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5G Technologies in Intelligent Transport Systems - Architectures, Virtualization and Network Slicing

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ABSTRACT

In the paper, 5G communication technologies implemented for Intelligent Transport Systems are discussed. Firstly, the essence of the 5G system concept is presented, and the problem of network functions virtualization (NFV) is analyzed. Moreover, the principle of virtualization is explained. Secondly, the analysis of network slicing is performed, from the point of view of transport systems implementation in the future 5G networks. The important part is the analysis of architecture proposals for the 5G communications system, implemented as ITS, for various scenarios of its work. The aim of this paper is the study on practice architecture of the 5G communication network for the ITS system, introduced as physical radio-informatics system implementation.

KEYWORDS: 5G, network slicing, ITS, 5G architecture

1. Introduction

Evolutional development of cellular radio communication networks is coming to the implementation of 5G networks allowing very large transmission rates, up to 1 Gbps, low latency, high reliability and service quality observed from user experience (QoE – Quality of Experience). A major target of their implementation is the revolution in the whole philosophy of network functionality, taking into account advanced Software Defined Networking (SDN), global expansion of the machine-type communications M2M (Machine-to-Machine) and the Internet of Things (IoT) era [1].

The 5G system is proposed for the improvement of new types of services dedicated to different solutions and applications. It allows global extension of transport services for Intelligent Transportation Systems, also dynamically developing in Poland [2]. From this point of view very important is the evolution process of Smart City applications directly connected to transport solutions, and development of road and traffic control systems, as well as the deployment of global systems for vehicle communications: V2V (Vehicle-to-Vehicle), V2I (Vehicle-to-Infrastructure) and V2X (Vehicle-to-Everything). A major result of vehicle control systems development can be a global implementation of autonomous driving for cars/vehicles, and systems for traffic safety improvement [3]. These systems will completely revolutionize the way vehicles move on the road, change traffic rules, and improve safety.

The realization of 5G system objectives needs the implementation of short-range access points, some small-cells, and Ultra Dense Networks (UDN) [1], which should be implemented using the heterogeneous concept of the network constructed from different radio interfaces. It is not the only one direction of 5G network development. Equally important is the development of network techniques regarding software and its virtualization. It means that many hardware functions of modern networks can be realized in the software domain, and the scale of it can be unprecedented in radio communications. The virtualization is a great technological challenge and changes the "philosophy" of both network implementation and functionality.

2. Properties of radio-informatics 5G systems

2.1 The definition of the 5G radio communications system

The 5G system should be defined taking into account its properties and overall philosophy of its work, including the revolutionary concept of network construction, network functions as well as major principles.

The 5G radio communications system is a global wireless access system or the set of systems, combining mechanisms, techniques, algorithms, and applications (IT and radio-communication), and thus, built in the radio-informatics techniques. It enables the transfer of data between persons, persons and devices, as well as devices themselves, without human intervention. It includes communication within the global IoT, and common communication between vehicles (V2V, V2I, V2X), as well as in-car solutions (Car-to-X), especially for the applications in the field of traffic safety, management, and control. The system can work with very high transmission rates, high stability and reliability of connections and achieved rates, as well as with very low latency and energy consumption, while the system provides services for handling a huge number of terminals supported per unit area.

The 5G system operates in such a way that the data transmission can be carried out without any hindrances in quasi-real time, using physical and virtual core network, physical and virtual radio access network, virtual software-logical network layers (called network slices), physical and virtual network resources and functions for their management and other network functions, fully or partially implemented in the computing cloud, as well as using the software-implemented network hardware functions or communication nodes on a large scale.

Objectives of 5G systems mean that it is necessary to correct the general definition of a communications system, especially for radio case. The communications system is a set of principles and rules of cooperation and information exchange between physical devices and their software equivalents (software), including virtual ones, that explicitly define both the functions of these devices and software as well as their relationships. The radio communications system is a communications system that allows radio (wireless) transmission of information. The network is a physical implementation of the system. Within the physical network, we can use virtual equivalents of devices, and there may also be implemented virtual-logical network slices. Note, that in this form the 5G radio communication system should be rather seen as the *radio-informatics* one. It is extremely important and fully justified for this notion to come into public use.

