protocol stack on the left hand side is connected to a proprietary network.

ITS-S router interconnects two different ITS protocol stacks at layer 3. One of these protocol stacks is typically connected to the ITS-S internal network. It may be capable to convert protocols.

ITS-S border router basically provides the same functionality as the ITS-S router. The difference is that the protocol stack related to the external network may not follow the management and security principles of ITS.

3.1 The architectures of the ITS subsystems and stations

3.1.1 The vehicle ITS sub-system

Shall contain a vehicle ITS station consisting of ITS-S host and optionally ITS-S interceptors. The interceptors in the vehicle sub-system are typically a vehicle ITS-S gateway and an router as presented in figure 5. The vehicle ITS-S gateway interconnects internal network of the ITS station and the components (in-car electronics units, ECU) connected to the proprietary in-vehicle network (typically CAN).

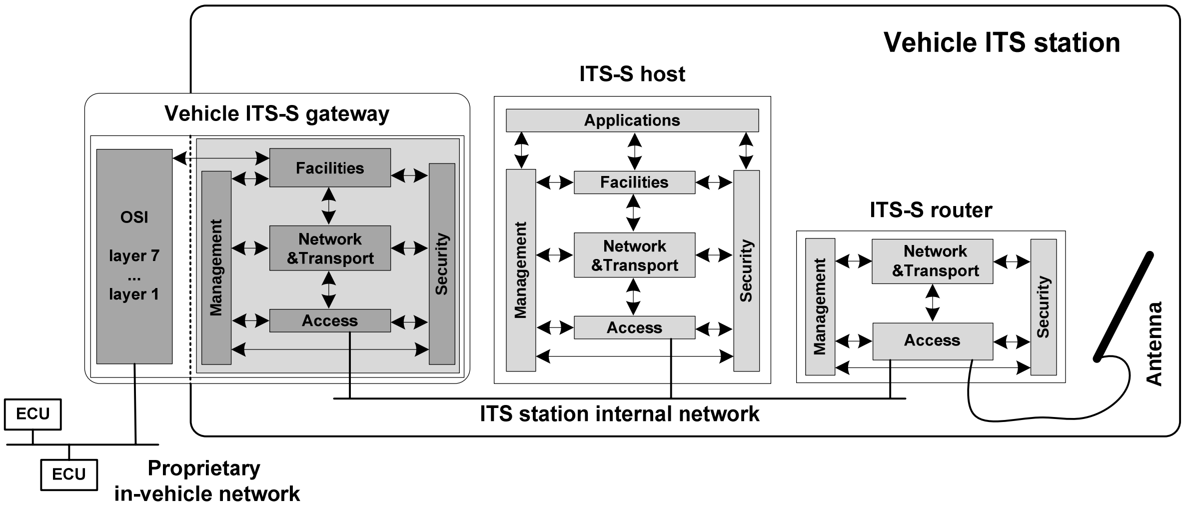

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Fig. 5 – Vehicle ITS station in a vehicle sub-system

3.1.2 The roadside ITS sub-system

shall contain a roadside ITS station consisting of ITS-S host and optionally ITS-S interceptors. The interceptors in the roadside sub-system are typically a roadside ITS-S gateway, an router and an border router as presented in figure 6.