At this moment, the results of standardization show that the 5G network architecture will not significantly differ from the LTE architecture [4, 5]. Moreover, during the implementation and dissemination of the network, these architectures will become a de facto unity, because they will complement and integrate each other. Major parts of the 5G network are as follows:

- **NG RAN** (New Generation Radio Access Network), and **UE** (User Equipment).
- **5GC** (5 Generation Core), which is the modern core network, at the initial stage fully integrated with Evolved Packet Core (EPC) of LTE.

2.2 The virtualization and softwarization concept

A key to the development of the 5G network is a softwarization [6]. In general, the softwarization is a replacing the mechanisms previously implemented with the use of physical devices (hardware), by software, which may be available in various places (distributed system) but not in a specific location, like a device. In this sense, the functions of devices can also be replaced by the software. The first stage of softwarization was the development of Software Defined Radio (SDR) which is typically used for implementation of modern wireless devices. The SDR implemented as software using a single physical device can be expanded, changed, reconfigured, and its actual limitation is the scope of technical capabilities of the physically used electronic device, which is a platform for software. The platform is in fact only a tool for sending/receiving packets and radio communications signals.

In the 5G network, the softwarization applies not only the SDR but overall network concepts. Thus, we can talk about Software Defined Network (SDN) [6]. In principle, through a simple analogy, we can say that the SDN network architecture has been reduced in such a way that from physical network devices (network nodes) we separate everything that determines their functions, management and control of these devices, and resources of a network and devices. So, extract as many elements as possible that provide technical capabilities of devices and leave them only functions related to receiving/sending data packets to other devices in the network. However, all of the separated functions can be software implemented in a completely different physical place – in a network cloud [6, 7]. Such mechanisms, therefore, lead to the automation of the network, by enabling the software implementation, management, configuration, reconfiguration, and maintenance of network equipment.

The virtualization has a wider significance than the softwarization [8]. The network virtualization has much to do with creating a certain illusion of the existence of a physical telecommunications network because it allows the construction of multiple virtual logical networks (or rather sub-networks) within a single physical network. Thus, such behavior creates a kind of an illusion of the existence of many networks, although there is only one physical network, and its virtual components use only its physical resources jointly and in parallel. Therefore, the concept of network virtualization usually means the simultaneous implementation of complex network functions in the software form, and thus the replacement of network functions by software, using mechanisms of imitating devices and network functions through this software. Individual elements of virtual network architecture are based on various virtualization techniques. It enables the virtualization of various network functions as well as entire groups of these functions traditionally provided by network nodes. These functions can be combined into certain integral functional groups implemented in the form of software, which allows sending information between these functional groups. Usually, such a process is called Network Function Virtualization (NFV). The softwarization is not the same as virtualization. The softwarization do not need the virtualization, but the virtualization needs the softwarization.

The virtualization of 5G network concerns both the software as well as the way of network functioning. So, the notion "virtual" means:

- Software-defined and implemented, and the software replaces and imitates devices and network functions to the extent that they become virtual.
- I**mplemented as parallel processes, and therefore also in parallel processed programs (applications)**, which allows creating logical equivalents of different networks within one set of devices forming a physical network.
- **Using resources, but only if they are physically used,** e.g.: network resources, radio resources, physical resources, energy resources.
-

The virtualization in 5G means, therefore, that there are parts of a network or their functions in the sphere of software (and not physical devices) and that they are activated on demand, only when the need arises. The implementation of such a defined radio communications network is undoubtedly tantamount to the development of the radio-informatics, but not only the radio communications.

Summarizing, the most distinctive features of the 5G system are:

- **Virtualization** – concerning many areas and functions of the network, as NFV.
- **Softwarization** – the software definition and implementation of the SDN network.
- **Network slicing** – the implementation of logical sub-networks (slices) within a single physical network.
- **Cloud-RAN** (Cloud-Radio Access Network) – the gradual transfer of many functions from RAN to the cloud, and centralized resource management.
- **Core network in the Cloud** – the implementation of core network functions in the cloud in a distributed way.

All of the set of listed solutions must be supervised not only by network management mechanisms but also using so-called orchestration. It is a mechanism for managing communications network and softwarized network functions, providing optimization of processes, applications delivery, and services, using a set of automated rules, methods and algorithms for configuration, coordination and management of physical and logical (softwarized and virtualized) parts of a network (computer, radio-informatics, radio-communication). The orchestration enables network and software parts interoperability to exchange control information, transfer user information, provide communications services, and set up physical and logical connections.