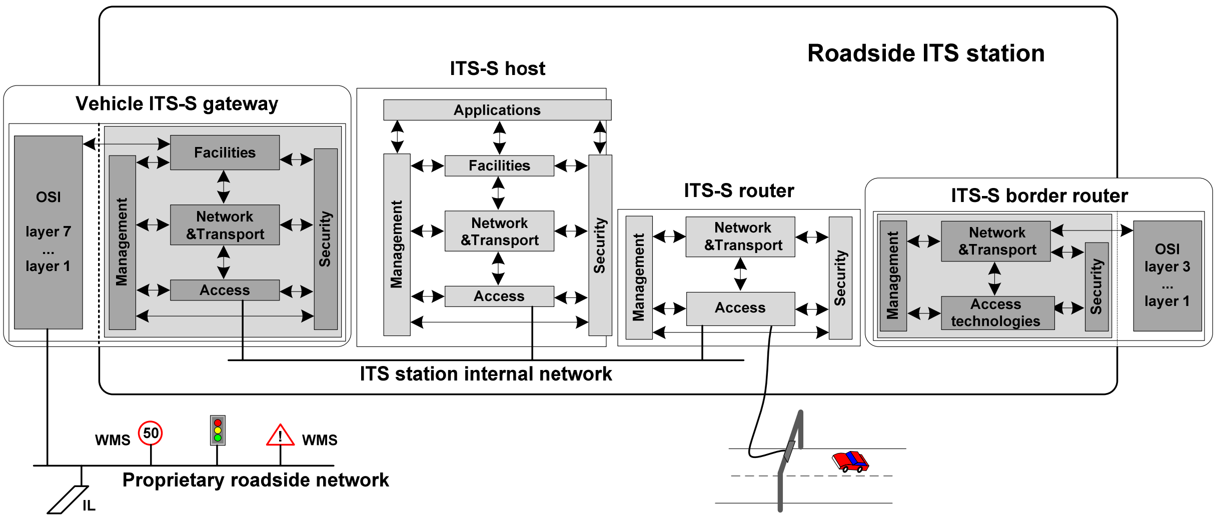

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Fig. 6 – Roadside ITS station in a roadside sub-system

The roadside ITS-S gateway interconnects internal network of the ITS station and the components of the roadside systems, e.g. semaphores, variable message signs (VMS), inductive loops (IL), etc. The border router typically interconnects the roadside ITS-S to an external network.

3.1.3 Central ITS sub-system

Shall contain a central ITS station which consists of the ITS-S host and typically ITS-S gateway as well as border router interceptors presented in informative figure 7. The central ITS-S gateway provides functionality to connect the components of the central system to internal network of the ITS station.

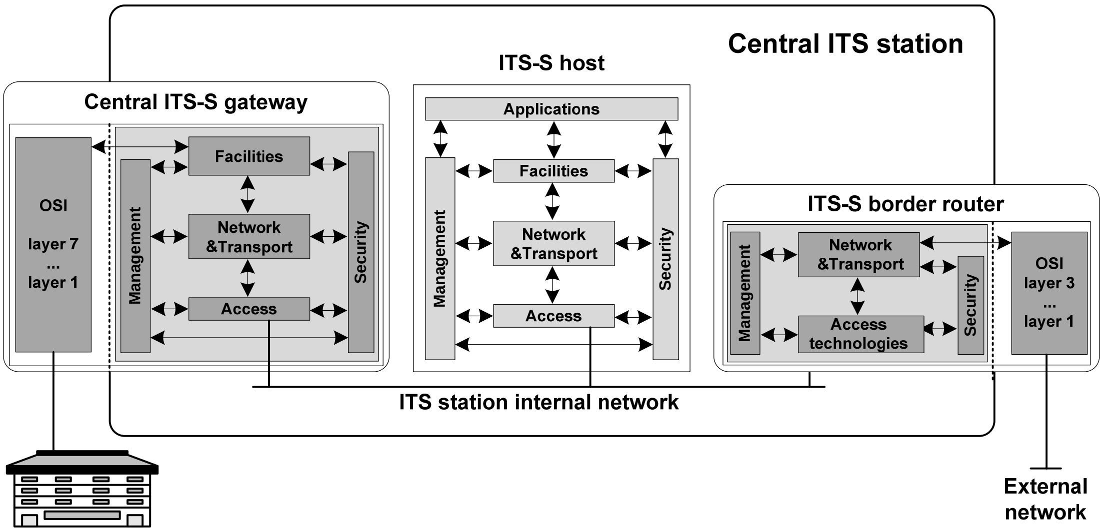

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Fig. 7 – Central ITS station in a central sub-system

3.1.4 Personal ITS sub-system

provides the application and communication functionality of ITS communication in hand-held devices, such as PDAs, mobile phones, etc. It shall contain a personal ITS station consisting of ITS-S host, see figure 8.