The orchestration is a slightly higher dimension of the network management intelligence, taking into account not only constantly changing parameters and conditions of working network and implementation of connections, but also parameters and conditions affecting applications, entire service groups, and virtualized services. It allows optimizing the use of resources and network parts.

On the other hand, network virtualization is implemented in its various areas and concerns both networking and service aspects [8-10]. In 5G virtualization will be implemented through the division of network resources into logical subnets, i.e., certain software-network type slices, which allows support for many virtual networks operating in the infrastructure of one physical network. All slices use the same infrastructure but can function (but do not have to) completely in separation from each other. With each created slice, the implementation of services with similar characteristics (groups of services – GOS) is associated, which enables optimization of the network for the entire service set. Creation of virtual slices is, therefore, a specific way of virtualization, consisting in the launch of multiple logical networks within one physical infrastructure. The main advantage is the ability to create virtual networks at the level of the end-to-end (E2E) application layer, in which not only networking functions but also computing and data storage are implemented. The aim is to provide the operators of cellular networks with the possibility of allocating at the application level certain areas of network resources for different users – the so-called tenants or virtual operators, for the multiplication of single network infrastructure.

3. The essence of virtualized network slicing

3.1 Network slicing concept

Network slicing is the new era in both 5G and ITS. In 5G RAN the division onto network slices is closely related to the way of providing communication services [9, 10]. By this, virtual operators can create unique services for different applications: enhanced Mobile Broadband Services (eMBB), massive – Machine-Type Communications services (mMTC), Ultra Reliable Low Latency Communications URRLC, and others. For each listed GOS, we can use a different set of network slices within the 5G network, as shown in Fig. 1. eMBB services are correlated as classical services provided by today's networks where the number of QoS requirements are specified. This set includes phone calls, internet, multimedia communications, etc. mMTC is the group of IoT services related to slow data transmission rate (at this moment), but requiring the service of a large set of devices (the M2M transmission).

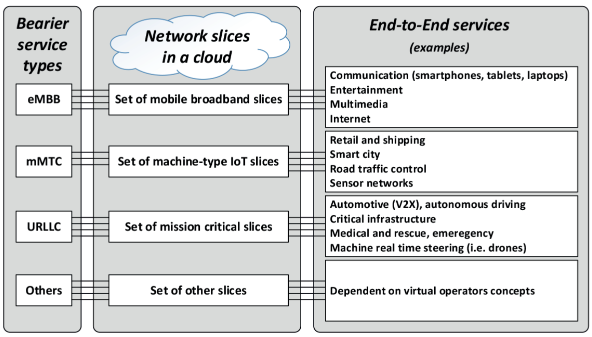

Fig. 1. Network slicing – virtual E2E slices tailored to application requirements [own study]

URLLC is the set of services of very low latency (eventually, < 1ms) related to control of devices and machines and other mission-critical services.

Each of these sets can be used as transport telematics applications of different requirements. For instance, V2X communications are strongly related to URLLC. It includes services supporting road traffic safety of critical importance, including communication and autonomous driving of vehicles. On the other hand, traffic control systems can be allocated in mMTC. However, some smart-city services can be allocated both in eMBB and mMTC, dependent on service requirements.

The network slice is a logical-virtual subnet of the real physical network, dedicated to the provision of services within one of GOS available in the network. A slice is a unit of programmable network resources, made available as a network service and allowing virtual use of physical network resources (networking functions), but also computing functions of this network, as well as functions related to saving and storing information in the computing cloud (storage functions). Logical slices include all required network resources that are cumulatively configured, which can be physical, virtual, dedicated or shared, and can be created, changed and deleted using orchestration and management functions. Resources in a given slice can be isolated from other slices, as well as shared in whole and part. Within slices, the services of many suppliers can be integrated, and also resources aggregation and roaming are possible. Also, it is possible to provide virtual operators with certain management functions and resource management within the slice.

The use of network slices in the physical network means the reduction of network exploitation and construction costs and, moreover, optimization of the physical resource management in a mobile network, and especially in ITS solutions. It also reduces energy consumption. However, a major important, from transport systems development, is a great possibility of the optimization of resource use and services quality control, due to the possible isolated configuration of different GOSs. The revolution is the possibility of entire GOS optimization and control of connections within a group, but not the separated optimization of all connections and services performed. It is important for the development of advanced and extensive ITS.