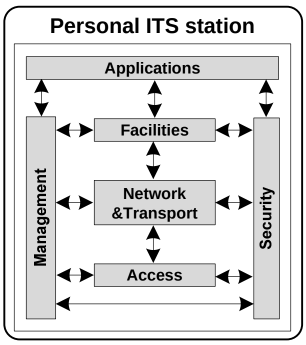

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Fig. 8 – Personal ITS station in a central sub-system

3. ITS STATION REFERENCE ARCHITECTURE

In 5.8.2008, EU Committee decided to allocate frequency band from 5875 to 5905 MHz for ITS applications, which is used on non-exclusive basis. ITS communication frequency band as well as maximum limit of mean spectral power density (EIRP) is illustrated in Fig. 9.

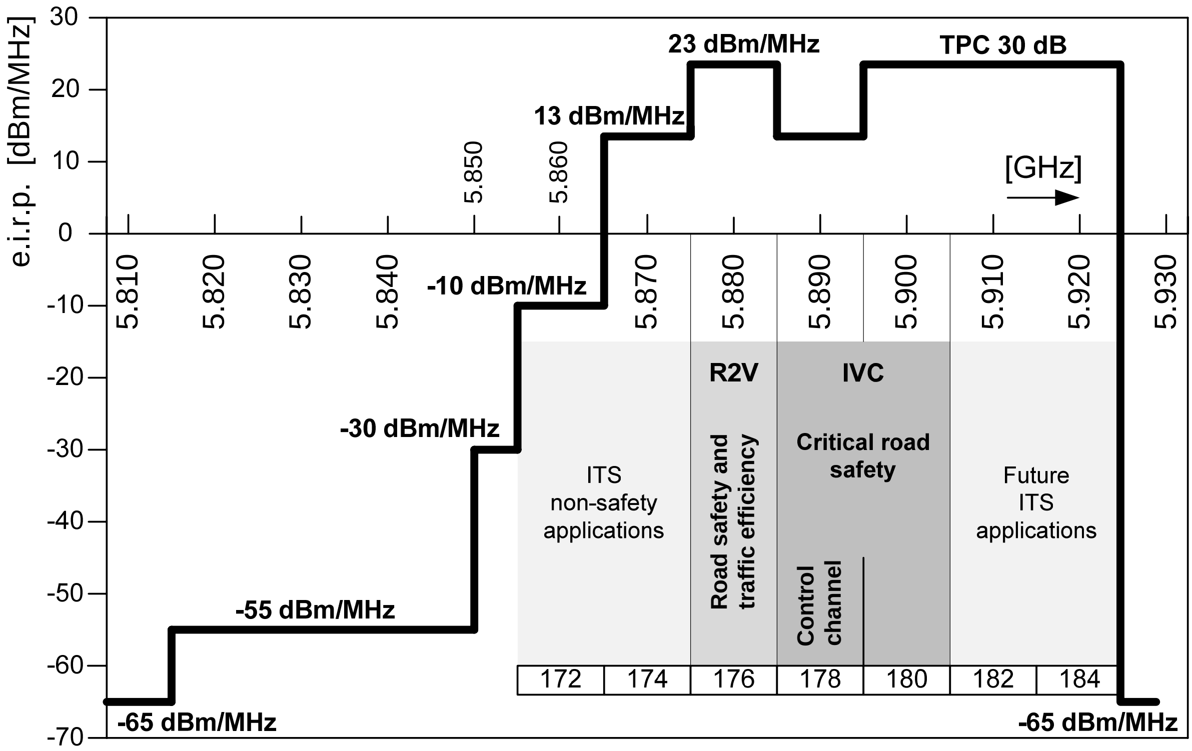

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Fig. 9 – Power density limits of ITS transmitting units at frequency band 5.9 GHz

Channel allocation is defined as specified in table 1, (6).

Tab. 1 - European channel allocation

Channel type	Centre frequency [MHz]	Channel number	Channel spacing [MHz]	Default data rate [Mbit/s]	TX power limit [dBm]	TX power density limit [dBm/MHz]
G5CC	5 900	180	10	6	33 EIRP	23
G5SC2	5 890	178	10	12	23 EIRP	13
G5SC1	5 880	176	10	6	33 EIRP	23
G5SC3	5 870	174	10	6	23 EIRP	13
G5SC4	5 860	172	10	6	0 EIRP	-10

Source: authors

One physical channel is allocated as a G5CC and four fixed channels are identified as G5SCs. G5CC and G5SC1 to G5SC4 are dedicated for the following usage:

- the G5CC shall be used for road safety and traffic efficiency applications and may be used for ITS service announcements of services operated on G5SC1 to G5SC4,
- G5SC1 and G5SC2 shall be used for ITS road safety and traffic efficiency applications,
- G5SC3 and G5SC4 shall be used for other ITS user applications.

Figure 9 is presenting power density limits of ITS transmitting units at frequency band 5.9 GHz. Transmit power limit as well as power density limit for a defined channel is presented in table 1. Maximal transmit power limit equal to 33dBm was defined on the basis of study of electromagnetic compatibility between ITS and other radio systems for fixed, mobile and satellite services, (4).
Data rates for 10 MHz channel spacing are defined in table 2, (3).

Tab. 2 - Data rates and channel spacing

Modulation coding scheme (MCS)	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Data rate in Mbit/s 10 MHz channel	3	4.5	6	9	12	18	24	27
Modulation scheme	BPSK	BPSK	QPSK	QPSK	16-QAM	16-QAM	64-QAM	64-QAM
Coding rate R	1/2	3/4	1/2	3/4	1/2	3/4	2/3	3/4

Source: ETSI ES 202 663

Tab. 3 - Comparison of Physical Layer between IEEE 802.11p and 802.11a

Parameter	**IEEE 802.11p**	**IEEE 802.11a**
Data Rate [Mbps]	3, 4.5, 6, 9, 12 18, 24, 27	6, 9, 12, 18, 24, 36, 48, 54
Modulation	BPSK OFMD QPSK OFMD 16-QAM OFDM 64-QAM OFDM	BPSK OFMD QPSK OFMD 16-QAM OFDM 64-QAM OFDM
Error Correction Coding	64 states, Convolutional Coding with K=7	64 states,Convolutional Coding with K=7
Coding Rate	1/2, 2/3, 4/3	1/2, 2/3, 4/3
Number of subcarriers	52	52
OFDM Symbol Duration [µs]	8	4
Bandwidth [MHz]	10	20
Frequency [GHz]	5.855 – 5.925	5.15-5.35, 5.725-5.850 (ISM)

Source: authors

Thanks to concentrated effort of research and development teams as well as producers in the field of info-communication techniques for transportation applications, the first commercially produced on-board communication units started being produced at the end of 2008. The units are fully operating according to Std. IEEE 802.11p. The development of physical layer of communication modules was partially simplified because of required technical parameters which are only slightly differentiate from WiFi standard IEEE 802.11a. Comparison of the technical parameters is presented in table 3, (5).

CONCLUSION

The article presents detailed analysis and design of the architecture of ITS communication platform focused on road transport domain. The platform plays core role in inter-vehicle as well as roadside-to-vehicle communications on the basis of which it is possible to be developing of new flexible services and applications increasing transport safety and traffic flow distribution efficiency in the road network. All topics are presented in principal and understandable manner. Technical data for the purposes of theoretical analysis of the communication channels at frequency band 5.9 GHz are involved as well.

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