In traditional models for services management, QoS quality indicators analyzed for each connection are typically taken into account. These are indicators defining the target parameters of each service of any type, and they are taken into account during the physical time-frequency resource allocation process for each connection. In general, the model of service realization is then based on selection network parameters (resources, transmission rate, latency, SINR, BER, etc.) using QoS sets for each service type and each connection.

In the case of the virtual-sliced network, the model of service realization can be based on optimization of all connections within a slice, based on analysis of an entire GOS of similar type, what we can see in Fig. 2. In this model, network resource management refers totally or partially to the entire GOS. Therefore, it is not based only on QoS itself but is related to the parallel implementation of services from the group of similar type, i.e., services with the same or similar characteristics defined by QoS. It gives completely new possibilities in the area of applied physical resource management methods in the 5G network. It enables creating physical network management mechanisms specialized for a given service, and optimization of radio communication traffic, and also optimization of RAN itself and many others.

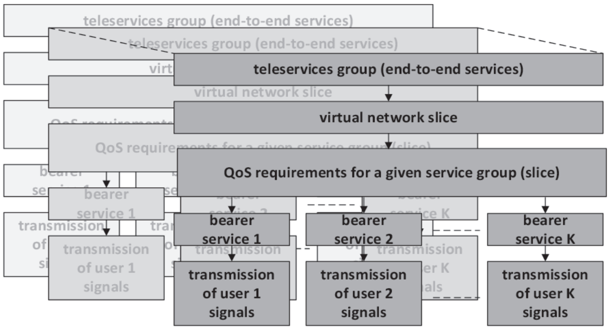

Fig. 2. Model for services implementation using GOSs in the sliced network [own study]

4. Revolutionary benefits from ITS implementation in the virtualized 5G network and ITS applications

4.1 Properties of 5G network important for ITS implementation

One can see that a key to the development of the 5G network is a softwarization and virtualization of network functions. In general, from ITS implementation within 5G virtualized networks, we can highlight the major benefits presented below.

Infrastructure as a Service (IaaS): ITS operators can use physical networks and implement their virtual E2E slices. It provides the ITS operator (provider) with the entire IT and physical infrastructures, such as virtualized equipment and nodes, scaled according to the ITS operator's needs, using cloud computing.

Simple implementation and development of ITS functions in 5G networks: ITS functions can be implemented, modified, configured, and optimized by virtual ITS operator, but not only the operator of a mobile network. It reduces costs, time for implementation and reconfiguration, and gives great freedom of action.

The low latency of transmitted, stored and computed information: Services will be implemented as E2E services, as well as connections will be defined and established as E2E, independently on the type of intermediary networks and interfaces used for the connection (wireless and stationary).

The modern concept of services, their implementation, and sharing as well as service providing: Services can be dedicated directly to ITS communication, and only for ITS. Additionally, virtual ITS operators can create a set of services of similar characteristics, QoS and QoE, including priority, resource management, quality management and reliability of service.

Greater impact for resource allocation for a network slice dedicated to ITS: The virtual ITS operator will influence resource allocation dependent on actual service necessity, general requirements for ITS services, minimum needs, etc., including multimodal transport systems requirements.

Guaranteed real-time connections for vehicles control and autonomous driving: A key role for real-time applications, meeting critical requirements regarding service reliability and low delays, depend on two major factors. First, it is a group of different quality indicators, as short transmission time, short wireless transmission distance, not limited transmission rate (from real requirements for a service), short network ping, etc. Second, it is virtualization and softwarization of slow hardware nodes and replacing the hardware with fast software working in a cloud environment. The second one is, in general, the condition of efficient network slices implementation and providing E2E services without unnecessary delays of connections execution.

Short distance, from served vehicles or other devices to a central part of ITS management system using cloud computation: The result of implementation of this network model means low latency for a service establishment and realization, as well as handover procedures, important for different functions of ITS, as, e.g., real-time connections, critical infrastructure, and systems, rescue services, medical assistance, emergency systems for cars and vehicles, etc.

Scalable and flexible infrastructure and network architecture: The infrastructure should not be limited for ITS expansion and evolution, concepts development, evolution and integration, new models and types of service and applications.

Simple ITS management procedures and low cost of implementation and exploitation: ITS operators who migrate to a virtualized network model in 5G infrastructure can worry only for sufficient resources allocation, but do not worry for network exploitation problems, wasted costs of its implementation, and physical network management or maintenance problems.

Flexible implementation of slices dedicated to different ITS applications: We can use many slices for different transport solutions, taking into account requirements and service-specific optimization of a given network slice.

Higher security of communication, safety network, and services: Virtualized operators have an influence on security requirements, authentication, and levels of cryptographic security, which can be configured dependently on needs, and, partially, independently on mobile network operators.

Solutions open for additional services: We can simply provide additional services, not directly related to ITS services, e.g., providing internet access within trains, buses, etc., subject to requirements and regulations.

Big data analysis services possible in road transport: Possible the analysis of traffic, routes, service requirements, market analyses, etc.

The presented set of potential benefits for the implementation of ITS systems and services within the virtual 5G network can be revolutionary from many solutions. It will result in a rapid demise of new services, above all, connected with the global communication between machines and vehicles without direct human participation. It will be the era of a global revolution in the telematics of different transport systems.

4.2 Revolutionary ITS applications within the 5G network

We can exclude six major ways to the development of ITS:

- Global intelligent vehicle coordination and control systems based on V2X communication for Smart City applications, smart roads (highways, expressways).
- Autonomous Driving applications.
- Emergency Services expansion for different road safety systems, especially car-crash management and notification systems and solutions based on BAN (Body Area Networks) [11] and other emergency systems.
- Smart City applications for ITS, transport control, traffic control, charging road tolls, electronic road signs control, traffic and road statements, road warnings, etc.
- Intelligent systems and applications for drone communications, e.g., for traffic safety solutions of a new generation: new concepts of rescue operation methodology, fast transport of tools, medical supplies and rescuers, air ambulance, etc. (helicopters – a small number, very expensive, but drones – large number and relatively low cost).
- Software-defined applications and systems mean simple evolution of ITS systems and applications as well as the simple implementation of modern sensor-based solutions and other not-known ideas for intelligent transportation.
- Future-Proof Infrastructure: 5G network infrastructure also promises to allow us a much easier time when it comes to upgrading ITS technologies in the future, compared to previous generations of cellular networks.

5. The general 5G architectures for ITS implementation

5.1 General architecture concept

The architecture of the 5G network will be fully integrated with LTE [4, 5]. At the first stage, the 5GC will not be implemented. The role of the core network will be realized by EPC only. However, the target is the development of 5GC which will coordinate both LTE RANs dedicated to service of connections in macro-cells and microcells, as well as NG RANs of 5G, used to service of connections in small cells. It means that the LTE will be an integral part of 5G. A key to the release of some of the network management mechanisms, impossible to implement so far, requires separation of functions related to network control in CP (control plane) from UP (user plane) functions related to the transmission of individual network users data. The CP can be controlled by EPC, and ultimately by 5GC in macrocells. While UP will be supervised by 5GC in small or EPC in large cells. Ultimately, its control will be managed by a common 5GC.

One can see that the separation of UP from CP is to simplify the control of each connection, simplifying control within GOS in the logical sliced network, reducing the amount of control data, providing transferring control data with another QoS requirements than user data. It is very important to ensure the ability to control user terminals from the macrocell level (full and stable coverage, combined control, providing better conditions for handover due to large macrocell size). On the other hand, the transmission of user data can take place over short distances in small cells (and therefore with a high rate, excellent transmission quality, low latency, etc.).

Everything indicates that the 5G NR air interface can be similar to LTE [12] and is OFDMA-based (Orthogonal Frequency Division Multiple Access). It is a scalable and flexible solution from the perspective of the allocation of physical resources (see [13]). Also, compatibility with LTE is the reason to develop a similar solution.

Base stations of 5G consist of two major parts. It can be Base Band Units (BBUs), and Remote Radio Units (RRU) sometimes called Remote Radio Heads (RRH). Radio communication signals will be received (or transmitted) by RRUs, and then they will be transmitted (or received) to BBUs, using, typically, fiber optic connections (fronthaul). Next, signals will be forwarded to 5GC via a backhaul interface (also fiber optic). In the first phase, 5GC will be able to be implemented in a cloud, but in the next, BBUs will be able to be implemented in the cloud, too. Thus, the first core network will be created in the cloud (it is already partially implemented in this way), and then the access network will become a Cloud-RAN [14] network (also called C-RAN or Centralized-RAN).

The use of cloud computing to implement various RAN functions has potentially many benefits, including:

- The ability to reduce access network complexity by moving BBUs to 5GC, which opens up new possibilities in the field of network resources management, will reduce delays and simplify the construction of the entire network.
- Faster access from gNB to the virtual core connected to RAN is possible because it can be implemented anywhere, within a short distance from gNB.
- The physical parts of the core and RAN can be easily destroyed, blocked by attacks on the network, while the virtual elements of 5GC and C-RAN can be attacked on the network, but if blocked, their virtual counterpart can be run elsewhere, which is crucial for security evolution in a network.
- Data processing in the cloud is generally faster than local processing. The real issue is the separation of virtual network slices for needs of GOS, configurable depending on the needs, easily adaptable, quickly created and reconfigurable.
- Less energy consumption due to the possible optimization of network traffic.
- Lower costs of building and extending the network and its maintenance.

On the other hand, the transfer of 5GC to the cloud enables aggregation of traffic in the appropriate transport network aggregation nodes, thanks to which they can be virtualized, can change over time, and their location does not have to be clearly defined physically and can be changed. Likewise, the transfer of RAN functions to aggregation nodes enables the combined processing of signals from many small cells at the central node of the entire macrocell in the cloud. The communication network constructed in this way can act as a complex cluster with central processing of macrocellular signals and support many gNBs, access points, relay nodes, and others, as well as support terminal connections with a huge density of distribution on the surface. Also, access points and other nodes may be directly connected to 5GC or wirelessly to other nodes connecting to 5GC, and signal processing may in principle be sent from access nodes to the cloud network.

5.2 5G network architecture and major network functions

The general architecture of the 5G network is shown in Fig. 3.

MME server (Mobile Management Entity) – in general, has similar functions as in LTE, but extended by functions related to network slicing support. Functions of this server include [4, 5]:

- Access and Mobility Management Function (AMF) – network access management, resource management, mobility management, physical resource allocation, access authorization, and localization functions management.
- Unstructured Data Storage Function (UDSF) – storage, computing and charging data from different network functions.
- Network Exposure Function (NEF) – service of a set of available events and possibilities for various network functions, secure transfer of information from external applications to the 5G network, as well as for translating (in the IT sense) information between external networks and internal networks (i.e. 5GC), and thus supports the 5G network contact with external networks.
- Network Repository Function (NRF) – support of NEF functions and storage of identification information of different network functions (5G and other networks).
- Network Slice Selection Function (NSSF) – control of network slicing and valid transfer of data to a given slice.
- Session Management Function (SMF) – includes activities related to session assembly, release and management, management of IP address allocation for the user equipment, support for DHCPv4 server functions and DCHPv6 (server/client) and others; this function is also implemented by SGW-CP and PGW-CP gates.
- Application Function (AF) – supports interactions between core networks related to the implementation of various applications.
- Network Data Analytics Function (NWDAF) – the function manager by an operator for network data analysis related to slices service, and resource allocation and management for a given slice.

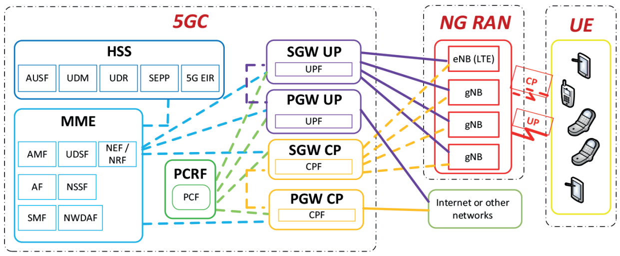

Fig. 3. The general 5G network architecture [own study]

HSS server with databases (Home Subscription Server) – in general, has similar functions as in LTE but expanded. The functions of HSS are as follows [4, 5]:

- Authentication Server Function (AUSF) – user authentication.
- Unified Data Management (UDM) – subscription user data management, access authorization, and SMS management.
- Unified Data Repository (UDR) – management of subscription data for UDM.
- 5G-Equipment Identity Register (5G-EIR) – management of the database of user equipment (optional).

PCRF server (Policy and Charging Rules Function) – in general, has similar functions as in LTE – management of services charging.

SGW and PGW servers (Serving Gateway, Packet Data Network Gateway) – they are, as in LTE, the gateways for user data transit functions. However, in 5G the UP and CP functions are separated. Thus, SGW CP and PGW CP use Control Plane Function [5], for control of all connections in a network. While SGW UP and PGW UP are specified for user data transmission using User Plane Function (UPF) [5], which supports user data transmission, terminal mobility, traffic control, routing, QoS management, etc.

5.3 5G ITS architecture scenario for Smart City transport management

The architecture of ITS in Smart City should take into account benefits resulting from the development of the 5G network. It is presented in Fig. 4. As we can see in Fig. 4a, the ITS configures sets of applications defined for GOS, which are orchestrated by Orchestration Controller. At this moment there are defined logical network slices and their QoS/QoE requirements. As mentioned before an orchestrator plays a major role in both network management as well as ITS [15]. Efficient work of the orchestrator needs to take into account information from radio access, slices and resource management controller, managing the functions of C-RAN. On the other hand, we need to use the ITS functions controller for all transport functions as well as traffic management and aggregation. It is rather dedicated to functions of the 5GC network and ITS-dedicated networks both metropolitan as well as the national backbone.

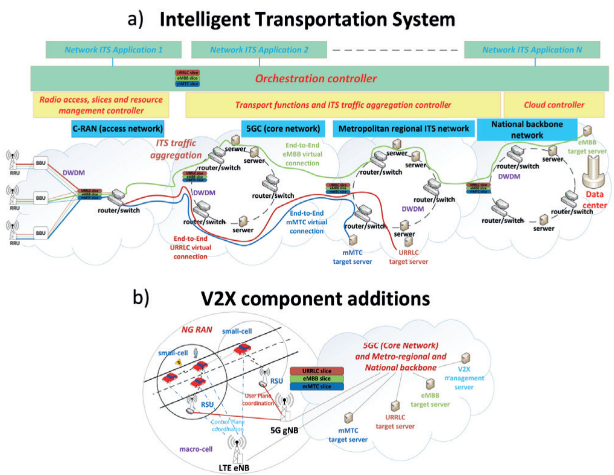

Fig. 4. ITS architecture for Smart City: a) general architecture, b) V2X component (RRU – radio resource unit, BBU – baseband unit, DWDM – Dense Wavelength Division Multiplexing)[own study]

Overall ITS traffic is transferred from gNBs (RRU and BBU) to the cloud after logical aggregation. Dependent on traffic type virtual E2E connections can be established within a given network slice. Note that symbolically marked routes changing over time due to practical IP traffic in a packet switched mode. Target servers can be implemented in each part of the ITS network: metropolitan and backbone, dependent on the type of service and its requirements.

The ITS traffic within the 5G network needs advanced methods of its aggregation, division, management, and orchestration. It is necessary to know slice characteristics and how ITS or RAN resources should be allocated, dependent on the type of service and QoS/QoE. The allocation should be dynamic and flexible.

In the case of V2X implementation, shown in Fig. 3b, the problem of cells management is important due to the high mobility of terminals located in vehicles and low-mobility terminals of persons, as well as stationary locations of road infrastructure nodes, called RSU (roadside units) [16]. Typically, small cells can be served by road-side equipment and 5G gNBs. Probably the user traffic in User Plane (UP) can be transferred to RSUs, while the control traffic can be served by macro-cell base stations (eNB) of 5G LTE component, but it has not been critical. The problem of the handover of high-speed vehicles is not resolved yet. Interfaces between vehicles and road infrastructure, working typically in cooperated mode, can use both LTE-V (C-V2X) as well as IEEE 802.11p interfaces, and others.

6. Conclusion

The development of 5G radio-informatics networks gives unprecedented possibilities for ITS network implementation. As we can see in this paper, major objectives of 5G network implementation are defined within UDN network model, virtualization of network functions (NFV), network softwarization (SDN) and, finally, network slicing concept for support of fast E2E connections as well as unbelievable flexibility and scalability. It will be a great pulse to the development of different ITS solutions and Smart City networks implementation. One of the most important revolutions in telematics will be V2X systems implementation supporting traffic safety, efficiency and autonomous driving. As we can see, the architecture of the 5G network does not differ significantly from the LTE architecture. First, it results from the LTE architecture has been strongly reduced compared to systems of previous generations (2G, 3G), and, secondly, the essence of 5G is softwarization and virtualization of network functions and nodes, but not hardware growth.

Moreover, network functions of 5G significantly differ from 4G network functions. Finally, the 5G network will integrate both 5G NR solutions, 5GC and LTE-5G network. Thus, the gigabit LTE evolution is going to full integration with 5G solutions. One thing is for sure: *The implementation of the 5G network has been an unprecedented development impulse for both ITS and IoT systems growth. So, it is a chance for a global ITS extension.*

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